EXPERIMENTING WITH SLINKY SPRINGS: INVESTIGATION 1

Aim: To measure the velocity of a pulse (transverse) travelling through a slinky spring

Context: To calculate velocity, we can use:

$\text{velocity} = \frac{\text{distance}}{\text{time}}$ or $v = \frac{s}{t}$.

We are also assuming that the pulse will reflect back and at the same speed.

Equipment:
Slinky spring (long with small diameter, snake-like)
Stopwatch
Metre ruler

Method:

1. Stretch the spring and place it on a smooth section of the floor, with a person holding it tightly at each end.
2. At one end, one of the people holding the spring uses his/her hand to give the spring a quick flick, creating a pulse with amplitude of approximately 10-15 cm.
3. The timer starts the stopwatch just as the person flicks the spring.
4. Observe that the pulse reaches the other end and reflects back. When the reflection of the pulse returns to the person flicking the spring, the person flicks the spring again.
5. Repeat step 4 four times, so that the pulse travels to and back five times in total.
6. Stop the stopwatch when the fifth reflection returns to the person doing the flicking, and record the time in a table.
7. Repeat steps 2 to 7 four times in total.

Variables: Because the aim is to measure the velocity of a pulse in this particular slinky spring, all variables must be kept constant between measurements. We are measuring the velocity in one medium only (the one slinky spring). Examples of variables kept constant include distance that the spring was stretched, the amplitude and the type of spring. The dependent variable is time.

Risk Assessment: Danger lies where there is no relationship of trust between the two people holding the opposite ends of the stretched slinky spring. If one (or both) of them release the taut spring, then the unpredictable behaviour of the slinky spring may cause irreparable damage to people's eyes. The safest option is to wear goggles over the eyes and to stay well away from any ongoing experiments.

Results:

Measurement Number	*Time recorded by pulse travel (s)*
1	5.67
2	5.04
3	5.28
4	5.73
Average	**5.43**

The distance that the slinky spring was stretched out to was a constant **7m**.
Average time for pulse travel is **5.43s**.

CALCULATIONS:
Using the formula described above, we can determine the velocity at which the pulse travels.
However, our measurements show how long it took the pulse to travel along the spring and back to the pulse generator, five times.
Hence: $s = 7 \times 5 \times 2 = 70\text{m}$, $t = 5.43\text{s}$, $v_{pulse} = ?$

$$\therefore v_{pulse} = \frac{s}{t} = \frac{70}{5.43} = 13\text{ms}^{-1} \text{ (nearest ms}^{-1}\text{)}$$

Discussion: The velocity of the pulse was calculated from the data, but as the results clearly show, each attempt produced a different result; most of this can be attributed to *human error* and inaccuracies during measurement. The reaction of the time of the person operating the stopwatch would have had an effect on the measurements, as would the reaction time of the person who must repeat the flicking every time the reflection arrives at his/her end of the spring. The person may flick the spring slightly before or after the reflection arrives, thus affecting the time recorded.

In addition, the fact that the slinky spring was placed on the floor would have had an effect due to friction slowing the pulse down. Other factors that might have had an impact on the accuracy of the measurements could be inaccuracy in the measurements of the distance (as we used a metre rule), or imperfections (such as kinks) in the spring.

Improvements to this investigation could include:

- Use of a measuring rape for greater accuracy
- A brand new slinky
- Electronic timing equipment / Videotaping the movement
- Repeat investigation with different sized springs

Conclusion: The velocity of the wave was calculated successfully by measuring the distance and the time taken for the pulse to travel along it, and then applying the formula $v = \frac{s}{t}$.

EXPERIMENTING WITH SLINKY SPRINGS: INVESTIGATION 2

Aim: To find ways of altering the wave velocity of a pulse (transverse) in the same spring as Investigation 1

Context: Again, we will use the formula $v = \frac{s}{t}$ to calculate the velocity of the pulse travelling along the spring. We will investigate whether factors such as changes in the amplitude and changes in distance will have an effect on the velocity. The velocity of the pulse measured in investigation 1 will become the control for this experiment.

Equipment: Slinky spring (long with small diameter, snake-like)
Stopwatch
Metre ruler

Method: PART 1:

1. Repeat Investigation 1 only that the *amplitude* has been made *larger* to around 30cm.
2. Record the results in the table.

PART 2:

3. Repeat Investigation 1 only that the *amplitude* has been made *smaller* (just a slight tap so that it is just visible).
4. Record the results in the table.

PART 3:

5. Repeat Investigation 1 only that the spring has been stretched over a *shorter distance* (5 metres). Use the same amplitude (approximately 10-15cm).
6. Record the results in the table.

Variables: Investigation 1 is the control for this experiment. Therefore, only one variable can be changed for each part of this investigation, such as **increasing or decreasing amplitude and the distance over which the slinky spring is stretched**.
Variables that have been kept constant (for all parts) include the spring that was used and the person who flicked the spring. We tried to keep ALL variables constant for all four measurements in each part. The dependent variable is time.

Risk Assessment: The risk is the same as Investigation 1, as it too involves stretched springs.

Results: [Note: Control is Investigation 1 – results repeated below]

Experiment	*Times (s)*	***Average (s)***
1. (Control)	5.67, 5.04, 5.28, 5.73	**5.43**
2. Larger Amplitude	5.30, 5.39, 5.48, 5.27	**5.36**
3. Smaller Amplitude	5.42, 5.51, 5.21, 5.34	**5.37**
4. Shorter Distance	5.57, 5.38, 5.69, 5.52	**5.54**

Amplitudes

1. (Control) = 10-15cm
2. Larger Amplitude = 30cm
3. Smaller Amplitude = small but just visible (about 1-5cm)
4. Shorter distance = 10-15cm

Distances

1-3. Distance is 7m
4. Shorter distance = 5m

Velocity of control was **$13ms^{-1}$** (nearest ms^{-1}) from Investigation 1.

CALCULATIONS:

- Part 1

Again, as we simply repeated the method from investigation 1, the slinky spring was set in motion 5 times, ie:

$s = 7m \times 5 \text{ times} \times 2 = 70m$
$t = 5.36s$ (from table)
$v_{pulse} = ?$

$$\therefore v_{pulse} = \frac{s}{t} = \frac{70}{5.36} = 13ms^{-1} \text{ (nearest } ms^{-1}\text{)}$$

This is roughly identical to the value from the control, so increasing the amplitude has no effect on the velocity.

- Part 2

Same, only with a smaller amplitude:

$s = 7m \times 5 \text{ times} \times 2 = 70m$
$t = 5.37s$ (from table)
$v_{pulse} = ?$

$$\therefore v_{pulse} = \frac{s}{t} = \frac{70}{5.37} = 13ms^{-1} \text{ (nearest } ms^{-1}\text{)}$$

Decreasing the amplitude also has no effect on the velocity.

- Part 3

This is the part of the investigation where the distance was changed.

$s = 5m \times 5 \text{ times} \times 2 = 50m$
$t = 5.54s$ (from table)
$v_{pulse} = ?$

$$\therefore v_{pulse} = \frac{s}{t} = \frac{50}{5.54} = 9ms^{-1} \text{ (nearest } ms^{-1}\text{)}$$

The velocity of the pulse changed when the distance over which the spring was stretched was changed.

Discussion: Investigation 1 was about trying to determine the velocity of the pulse travelling through a slinky spring. This investigation builds on that by repeating this investigation but with some variables changed in order to see what affects the velocity. A control was used, and only one variable was changed for each part so that we can identify the relationship between factors such as amplitude and distance.

Improvements could include:

- Investigating the effects of changing variables in other springs
- Investigating other factors such as putting the spring in a vacuum
- Investigating the effect in a compression wave

Sources of error would be similar to those of Investigation 1. The fact that the slinky spring was placed on the floor would have had an effect due to friction slowing the pulse down. Other sources of error could include inaccuracy in the measurements of the distance (as we used a metre rule), or imperfections (such as kinks) in the equipment used. To fix this:

- Use of a measuring rape for greater accuracy
- A brand new slinky
- Electronic timing equipment / Videotaping the movement
- Repeat investigation with different sized springs

Conclusion: This investigation was able to determine whether two factors had an impact on the velocity of a pulse travelling through the slinky spring. Amplitude of the pulse had NO impact on the velocity. Decreasing the distance over which the spring was stretched (and therefore the distance between the ‘rings’ of the spring) slowed the pulse down.

EXPERIMENTING WITH SLINKY SPRINGS: INVESTIGATION 3

Aim: To investigate how the diameter of a slinky spring will affect the velocity of a pulse (transverse) travelling along it.

Context: In the last investigation, we discovered that changing the distance over which the spring was stretched affects the velocity of the pulse travelling along it. This investigation explores other factors that could change the velocity of the pulse.

For this we need the formula $v = \frac{s}{t}$. We assume that the reflection of a pulse travels at the same speed as the incident pulse.
Since Investigation 1 used the snake-like spring with a small diameter, the results can be reused; we only have to repeat the experiment with the larger diameter spring.

Equipment: Two slinky springs (long with small diameter, snake-like; short with larger diameter)
Stopwatch
Metre ruler

Method:
1. Repeat Investigation 1, only replace the spring mentioned with a larger diameter spring.
2. Write down the data in a table and compare with the results from Investigation 1.

Variables: The only variable that changes is the spring that we used. All other factors such as distance, person flicking the spring and number of times that the spring was flicked remains the same.

Risk Assessment: Again, stretched slinky springs have to ability to cause serious injury if let go suddenly, so goggles are suggested.

Results: [Results for the control have been copied from Investigation 1]

Size of slinky spring	*Time (s)*	***Average (s)***
Smaller diameter	5.67, 5.04, 5.28, 5.73	**5.43**
Larger diameter	4.34, 4.45, 4.63, 4.46	**4.47**

The smaller diameter spring (long one) was stretched over 7m.
The larger diameter spring (but shorter) was stretched over 4.53m, a distance that we felt gave an equivalent tautness.

CALCULATIONS:

$v_{small\ diameter} = 13ms^{-1}$ (from before)

$s = 4.53 \times 5 \times 2 = 45.3m$ (the spring was flicked 5 times)
$t = 4.47s$ (from table)
$v = ?$

$$v_{large\ diameter} = \frac{4.53 \times 5 \times 2}{4.47}$$
$$= 10ms^{-1} \text{ (nearest } ms^{-1}\text{)}$$

Discussion: The result above may make it seem as though the wave travels slower in a slinky with a larger diameter compared with one that has a smaller diameter. However, it was not possible to obtain slinkies with different diameters and with the same length. As we discovered in the previous investigation, how taut a spring is will affect the velocity of a pulse travelling through it. We picked 4.53m as the distance to stretch the larger-diameter slinky because it felt that it was to some relatively same degree of tautness; this of course, is quite subjective. If we had made the small-diameter spring 4.53m long, it would not have been tight enough for a pulse to travel along it. Overall, it made for a difficult comparison of the two springs, and we could not conclusively determine how the diameter affects velocity.

Again, this investigation suffered from the usual measurement errors due to human inaccuracies. The sources of error are identical to those of the preceding investigations.

Conclusion: Although the data suggests that a pulse would travel faster through a slinky spring with a larger diameter, it is not possible to determine this conclusively.

EXPERIMENTING WITH SLINKY SPRINGS: INVESTIGATION 4

Aim: To create a longitudinal wave and measure its velocity

Context: The formula to calculate speed, $v = \frac{s}{t}$, is necessary in this situation.

Equipment: Large diameter spring (easier to see compression waves)
Stopwatch
1m Ruler

Method:

1. Stretch the spring to 7m long (almost to the verge of breaking).
2. Create a compression by bunching together a section of the spring together and then letting go.
3. “Push” suddenly from one end.
4. Decide which of methods 2 or 3 is better and record the time for the pulse to travel to the other end once. Do that 5 times.

Variables: Since we are trying to measure the velocity of the wave in one context, no variables change from between measurements. Controlled variables include the distance over which the spring is stretch, the spring that is used and the person flicking the spring. The dependent variable is time.

Risk Assessment: Again, the risk lies in the fact that a stretched slinky can cause serious damage to the eyes if it is let go suddenly. Goggles are suggested, although the risk is lower because the spring is made of plastic not metal.

Results: The method from step 2 created a more visible compression wave (compression/rarefactions more distinct).

Measurement	*Time (s)*
1	0.47
2	0.46
3	0.47
4	0.50
5	0.56
Average	**0.492**

CALCULATIONS:

s = 7m (it travelled in one direction only, once)
t = 0.492s (from table)
v = ?

$$\therefore v_{pulse} = \frac{s}{t} = \frac{7}{0.492} = 14ms^{-1} \text{ (nearest } ms^{-1}\text{)}$$

ANALYSIS OF RESULTS SO FAR:

In investigation 2, we discovered that the velocity of a pulse travelling along the spring changed if the distance was changed. However, *the time that the transverse pulse took to travel the entire length of the small-diameter spring did not change*. That means, the velocity was slower, but the distance was shorter, and the overall time was roughly the same.

If we apply this principle to the larger-diameter spring, then we could arrive at the conclusion that the time that it would take a transverse pulse to travel 7m along the larger-diameter spring, would remain approximately the same as it took to travel the 4.53 metres. That is, it would take around 4.47s (from investigation 3).

Since the compression pulse in this investigation only travelled in one direction once, if we multiply the result by 5 times $\times$ 2 (to and back) = 10:

Time for compression pulse to travel 70m = 4.92s

This is remarkably close, and the difference can be explained by the fact that human error played a larger part in this investigation (see below for more).

Discussion: Inaccuracies of measurement are more of a problem in this investigation than in the preceding ones. Because the time between the pulse being created and the pulse reaching the other end is so small, the reaction time of the timer plays a large part. we could not create longitudinal pulses one after the other because: a) the reflection had too small an amplitude to see; b) creating a compression pulse was too slow in comparison to how fast the pulse moves. Factors such as imperfections in the spring and friction all play a part (this is similar to the sources of errors for preceding investigations).

Conclusion: A longitudinal wave can be created in a slinky spring by giving a push suddenly from one end, which has the effect of creating a compression that travels along the spring. Correlation between the velocity of a longitudinal wave and the velocity of a transverse wave could not be determined directly, but it appears to be similar.

EXPERIMENTING WITH SLINKY SPRINGS: INVESTIGATION 5

Aim: To investigate reflection of a pulse (transverse)

Context: Velocity can be determined by $v = \frac{s}{t}$.

Equipment: Slinky spring (small-diameter, snake-like)
Stopwatch

Method:

1. Put the slinky on the floor and stretch it out so that it is taut.
2. A person holds the spring at each end.

PART 1: Speed of the incident pulse

3. One of the people holding the spring gives the spring a sidewards flick so that a transverse pulse can be seen travelling along it and back again (the reflection).
4. Start the stopwatch when the person gives it a flick, and stop it when the pulse reaches the other end.
5. Repeat steps 3 to 4 four times.

PART 2: Speed of the reflected pulse

6. Flick the spring from one end.
7. Wait until the pulse reflects before starting the stopwatch.
8. Stop the stopwatch when the reflected pulse reaches the person who flicked it.
9. Repeat steps 6 to 8 four times.

PART 3: Observations

10. Flick the spring from one end.
11. Observe the amplitude of the incident and reflected pulses.
12. Observe whether the pulse is reflected on the same side or inverted.

Variables: All variables have been controlled because this experiment involves repeating only one case to observe it.

Risk Assessment: Same as before – wear goggles for safety from the springs.

Results: PARTS 1 and 2:

Measurement	*Incident pulse time (s)*	*Reflection pulse time (s)*
1	0.49	0.55
2	0.51	0.57
3	0.44	0.41
4	0.53	0.48
Average	**0.49**	**0.50**

(All figures to 2 decimal places)

There is not much of a difference between the times for the incident pulse and the reflected pulse.

PART 3:
Observations:

- The reflected pulse is reflected with smaller amplitude.
- The reflected pulse is reflected on the other side.

Discussion: Again, sources of error are present in this investigation. Human error and inaccuracies in measurement are apparent in this investigation, especially since the times are so short. This allows for a greater percentage error in the measurement. As for the observations, although it was visible that the reflected ray was smaller and on the other side, it was not measured (size is a subjective measure). Using a ruler to measure it, or analysing it via a photo, would have been a better solution.

Conclusion: A reflected ray:

- Reflects at the same speed
- Reflects with smaller amplitude
- Reflects on the other side (inverted)

EXPERIMENTING WITH SLINKY SPRINGS: INVESTIGATION 6

Aim: To investigate refraction of pulses

Context: The velocity of a pulse can be worked out using $v = \frac{s}{t}$.

Using two different springs count as different mediums.

Equipment: Two different slinky springs (wide plastic one/narrow metal one)
String/rubber band

Method:

1. Join the two slinky springs together using string/rubber band.
2. Place the combined springs together on the floor and stretch between two people so that it is taut.
3. On the end with the spring with the larger diameter (plastic one), create a pulse by flicking the spring.
4. Observe what happens to the pulse as it travels from spring to spring.

Variables: We are using two different springs at the same time, but all other variables have been controlled as we are simply repeating the same situation to observe it.

Risk Assessment: Wear goggles!

Results: OBSERVATIONS:

- The reflected pulse (in large diameter, plastic spring) arrived at its end before the refracted pulse (in small diameter, metal spring) arrived at the other end. As the join between the two springs was roughly in the middle, we could assume that the reflected pulse is faster.
- Both the refracted and reflected pulses have smaller amplitude than the original pulse
- The pulses stay on the same side.

Discussion: This investigation had inaccuracies. No measuring equipment was used other than our eyes. The fact that the pulse arrived at different times could have been attributed to the observers not seeing it correctly, or the join between the two springs was not exactly in the middle. Again, the amplitude was not measured (it is of course, quite impractical without a camera since it is so fast).

A subsequent investigation could involve observing refraction in longitudinal waves.

Conclusion: When the pulse travelled from the plastic slinky to the metal slinky:

- It was slower than the reflected pulse which travelled from the centre back to the generator of the pulse – probably due to the fact that the metal spring is heavier than the plastic spring
- Refracted pulse amplitude was smaller.
- Refracted pulse did not change in phase.

EXPERIMENTING WITH SLINKY SPRINGS: INVESTIGATION 7

Aim: To create pure standing wave patterns

Context: Springs can form stationary points called nodes. The points of maximum movement are called antinodes.

Equipment: One slinky spring (large diameter, plastic)

Method:

1. One person holds the slinky spring in the air at each end.
2. One of the people vibrates the spring up and down at different speeds, and all observe the resulting wave patterns.

Variables: The variable that varies in this investigation is the speed at which the spring is vibrated. All other factors are controlled, as we are only investigating this effect. The dependent variable is the number of pure standing wave patterns formed by such movement.

Risk Assessment: Goggle, goggles, goggles

Results: We observed that the faster that the spring was vibrated up and down, the more pure standing wave patterns were formed.

Slow movement:

Fast movement:

Discussion: This investigation is quite effective, as we managed to produce what we set out to produce. Improvements could include trying this on other springs, ropes and other mediums that can carry waves.

Conclusion: To change the wave pattern to create more standing waves, you vibrate the spring up and down faster.