Waves on a Coiled Spring

Background Information:
A mechanical pulse, or wave, is a disturbance that travels through some material medium transporting energy, but not matter. In this laboratory you will explore the properties of pulses and waves traveling on a coiled spring. Both transverse and longitudinal waves will be investigated. With transverse waves, particles in the medium move perpendicular to the direction of wave propagation. In the case of longitudinal waves, the particles in a medium vibrate parallel to the direction of propagation.

Materials:
coiled spring (Slinky™)
masking tape
string

I. One-Dimensional Transverse Waves

Procedure:

1. Attach small pieces of masking tape at equal intervals along the coiled spring. With the aid of your partner, stretch the spring to a length of approximately 8-m on a smooth horizontal surface. To prevent possible tangling, be careful not to let go of the spring.

2. Produce a pulse by quickly moving your hand in a back and forth motion parallel to the floor. Sketch the shape of the spring with the pulse on it.

3. Does the spring remain permanently altered by the pulse's transitory presence or does it return to its original state?

   Describe the motion of the pieces of masking tape when the pulse reaches them. Do the pieces of tape move parallel or perpendicular to the direction of motion of the pulse? Is this pulse transverse or longitudinal?

4. Create a pulse and describe any changes in the shape and amplitude (height) of the pulse as it travels down and back up the spring. What do you think causes these changes?

5. Does the speed of the pulse appear to increase, decrease, or remain the same as the pulse moves along the spring? Suggest a procedure that would enable you to answer this question.

6. Produce two pulses in rapid succession. The second pulse should have a considerably larger amplitude than the first. Does the distance between the pulses change as they travel along the spring? What does this indicate about the relationship between amplitude and wave speed?

7. Send another pulse down the spring and observe what happens when it reaches your partner's hand. Note that the pulse reflects from the fixed end. How does the shape and amplitude of the reflected pulse compare to the incoming pulse? Does the reflected pulse come back on the same side or opposite side of the spring?

8. Gather up several coils of the spring. This will increase the tension in the spring without altering its length. Send a pulse down the spring. How does increasing the tension seem to affect the speed of the pulse? Do springs under different tensions behave like different media? Is any other property of the spring being altered when coils are gathered up? If there is, how should this change affect the speed of the wave?

9. You have seen how a pulse reflects from a fixed end. To investigate reflection from a free end, tie approximately 3 meters of string to one end of the spring. After establishing tension in the spring, generate a transverse pulse by shaking end of the spring. Do you observe a reflected pulse? If so, does it return on the same or opposite side of the spring?

10. Instead of sending a single pulse down the spring, produce a continuous train of waves by moving your hand back and forth with a constant frequency. How does the frequency of waves passing any point along the spring compare to the frequency of your hand movement?

11. Send two pulses, one from each end, down the spring. The pulses should be on the same side of the spring. That is, both crests or both troughs. What happens when the pulses meet? Do they bounce off or pass through each other? One way to answer this question is to produce two pulses of markedly different amplitudes. This will enable you to keep track of the pulses before and after they meet. Study the spring's amplitude very carefully at the instant the pulses meet. Describe the amplitude of the spring at that instant. Is it greater than, less than, or the same as that of the individual pulses?

    Now, with the assistance of your partner, simultaneously send a crest and trough of equal amplitude from each end of the spring. Describe the shape of the spring when the two pulses meet.

II. One-Dimensional Longitudinal Waves

Procedure:

1. With your partner holding one end of the coiled spring, stretch it to a length of approximately 8 m.

2. Gather together 10 to 15 coils at one end of the spring. Watch the pieces of tape carefully as you release the coils. Does a disturbance travel down the spring? How do the pieces of tape move relative to the motion of the pulse? That is, do they move perpendicular or parallel to the spring? Is the pulse transverse or longitudinal?

3. Disturb the spring by quickly moving your hand forward. This produces a region of *compression* where the coils are bunched together. Does a pulse of compression travel down the length of the spring? Does this pulse of compression reflect when it reaches the fixed end at your partner's hand?

4. Quickly pull the spring backward. You should observe a region of *rarefaction*, where the coils are spread out, move down the spring. Does the rarefaction reflect at the fixed end?

5. Produce a series of longitudinal waves by moving your hand forward and backward with a constant frequency. Describe the motion of any piece of tape on the spring.

Questions:

1. Distinguish between transverse and longitudinal waves. Give two examples of each.

2. What factor(s) determines the speed of a wave on a spring?

3. What happens when a crest, traveling on a spring, encounters a fixed end? A free end?

4. When two waves meet on a spring, do they "bounce off " or just pass through each other? Cite experimental evidence for your answer.

5. How does the frequency of the waves that pass a particular point on the spring compare to the frequency of the source of the waves?

6. (a) Suppose two identical crests meet on a spring. Describe the amplitude of the resultant disturbance at the instant that the crests overlap.

   (b) Suppose a crest and a trough meet on a spring. Assuming that the two pulses are mirror images of each other, describe the resultant disturbance at the instant the pulses oppose each other on the spring.