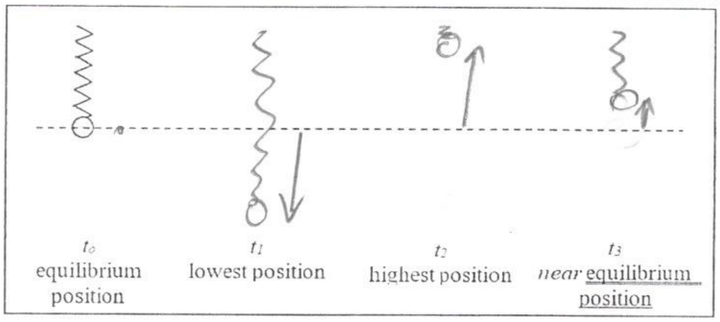
SPH3U: Good Vibrations

A: Amplitude and Period of Oscillations

Your teacher will use a metal spring (or elastic) and a small attached object attached to demonstrate *oscillation*, which is an example of periodic motion. This is motion that repeats itself in a regular pattern.

1. In the diagram to the right, draw three images of the spring and moving object at the indicated moments.

2. Draw a vector for each moment in time carefully showing the object's displacement from equilibrium.



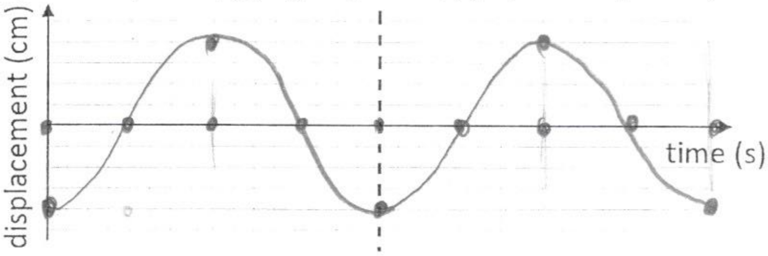
The largest displacement of the object from equilibrium is the *amplitude*. A *cycle* is one complete oscillation, starting and ending at the same position after completing one whole motion. The time to complete one cycle is the *period* (T).

3. As a class, measure the *amplitude* and *period* of the oscillating object.

amp ≐ 9 units
perod ≈ 2 s

4. Plot ***two*** full cycles of the oscillation on the graph below. Each cycle should consist of five points: (a) lowest position, (b) equilibrium position, (c) highest position, (d) equilibrium position, and finally back to (e) lowest position.

Draw a smooth curve



5. How many cycles does your object go through in one second of time? You can use your data from question #3.

0.5 cycles per second

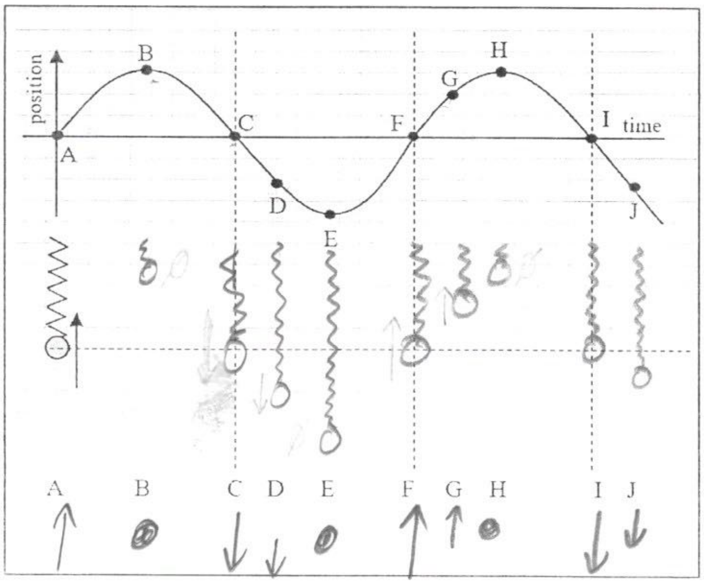
The *frequency* of periodic motion (*f*) is the number of cycles of the motion per unit of time, given by $f = (\# \text{ of cycles})/\text{time}$. The units of frequency are *hertz* (Hz) and mean "cycles per second". Frequency and period are related by: $f = 1/T$ or $T = 1/f$.

B: Phase

Consider the graph, showing an oscillating object.

1. Draw the position of the object and spring according to the graph for each labeled moment in time.

2. Draw an *instantaneous* velocity vector beside each image of the object. If it is zero, write a zero. (below)



The *phase* of a particle in periodic motion can be described by its position and velocity. When two points have the same position and velocity, we call them *"in phase"*, otherwise they are *"out of phase"* When two states are half a cycle apart they have *opposite phase*.

3. Find all the points which have the same phase as:

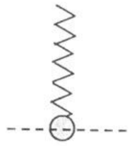
B: H	C: I	D: J

4. Find all the points which have the opposite phase as:

A: C	B: E	D: G

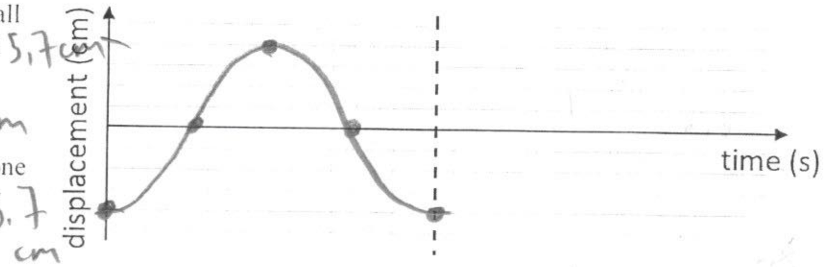
SPH3U: Good Vibrations Homework   Name:

A: The Follow the Bouncing Ball



A ball attached to a spring. You pull down the ball and release it. It vibrates up and down with a steady, repeating motion. You measure that it takes 0.73 s to complete one cycle of its motion. During that time, the farthest distance it travels from the equilibrium position is 5.7 cm.

1. **Represent.** Draw a position-time graph for the ball starting at the moment you release the ball. Label and give the values for its period and amplitude.



period = 0.73 s   amp = 5.7 cm

2. **Calculate.** What distance does the ball travel in one cycle? What is its average speed?

5.7 cm × 4 = 22.8 cm   speed = 22.8 cm / 0.73 s = 31.2 cm/s

3. **Calculate.** What is the displacement of the ball during one cycle? What is its average velocity?

zero   zero

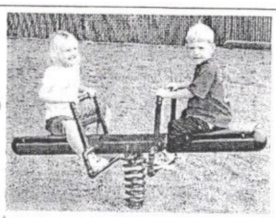
4. **Reason.** At which moments is the ball traveling the fastest? The slowest?

Top and bottom

5. **Calculate.** What is the frequency of the ball's motion?

$F = \frac{1}{t}$ $F = \frac{1}{0.73} \doteq 1.4$ cycles/second.

B: The Teeter-Totter



Who doesn't like playing on the teeter-totter in the local park? Two kids are bouncing away and you measure that they bounce up and down 10 times in 17.9 s.

1. **Calculate.** What is the period and frequency of their motion?

period = 17.9 s / 10 cycles = 1.79 cycles/sec. $F = \frac{1}{1.79} = 0.56$ s/cycle.

2. **Reason.** Two larger kids get on and start bouncing. Will the period increase or decrease? Explain.

Increase – heavier kids will cause more displacement, so more time

3. **Reason.** With the new, older kids, the period of the teeter-totter is now double what it was before. Explain (don't calculate) how the frequency will change.

Frequency will be halved... period & frequency are inversely proportional $F = \frac{1}{t}$ $t = \frac{1}{F}$

4. **Reason.** How does the phase of the two kids who are bouncing together on the teeter totter compare with one another?

Opposite phase – always a half cycle apart.

SPH3U: Making Waves

In our work so far, we have had only one particle to keep track of. Imagine now that we connect a whole series of particles together such that the movement of one particle affects the others around it. When we start a vibration in one particle, an effect will travel from one particle to the next – a *wave* has been created.
We will use an online wave simulator to investigate this behaviour: phet.colorado.edu/en/simulation/wave-on-a-string

A: Particle Motion

Make a single pulse, which is single bump above the equilibrium position.

Important Settings:
-"Pulse" mode
-"Damping" to none
-Fixed End

using step feature

Pro tip: to get rid of a wave, increase damping briefly

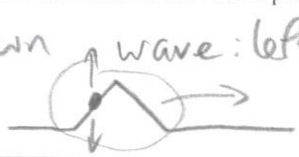
or set to manual

1. Describe the motion of the pulse in the wave machine.

Travels with same shape to other end, then flips to other side & returns.

2. Watch one green particle carefully as the pulse travels by it. Compare the direction of a particle's motion with the direction of the wave pulse's motion. Draw a simple illustration.

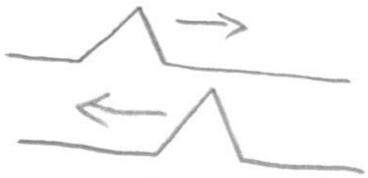
Particle : up/down wave : left/right



In a *transverse wave*, the particles of the medium oscillate in a direction that is perpendicular to the direction of the wave motion.

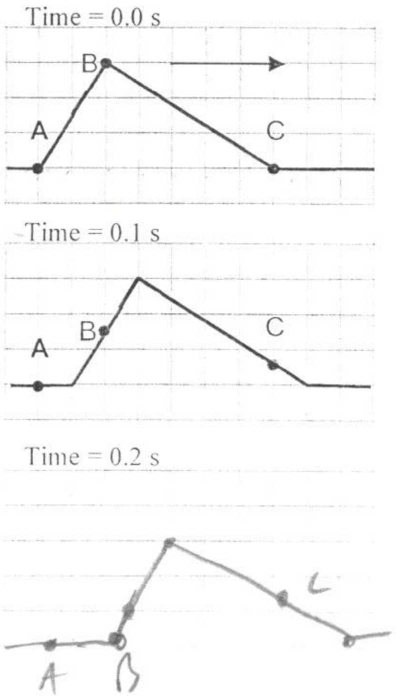
3. Now switch your settings to "Loose End", and send another pulse. Use a diagram to show how the waves with a fixed end and loose end differ.

Important Settings:
-Loose End



does not change sides (top to bottom)

4. A "snapshot" of a transverse pulse travelling through a wave machine is shown in the diagram to the right. The pulse is traveling to the right at 50 cm/s. Three particles in the medium are marked with tape, A, B, and C. Each square in the diagram is 5.0 cm.



(a) Between 0.0 s and 0.1 s, in what direction did each particle move?

A: Ø B: UP C: DOWN

(b) How in what direction did the "peak" of the wave move? How far did it travel?

RIGHT BY 5.0 cm

(c) Draw the pulse and label the position of the three particles at the time of 0.2 s.

(d) At what time will the complete pulse have passed through particle C?

0.7 s

(e) What is the total distance that particle C will move by the time the pulse completely passed? 15 + 15 = 30 cm

(f) At what time will particle B return to the rest position? 0.2 s

(g) What is the average velocity of particle B between t = 0s and t = 0.1 s?

7.5 cm / 0.1 s = 75 cm/s

move to next page

So what exactly is a wave? What is travelling down the string? We'll discuss...

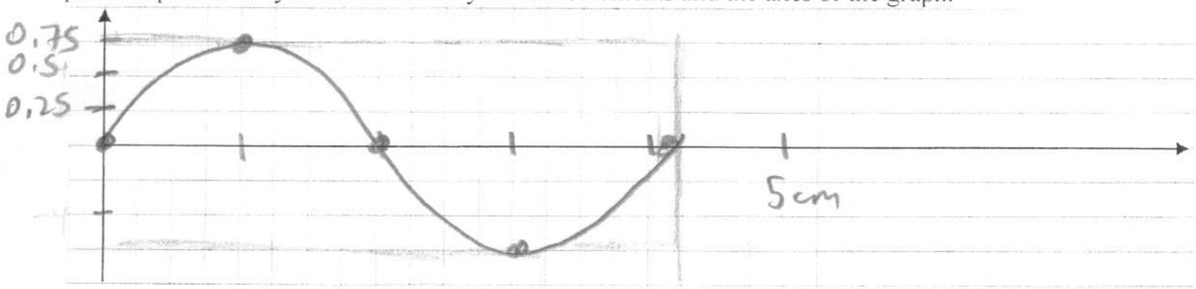
B: The Periodic Wave

Use the settings to the right, and create a single gentle, continuous, periodic wave.

A continuous or *periodic wave* has two parts that we call the *crest* and *trough* of the wave which correspond to the top of the positive and bottom of the negative displacements. The distance the wave travels in one cycle is equal to the distance between the two nearest points of equal phase. This distance is called the *wavelength* and is represented by the greek letter *lambda* (λ). To measure such a distance, you can choose two adjacent crests as the nearest points of equal phase.

Important Settings:
-"Oscillate" mode
-"Damping" to none
-No End

1. Freeze the wave using the pause button. Turn on rulers and measure the amplitude and wavelength of the wave. Then sketch a position picture for your wave. Label your measurements and the axes of the graph.



AMP: 0.75 cm

WAVELENGTH 4.2 cm

2. Choose one green particle and find the period of the oscillations – in other words, how long for one cycle. Caution – this moves quickly, and trying to measure the time for a single oscillation is not very accurate…try to find a more accurate method.

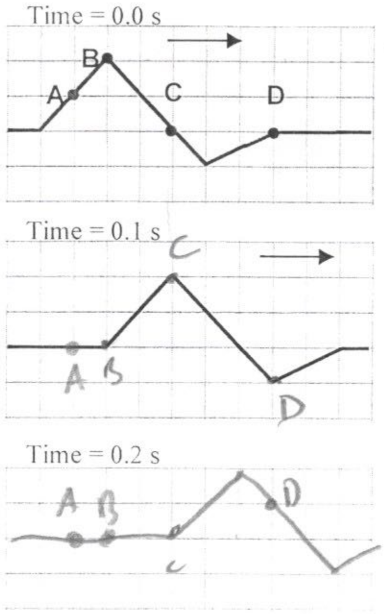
10 cycles: 6 seconds period = $\frac{6.7 s}{10 \text{ cycles}}$ = 0.67 cycles/sec.

* calculate frequency & compare to setting

SPH3U: Making Waves Homework Name:

A: Tracking the Particles

A pulse travels through a spring as illustrated in the diagram to the right. Four particles of the spring are labeled A, B, C and D. (Imagine a piece of tape is attached to label those particles.) Each box of the gird represents a distance of 5.0 cm.



1. **Represent.** The pulse is shown in the second diagram at a time of 0.1 s after the first. Label the four particles A, B, C and D in the second diagram.
2. **Calculate.** What is the speed of the wave?

   5 cm/0.1s = 50 cm/s
3. **Interpret.** What distance did particle B move in the interval between 0 and 0.1 s?

   10 cm
4. **Interpret.** At the time of 0 s, what direction is particle A moving in?particle C?

   down up
5. **Represent.** Draw the pulse at a time of 0.2 s. Label the four particles A, B, C and D.
6. **Calculate.** At what time does the pulse completely pass through particle D?

   0.35 s
7. **Calculate.** What distance had particle D traveled once the pulse has completely passed by?

   5 + 15 + 10 = 30 cm
8. **Explain.** Explain why this is a transverse wave.

   particles moving perpendicular to wave direction

SPH3U: Properties of waves in a coiled spring

How do waves and pulses behave in a coiled spring? We'll continue using phet.colorado.edu/en/simulation/wave-on-a-string

A: Ideal Waves and Pulses

As a real wave or pulse travels or *propagates* through a medium it may gradually change.

1. Create a single pulse with a fixed end, and set the "Damping" to somewhere in the middle. Describe how the pulse changes while it travels back and forth through the medium.

Gradually reduced in amplitude until it disappears.

Real waves lose energy as they travel causing their amplitude to decrease. The shape of a pulse also changes – often spreading out. We will always ignore these important and realistic effects and instead focus on studying *ideal waves* in a medium that does not lose energy or cause wave shapes to change.

Set the damping to **none** for the rest of the investigations.

B: Speed of Waves

Make a pulse which will be your "standard" pulse. Record the amplitude and width, and get a feel for how quickly it travels back and forth through the medium.

amp = 0.75 cm width = 0.4 s

1. Can you make your pulse travel slower? Faster? Vary the pulse in a number of different ways and make a rough judgement about the speed – does it appear to travel back and forth faster, slower or the same? Remember to only vary one thing at once.

Characteristic to Vary	Observations
Amplitude	Does not change speed
Wavelength (pulse width)	Does not change speed
Tension	changes speed of wave

2. Use a ruler and timer to measure the distance and time the wave travels to a fixed end. Then calculate the wave speed.

Tension	Distance	Time	Speed
High	7.6 cm	1.6 s	4.75 cm/s
Medium	7.6 cm	2.3 s	3.3 cm/s
Low	7.6 cm	6.2 s	1.2 cm/s

D: Wavelength and Frequency

Create a wave (set to oscillate), set the frequency and pause the wave once you have a full wavelength.

1. How are wavelength and frequency related?

Bigger frequency <-> smaller wavelength

Frequency	Wavelength
0.6 Hz	2.2 cm
1.2 Hz	1.2 cm
2.4 Hz	0.6 cm

2. Write the relationship between frequency f and period T

$F = \frac{1}{\text{period}}$ $\text{period} = \frac{1}{\text{frequency}}$

use 1▶

E: Speed, Wavelength and Frequency

Let's explore the relationship between speed, wavelength, frequency and period. The diagrams below indicate a disc moving in one complete circle, creating a full wavelength.

1. What fraction of a cycle does the circle/piston move between each picture? $\frac{1}{4}$
2. What fraction of a wavelength do we see in each diagram? Label these wavelengths on the diagrams. $\frac{1}{4}$
3. How far does a wave travel in the time of 1 period? 1 wavelength
4. Write an equation for the speed of the wave using its period T and wavelength λ? Hint: velocity = $\frac{\text{distance}}{\text{time}}$

$V = \frac{d}{t}$ $V = \frac{\text{wavelength}}{\text{period}}$

The speed of a wave v (m/s) can also be expressed with the *universal wave equation*, $v = f\lambda$, with frequency f (Hz) and wavelength λ (m). Note that a change in frequency affects the wavelength and vice versa, but **do not affect the wave speed.**

5. Set your wave to oscillate, press play and pause it when you see one full wavelength. Calculate the wave speed using the universal wave equation: $v = f\lambda$. Compare your speeds to those on the previous page. Are they the same? pretty close

Tension	wavelength	frequency	Speed
High	4.2 cm	1.5	6.3 cm/s
Medium	2.6 cm	1.5	3.9 cm/s
Low	0.9 cm	1.5	1.35 cm/s

E: Reflection of Waves & Pulses

How to pulses reflect off a boundary?

1. Set a pulse towards a loose end and observe its behavior. What happens after the fixed end? What happens after the loose end? Draw the reflected pulse below.

2. In which situation would you say the pulses or waves reflect *in phase* and in which situation would you say they reflect in *opposite phase.*

Loose end – in phase

Fixed end – opposite phase.

★ add some damping

F: Standing Waves

Standing waves are produced when certain points (not all points) along the wave are not moving.

1. Try to produce different standing waves in your coiled spring by playing with the frequency. What was the frequency of your hand in order to produce this pattern? Draw each pattern produced and write down the frequency required to produce the pattern.

★ Fixed end.

Don't do.

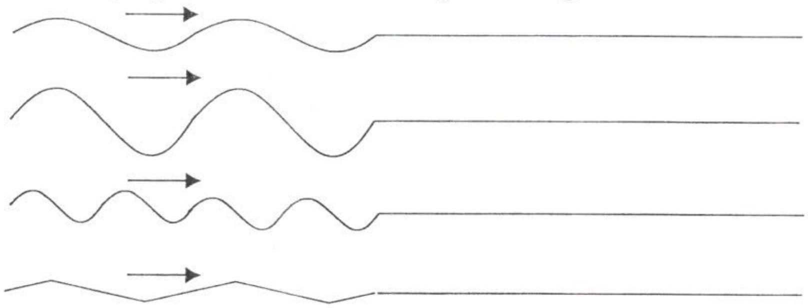
SPH3U: Properties of Waves Homework

Name:

1. **Reason.** Four different waves travel along four identical springs as shown below. All begin travelling at the same time.

   (a) Describe what is different about each wave.

   shape
   wavelength
   period



   (b) Rank the amount of time it will take for the four waves to arrive at the ends of the springs. Explain your reasoning.

   Same – speed only affected by tension

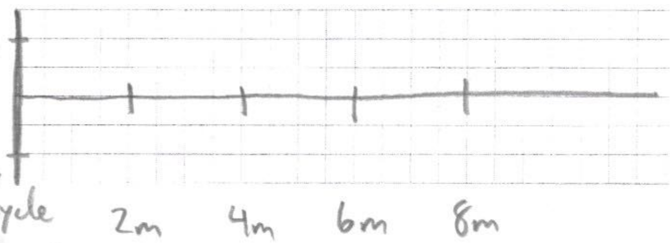
2. **Reason.** Your friend is sending a wave along a spring and says, "I want the wave to reach the other end of the spring in less time, so all I have to do is shake my hand faster." Do you agree with your friend? Explain.

   No. see (b) above

3. **Represent.** You have a spring stretched out 7.3 m along the floor between you and your friend. You shake your hand side-to-side and create a wave that travels down the spring. Your hand starts at the equilibrium position and moves 10 cm to the right, back to the equilibrium, 10 cm to the left and back to the equilibrium position. Your hand executes this three times in a row in 1.2 seconds. Your friend times that it takes 0.84 s for the wave to travel from your hand to your friend's.

   Last.

   (a) **Represent.** Sketch a graph for the wave. Label all the quantities in the description.



   (b) **Calculate and Explain.** What is the period of this wave? Explain how you chose which time values to use.

   period $= \frac{1.2\ s}{3} = 0.4$ s/cycle

   $P = \frac{1}{f}$ $\quad v = f\lambda$ $\quad v = \frac{d}{t}$

   frequency = 2.5 cycles/s

   (c) **Calculate and Explain.** What is the speed of the wave in this spring? Explain how you chose which distance and time values to use.

   $V = \frac{7.3\ m}{0.84\ s} = 8.7\ m/s$

   (d) **Calculate and Explain.** What is the amplitude of the wave? Explain how you chose which distance values to use.

   10 cm

   (e) **Calculate and Explain.** What is the wavelength of this wave? Explain how you chose which values to use.

   $V = \frac{\text{wavelength}}{\text{period}}$ $\quad 8.7 = \frac{\lambda}{0.4}$ $\quad \lambda = (8.7)(0.4) = 3.48\,m$

   ~~(f)~~ **Calculate and Explain.** What distance does a particle in the wave move once the wave has passed by?

   (g) **Represent.** Label all the quantities you calculated on your sketch above.