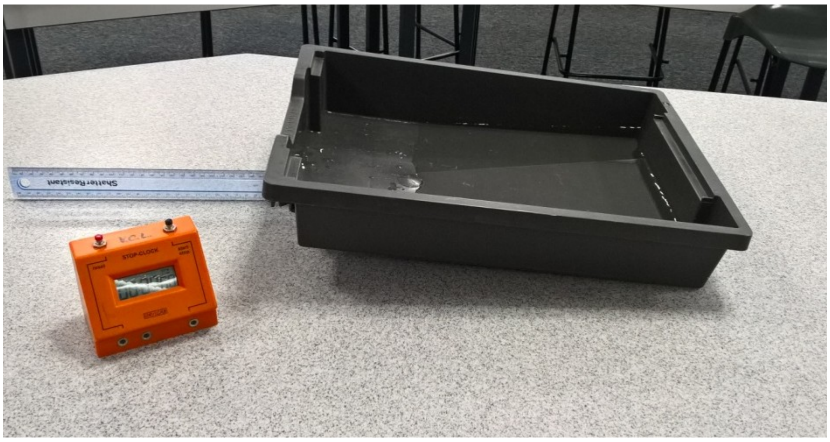
WAVES PRACTICALS

Your first tasks (a lesson each) are to perform two experiments to answer two questions:

1. **What happens to the speed of a wave as it travels further and further**
2. **What happens to the speed of a water wave when the depth of water is changed.**

For both questions you will be using the kit pictured below:



Waves are reproducibly created by sharply pulling the ruler out.

EXPERIMENT 1

Assemble the kit. With the tray flat add about 1cm of water.

Use a ruler to measure the depth of the water in three widely spread places across the tray.

Record these depths and work out an average:

Depth 1 ………………… Depth 2 ………………… Depth 3 ……………….. Average …………………..

Which point in the tray had a measured depth that best matched the average?

Try creating waves. Look really carefully at the way the waves form.

Thinking about how they form when would you start the stop clock to measure the time taken for a wave to cross the tray?

METHOD

Create and time waves using the kit pictured above. Time the time necessary for one single crossing of the tray, then time the total time necessary for the wave to do two crossings, the total time for the wave to do three crossing, and so on. Continue until you get to a point where you can no longer make out the waves because they have done so many crossings.

Go back and repeat twice more. Work out an average time for each number of crossings.

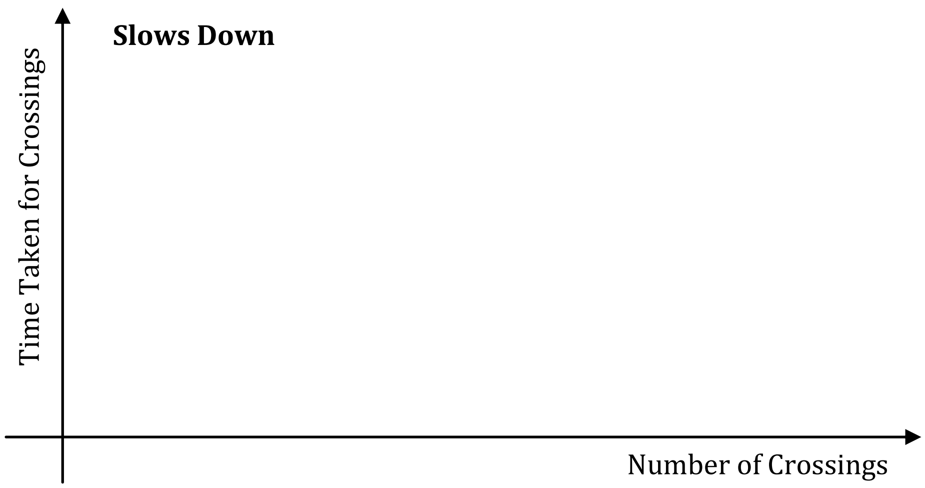
You independent variable will be the number of crossings the wave has done, and your dependent variable will be the time taken to do those crossings. Important control variables are not spilling any water so that the depth is constant, and always waiting for the wave to form and touch the side before starting the stop clock.

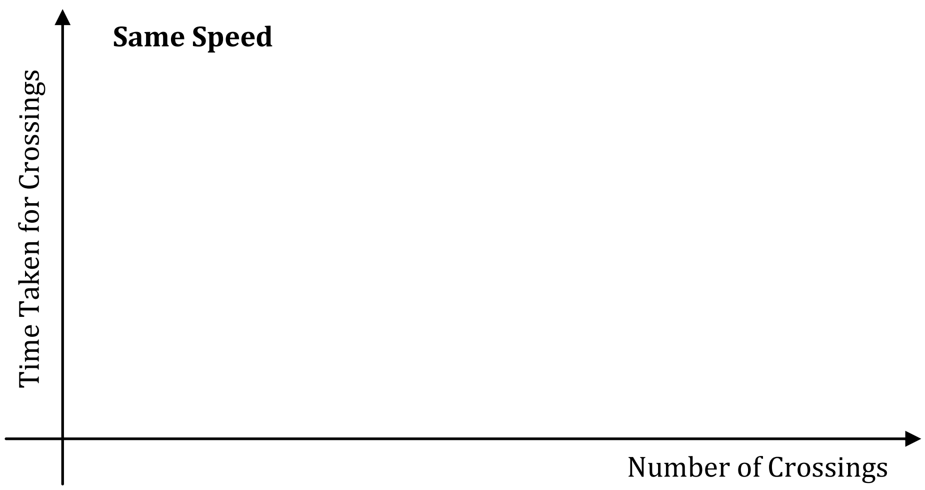
HYPOTHESIS

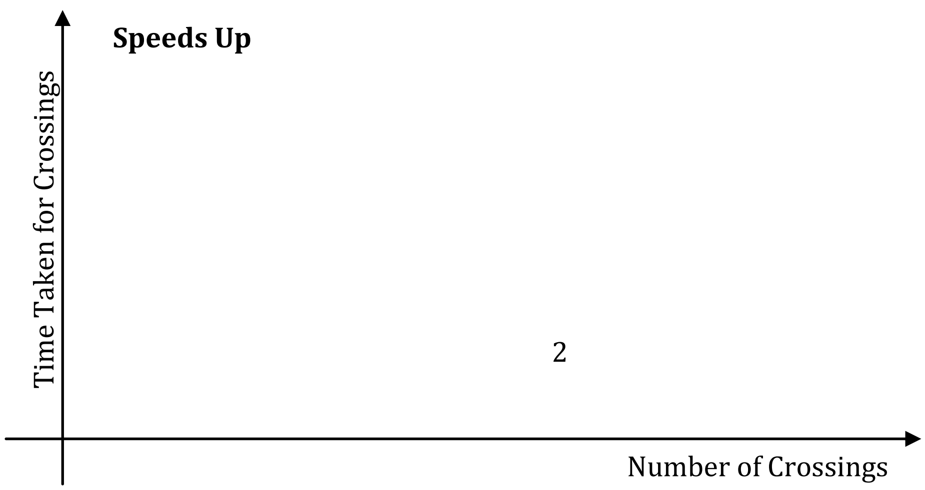
A hypothesis is a theory about what your experiment will show. There are three possible hypotheses for this experiment, the wave will slow down, the wave will stay at the same speed, the wave will speed up.

Before you start your think about the graph your experiment will produce, what will it look like if the wave slows down? If the wave stays at the same speed? If the wavespeeds up?

Sketch what you think each graph would look like on the axes below. We will discuss them as a class before you start the experiment.







Complete the Hypothesis sheet before starting the Practical

In your Lab Practical Book give this first experiment a title.

Leave space to draw a diagram and then lay out the table to record your results, you will need six or seven lines for your different crossings. Remember to add columns for each repeat and for the average. Units go into the column headings.

Conduct the experiment with your partner.

HOMEWORK WRITE-UP

At home, or in class if you have time left after you have tidied up and worked out the averages, draw a labeled diagram.

You have been given the method so there is no need to write one out, cut out this one and stick it in.

Draw the graph from your results on a graph paper page of your practical book. Make sure you choose axes that mean your points fill as much of the page as possible.

Trim down and stick in a copy of the competed hypothesis sheet into your Lab Book.

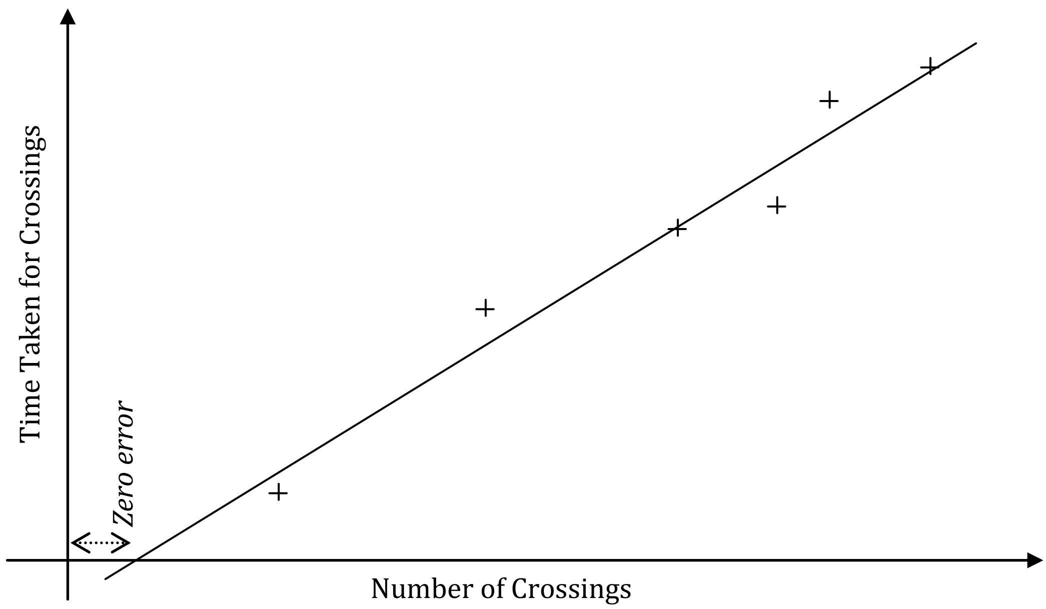
Look at your three hypothesis graphs and your actual graph.

Write a conclusion that comments on how close your repeats where, how close your points were to your line of best fit and which of the three hypotheses your experiment most supports. If your graph mostly, but not completely, matches one of the hypotheses explain why you think your experiment or your hypothesis might have not be as good as it could be.

Explain clearly what your answer to the question "**What happens to the speed of a wave as it travels further and further**" is.

EXPERIMENT 1 OUTCOME

If you performed the first experiment well you should have found that the graph was a straight line.



A straight line means that each crossing took the same amount of time. In which case your answer to the question: **"What happens to the speed of a wave as it travels further and further"** is **the speed of a wave does not change**.

The energy of a wave is **dissipated** (spread out into its surroundings), with a wave however, this shows up not as a change in speed, but by the height (**amplitude**) of the wave decreasing as it travels.

You may have a little **scatter** in your graph – that is some of the points being distributed around your line of best fit instead of all lying on it (as in the diagram above). You may also have a **zero error**, also shown in the diagram above, that is the line of best fit that best matches your points not going through zero on the graph when you think it should do. Mention of both of these problems should be in your conclusion and if you can you should try to explain how doing the experiment better would eliminate them.

EXPERIMENT 2

Now we know that repeated crossings of the tray do not alter the speed of the wave we can use this in the design of our second experiment to answer the second question:

What happens to the speed of a water wave when the depth of water is changed?

A hypothesis for this question is not interesting – "We do expect the depth of water to change the speed", anything more will be a guess. Science is not about guessing, we need to perform the experiment to find out what happens.

You should have realised from the last experiment that one crossing is too fast for you to be able to time it accurately. However, we now understand that we can we can time several crossings and know that the speed has not changed.

Four crossings is a good choice, long enough for accurate timing but not so long that the wave starts to disappear.

METHOD

Measure the distance that a wave will travel in crossing the tray once. Work out and record how far a wave will travel in four crossings.

Using a beaker fill the tray to a depth of about 5mm, keep an note of how much water you needed to add.

Measure the depth in three places. Choose the place that best represents the average depth and from then onwards always measure depth at that point. Record the time it takes for a wave to cross the tray 4 times. Repeat this twice more.

Add the same amount of water as before to roughly double the depth.

Measure and record the depth in three places. Record the time it takes for a wave to cross the tray 4 times. Repeat this twice more.

Add the same amount of water again and repeat the above.

Keep going until you reach a point where the water starts to splash out too much for accurate measurements.

Record all of the above in a table in your lab book. Table headings for this experiment might look like:

Average depth / mm	**Times /s**				**Average speed / m/s**
	Time 1	Time 2	Time 3	Average time for four crossings	

The average speed is calculated for each row by dividing the distance travelled in four crossings by the average time for four crossings.

HOMEWORK WRITE-UP

At home, or in class if you have time left after you have tidied up and worked out the averages, draw a labeled diagram.

You have been given the method so there is no need to write one out, but this time **do** list the experimental variables as well as sticking in the method.

Draw the graph from your results on a graph paper page of your practical book (Average Speed against Average Depth). There is no reason to expect a straight line for this graph, if it is not a straight line draw a smooth curve through as many points a possible to be your line of best fit.

Write a conclusion as before. This time explain clearly **what does happen to the speed of a water wave when the depth of water is changed.**

The most important property of all waves is that **waves move energy across distances, the particles move up and down or side to side, but end up in the same place as they started**.

Evidence for this in water waves is:

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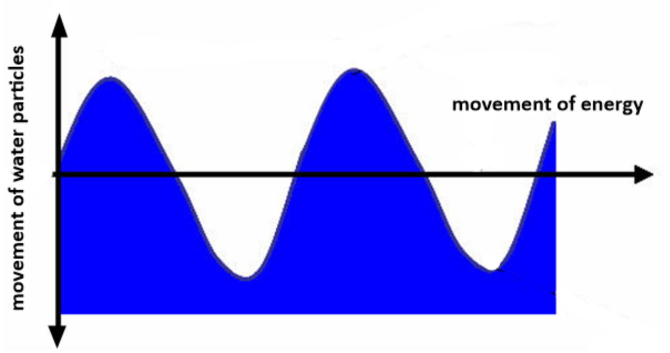


Most waves in Physics are "wave trains" and not the single waves that we have investigated in Experiments 1 & 2. A wave train is a group of waves, travelling in the same direction, that go past at regular intervals.

In the lab we often demonstrate the properties of wave trains using a **ripple tank**.

Wave trains are described by several physical quantities:

- **Time Period**
- **Frequency**
- **Wavelength**
- **Amplitude**

The time between one wave and the arrival of the next is called the **time period** (symbol *T*). The measurement of how often waves arrive is called the **frequency** (symbol *f*). Frequency is the reciprocal of time period measured in seconds. The reciprocal of a number is one divided by that number so:

$$frequency = \frac{1}{time\ period}$$

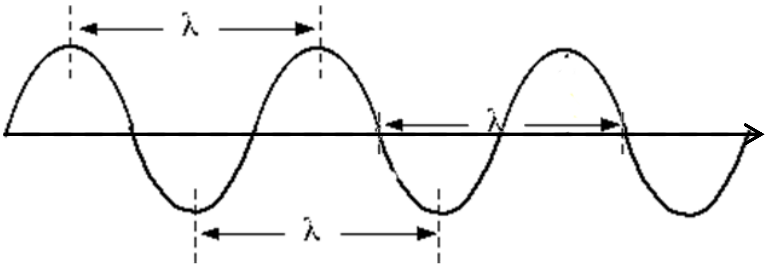
The units of frequency are **hertz** (symbol **Hz**).

Example Question: The average time period between waves arriving at a beach is measured to be 18.4s, what is their frequency in hertz?

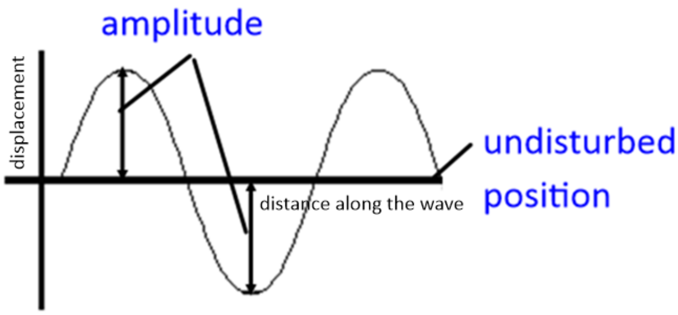
$f = \frac{1}{T} = \frac{1}{18.4} = 0.05434$

The wave frequency is 0.0543Hz

As well as frequency waves in a train have a **wavelength** (the symbol for wavelength is a greek letter λ – known as lambda). The wavelength is the distance moved forward by a wave in its time period. It is also the distance between two similar points on adjacent waves; wavelength is the distance between two troughs or two peaks. It is a length so its unit is metres.



The final physical quantity, **amplitude**, changes depending on the type of wave. For water waves the amplitude represents the height of the wave peak, or depth of a wave trough, compared with flat water.



THE WAVE EQUATION

Wavespeed (symbol c), in the same depth of water, should be the same for single waves and for wave trains, but with wave trains we can use the equation for wavespeed:

$$wave\ speed = wavelength\ \times frequency$$

$$c = \lambda f$$

(you should remember that two symbols with nothing between them in a formula means they are being multiplied.)

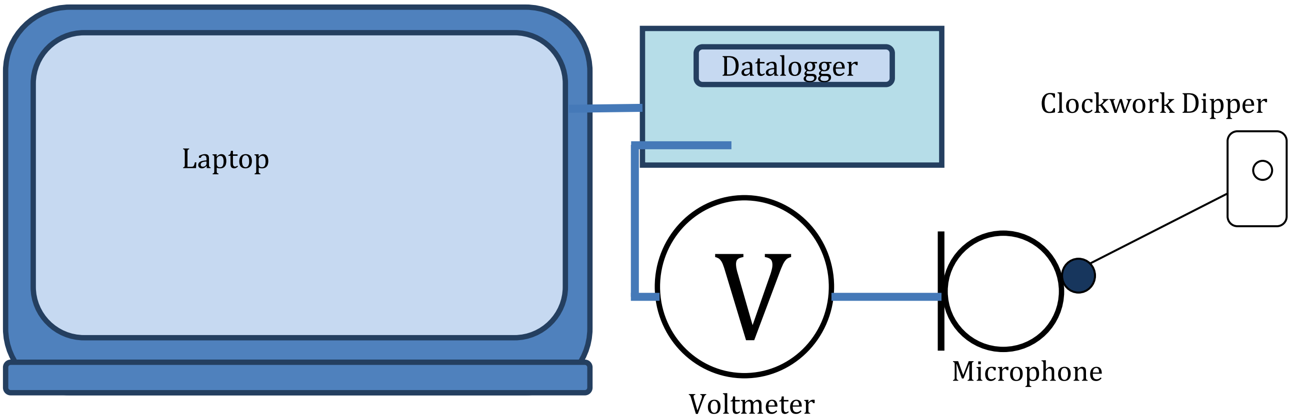
We are going to test the assumption that the speed of a train of waves calculated using the wave equation matches the speed of a single wave next week. In order to do this we need the average frequency of operation of the clockwork dippers.

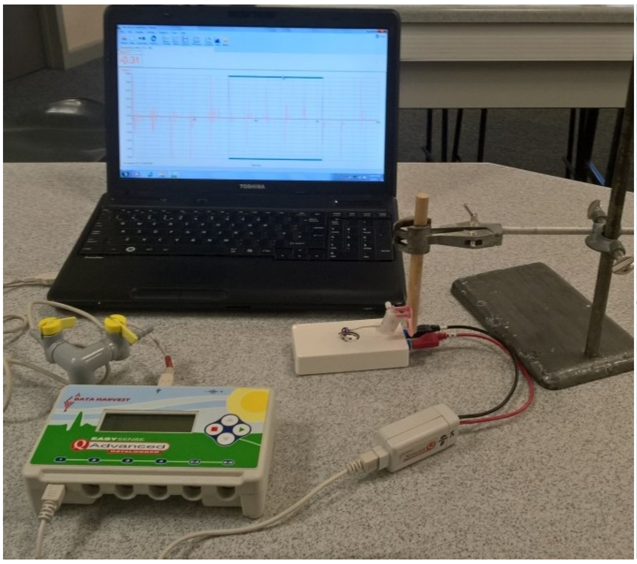
The measurement of this frequency will be performed this lesson, you need to record the value:

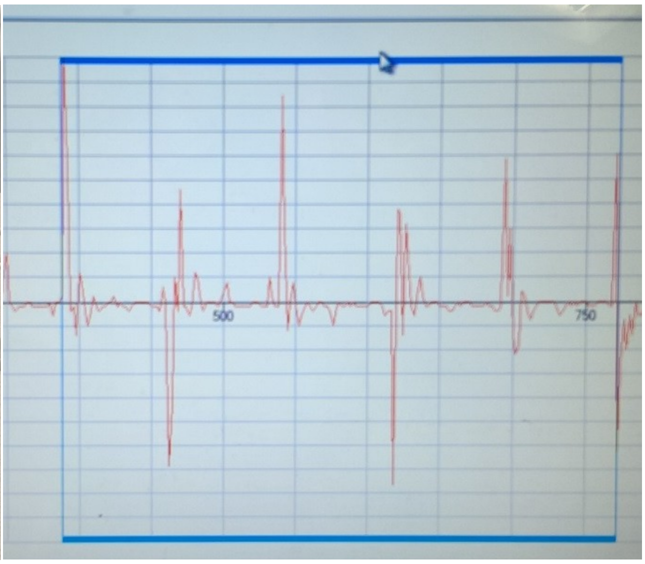
Dipper frequency:…………………………………………………………………..

The frequency of operation of the clockwork dippers can be calculated if we can find the time period between taps from the dipper

To do this we use a voltmeter, datalogger, computer and microphone:







You can see that each time the dipper hits the microphone is clear on the trace recorded by the computer. This is because the vibration of the dipper hitting it is turned into a tiny voltage by the microphone and that voltage is measured by the voltmeter and is transmitted by the datalogger to the computer.

Using an app on the computer we can measure the time for five time periods and then divide by 5 to get the time period of the dipper.

$$frequency = \frac{1}{time\ period}$$

Thus we can find the dipper frequency.

EXPERIMENT TO TEST THE WAVE EQUATION

Last week we learnt that the wave equation said:

$$c = \lambda f$$

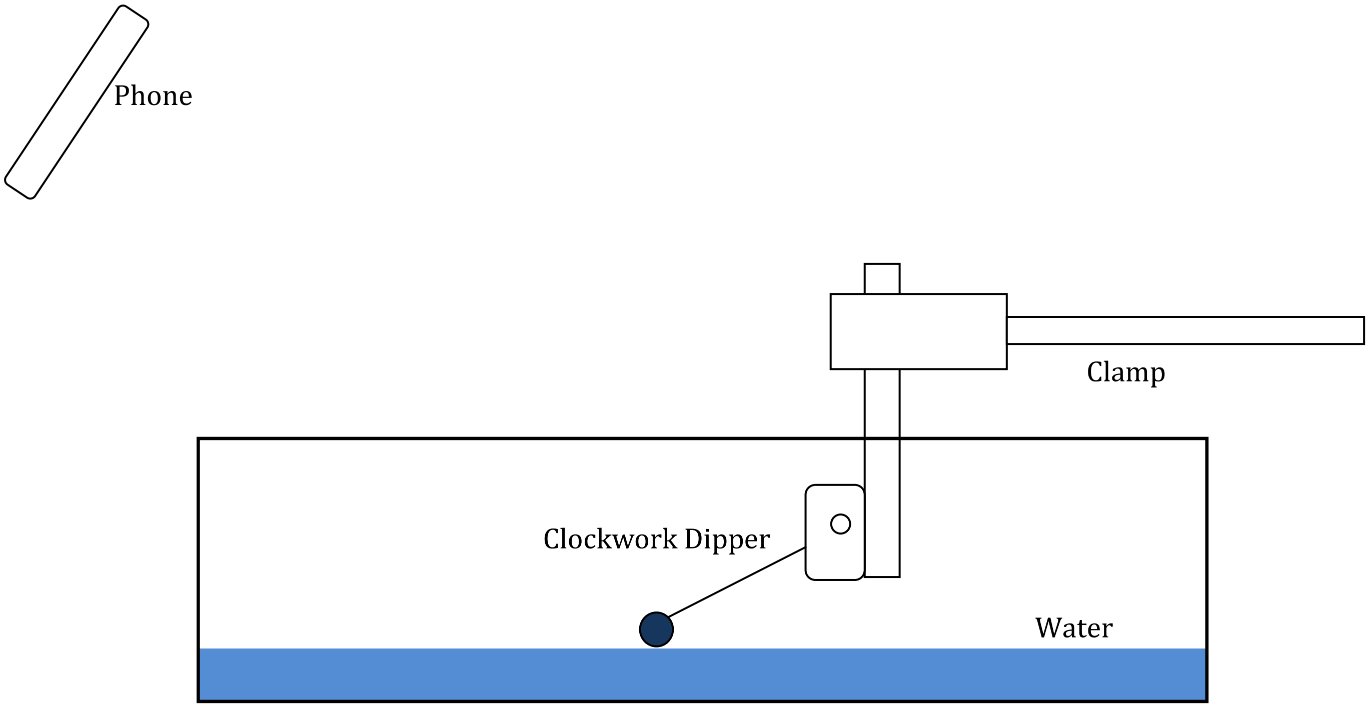
From the second experiment in this series you should now have a graph that describes wavespeed for a single wave against depth.

To test whether the wavespeed *c* as described in the wave equation is the same as those wavespeeds for the single waves, we need to find the wavelengths of wave trains in different depths of water. Of course we also need to know the frequency that the waves are being created at.

Last week we also established the frequency which a clockwork dipper oscillated at so if we use those same dippers to create our waves then we will know the approximate wave frequency (the dippers will probably vary a bit).

MEASURING WAVELENGTH

Set up the equipment as shown:



The scale sheet should be in the bottom of the tray. Water should then be added as in Experiment 2 to give a depth of 5mm. The clockwork dipper should be set up so that the dipping bead is roughly in the middle of the tray and just touching the water's surface. Wind up (do not over wind) and release the dipper to check that concentric ripples are created.

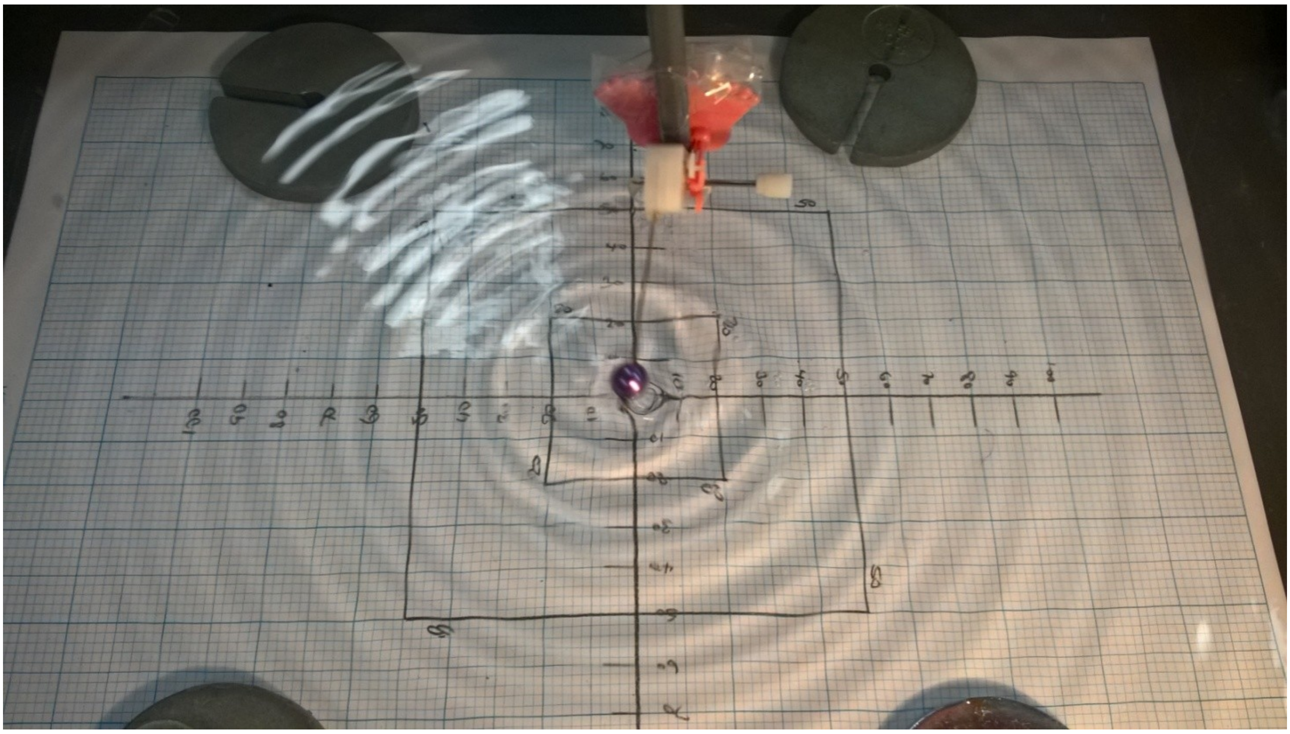
A desk lamp angled so that it throws light across the tray will make the ripples more obvious, but be careful the lamp will get hot.

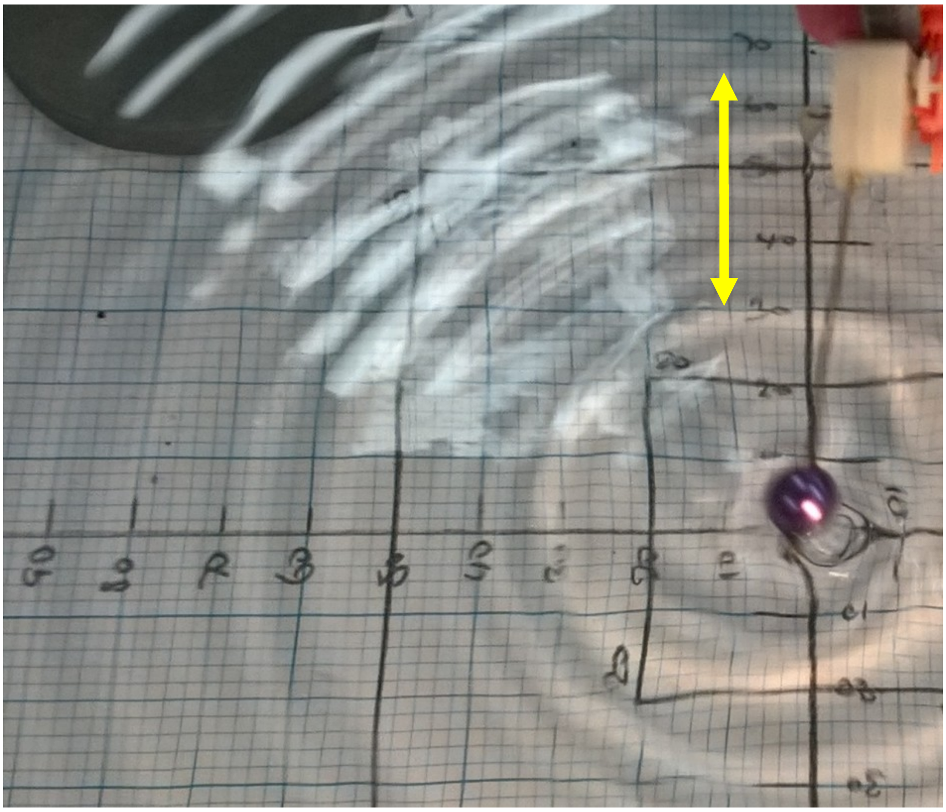
Activate your camera phone and position it over, BUT TO THE SIDE of the tray of water – WE DO NOT WANT ANY PHONES ENDING UP IN THE WATER. If you are not confident, get your partner to use their phone. Now one of you should wind and release the dipper while the other photographs the resulting ripples – do not try to do both on your own.

Away from the tray of water use your phone to blow up your best picture of the ripples, (you might need several goes until you get a good photo).

As in the example below you should be able to obtain a value for the length across several wavelengths from the scale in the picture. Divide by how many wavelengths you are measuring across and record the wavelength of the ripples.

Repeat this in a new photo, or in a different place in the same photo, so that you get at least three values of wavelength recorded for a 5mm depth.





Hopefully you can see that the arrow (top right) in the blow up of the top picture covers 4 waves. It runs from 30mm to 66mm on the scale underneath, 36mm in total, meaning that the average wavelength is 9mm.

Move the phone and the desk lamp out of the way. Use a beaker to add more water to the tray to bring the depth up to 10mm and then, making sure the desk is dry again, repeat the above.

If there is time, get results from a third depth.

ANALYSING THE RESULTS

You might get time to do some of this in class, but if not this is homework.

Find an average wavelength for each depth that you have measurements for.

Convert the average wavelengths into metres and multiply the wavelengths by the frequency of the dipper that we recorded last week.

The values you have obtained are the wavespeeds for those depths according to the wave equation. Draw a table in your lab books recording these values.

You should have a graph showing wavespeed against depth for Experiment 2. If you did not draw a graph of wavespeed against depth (maybe you put **time** on the *y*-axis instead, because you did not read the instructions) then you will need to do the speed calculations from that experiment and draw one.

Mark on that graph where the wavespeeds calculated in this experiment are for their correct depths. These points can be made to stand out by using a different colour or by circling them.

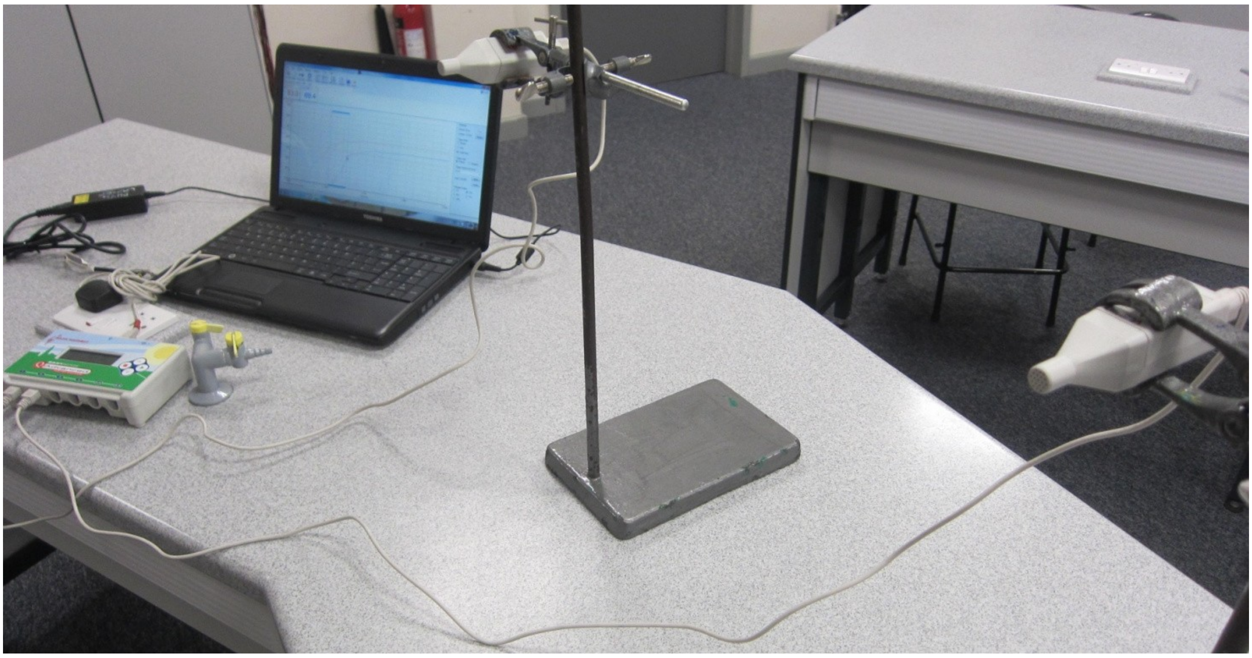
Think about how closely those point match your line of best fit. If they do not match the line of best fit do they follow the same trend? What might explain this?

Write a conclusion in your lab book answering the question that we set out to test:

"**Do your results support the hypothesis that the wavespeed calculated from the wave equation for any depth is the same as the wavespeed measured for a single wave at the same depth**."

Explain any problems you noticed with the experiments (especially the wavelength one) that might mean that your results are not very reliable, and what improvements could be made to improve the results of our test of the hypothesis.

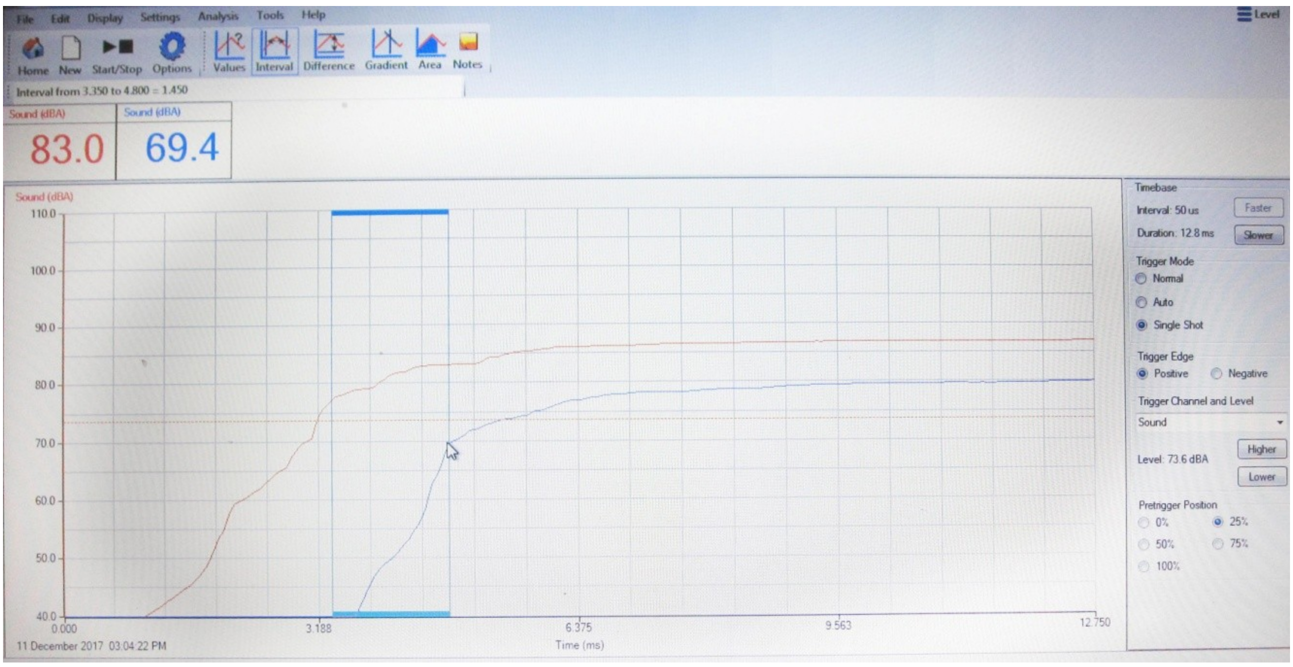
In this experiment we are going to make use of the dataloggers paired with a computer to measure the time difference between sound arriving at two spaced apart sound sensors. The set up is as per the picture.



The two sound sensors are mounted on stands and the distance between them can be changed from between 20cm to one metre. They are both connected to a single datalogger and that datalogger is connected via a red tagged USB cable to the laptop.

Make sure the datalogger is on “Meter” and is showing both sound sensors. The app to run on the laptop is Easysense.

Your teacher will help set up the app, but if you want to try it yourself: “OK” the first couple of screens, then on the main menu choose “Scope”. Click “Finish” and you can then copy the settings in the picture below.



The trigger level shows up on the graph as a yellow dotted line, and is controlled by the higher and lower buttons. You are going to trigger the system to record sounds by clapping loudly. The trigger level needs to be low enough that you will not hurt your hands when clapping, but high enough so that people around about to not trigger it all the time. This will take a bit of adjusting to get right

A loud clap to one side of the sound sensors will arrive at one and then the other sensor. The leftmost line on the graph in the previous picture is the sound arriving at the first sensor and the second line is it arriving at the second sensor. Notice how the sound graphs are roughly the same shape but the sound is lower, quieter, at the second sensor.

Your graphs might start higher up because of the noise in the classroom.

Record the graphs by using the Start/Stop button at the top.

Answer “No” when asked if you want to save your data.

Your task is to measure the time difference between similar points on the two graphs. Do this by pressing the “Interval” button at the top and then dragging the mouse between the points you want to measure. The time interval appears top left above the two boxes with the sound level values. You might be able to see in the picture it is 1.450. This interval is in milliseconds.

Each time you do this make sure you press the “Interval” button.

METHOD

Set up the equipment and computer as explained above.

Set the sensors to 20cm apart, clap and record the time interval between the sounds arriving at the two sensors (you will need a table). Increase the distance by 20cm and repeat. Keep going until they are a metre apart.

Return the sensors to 20cm apart and repeat.

If you have time repeat the experiment a third time.

ANALYSIS

Find the average time interval across your three repeats.

The speed of sound will be the distance apart of the sensors in metres divided by the time interval in seconds. You will therefore need to convert the distances into metres and the times into seconds.

Milliseconds are converted to seconds by dividing by one thousand.

Calculate the speed of sound for each distance.

Homework will be a full write up of the experiment, to include; a good diagram, a brief explanation of using the computer in a method, a graph of your results and a conclusion about how your results compare with the known speed of sound and why they might be different.

RESONANCE EXPERIMENT TO MEASURE SPEED OF SOUND

This experiment is usually performed after you have measured the speed of sound electronically in class.

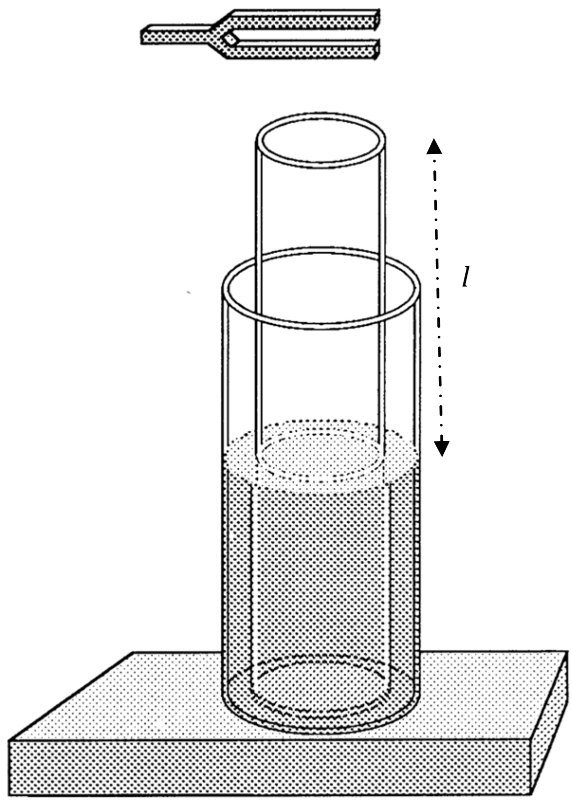
METHOD

Take a large plastic beaker and nearly fill it with water.

Place the provided wide plastic tube into the water, clamp it with a retort stand so that the tube will always remain upright.

Take a tuning fork and record its frequency in your table. You will need four columns; fork frequency, f /Hz, tube length, l /m, wavelength, λ /m, and wavespeed, v / m/s

Hold the end of the tuning fork and tap it on the table to make it vibrate, then hold it flat above the tube, but without it touching.



Loosen off the clamp and move the tube up and down with one end in the water, keep the vibrating You will find one point where the note of the tuning fork becomes noticeably louder. Clamp the tube again and check you still have it at the point where the sound is loudest.

Where the sound is loudest is where it *resonates*. This occurs where the length of the tube above the water is one quarter of the wavelength of the sound in air.

Record the length, l, of tube above the water in your table in metres.

Record the wavelength, λ, which is four times the tube length, $4l$.

Swap you tuning fork for another and repeat.

When you have tested several tuning forks calculate the speed of sound, v, for each using the wave equation:

$$v = \lambda f$$

ANALYSIS

Your analysis of this experiment is to discuss how close each of your results calculated at different frequencies is to the actual speed of sound; about 343m/s.

Think about what might have prevented each measurement giving exactly the same result, what were the sources of inaccuracy in this experiment?

Simply stating it was “Human error” will never get any credit in any write up or any exam.