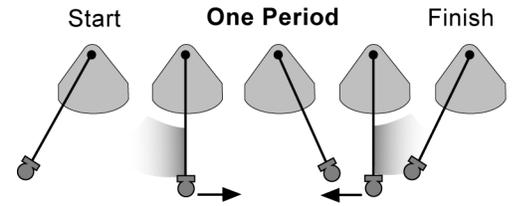


Period and Frequency



The **period** of a pendulum is the time it takes to move through one cycle. As the ball on the string is pulled to one side and then let go, the ball moves to the side opposite the starting place and then returns to the start. This entire motion equals one cycle.

Frequency is a term that refers to how many cycles can occur in one second. For example, the frequency of the sound wave that corresponds to the musical note “A” is 440 cycles per second or 440 hertz. The unit *hertz* (Hz) is defined as the number of cycles per second.



The terms period and frequency are related by the following equation:

$$\begin{array}{c}
 \text{Period (seconds)} \rightarrow \mathbf{T} = \frac{1}{\mathbf{f}} \\
 \text{Frequency (hertz)} \rightarrow \mathbf{f} = \frac{1}{\mathbf{T}} \leftarrow \text{Period (seconds)}
 \end{array}$$

Frequency (hertz) ↓

PRACTICE

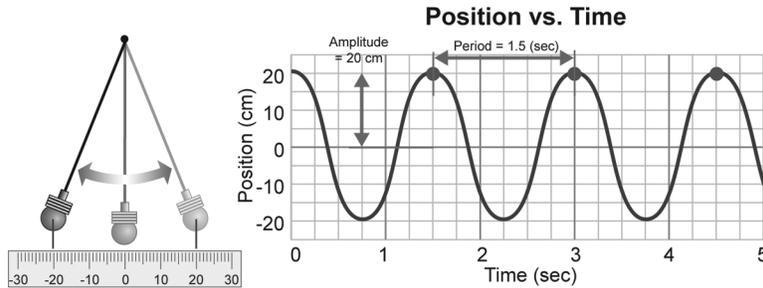
- A string vibrates at a frequency of 20 Hz. What is its period?
- A speaker vibrates at a frequency of 200 Hz. What is its period?
- A swing has a period of 10 seconds. What is its frequency?
- A pendulum has a period of 0.3 second. What is its frequency?
- You want to describe the harmonic motion of a swing. You find out that it take 2 seconds for the swing to complete one cycle. What is the swing's period and frequency?
- An oscillator makes four vibrations in one second. What is its period and frequency?
- A pendulum takes 0.5 second to complete one cycle. What is the pendulum's period and frequency?
- A pendulum takes 10 seconds to swing through 2 complete cycles.
 - How long does it take to complete one cycle?
 - What is its period?
 - What is its frequency?
- An oscillator makes 360 vibrations in 3 minutes.
 - How many vibrations does it make in one minute?
 - How many vibrations does it make in one second?
 - What is its period in seconds?
 - What is its frequency in hertz?

Harmonic Motion Graphs

READ



A graph can be used to show the amplitude and period of an object in harmonic motion. An example of a graph of a pendulum's motion is shown below.



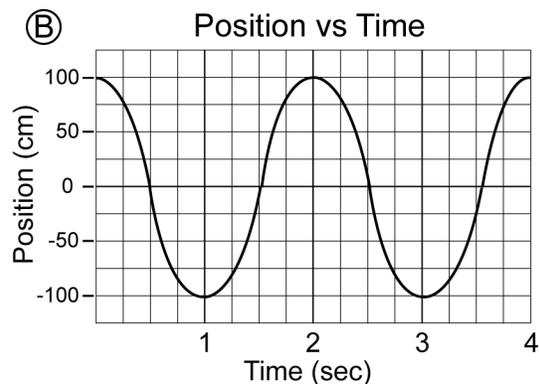
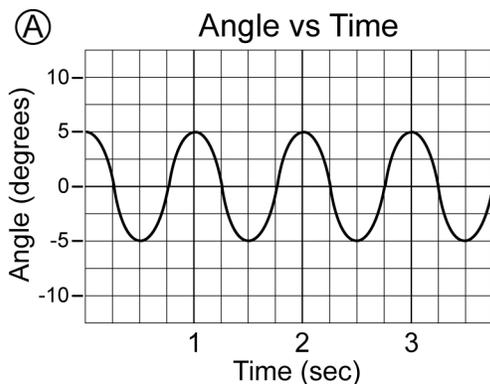
The distance to which the pendulum moves away from this center point is called the **amplitude**. The amplitude of a pendulum can be measured in units of length (centimeters or meters) or in degrees. On a graph, the amplitude is the distance from the x-axis to the highest point of the graph. The pendulum shown above moves 20 cm to each side of its center position, so its amplitude is 20 cm.

The **period** is the time for the pendulum to make one complete cycle. It is the time from one peak to the next on the graph. On the graph above, one peak occurs at 1.5 seconds, and the next peak occurs at 3.0 seconds. The period is $3.0 - 1.5 = 1.5$ seconds.

PRACTICE



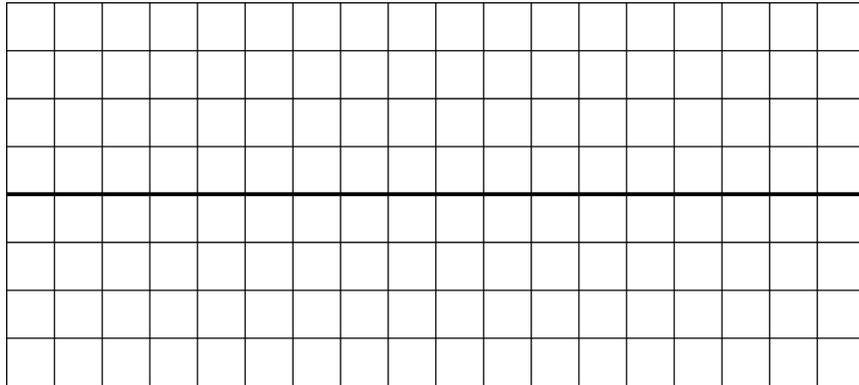
1. Use the graphs to answer the following questions



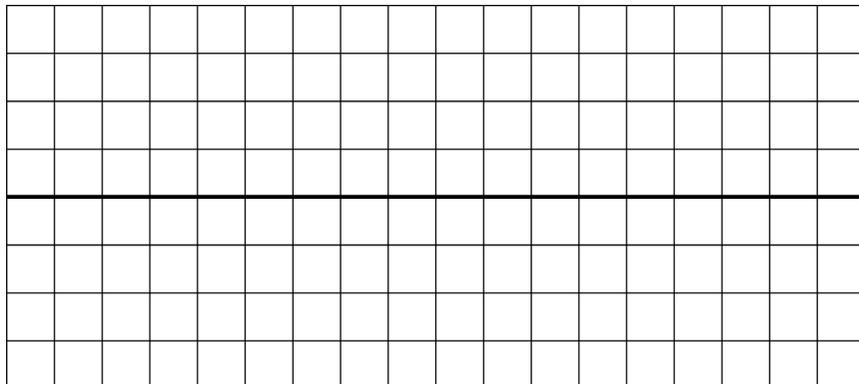
- What is the amplitude of each vibration?
- What is the period of each vibration?

2. Use the grids below to draw the following harmonic motion graphs. Be sure to label the y-axis to indicate the measurement scale.

a. A pendulum with an amplitude of 2 cm and a period of 1 second.



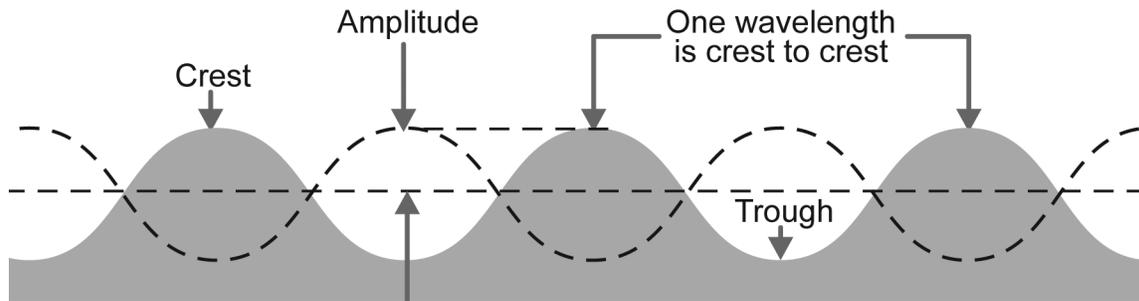
b. A pendulum with an amplitude of 5 degrees and a period of 4 seconds.



Waves



A **wave** is a traveling oscillator that carries energy from one place to another. A high point of a wave is called a **crest**. A low point is called a **trough**. The amplitude of a wave is half the distance from a crest to a trough. The distance from one crest to the next is called the **wavelength**. Wavelength can also be measured from trough to trough or from any point on the wave to the next place where that point occurs.



The speed of a wave

$$\text{Speed (m/sec)} \rightarrow v = f \lambda$$

← Frequency (hertz)
← Wavelength (meters)

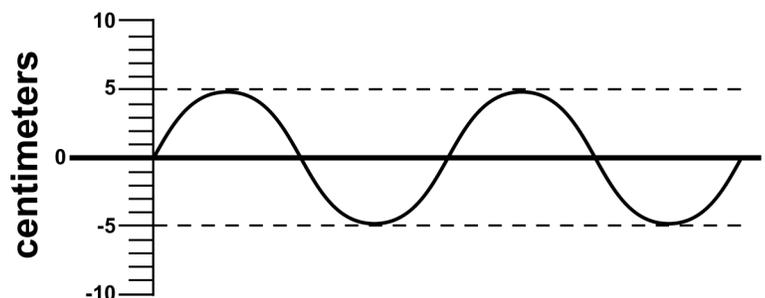
EXAMPLE

The frequency of a wave is 40 Hz and its speed is 100 meters per second. What is the wavelength of this wave?

<p>Given Frequency = 40 Hz; Speed = 100 m/sec</p>	<p>Solution</p> $\frac{100 \text{ m/sec}}{40 \text{ Hz}} = \frac{100 \text{ m/sec}}{40 \text{ cycles/sec}} = \text{Wavelength}$ $2.5 \text{ meters} = \text{Wavelength}$ <p>The wavelength of this wave is 2.5 meters.</p>
<p>Looking for The wavelength</p>	
<p>Relationships Speed = Frequency × Wavelength, therefore Speed ÷ Frequency = Wavelength</p>	

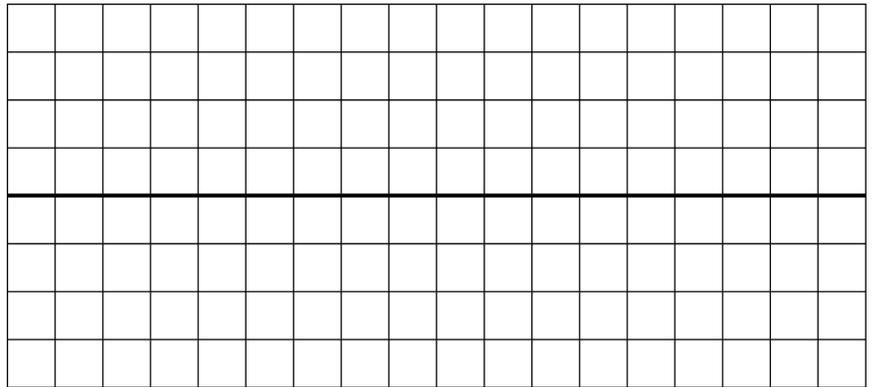
PRACTICE

1. On the graphic at right label the following parts of a wave: one wavelength, half of a wavelength, the amplitude, a crest, and a trough.
 - a. How many wavelengths are represented in the wave above?
 - b. What is the amplitude of the wave shown above?

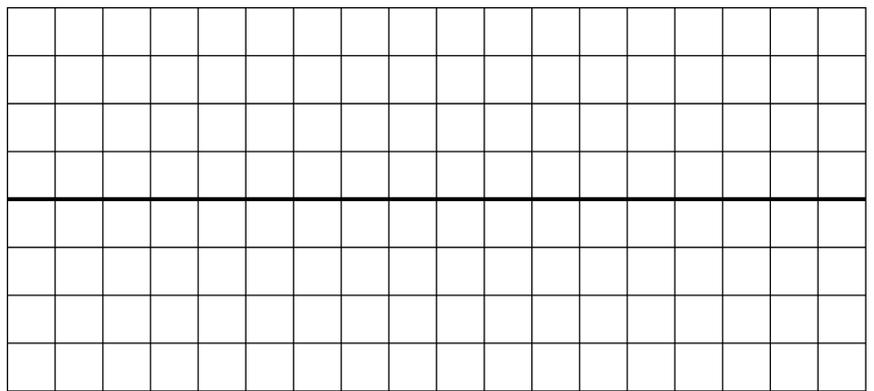


2. Use the grids below to draw the following waves. Be sure to label the y-axis to indicate the measurement scale.

a. A wave with an amplitude of 1 cm and a wavelength of 2 cm



b. A wave with an amplitude of 1.5 cm and a wavelength of 3 cm



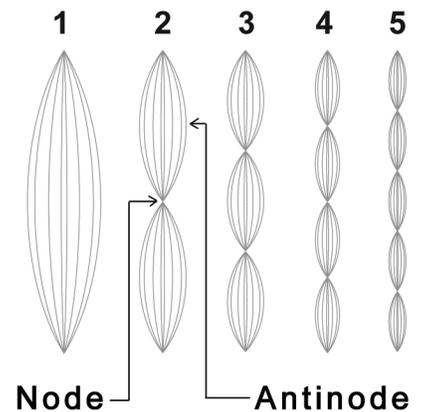
3. A water wave has a frequency of 2 hertz and a wavelength of 5 meters. Calculate its speed.
4. A wave has a speed of 50 m/sec and a frequency of 10 Hz. Calculate its wavelength.
5. A wave has a speed of 30 m/sec and a wavelength of 3 meters. Calculate its frequency.
6. A wave has a period of 2 seconds and a wavelength of 4 meters. Calculate its frequency and speed.
Note: Recall that the frequency of a wave equals 1/period and the period of a wave equals 1/frequency.
7. A sound wave travels at 330 m/sec and has a wavelength of 2 meters. Calculate its frequency and period.
8. The frequency of wave A is 250 hertz and the wavelength is 30 centimeters. The frequency of wave B is 260 hertz and the wavelength is 25 centimeters. Which is the faster wave?
9. The period of a wave is equal to the time it takes for one wavelength to pass by a fixed point. You stand on a pier watching water waves and see 10 wavelengths pass by in a time of 40 seconds.
 - a. What is the period of the water waves?
 - b. What is the frequency of the water waves?
 - c. If the wavelength is 3 meters, what is the wave speed?

Standing Waves

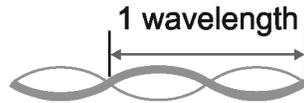
A wave that is confined in a space is called a **standing wave**. Standing waves on the vibrating strings of a guitar produce the sounds you hear. Standing waves are also present inside the chamber of a wind instrument.

A string that contains a standing wave is an oscillator. Like any oscillator, it has natural frequencies. The lowest natural frequency is called the **fundamental**. Other natural frequencies are called **harmonics**. The first five harmonics of a standing wave on a string are shown to the right.

There are two main parts of a standing wave. The **nodes** are the points where the string does not move at all. The **antinodes** are the places where the string moves with the greatest amplitude.



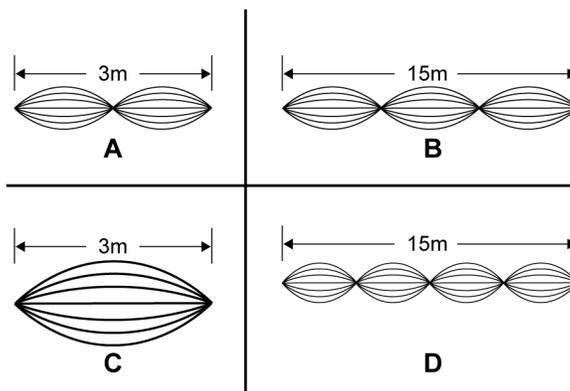
The wavelength of a standing wave can be found by measuring the length of two of the “bumps” on the string. The first harmonic only contains one bump, so the wavelength is twice the length of the individual bump.



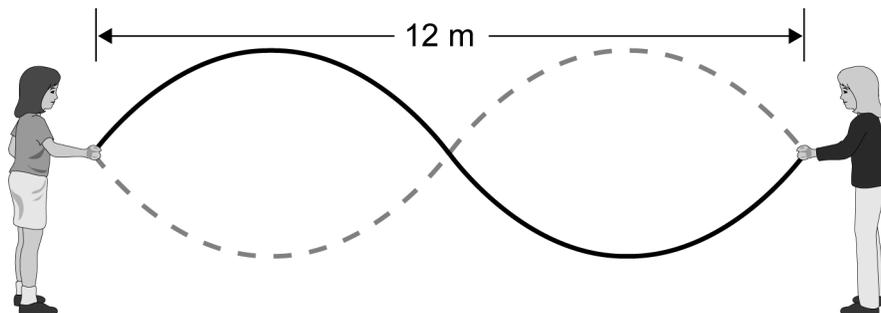
PRACTICE



1. Use the graphic below to answer these questions.
 - a. Which harmonic is shown in each of the strings below?
 - b. Label the nodes and antinodes on each of the standing waves shown below.
 - c. How many wavelengths does each standing wave contain?
 - d. Determine the wavelength of each standing wave.



2. Two students want to use a 12-meter long rope to create standing waves. They first measure the speed at which a single wave pulse moves from one end of the rope to another and find that it is 36 m/sec. This information can be used to determine the frequency at which they must vibrate the rope to create each harmonic. Follow the steps below to calculate these frequencies.



- Draw the standing wave patterns for the first six harmonics.
- Determine the wavelength for each harmonic on the 12 meter rope. Record the values in the table below.
- Use the equation for wave speed ($v = f\lambda$) to calculate each frequency.

Harmonic	Speed (m/sec)	Wavelength (m)	Frequency (Hz)
1	36		
2	36		
3	36		
4	36		
5	36		
6	36		

- What happens to the frequency as the wavelength increases?
- Suppose the students cut the rope in half. The speed of the wave on the rope only depends on the material from which the rope is made and its tension, so it will not change. Determine the wavelength and frequency for each harmonic on the 6 meter rope.

Harmonic	Speed (m/sec)	Wavelength (m)	Frequency (Hz)
1	36		
2	36		
3	36		
4	36		
5	36		
6	36		

- What effect did using a shorter rope have on the wavelength and frequency?

Name: _____

Date: _____



Wave Interference



Interference occurs when two or more waves are at the same location at the same time. For example, the wind may create tiny ripples on top of larger waves in the ocean. The **superposition principle** states that the total vibration at any point is the sum of the vibrations produced by the individual waves.

Constructive interference is when waves combine to make a larger wave. Destructive interference is when waves combine to make a wave that is smaller than either of the individual waves. Noise cancelling headphones work by producing a sound wave that perfectly cancels the sounds in the room.

PRACTICE

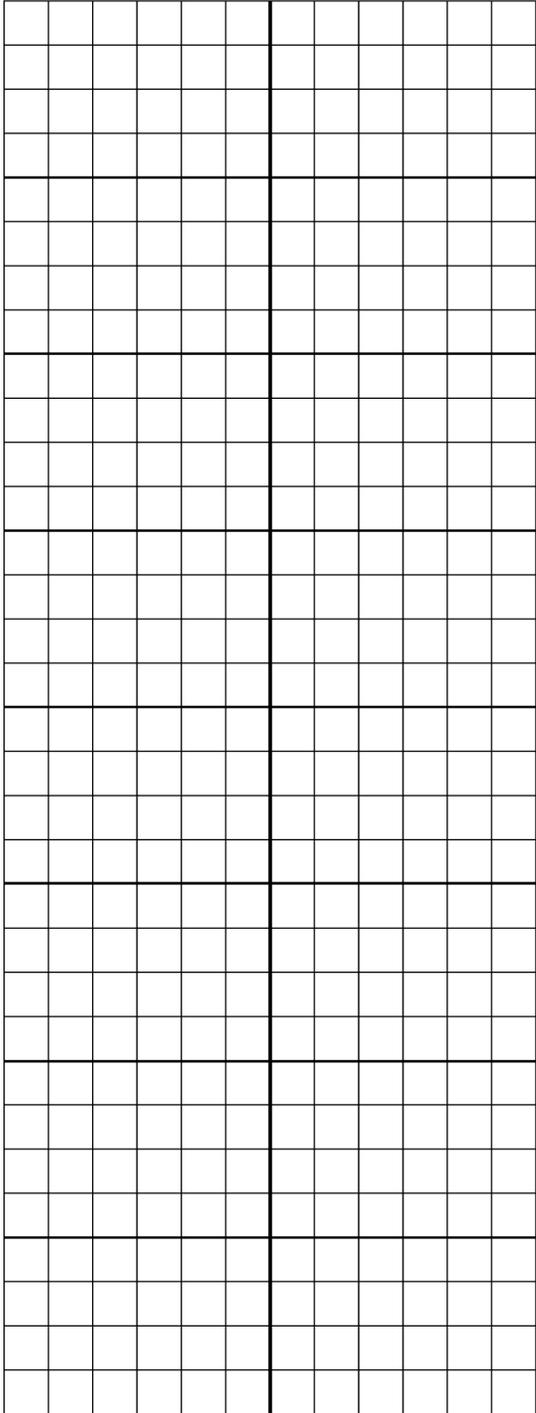
This worksheet will allow you to find the sum of two waves with different wavelengths and amplitudes. The table below (and continued on the next page) lists the coordinates of points on the two waves.

- Use coordinates on the table and the graph paper (see last page) to graph wave 1 and wave 2 individually. Connect each set of points with a smooth curve that looks like a wave. Then, answer questions 2 – 9.
- What is the amplitude of wave 1?
- What is the amplitude of wave 2?
- What is the wavelength of wave 1?
- What is the wavelength of wave 2?
- How many wavelengths of wave 1 did you draw?
- How many wavelength of wave 2 did you draw?
- Use the superposition principle to find the wave that results from the interference of the two waves.
 - To do this, simply add the heights of wave 1 and wave 2 at each point and record the values in the last column. The first four points are done for you.
 - Then use the points in last column to graph the new wave. Connect the points with a smooth curve. You should see a pattern that combines the two original waves.
- Describe the wave created by adding the two original waves.

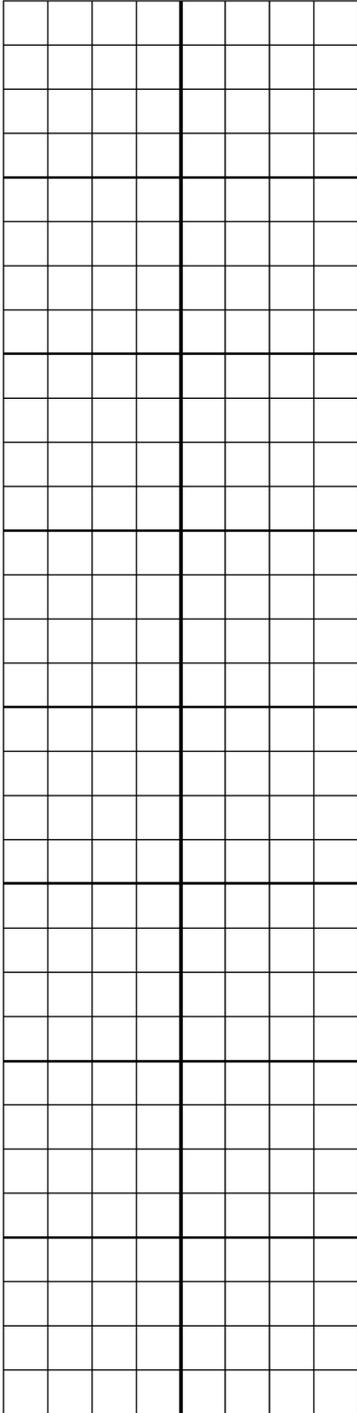
x-axis (blocks)	Height of wave 1 (y-axis blocks)	Height of wave 2 (y-axis blocks)	Height of wave 1 + wave 2 (y-axis blocks)
0	0	0	0
1	0.8	2	2.8
2	1.5	0	1.5
3	2.2	-2	0.2
4	2.8	0	

x -axis (blocks)	Height of wave 1 (y -axis blocks)	Height of wave 2 (y -axis blocks)	Height of wave 1 + wave 2 (y -axis blocks)
5	3.3	2	
6	3.7	0	
7	3.9	-2	
8	4	0	
9	3.9	2	
10	3.7	0	
11	3.3	-2	
12	2.8	0	
13	2.2	2	
14	1.5	0	
15	0.8	-2	
16	0	0	
17	-0.8	2	
18	-1.5	0	
19	-2.2	-2	
20	-2.8	0	
21	-3.3	2	
22	-3.7	0	
23	-3.9	-2	
24	-4	0	
25	-3.9	2	
26	-3.7	0	
27	-3.3	-2	
28	-2.8	0	
29	-2.2	2	
30	-1.5	0	
31	-0.8	-2	
32	0	0	

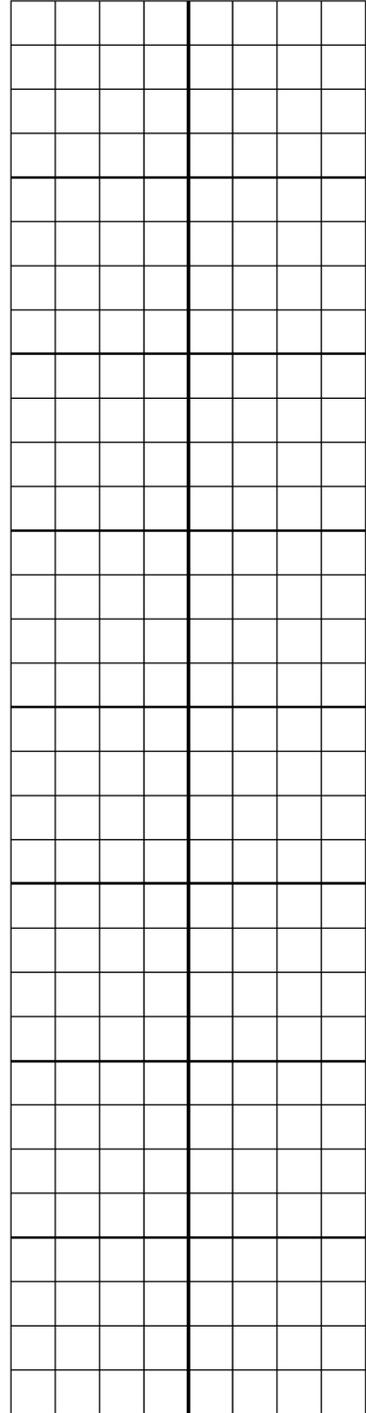
Wave 1
+
Wave 2



Wave 2



Wave 1



Decibel Scale

READ



The loudness of sound is measured in decibels (dB). Most sounds fall between zero and 100 on the decibel scale making it a very convenient scale to understand and use. Each increase of 20 decibels (dB) for a sound will be about twice as loud to your ears. Use the following table to help you answer the questions.

10-15 dB	A quiet whisper 3 feet away
30-40 dB	Background noise in a house
65 dB	Ordinary conversation 3 feet away
70 dB	City traffic
90 dB	A jackhammer cutting up the street 10 feet away
100 dB	Listening to headphones at maximum volume
110 dB	Front row at a rock concert
120 dB	The threshold of physical pain from loudness

EXAMPLE



How many decibels would a sound have if its loudness was twice that of city traffic?

<p>Given</p> <p>From the table, the loudness of city traffic is 70 dB.</p>	<p>Solution</p> <p>City traffic = 70 dB</p> <p>Adding 20 dB doubles the loudness.</p> <p>$70 \text{ dB} + 20 \text{ dB} = 90 \text{ dB}$</p> <p>90 dB is twice as loud as city traffic.</p>
<p>Looking for</p> <p>The decibel reading for a sound twice as loud as traffic.</p>	
<p>Relationship</p> <p>For every 20 dB increase, a sound is twice as loud.</p>	

PRACTICE



- How many times louder than a jackhammer does the front row at a rock concert sound?
- How many decibels would you hear in a room that sounds twice as loud as an average (35 dB) house?
- You have your headphones turned all the way up.
 - If you want them to sound half as loud, to what decibel level must the music be set?
 - If you want them to sound 1/4 as loud, to what decibel level must the music be set?
- How many times louder than city traffic does the front row at a rock concert sound?
- When you whisper, you produce a 10-dB sound.
 - When you speak quietly, your voice sounds twice as loud as a whisper. How many decibels is this?
 - When you speak normally, your voice sounds 4 times as loud as a whisper. How many decibels is this?
 - When you yell, your voice sounds 8 times as loud as a whisper. How many decibels is this?

Thomas Edison



Thomas Alva Edison holds the record for the most patents issued to an individual in the United States: 1,093. He is famous for saying that “Genius is one percent inspiration and ninety-nine percent perspiration.” Edison’s hard work and imagination brought us the phonograph, practical incandescent lighting, motion pictures, and the alkaline storage battery.

The young entrepreneur

Thomas Alva Edison was born February 11, 1847, in Milan, Ohio, the youngest of seven children. His family moved to Port Huron, Michigan, in 1854 and Thomas attended school there—for a few months. He was taught reading, writing, and simple arithmetic by his mother, a former teacher, and he read widely and voraciously. The basement was his first laboratory.

When he was 13, Thomas started selling newspapers and candy on the train from Port Huron to Detroit. Waiting for the return train, he often read science and technology books. He set up a chemistry lab in an empty boxcar, until he accidentally set the car on fire.

At 16, Thomas learned to be a telegraph operator and began to travel the country for work. His interest in experiments and gadgets grew and he invented an automatic timer to send telegraph messages while he slept. About this time his hearing was deteriorating; he was left with only about 20 percent hearing in one ear.

First a patent, then business

In 1868 Edison arrived in Boston. His first patent was issued there for an electronic vote recorder. While the device worked very well, it was a commercial failure. Edison vowed that, in the future, he would only invent things he was certain the public would want.

He moved on to New York, where he invented a “Universal Stock Printer” for which he was paid \$40,000, a huge sum he found hard to comprehend. After developing some devices to improve telegraph communications, Edison had enough money to build a research lab in Menlo Park, New Jersey.

The invention factory

Edison’s facility had everything he needed for inventing: machine and carpentry shops, a lab, offices, and a library. He hired assistants who specialized where he felt he was lacking, in mathematics, for instance. The concept of a commercial research facility—an “invention factory” of sorts—was new.

Some consider Menlo Park itself to be one of Edison’s most important inventions.

It was there Edison invented the tin foil phonograph, the first machine to record and play back sounds. Next, he developed a practical, safe, and affordable incandescent light. The company he formed to manufacture and market this invention eventually became General Electric.

In 1888, Edison opened an even larger research complex in West Orange, New Jersey. Here he improved the phonograph and created a device that “does for the eye what the phonograph does for the ear.” This was the first motion picture player.

Not a man to be discouraged

Not all of Edison’s ideas were successful. In the 1890s he sold all his stock in General Electric and invested millions to develop better methods of mining iron ore. He never was able to come up with a workable process and the investment was a loss.

One of the most remarkable aspects of Edison’s character was his refusal to be discouraged by failure. The 3,500 notebooks he kept illustrate his typical approach to inventing: brainstorm as many avenues as possible to create a product, try anything that seems remotely workable, and record everything. Failed experiments, he said, helped direct his thinking toward more useful designs.

Edison also worked to create an efficient storage battery to use in electric cars. By the time his alkaline battery was ready, electric cars were uncommon. But the invention proved useful in other devices, like lighting railway cars and miners’ lamps. Edison’s last patent was granted when he was 83, the year before he died, and his last big undertaking was an attempt, at Henry Ford’s request, to develop an alternative source of rubber. He was still working on the project when he died in 1931.

Name: _____

Date: _____



Reading reflection

1. Name three different avenues by which Thomas Edison received an education.
2. What did Edison learn from his attempts to sell his first patented invention?
3. Describe Edison's "invention factory."
4. Name two important inventions that came out of Menlo Park.
5. Describe the process Edison used to invent things.
6. How did Edison view his projects that failed?
7. How do you think the tin foil phonograph worked? Discuss and compare your ideas with a fellow member of your class.
8. **Research:** Edison holds the record for the most patents issued to an individual in the United States. Use a library or the Internet to research three of his inventions that are not mentioned in this biography, and briefly describe each one.



Reciprocals and Negative One as an Exponent



All real numbers, except zero, have a reciprocal. To find the reciprocal, you *write the number as a fraction* and then invert the numerator and the denominator. The reciprocal is another name for the multiplicative inverse.

In algebra, we use a negative one as an exponent for a number or expression to indicate the reciprocal. If the numerator or denominator has more than a single number then parentheses must be used to indicate what the base of the exponent is.

EXAMPLES

Example 1:

$$\left(\frac{3}{7}\right)^{-1} = \left(\frac{7}{3}\right) \quad \text{Notice that the number did not become negative.}$$

Example 2:

$$(5a)^{-1} = \frac{1}{5a}$$

Example 3:

$$\frac{\left(\frac{1}{2}\right)^{-1}}{3} = \frac{1}{3\left(\frac{1}{2}\right)}$$

$$= \frac{1}{\frac{3}{2}}$$

$$= \left(\frac{3}{2}\right)^{-1}$$

$$= \frac{2}{3}$$

Convert the fraction to a number without a negative exponent. Notice that because of the parentheses, the negative exponent only applies to the numerator of this fraction.

This fraction can easily be expressed as a reciprocal with a negative exponent.

The reciprocal is found by inverting the numerator and denominator.

PRACTICE 

Find the reciprocal for the following numbers:

1. $\frac{3}{4}$

2. $\frac{1}{5}$

3. 7

4. $8\frac{1}{4}$

5. $-\frac{1}{4}$

6. $-4\frac{1}{8}$

7. $-\frac{6}{13}$

8. -100

Convert the following to numbers that do not have a negative exponent.

9. 20^{-1}

10. $\left(\frac{2}{3}\right)^{-1}$

11. $(-3b)^{-1}$

12. $\frac{\left(\frac{3}{4}\right)^{-1}}{5}$

13. $\left(5\frac{2}{3}\right)^{-1}$

14. $(6d)^{-1}$

15. $6d^{(-1)}$

16. $\left(\frac{(2 \times 8)}{(3 \times 6)}\right)^{-1}$

17. $(-8)^{-1}$

18. $8(3a)^{-1}$

19. $\left(\frac{3}{5}\right)^{-1} \times \left(\frac{6}{15}\right)^{-1}$