Physics I

April 27 – May 1

Time Allotment: 40 minutes per day

Student Name: ________________________________

Teacher Name: Mr. Bailey

Packet Overview

Date	Objective(s)	Page Number
Monday, April 27	Angular Momentum	2-6
Tuesday, April 28	Pendulum Lab: Day 1	7-9
Wednesday, April 29	Pendulum Lab: Day 2	10-11
Thursday, April 30	Pendulum Lab: Day 3	12-13
Friday, May 1	1. Graphing Periodic Motion 2. Introduction to Wave Anatomy	14-17

Additional Notes:

Khan Academy is a great online resource for physics, though this packet does not require access to the Internet. The Physics videos can help with rotational motion concepts, while the algebra and geometry videos can help with the concept of radians.

Another great resource is a YouTube channel called “Doc Schuster”. Dr. Schuster is a high school physics teacher in St. Louis who makes great video lectures with magic markers and paper. His playlist “AP Ch 13 – Periodic Motion and Resonance of Oscillators” will be helpful in this new unit.

Academic Honesty

I certify that I completed this assignment independently in accordance with the GHNO Academy Honor Code.

Student signature:

____

I certify that my student completed this assignment independently in accordance with the GHNO Academy Honor Code.

Parent signature:

____

Monday, April 27

Physics Unit: Rotational Motion
Lesson 4: Angular Momentum
Requirements: Read p. 213-214. Complete the guided worksheet below. Do Problems 51 and 52 on p. 222.

Objectives: Be able to do this by the end of this lesson.
1. Define angular momentum. Derive its equation.
2. Compare angular momentum to linear momentum.
3. Explain why ice skaters can spin faster when they tuck their arms toward their body.

Introduction to Lesson 1: Why is it the case that when an ice skater tucks her arms close to his body or a diver tucks her arms and legs towards her body, they both start spinning *faster*? We'll learn today that the reason is because each are changing their rotational inertia, and in turn, their angular momentum. Today's lesson is focused on defining angular momentum, comparing it to linear momentum, and solving problems using angular momentum.

Important information for tomorrow's lesson! On Tuesday, Wednesday, and Thursday, you'll get to do another lab! In preparation for the lab, gather the following materials today so you'll be able to make the pendulums for the lab: a stopwatch or timer, string or fishline, coins or small weights, a ruler, tape, and a stable place to attach the string to that will allow the weight to swing freely. Feel free to flip ahead to the materials page of the lab for Tuesday's lesson if you'd like to see more details to prepare.

1. Write the equation for linear momentum below.

2. The rotational analog to linear momentum is ______________________ momentum.

The symbol we use for this quantity is _____.

3. For an object rotating on a fixed axis, we can define this quantity as __________________ (Eq. 8-18).

4. Do dimensional analysis on the equation you wrote above? What are the units for angular momentum?

5. How can we rewrite Newton's second law for rotating objects?

6. What is another way we can write Newton's second law in terms of angular momentum?

7. Is angular momentum a conserved quantity?

8. Write the law of conservation of angular momentum.

9. Take a look at the following drawing. Label which skater has a greater angular velocity, and which has a greater angular momentum. Then use the first full paragraph on the top of p. 214 to write 3 sentences explaining why the ice skater spins faster when she takes her arms from being outstretched to bringing them close to her body.

10. Do Exercise C on p. 214. (You can check your answer with the book's on p. 225).

11. Label which parts of the diver's jump is she spinning the fastest? In which part(s) is she spinning slowest? Why?

12. In the space below, write the question for Example 8-15: Object rotating on a string of changing length on p. 214. Draw Figure 8-30. Then work all steps to get the solution. Try to work it on your own before looking at the textbook's solution!

13. Do Exercise D on p. 214. (You can check your answer with the book's on p. 225).

Physics I
April 27 – May 1

Problems on p. 222

51)

1. Draw your diagram here

2. Write down all your known and unknown variables here.

3.
Write down all equations you need here.

4. Show your work solving the problem here.

5. Final answer with units

52)

<table>
<tr><td colspan="2">1. Draw your diagram here</td><td colspan="2">2. Write down all your known and unknown variables here.</td></tr>
<tr><td rowspan="2">3.
Write down all equations you need here.</td><td colspan="3">4. Show your work solving the problem here.</td></tr>
<tr><td colspan="3">5. Final answer with units

a) b)</td></tr>
</table>

Physics I
April 27 – May 1

Tuesday, April 28

Physics Unit: Vibrations and Waves
Lesson 2: Pendulum Lab
Requirements: Read the pendulum lab in your packet carefully.

Objective: Be able to do this by the end of this lesson.
1. Gather all materials needed for lab.
2. Construct pendulum.
3. Begin collecting timing data and measuring pendulum lengths.

Introduction to Lesson 2 and New Unit on Waves and Vibrations
Today we're going to do a lab!! Before we start our new unit on periodic motion and mechanical waves, I want you to be able to see what periodic motion looks like and plot periodic motion on a graph. Then we can move deeper into wave theory and derive equations to explain and predict the nature of wave motion. The goal of today is to construct one pendulum and practice observing and timing its motion. Of course you've seen swinging pendulums many times in your lives, but I want you to really *look* at it this time, knowing that in a few weeks, you'll be learning equations to describe a swinging pendulum that are so unimaginably beautiful, you'll never be able to look at a pendulum the same way again.

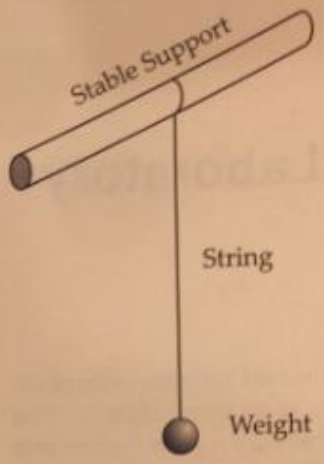
1. First read the following introduction carefully and gather all materials the author asks:

Introduction

Galileo Galilei, who frequently and famously stressed the importance of experimental investigations, had exceptional gifts as an experimentalist. This appendix offers the reader the opportunity to carry out a set of experiments in pendular motion using easily accessible materials. The first three experiments are quite straightforward and are no doubt comparable to those in many manuals for physics labs. The fourth experiment, however, is more challenging in that (1) it involves an attempt to replicate an experiment that Galileo actually reported, and (2) if carefully performed, the experiment should yield results that may provide some interesting historical information as well as a surprise and a significant insight.

The materials needed for the experiments are:

- Some string, fishline, or heavy thread.
- A stopwatch and ruler.
- Three small weights, for example, weights used to hold down a fishing line. Alternatively, three identical coins, for example, three quarters (25-cent pieces) will suffice.
- Adhesive or duct tape for attaching the weights to the string.
- A stable support from which to suspend the pendulums formed from the weights and string. The support could be a one foot long two-by-four or a metal rod clamped to a sturdy table, or any comparable object that can be made sufficiently stable that it will not be affected by the swing of a pendulum suspended from it. An ideal support would be metal rod held in a vise.



With these materials one can easily construct a device such as that shown in the accompanying diagram.

As we saw in the chapter on Galileo, he made the striking claims that the period of a pendulum's motion is independent of the weight of the pendulum and is also independent of the arc through which it is displaced. Moreover, he not only claimed that its period of motion depends on the length of the pendulum, but also specified that for pendulums of lengths L_1 and L_2, their periods will be related to their lengths according to the equation

$$\frac{T_1}{T_2} = \frac{\sqrt{L_1}}{\sqrt{L_2}}.$$

This means that a pendulum four times longer than another will swing with a period twice as long as that of the shorter pendulum. We will test each of these claims.

2. After reading, make a list of all the possible ways you can vary your pendulum. According to the passage above, which of these ways does not affect the period of the pendulum?

3. How does Galileo claim the lengths of pendulums and their periods are related?

4. Define frequency and period. Go back and look them up in the textbook or your notes if you forget. How can you describe the frequency and period of a swinging pendulum?

5. Follow the instructions for Experiment 1. Fill in both of the tables below to record your data.

Experiment 1

Before beginning this experiment, reflect on what factors could influence the period of swing of a pendulum. Also reflect on what difficulties Galileo might have encountered in performing experiments that would test his claims. For example, because Galileo lived centuries before the ready availability of electronic stop watches, he had to use far more elementary devices for time measurement. A striking example of this is that for some experiments he used his pulse as a measure of equal units of time. At other points, he used water clocks.

Construct a pendulum one meter long by taping a string to a single quarter (25-cent coin) or some other small weight. The weight at the end of the string is called the bob. Measure the length of the string from the point of attachment at the top to the middle of the bob. Tape a sheet of paper to the floor below the low point of the pendulum and draw a line directly below the weight and perpendicular to the arc through which the weight swings. Sighting the vertical line from the center of the bob to the floor, displace the pendulum 10 centimeters to the left of its vertical rest position, and allow it to swing for 10 complete cycles. Use of a large carpenter's square will help

Experiment 2 301

in setting this up. By sighting on the line on the paper, time 10 of these cycles. (Note that one complete cycle will pass the mark twice.) Repeat this observation for displacements of 20, 30, and 50 cm. Be sure to divide your times by 10. Record your results below.

For 10 cm displacement, period of swing = __________

For 20 cm displacement, period of swing = __________

For 30 cm displacement, period of swing = __________

For 50 cm displacement, period of swing = __________

6. Now divide each displacement by the period you recorded to get a ratio of displacement to period.

$\frac{10cm\ displacement}{Period} =$	
$\frac{20cm\ displacement}{Period} =$	
$\frac{30cm\ displacement}{Period}$	
$\frac{50cm\ displacement}{Period}$	

7. What do you notice about the ratios as the displacement increases?

Physics I
April 27 – May 1

Wednesday, April 29

Physics Unit: Vibrations and Waves
Lesson 3: Pendulum Lab Continued
Requirements: Follow the instructions in the guided worksheet below.

Objective: Be able to do this by the end of this lesson.
1. Discern whether adding more weight to the pendulum will make it swing faster.
2. Explore how different ratios of string lengths give different ratios of swinging periods.

Introduction to Lesson 3
Today we're going to work through two more pendulum experiments. What will happen if we make the pendulum weights heavier? What will happen if we make the string lengths shorter?

1. Follow the instructions for Experiment 2. Fill in both tables below as you collect your data.

Experiment 2

Construct a heavier pendulum bob by doubling the weight (e.g., by taping together two quarters instead of one), again making the pendulum length equal to one meter. Repeat the same set of measurements for this pendulum and record your results.

For 10 cm displacement, period of swing = ___________

For 20 cm displacement, period of swing = ___________

For 30 cm displacement, period of swing = ___________

For 50 cm displacement, period of swing = ___________

What conclusions can you draw from these data? After comparing your data for this experiment with the data from Experiment 1, can you draw any additional conclusions?

2. Now divide each displacement by the period you recorded to get a ratio of displacement to period.

$\frac{10cm\ displacement}{Period} =$	
$\frac{20cm\ displacement}{Period} =$	
$\frac{30cm\ displacement}{Period}$	
$\frac{50cm\ displacement}{Period}$	

3. What do you notice about the ratios as the displacement increases?

4. What do you notice about your data from Experiment 2 as compared with Experiment 1? Does the amount of weight on the end of the pendulum affect the period?

5. Follow instructions for Experiment 3 and fill in the blanks below.

Experiment 3

In this experiment you are to construct two pendulums such that when the first swings four times, the second will swing twice. Using two identical weights, make the first pendulum 20 centimeters in length and the second 80 centimeters in length, measuring from the point of suspension to the center of the bob. The two bobs should be of equal weight. Measure the periods of swing, T_1 and T_2, for these two pendulums, using the same techniques that you employed previously. At this point, we are testing Galileo's claim that the ratio of the periods (times) of swing of any two pendulums is equal to the ratio of the square roots of the lengths of their suspensions, or

$$\frac{T_1}{T_2} = \frac{\sqrt{L_1}}{\sqrt{L_2}}$$

Compare this with your own data:

Length of first pendulum = L_1 = 20 centimeters.

Length of second pendulum = L_2 = 80 centimeters.

Measured period of first pendulum = T_1 = ____________

Measured period of second pendulum = T_2 = ____________

Calculate the ratio of the square roots of the measured lengths:

$$\frac{\sqrt{L_1}}{\sqrt{L_2}} = \_\_\_\_\_\_\_\_\_\_\_\_$$

Calculate the ratio of the measured periods:

$$\frac{T_1}{T_2} = \_\_\_\_\_\_\_\_\_\_\_\_$$

6. Are the two ratios equal? If so, does that mean Galileo was correct? If they're not, was there some experimental error that you could account for? Could you re-do the experiment in some way to make the ratios equal?

Thursday, April 30

Physics Unit: Rotational Motion
Lesson 4: Pendulum Lab Continued
Requirements: Follow the instructions on the guided worksheet below.

Introduction to Lesson 4: Let's read a passage from Galileo's *Two New Sciences* and do one last pendulum experiment today that again deals with ratios of string length and periods of swinging. If you get confused about how to fill in the table on the next page, read the directions again carefully. If you're still confused, send me an email or come to my Zoom meetings.

Experiment 4

In his *Two New Sciences*, Galileo has his spokesperson, Salviati, describe an interesting experiment with pendulums.

> Seeing that you like these novelties so well, I must show you how the eye, too, and not just the hearing, can be amused by seeing the same play that the ear hears.
>
> Hang lead balls, or similar heavy bodies, from three threads of different lengths, so that in the time that the longest makes two oscillations, the shortest makes four and the other makes three. This will happen when the longest contains sixteen spans, or other units, of which the middle [length] contains nine, and the smallest, four. Removing all these from the vertical and releasing them, an interesting interlacing of the threads will be seen, with varied meetings such that at every fourth oscillation of the longest, all three arrive unitedly at the

same terminus; and from this they depart, repeating again the same period.[1]

The goal of Experiment 4 is to test the claims Galileo made in this paragraph, in particular, to duplicate this experiment. To do this construct three pendulums, one of length 20 cm, the second of length 45 cm, and the third of length 80 cm. (Note that these lengths preserve the ratios among the lengths of the pendulums in the experiment Galileo devised, i.e., $4 \times 5 = 20$, $9 \times 5 = 45$, and $16 \times 5 = 80$). The weights can be the same in all three pendulums.

Part 1. From the information provided by Galileo, it is possible to calculate what the relationships are between the periods of these pendulums. The information given entails that for some time period X, the first will swing 4 times, the second 3 times, and the third 2 times. From this it is evident that $X = 4T_1 = 3T_2 = 2T_3$. Use the information in this equation to derive Galileo's reported results for the ratios between the periods and enter it in the first column in Table I, below. For example, from knowing that $4T_1 = 3T_2$, one can conclude that $\frac{T_1}{T_2} = \frac{3}{4}$. Enter this value at the top of the first column. Then use the same method to calculate the values for $\frac{T_1}{T_3}$ and $\frac{T_2}{T_3}$. Enter these values.

Part 2. Make your own measurements of the three periods using your pendulums of lengths 20 cm., 45 cm., and 80 cm. After getting empirical values for T_1, T_2, and T_3, calculate the ratios between these values and enter them in the second column of Table I, below.

T_1 = Period of pendulum 1 (length = 20 cm) = ____________

T_2 = Period of pendulum 2 (length = 45 cm) = ____________

T_3 = Period of pendulum 3 (length = 80 cm) = ____________

Part 3. It is also possible to use the formula

$$\frac{T_x}{T_y} = \frac{\sqrt{L_x}}{\sqrt{L_y}}$$

to calculate the ratios between the periods. Calculate these theoretical values from the lengths of the three pendulums. Enter your results in the third column of the table.

TABLE I

	Values calculated from Galileo's report	Values calculated from your measurements	Values derived theoretically from the lengths
$\frac{T_1}{T_2}$	____________	____________	____________
$\frac{T_1}{T_3}$	____________	____________	____________
$\frac{T_2}{T_3}$	____________	____________	____________

Do you notice any patterns when looking at your table? Does your data match Galileo's? If not, why?

Friday, May 1

Physics Unit: Rotational Motion
Lesson 5: Graphing Pendulum Motion
Requirements: Follow the instructions on the guided worksheet below.

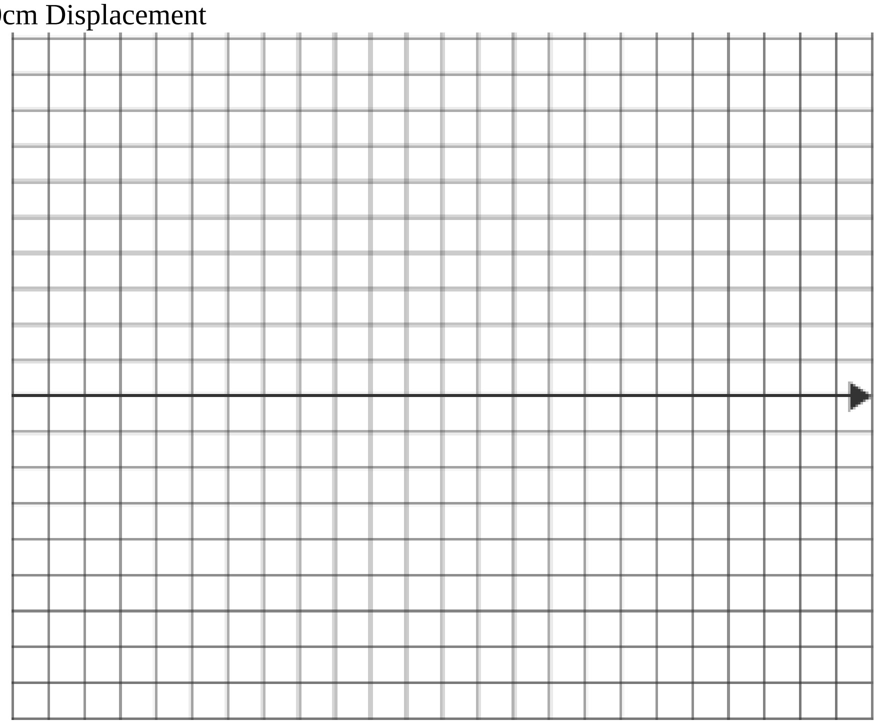
Objectives:
1. Make position vs. time graphs of observed periodic motion of pendulum swings.
2. Label parts of a mechanical wave.

Introduction to Lesson 5: Today we're going to put together the things we have learned this week as well as graph the motion of our pendulums. The work you do today will count as your weekly minor assessment. Email or come to Guided Instruction on Zoom if you need help with anything.

1. Go back to your 1m pendulum that you used in Experiment 1. Pull it back 10cm and watch it swing back and forth. Now imagine what it would look like to graph the motion of the weight at the end of the pendulum as it swings back and forth through time. What shape would it take? Describe with words and with a sketch.

2. Now let's say that the resting position of the pendulum is 0cm. When you pull the pendulum back 10cm, you have displaced it positive 10cm. When it swings back to the starting point, its displacement is once again 0cm, and finally when it swings to the other side, its displacement becomes negative 10cm. Plot those 3 points on the graph below, and try to connect the dots with smooth curves.

x = 10cm Displacement

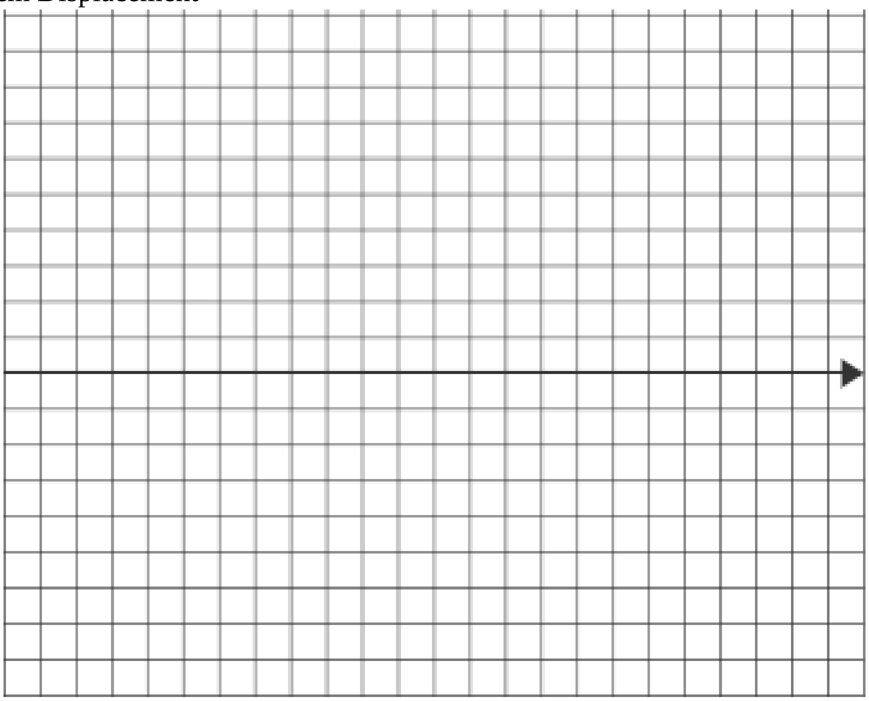


Time (make your own scale in tenths of seconds)

x = -10cm

3. Make the same graph when you pull the pendulum back 20cm. This time, graph 2 periods (when the pendulum swings back and forth two complete times).

x = 20cm Displacement

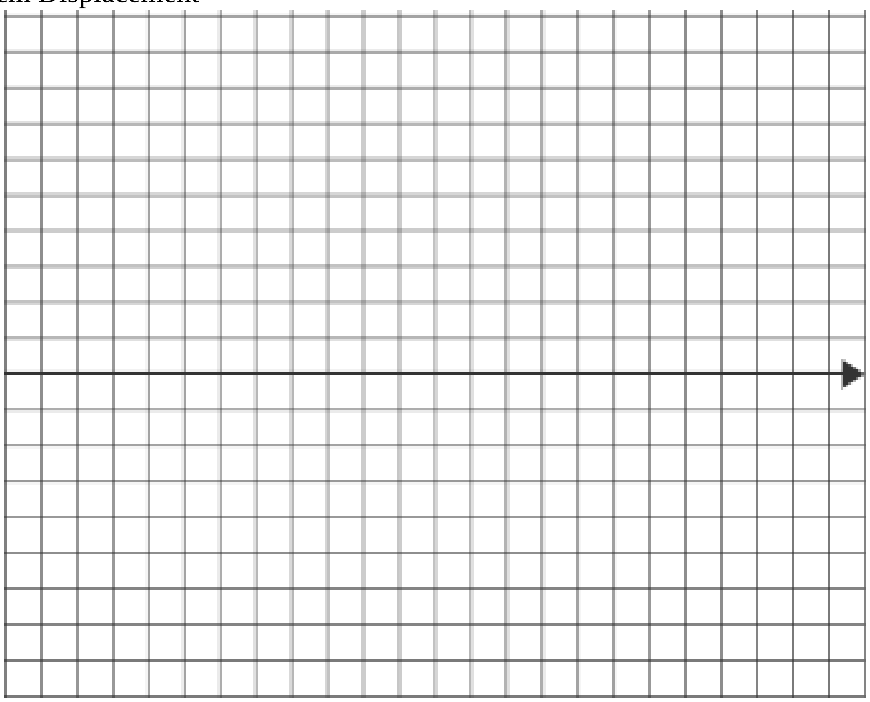


Time (make your own scale in seconds or tenths of seconds)

x = -20cm

4. Finally, make one last graph for your pendulum when you pull the weight back 30cm and let it swing. Graph 3 periods.

x = 30cm Displacement



Time (make your own scale in seconds or tenths of seconds)

x = -30cm

5. When you connected the dots with smooth curves in these graphs, did it look like a function you recognized? Which one?

6. How long did it take the 10cm, 20cm, and 30cm displacements to swing back to their original locations?

10cm:

20cm:

30cm:

7. As a last item, let's take a look at some wave anatomy. Read the next page carefully, fill in the blanks, and have a great weekend!

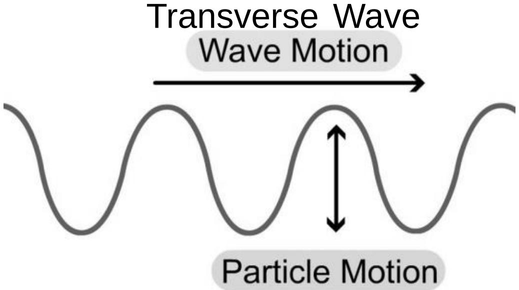
Waves: Introduction and Types

Name ________________

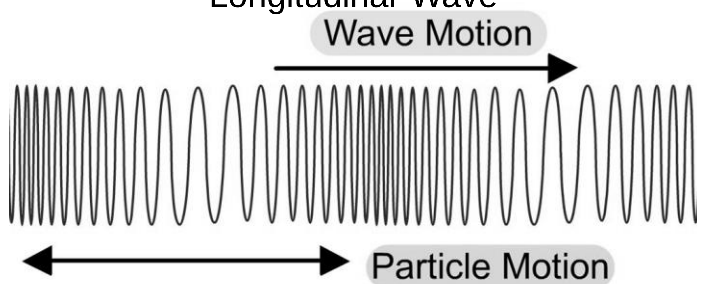
Instructions: Read through the information below. Then complete the statements at the bottom of the page using the BOLD words from the page.

A wave is a transfer of energy through a medium from one point to another. Some examples of waves include; water waves, sound waves, and radio waves. Waves come in two different forms; a **Transverse** Wave which moves the medium *perpendicular* to the wave motion, and a **Longitudinal** Wave, which moves the medium *parallel* to the wave motion.

Transverse Wave



Longitudinal Wave

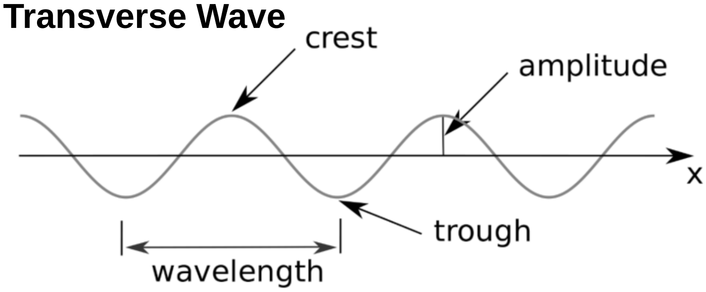


Examples of Transverse waves would be a vibrating guitar string or electromagnetic waves, while an example of a Longitudinal wave would be a "Slinky" wave that you push and pull.

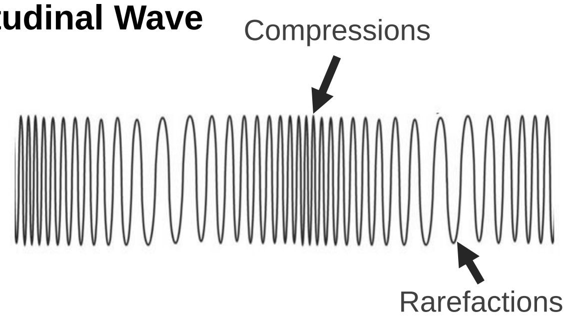
Waves have several properties which are represented in the diagrams below. In a Transverse wave the **Crest** and Troughs are the locations of maximum displacement up or down. The **Amplitude** is the measurement of maximum displacement. The **Wavelength** is the distance of one complete wave cycle. For example; the distance from crest to crest or trough to trough would be 1 wavelength.

In a Longitudinal wave, areas of maximum displacement are known as **Compressions** and **Rarefactions**. The stronger the wave, the more compressed and spread out the wave medium becomes.

Transverse Wave



Longitudinal Wave



Fill in the statements using the BOLD words from the above information.

1- Wave motion that is Parallel to wave direction describes a ___________________ wave.

2- A _________ is the maximum upwards displacement in a Transverse wave.

3- One complete wave cycle is referred to as a ____________________.

4- Wave motion that is Perpendicular to wave direction describes a ___________________ wave.

5- A ______________ or _______________ is the maximum displacement in a Longitudinal wave.

6- An Ocean wave would be an example of a ____________________ wave.

7- The distance from one trough to another trough is called a ____________________.

8- The measurement of displacement is called a wave's ____________________.

51)

Mass of ball $(m) = 0.210\ kg$

Radius of circle $(R) = 1.10\,m$

Angular speed $(\omega) = 10.4\,rad/\sec$

The angular momentum $L = I\,\omega$

$= MR^2\,\omega$

$= (0.210 \times (1.10)^2 \times 10.4)kgm^2/s$

$= 2.64\ kgm^2/s$

Angular momentum $\boxed{L = 2.64\ kg\ m^2/s}$

52)

Mass of grinding wheel $(m) = 2.8\,kg$

Radius of wheel $(r) = 0.18\,m$

Frequency of rotation (f) $= 1500\ rpm$

Or $\omega = \dfrac{1500 \times 2\pi}{60}\ rad/s$

(A) The angular momentum $L = I\,\omega$

$= \dfrac{1}{2} mR^2\,\omega$

Or $L = \left(\dfrac{1}{2} \times 2.8 \times 0.18^2 \times \dfrac{1500 \times 2\pi}{60}\right) kgm^2/s$

Or $\boxed{L = 7.12\ kg\,m^2/s}$

(B) The torque $\tau = \Delta L/\Delta t$

$\tau = \left(\dfrac{0 - 7.12}{6}\right)$N

Or $\tau = -1.19\ m\ N$

Or $\boxed{\tau = -1.2\,m\ N}$