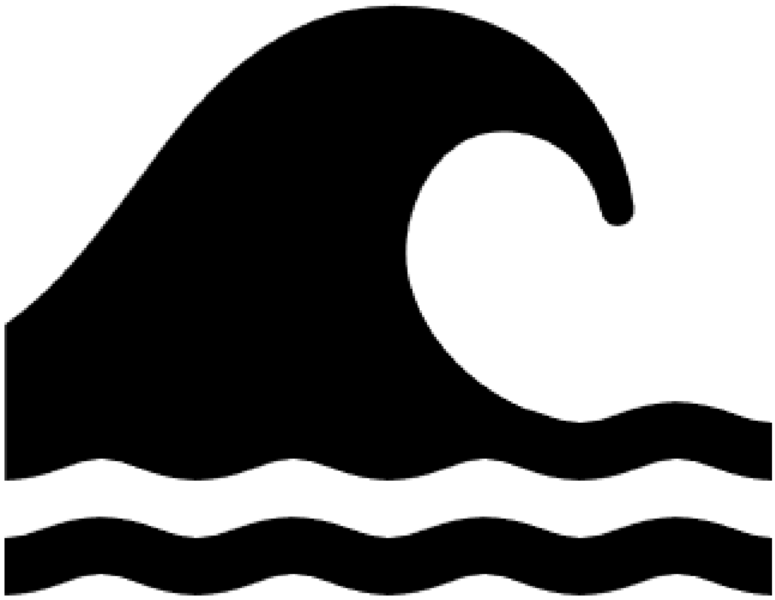
Measuring waves



Name ________________________________

Class ________________________________

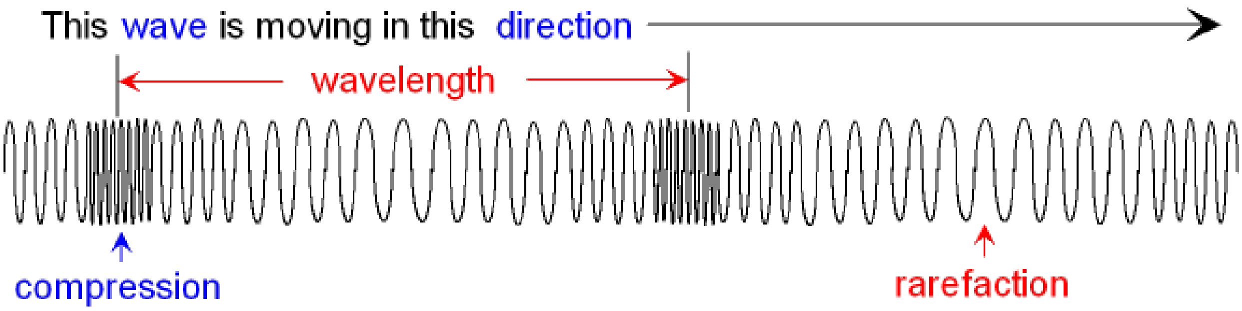
Teacher ________________________________

L1 Wave Properties

Waves transfer **energy** from one place to another.

There are two types of wave; **longitudinal** and **transverse**.

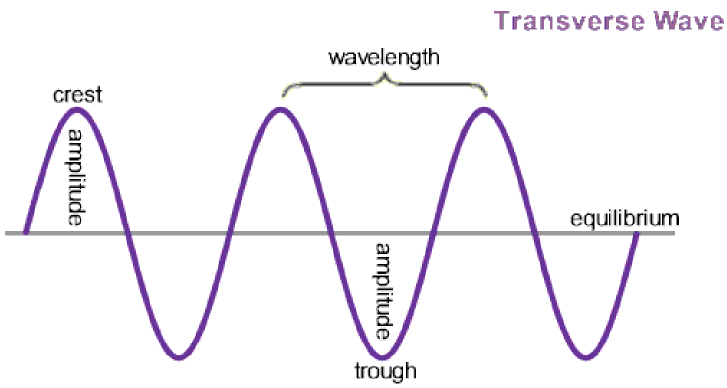
In **longitudinal waves**, the vibrations are parallel to the direction of wave travel.



In a longitudinal wave, the region where the particles are closest together is called a **compression**. The region where the particles are furthest apart is called a **rarefaction**. The distance between one compression/rarefaction and the next compression/rarefaction is called the **wavelength**.

In **transverse waves**, the vibrations are at right angles to the direction of wave travel.

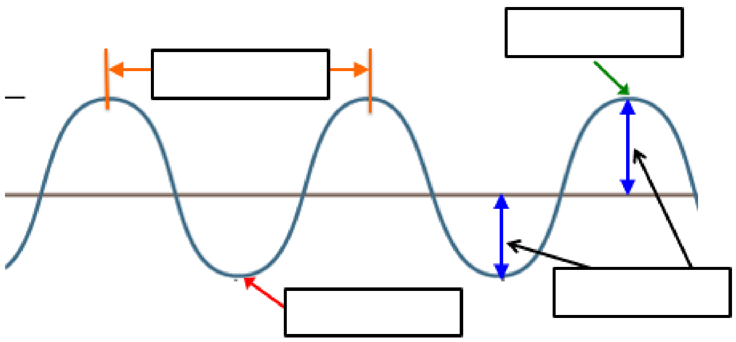
In a transverse wave, the area of zero displacement is called the **equilibrium position**. The top of a wave is called the **peak or crest**, and the bottom of a wave is called the **trough**. The distance between the equilibrium position and the peak/crest is called the **amplitude**. The distance between one crest/trough and the next crest/trough is called the **wavelength**.



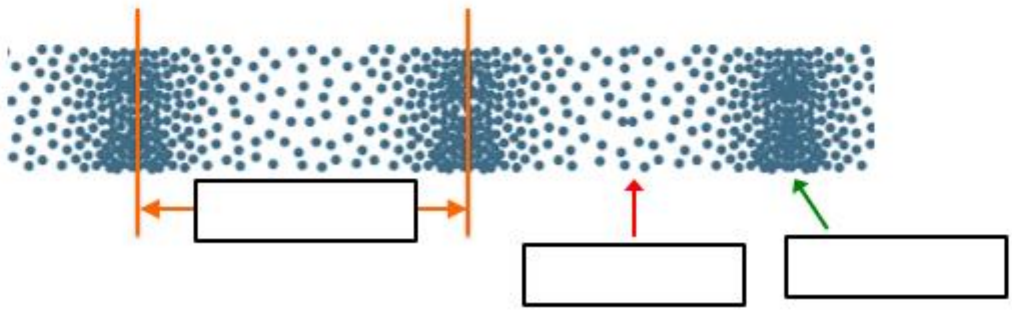
Independent practice

Basic:

1. What do waves transfer?
2. What are the two types of wave?
3. *Cross out the wrong one:*
   - **Transverse waves** vibrate parallel / at right angles to the direction of energy transfer
   - **Longitudinal waves** vibrate parallel / at right angles to the direction of energy transfer
4. The wave below is transverse / longitudinal. Label the wave.



5. The wave below is transverse / longitudinal. Label the wave.



Medium: Draw a line from the word to the correct definition.

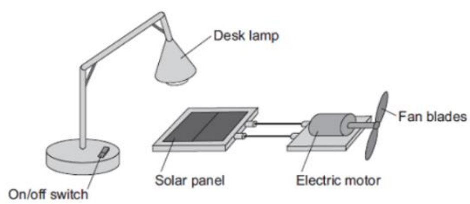
Wavelength
Amplitude
Crest
Trough
Compression
Rarefaction

Height of a wave
Bottom of a wave
Top of a wave
Distance between two waves
Where particles are closest together
Where particles are furthest apart

For each wave described below, identify the wave as a transverse or longitudinal wave.

1. The wave created by moving the end of a spring toy up and down.
2. The wave created by moving the end of a spring toy back and forth parallel to the length of the spring.
3. A sound wave.
4. An ocean wave.
5. An electromagnetic wave.

Hard: Use complete sentences. Look at the number of marks available.



1. Describe the differences between longitudinal waves and transverse waves (3).
2. Radio waves are electromagnetic waves. Describe how radio waves are different from sound waves. (4)

3. Describe how switching the desk lamp on and off shows that light waves transfer energy. (2)

L2 Period of a wave

The period of a wave refers to the time it takes for one complete cycle of a wave to pass a given point. This concept is fundamental in wave physics because it's linked to a wave's frequency. Frequency, in turn, is connected to many everyday phenomena, from radio signals to musical notes. So, let's break this down step by step.

Calculating the Period of a Wave:

To calculate the period (T) of a wave, you can use the following formula:

$$T = 1 \div f$$

Where:
T represents the period (in seconds).
f is the frequency (in hertz, Hz).

Now, let's understand how this formula works with a practical example. If you have a wave with a frequency of 10 Hz, you can calculate its period as follows:

V: 10Hz = f
E: T=1÷f
S: T=1÷10
R: no need
A: 0.1
U: s

This means that in 0.1 seconds, one complete cycle of the wave passes a given point. The period is like a wave's heartbeat; it tells you how long it takes for the wave to start over.

Using the Period to Calculate Frequency:

Conversely, if you know the period of a wave, you can calculate its frequency. The frequency (f) is measured in hertz (Hz) and can be calculated using the following formula:

$$f = 1 \div T$$

Where:
f is the frequency (in Hz).
T represents the period (in seconds).
For example, if you have a wave with a period of 0.2 seconds, you can calculate its frequency as follows:

V: f=0.2
E: $f = 1 \div T$
S: $f = 1 \div 0.2$
R: No need
A: 5
U: Hz

This means that the wave completes 5 cycles in one second. Frequency helps you understand how fast the wave is oscillating.

Independent practice

Basic

Q1: Write the equation that links time period and frequency.

Q2: What are the units of time period and frequency?

Q3: Calculate the time period when the frequency is:

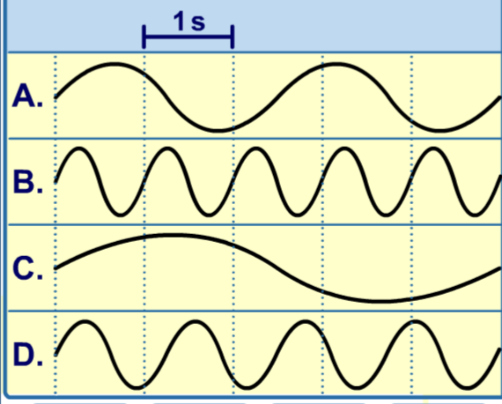
a) 10 Hz b) 5 Hz c) 0.2 Hz d) 1200 Hz e) 0.006 Hz

Q4: What is the definition of frequency?

Medium

Q5: Rearrange the equation to give an equation for frequency.

Q6: **Fill in the values for the properties of the waves.**



	number of waves on screen	time period (s)	frequency (Hz)
A.	?	2.5	?
B.	5	?	1
C.	1	?	?
D.	4	1.25	?

0.8 | 5 | 0.5 | 2 | 0.2 | 0.25 | 1 | 0.4

Hard

Q7: A note is played on an electric keyboard. The frequency of the note was 440 Hz. What does a frequency of 440 Hz mean?

Q8: Calculate the time period when the frequency is:

To go from kHz to Hz → × 1000

a) 2 kHz. b) 0.5 kHz c) 150 kHz d) 0.2 kHz e) 0.01 kHz

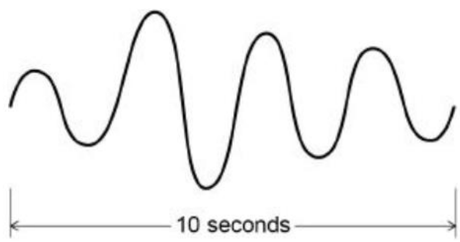
Q9: Calculate the frequency when the time period is:

a) 0.5 seconds b) 0.01 seconds b) 5 milliseconds c) 2 milliseconds
d) 1 minute e) 30 minutes f) 1 hour g) 1 year.

To go from milliseconds to seconds → ÷ 1000

Q10: What is the time period of the wave opposite?

Q11 Using the answer to Q10, what is the frequency of the wave opposite?



L3 Wave speed

The wavelength equation says that the **velocity of a wave is equal to the frequency multiplied by the wavelength**:

$$\boldsymbol{v} = \boldsymbol{f} \times \boldsymbol{\lambda}$$

where v is the **velocity** (m/s)

f is the **frequency** (Hz)

λ is the **wavelength** (m)

Example question: A wave has a frequency of 12 kHz and a wavelength of 20 cm. Calculate the wave speed.

Step 1: Write the equation.

$\boldsymbol{v} = \boldsymbol{f} \times \boldsymbol{\lambda}$

Step 2: Write down the variables

f = 12 kHz = 12,000 Hz

v = 20 cm = 0.2 m

Step 3: Calculate the answer

v = 12,000 × 0.2 = 2400 m/s

The speed of light is always constant at **300,000,000 m/s (3 x 10^8 m/s)**.

Nothing can travel faster than this.

All electro-magnetic waves travel at the speed of light.

Independent practice

Basic

Q1. Write down the wave equation.

Q2. Write down the units and symbols for velocity, frequency and wavelength.

Q3. What is the wave speed if:

a) $f = 5$ Hz, $\lambda = 1$ m b) $f = 6$ Hz, $\lambda = 0.25$ m c) $f = 10$ Hz, $\lambda = 0.2$ m

d) $f = 0.01$ Hz, $\lambda = 25$ m e) $f = 2000$ Hz, $\lambda = 4$ m f) $f = 0.05$ Hz, $\lambda = 80$ m

Medium (need to rearrange equations)

Q4. Re-arrange the equation to give two equations for f and λ.

Q5. What is the wave frequency if:

a) $v = 5$ m/s, $\lambda = 1$ m b) $v = 330$ m/s, $\lambda = 0.01$ m c) $v = 1{,}500$ m/s, $\lambda = 0.5$ m

d) $v = 0.1$ m/s, $\lambda = 80$ m e) $v = 17$ m/s, $\lambda = 0.1$ m f) $v = 300{,}000{,}000$ m/s, $\lambda = 0.002$ m

Q6. What is the wavelength if:

a) $f = 25$ Hz, $v = 2$ m/s b) $f = 15$ Hz, $v = 0.1$ m/s c) $f = 1{,}800$ Hz, $v = 0.2$ m/s

d) $f = 22$ Hz, $v = 2$ m/s e) $f = 1{,}300$ Hz, $v = 20$ m/s f) $f = 6{,}500{,}000$ Hz, $v = 343$ m/s

Hard (word questions with unit conversions)

Q7. A sound wave has a frequency of 3.43 kHz and a wavelength of 0.1m. Calculate the speed of sound.

To go from kHz to Hz → × 1000

Q8. Dr. Edmunds (strangely) decides to sing to the class and sings with a frequency of 6.86 kHz and a wavelength of 0.05 m. Calculate the speed.

Q9. A wave has a speed of 550 m/s and a frequency of 11 kHz. Calculate the wavelength.

Q10 A wave has a speed of 250 m/s and a frequency of 15 kHz. Calculate the wavelength.

Q11 The speed of any EM wave is 300,000,000 m/s. Calculate the frequency of a radio wave with wavelength of 10 cm.

To go from cm to m → ÷ 100

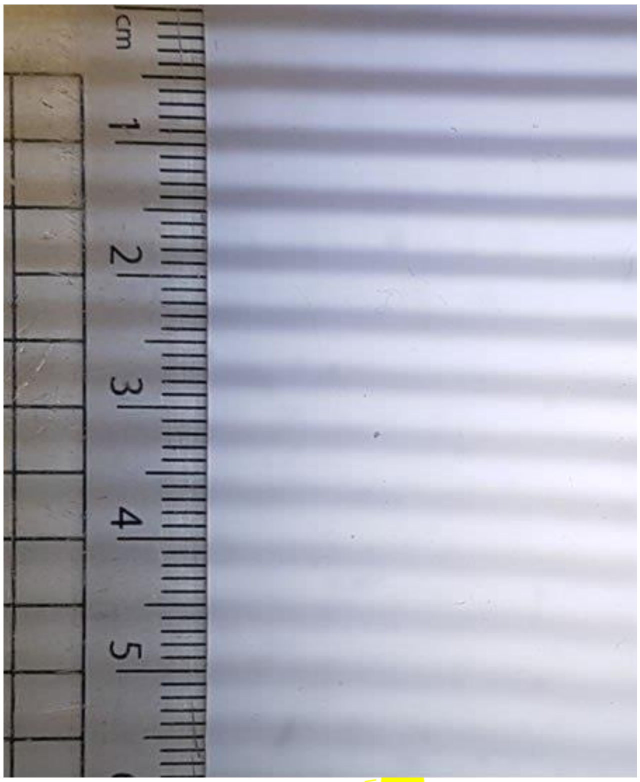
Q12 Microwaves are a transverse wave of wavelength 0.05 cm. Calculate the frequency of a microwave.

L4 Measurements for wave speed

To measure the **wavelength** of a wave in a ripple tank, use a **ruler** and take a picture with a **camera**.

Example question:

a) Use just one wave from the photo to get the wavelength of a wave.
b) Now use ten and take an average. Which is more accurate?



To measure the **frequency** count the number of waves that pass a point in 10 seconds and divide by 10. We can **record** it and play back in **slow motion**.

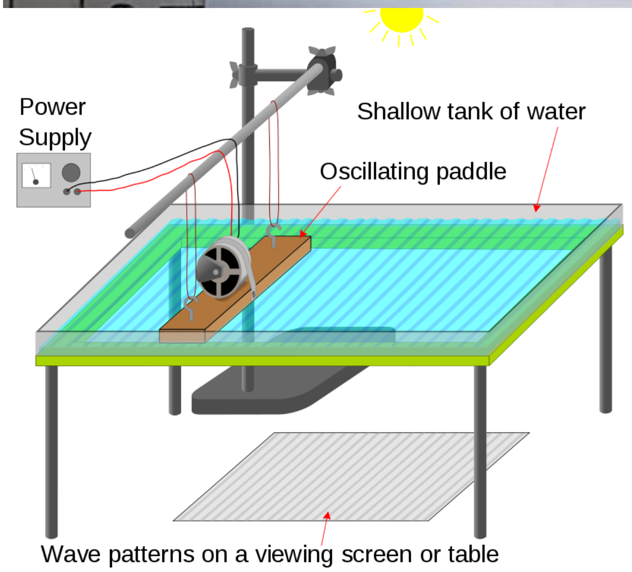
Example question: If 15 waves pass a point in 10 seconds, then the frequency is 15 ÷ 10 = **1.5 Hz**

Mini-task. Calculate the **frequency** if:

1) 120 waves pass every 10 seconds

2) 5 waves pass every 10 seconds

3) 1500 waves pass every 10 seconds.



When we've measured the frequency and the wavelength we can use the wave speed equation to calculate the speed of the wave

Independent practice

Basic

Q1. **Extended writing (paragraph required)**:How do we measure the wavelength of a wave in a ripple tank?

Q2. **Extended writing (paragraph required)**: How do we measure the frequency of a wave in a ripple tank?

Q3. Once we've measured the frequency and the wavelength of a wave in a ripple tank, how do we find out the wave speed?

Medium

Q4. Why is it a benefit to measure the length of ten wavelengths and then take an average?

Q5. Calculate the frequency if: a) 50 waves pass a point in 10 seconds.

b) 20 waves pass a point in 2 seconds.

c) 100 waves pass a point in 20 seconds.

Q6. The measured frequency of a wave is 5 Hz. Calculate the wave speed for each of the wavelengths:

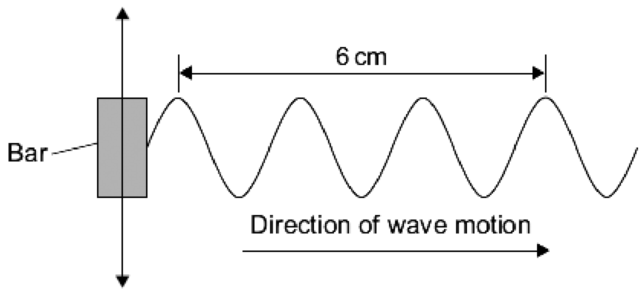
a) 0.1 m
b) 20 cm
c) 2 mm

Q7. The measured wavelength is 0.02m. Calculate the wave speed for each of the frequencies:

a) 10 Hz
b) 0.2 kHz
c) 5 kHz

Hard

A ripple tank is used to investigate the behaviour of water waves. A bar moves up and down to make the waves.
Q8. What is the wavelength of each wave in the diagram?

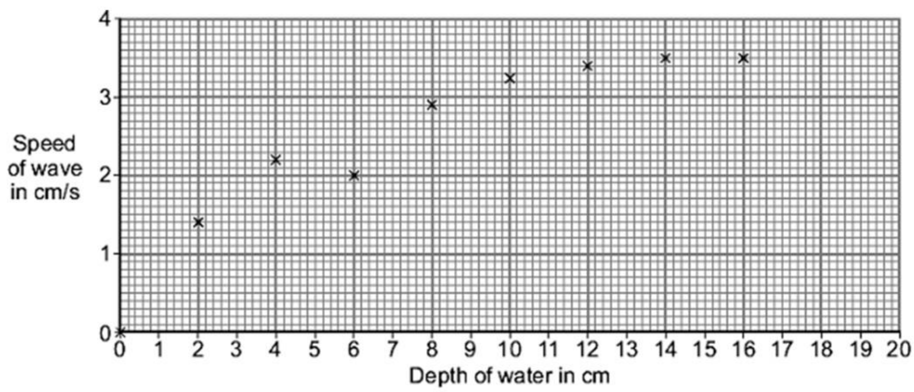


Q9. The ripple tank produces 10 waves in 2 seconds. What is the frequency of the waves?

Q10. The bar is made to move faster. It now produces waves with a frequency of 20 Hz and a wavelength of 0.5 cm. Calculate the speed of the waves in units of cm/s.

Q11. A student uses the ripple tank to investigate the relationship between depth of water and speed of waves. The graph shows the student's results.

There is one anomalous result. On the graph, draw a ring around the anomalous result.



Q12. On the graph, draw a line of best fit.

Q13. Use your line of best fit to find the speed of a wave at a depth of 20cm.

L4 Measurements for wave speed in air

Measuring the speed of sound in air

The air is made up of many tiny particles. When sound is created, the air particles vibrate and collide with each other, causing the vibrations to pass between air particles. The vibrating particles pass the sound through to a person's ear and vibrate the ear drum.

Light travels much faster than sound through air. For example, a person fires a starting pistol and raises their hand in the air at the same time. A distant observer stood 400 metres (m) away records the time between seeing the action (the light reaches the time keeper immediately) and hearing the sound (which takes more time to cover the same distance).

The speed of sound can be calculated using the equation:

$speed = distance \div time$

$v = d \div t$

This is when:

speed (v) is measured in metres per second (m/s)

distance (s) is measured in metres (m)

time (t) is measured in seconds (s)

Example

An observer 400 m away records a 1.2 s time difference between seeing the hand signal and hearing the bang of the starting pistol.

$v = d \div t$

$v = 400 \div 1.2$

$v = 333\ m/s\ (3\ sf)$

The accepted value for the speed of sound in air is 330 m/s.

However, this experimental method is flawed as humans do not use stop clocks identically to one another. One person might stop the timer a fraction of a second later than another person. The values recorded will be dependent on the reaction time of the observer and will not be entirely accurate. This explains why the answer of 333 m/s is slightly above the accepted value for the speed of sound in air.

Independent practice

1. Why does sound travel slower than light through air?
2. What happens to air particles when sound is created, and how does this contribute to the transmission of sound?
3. Explain how the speed of sound in air can be calculated using the provided equation. What are the units for distance, time, and speed in this equation?
4. Why might the experimental method described for measuring the speed of sound in air be flawed?

Calcs

Easy Calculation Questions:

1. If a person hears thunder 5 seconds after seeing a lightning flash, and the distance to the storm is 1,500 meters, what is the speed of sound in air?

2. A firework display is observed 800 meters away from the observer. If the time difference between seeing the fireworks and hearing the sound is 2.4 seconds, what is the speed of sound in air?

3. An echo is heard 1.5 seconds after shouting across a canyon, with the distance to the canyon wall being 500 meters. What is the speed of sound in air?

Medium Calculation Questions:

1. An observer standing 2 kilometres away from a fireworks display records a time difference of 6 seconds between seeing the fireworks and hearing the sound. What is the speed of sound in meters per second (m/s)?

2. A thunderstorm is observed from 3.5 kilometres away. If it takes 10 seconds for the thunder to be heard after the lightning is seen, what is the speed of sound in meters per second (m/s)?

3. A referee hears a whistle blown by the coach from a distance of 0.25 kilometres. If the speed of sound in air is 340 m/s, how long does it take for the sound to travel from the coach to the referee in seconds?

Hard Calculation Questions:

1. A hiker hears an echo of his voice bouncing off a canyon wall 3 seconds after shouting. If the speed of sound in air is 330 m/s, how far away is the canyon wall from the hiker in meters?

2. A submarine detects an enemy ship's sonar ping 15 seconds after it's emitted. If the speed of sound in water is approximately 1500 m/s, how far away is the enemy ship from the submarine?

3. During a lightning storm, a flash is seen, and 7 seconds later, the accompanying thunder is heard. Given that sound travels at approximately 340 m/s, how far away is the lightning strike from the observer in meters?