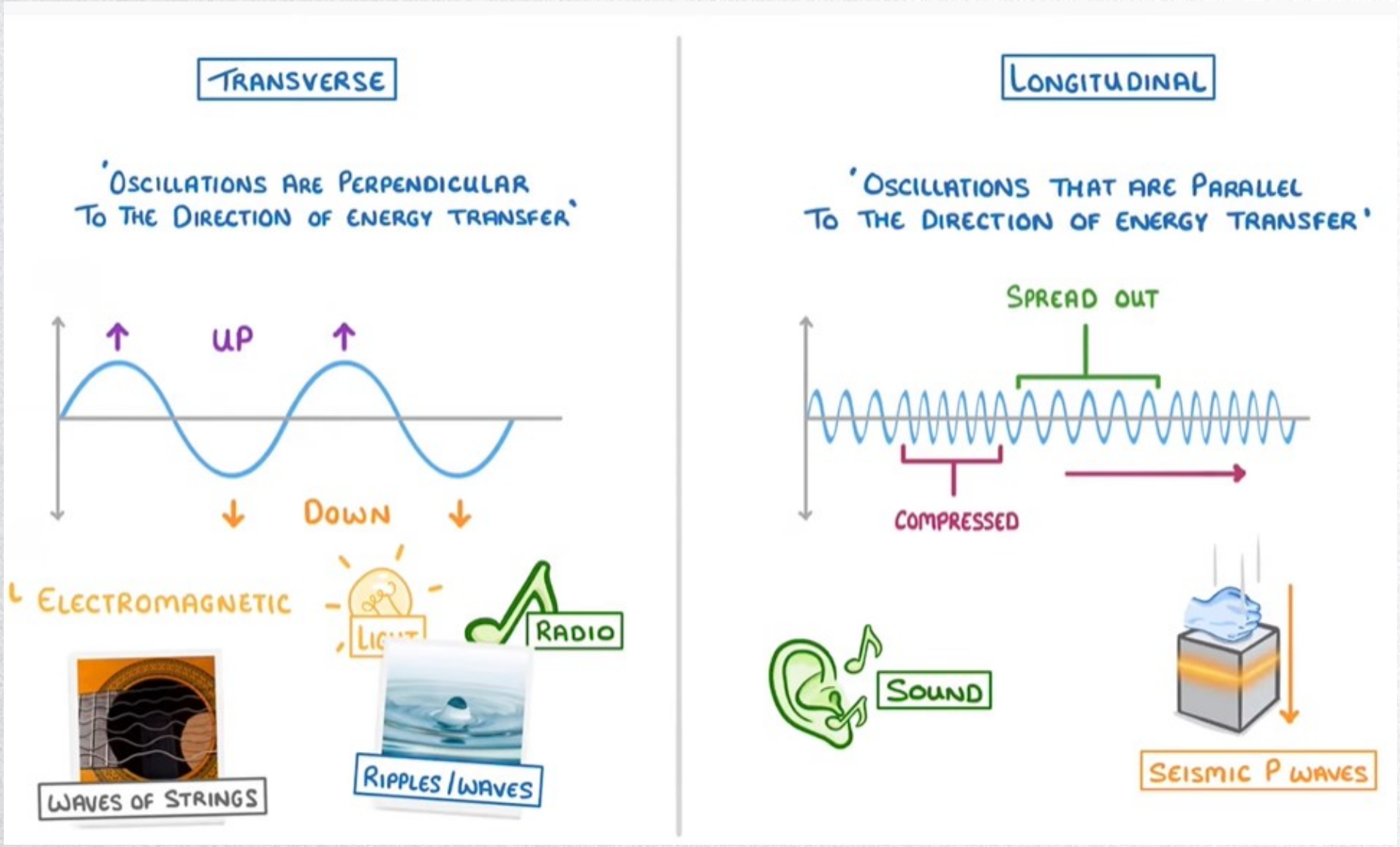
General properties of waves

What are waves

- All waves **transfer energy and information from one place to another without transferring matter** (particles themselves in the medium)
  - ✓ All waves carry and transfer energy in the direction they're travelling.
  - ✓ Waves can also be used as signals to transfer information from one place to another
  - ✓ Particles vibrate in fixed positions

Types of waves

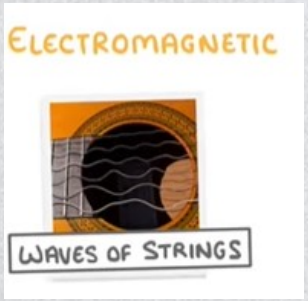


Types of waves

Waves

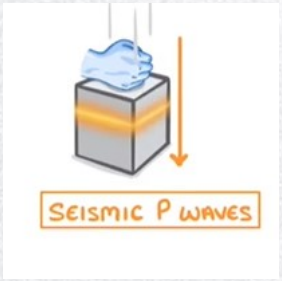
Transverse

Ex. light and all EM waves, ripples on water et al.



Longitudinal

Ex. sound & ultrasound, seismic waves et al.



Types of waves

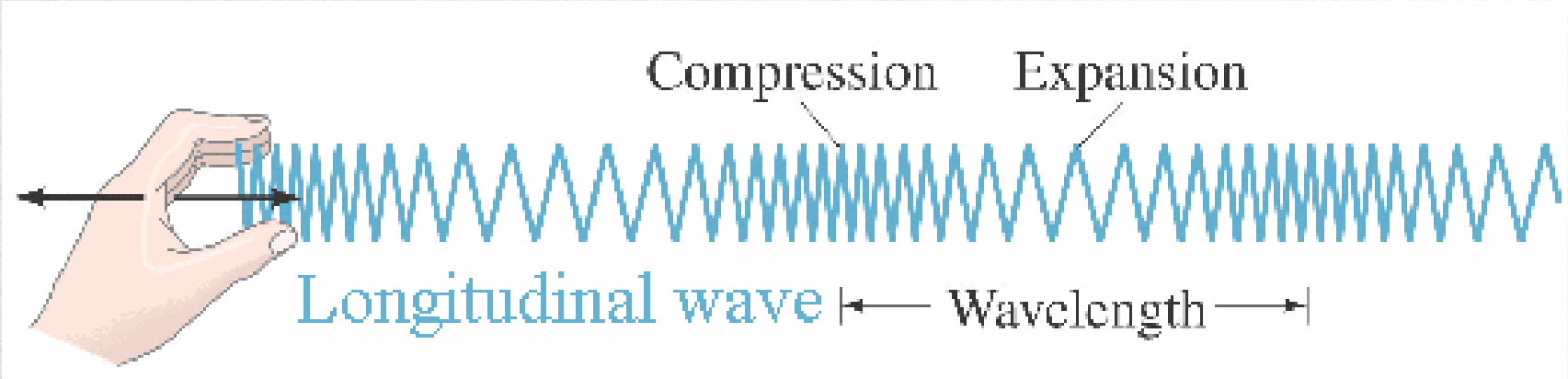
Longitudinal waves

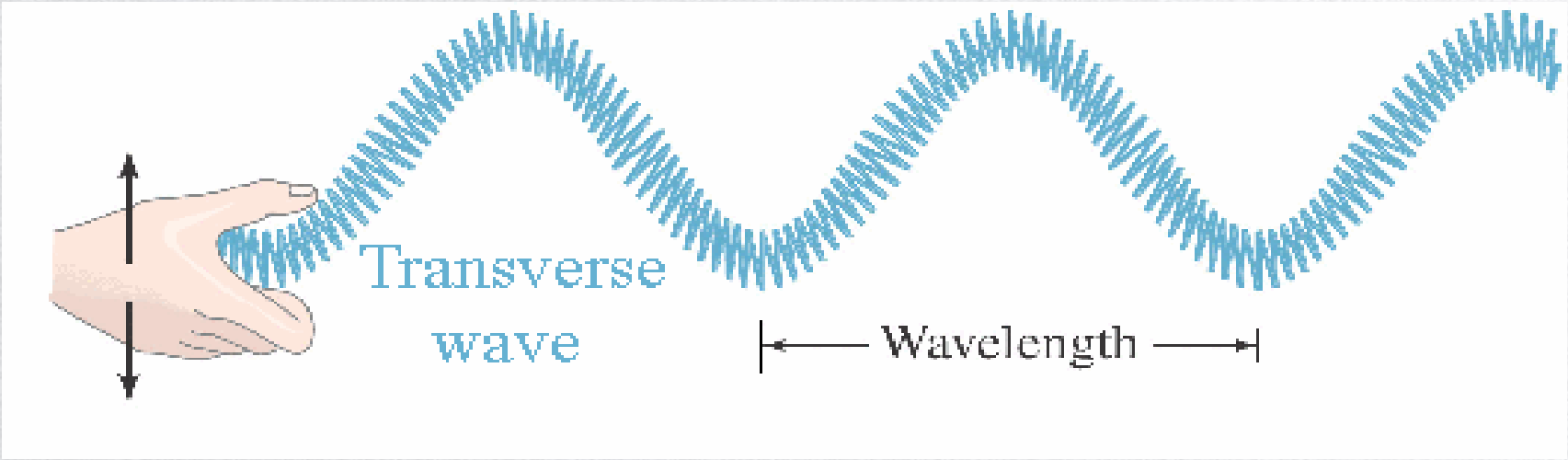
- Particles vibrate **parallel** to direction of wave
- The vibrations are along the same direction as the wave transfers energy
- **Compression**s (particles closest together) and **rarefaction**s (particles furthest apart)
- ex.: sound waves, ultrasound waves, seismic P-waves (primary), a slinky spring when you push the end

Transverse waves

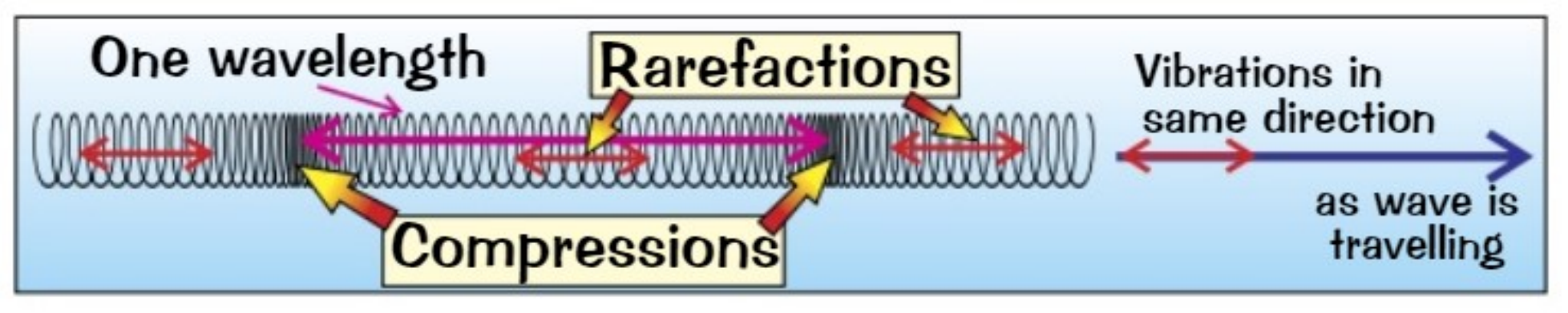
- Particles vibrate **perpendicular** to wave direction
- The vibrations are at 90◦ to the direction energy is transferred by the wave.
- **Peak**s (particles highest from rest position) and **trough**s (particles lowest from rest position)
- ex.: EM waves, light, ripples on water, seismic S-waves (secondary), a slinky spring wiggles up and down

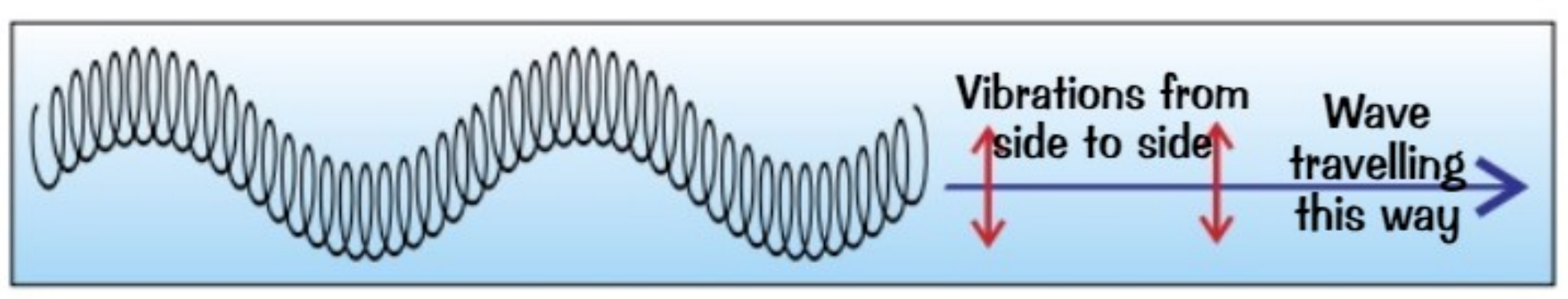
Types of waves





Types of waves (Cont'd)





Types of waves (Cont'd)

Longitudinal waves

- Particles vibrate **parallel** to direction of wave
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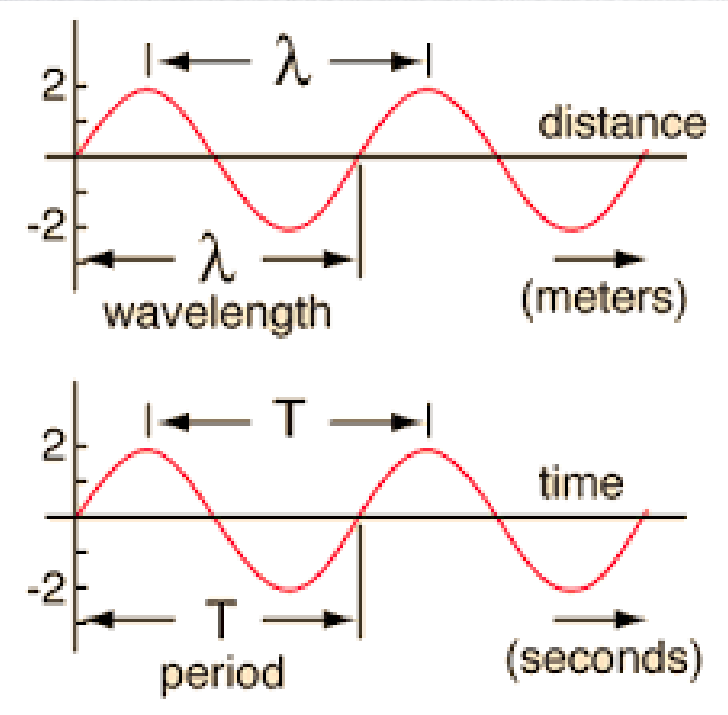
Wave as a function of time or distance



Waves may be graphed as **a function of time or distance**.

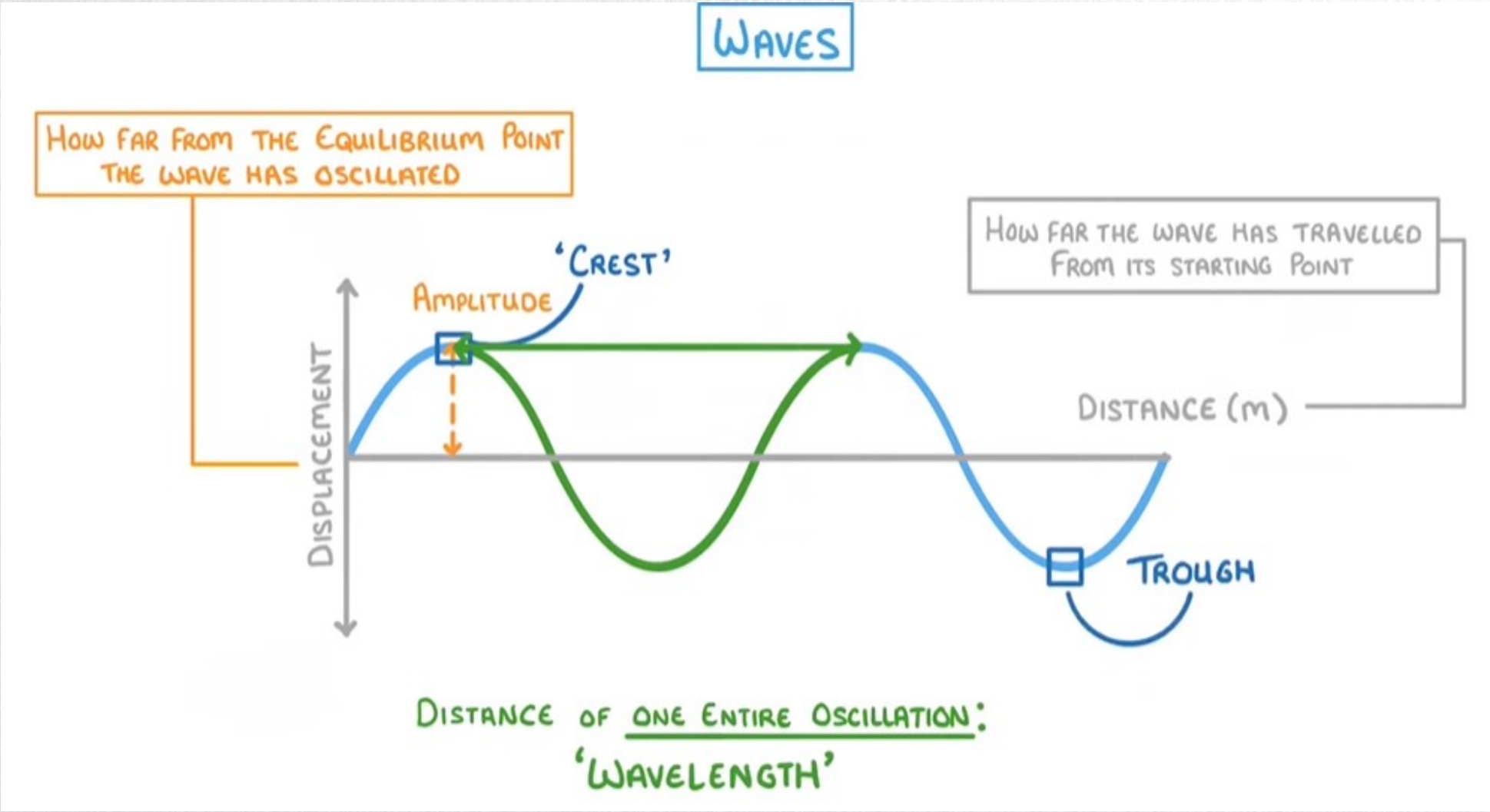
A **single frequency** wave will appear as **a sine wave** in either case.

From the **distance graph** the **wavelength** may be determined.

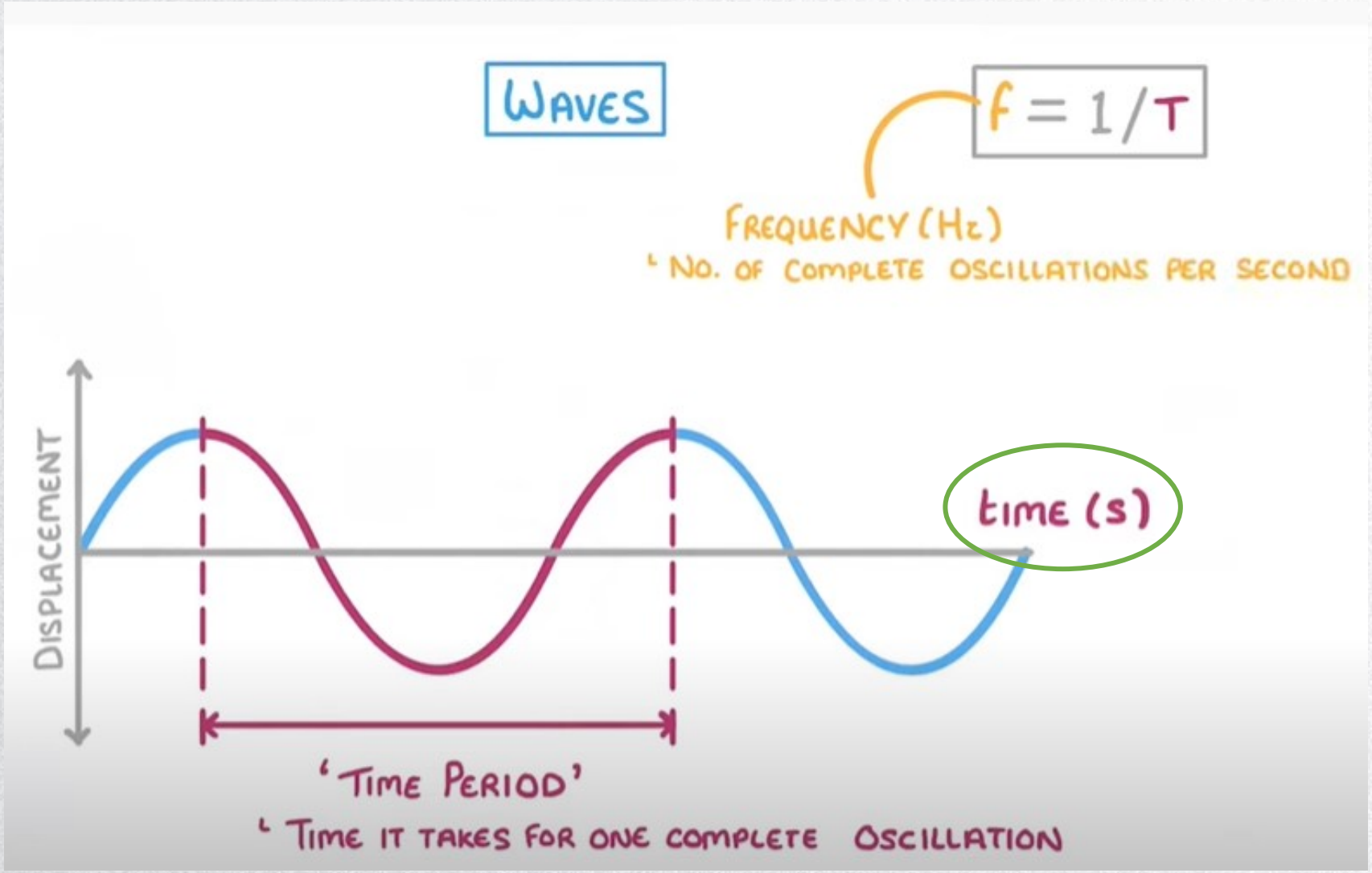
From the **time graph** the **period** may be determined.

From both together, the **wave speed** can be determined.

Features of a wave



Features of a wave



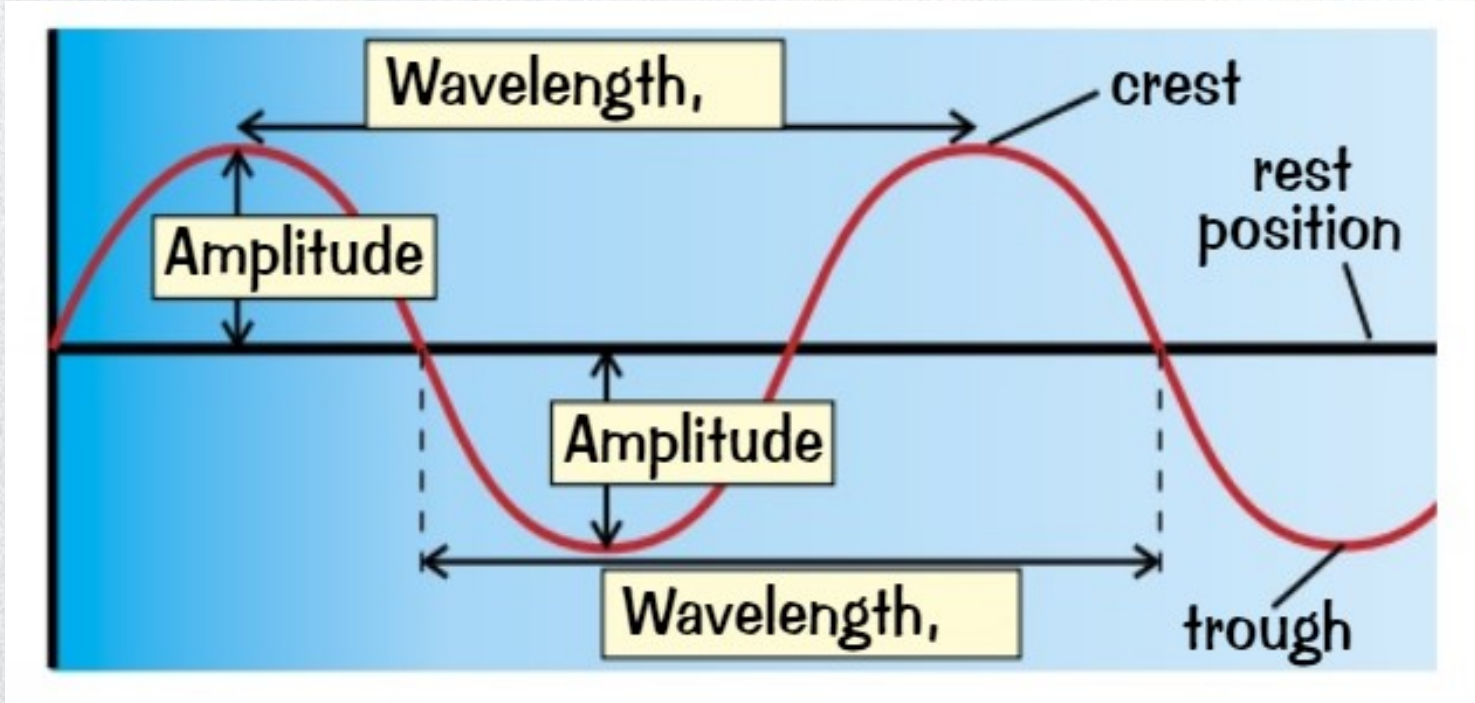
Properties

wavelength (λ)

frequency (f)

amplitude

speed (v)



Features of a wave

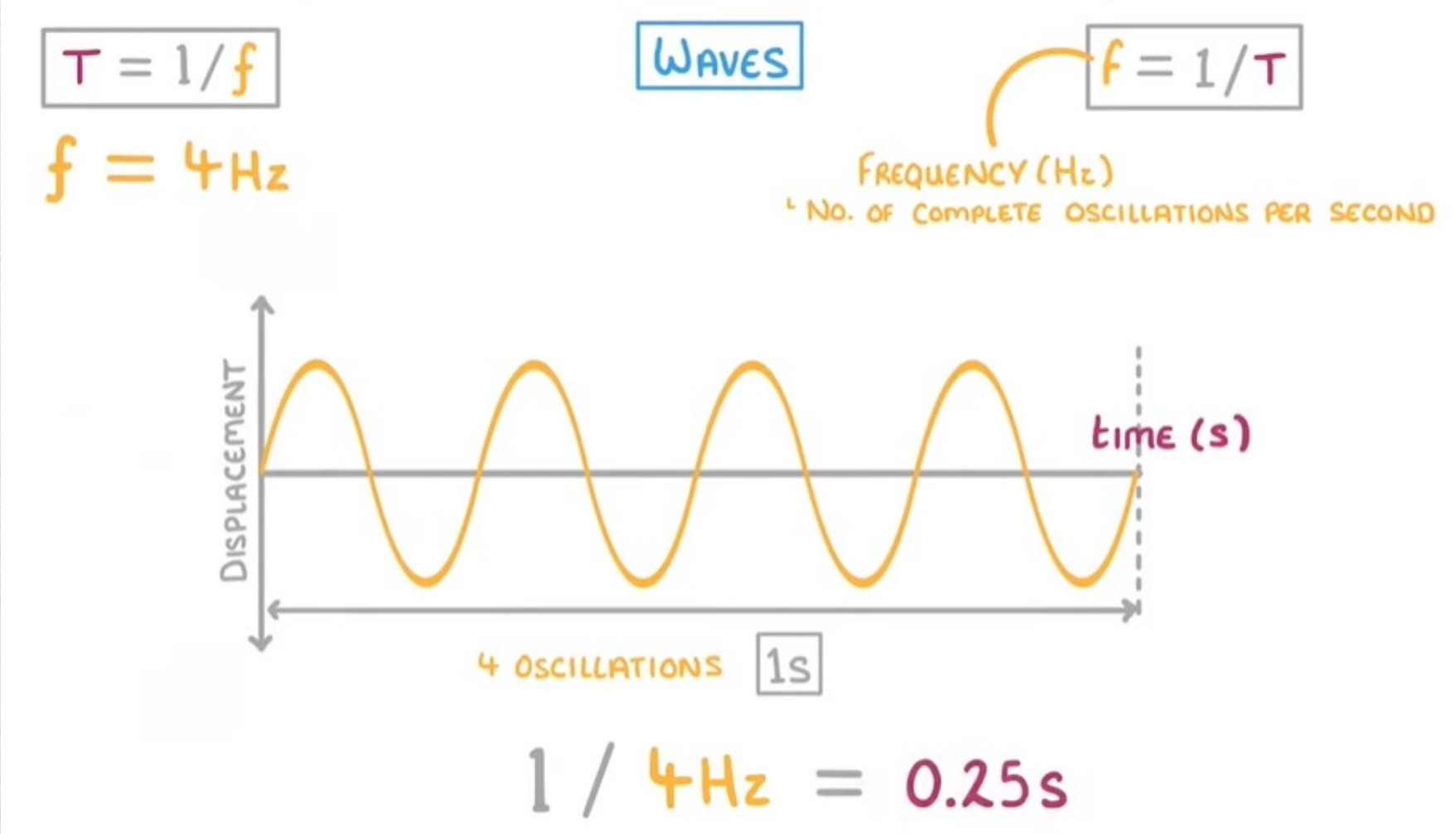
Wavelength:

- is the distance between **adjacent particles** that are **at the same point in their vibration** (the distance from one peak to the next)
  - ✓ In a transverse wave, it is the distance between two adjacent peaks or troughs
  - ✓ In longitudinal wave, it is the distance between two adjacent compressions or rarefactions

Amplitude:

- is the maximum displacement of particles from **rest position** (the height of the wave from rest to crest)
  - ✓ In transverse waves, it is the distance between the rest position to the peak

Features of a wave (Cont'd)



Features of a wave (Cont'd)

Speed:

- is the distance traveled per second, and is measured in m/s
- How fast the wave goes

Frequency:

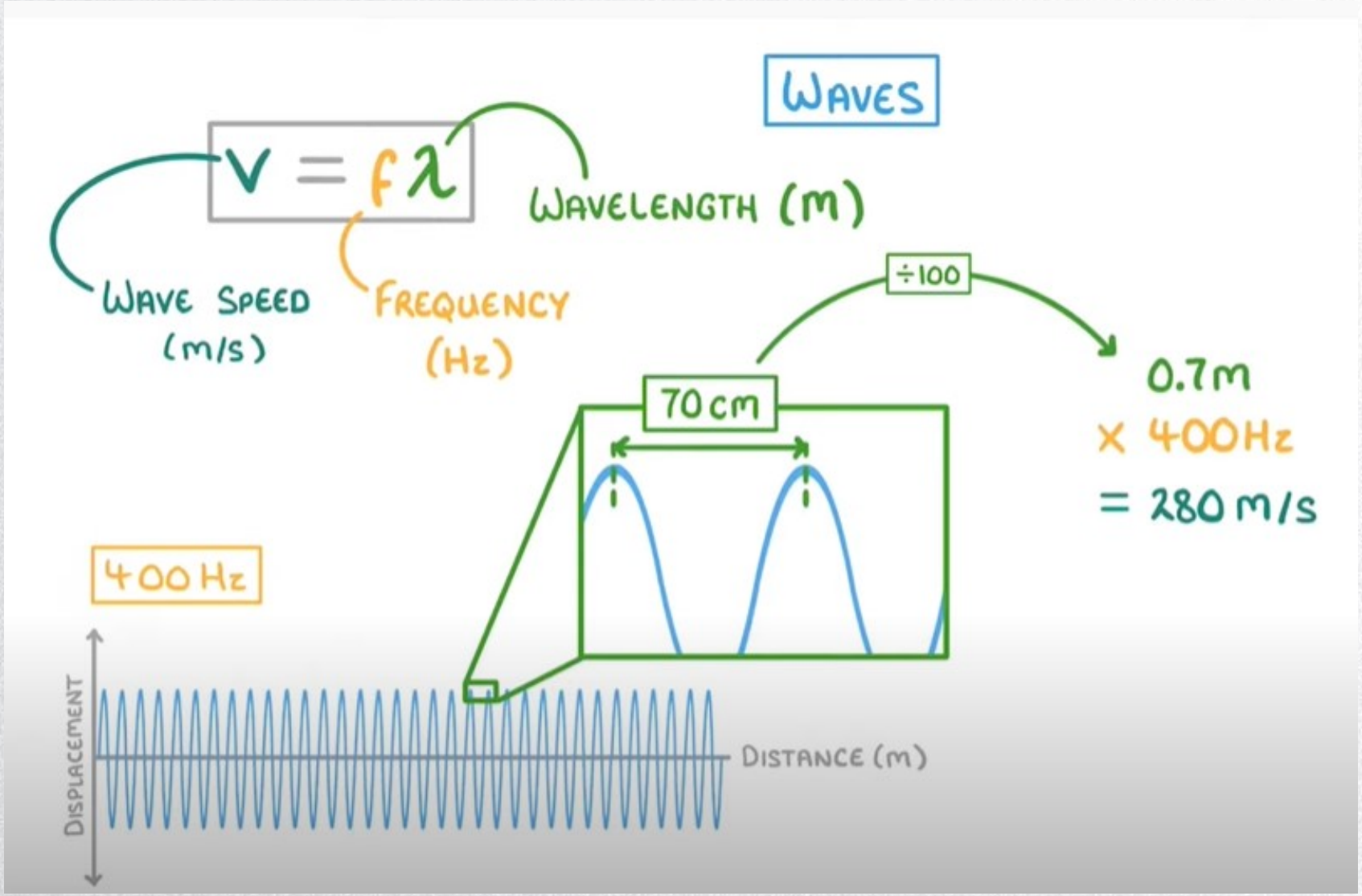
- the number of complete waves passing a point per second, and is measured in Hertz (Hz)
- How many compete waves there are per second (passing a certain point)
- 1 Hz = 1 per second = 1/s *or* s^{-1}

Time period:

- the time takes (in s) for one complete wave to pass a point

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

Features of a wave



Features of a wave (Cont'd)

$$Speed = frequency \times wavelength$$

$$v = \lambda \cdot f$$

where

v = speed (m/s)

f = frequency (Hz)

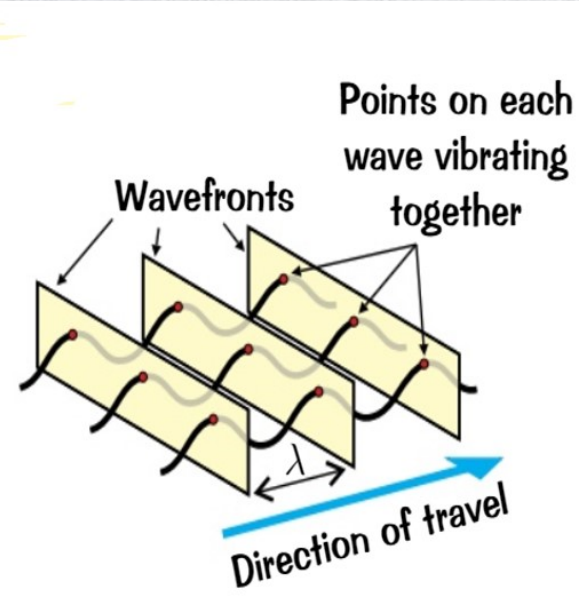
λ = wavelength (m)

* About units of frequency:

1 kHz (kilohertz) = 1 000 Hz

1 MHz (megahertz) = 1 000 000 Hz

Features of a wave (Cont'd)



Wavefronts:

- Often when we talk about waves approaching an obstacle or boundary, there are **multiple waves moving together in the same direction**.
- In this case, it's useful to talk about wavefronts. Wavefronts are **imaginary planes** that cut across all the waves, connecting the points on adjacent waves which are vibrating together.
- The distance between each wavefront is equal to one wavelength. i.e. each wavefront is at the same point in the cycle.

Wave behavior

Reflection (at a plane surface)

- The change in direction of a ray of light when it strikes a surface without passing through it.
- This causes **the direction of wave to change**
- The frequency/speed/wavelength stays the same

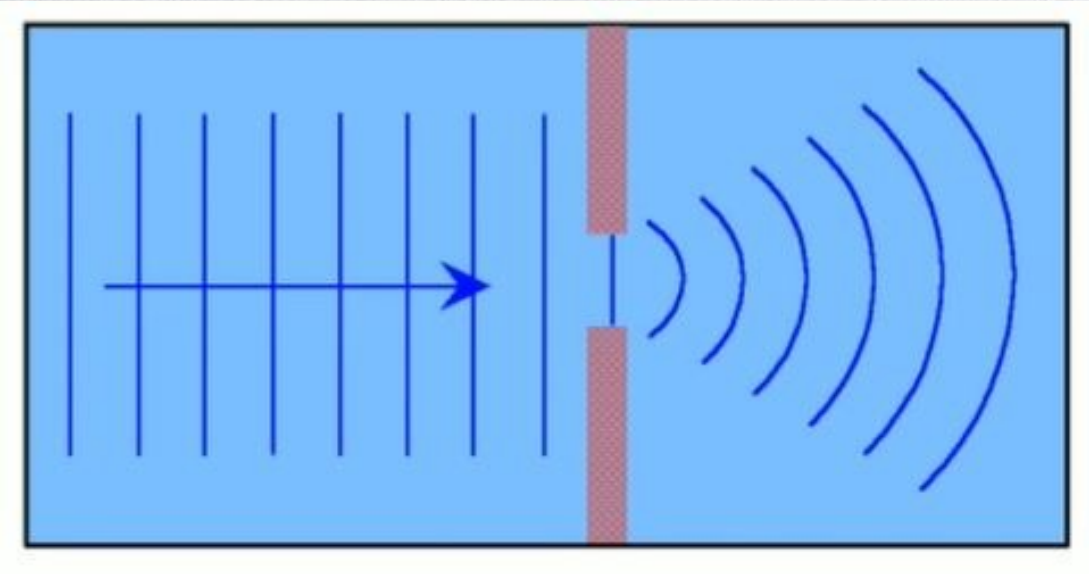
Wave behavior (Cont'd)

Refraction

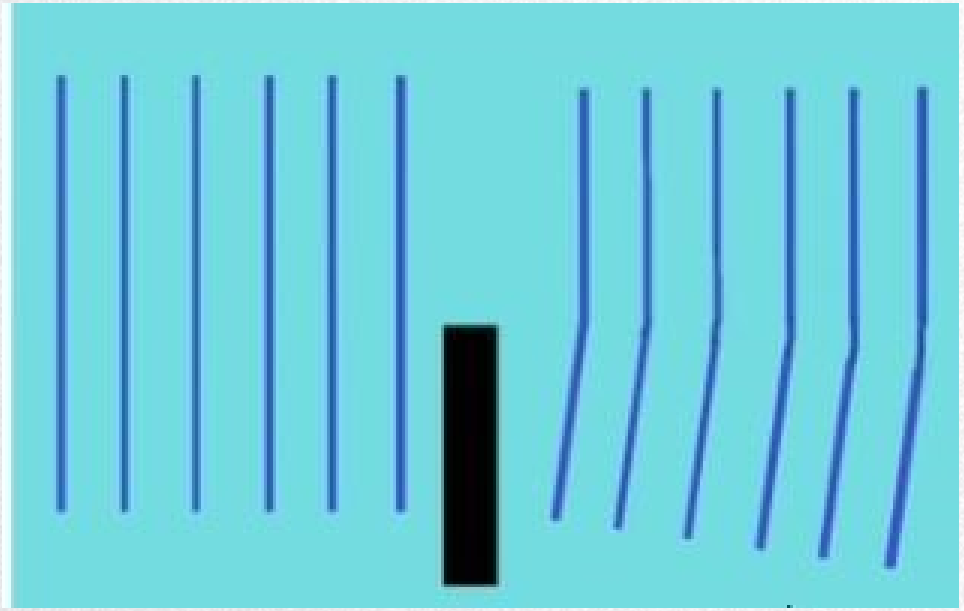
- The bending of waves on passing from one material to another
- Speed of a wave changes when a wave travels from one medium to another medium with a different density (different medium / density)
- This causes **the direction of wave to change**

Wave behavior (Cont'd)

Diffraction due to a gap



Diffraction due to an edge



Wave behavior (Cont'd)

Diffraction:

- **None** of the properties of a wave are changed by diffraction.
- When a wave spreads out as it travels through **a narrow gap** or pass the **edge of an object (obstacle)**
- Diffraction happens best when the **wavelength equals the size of the gap**
- As water passes the gap, it spreads out as follows:
  - ✓ Extent of diffraction depends on **size of gap** compared to wavelength
  - ✓ Diffraction can also occur **at edge of barrier**

Wave behavior (Cont'd)

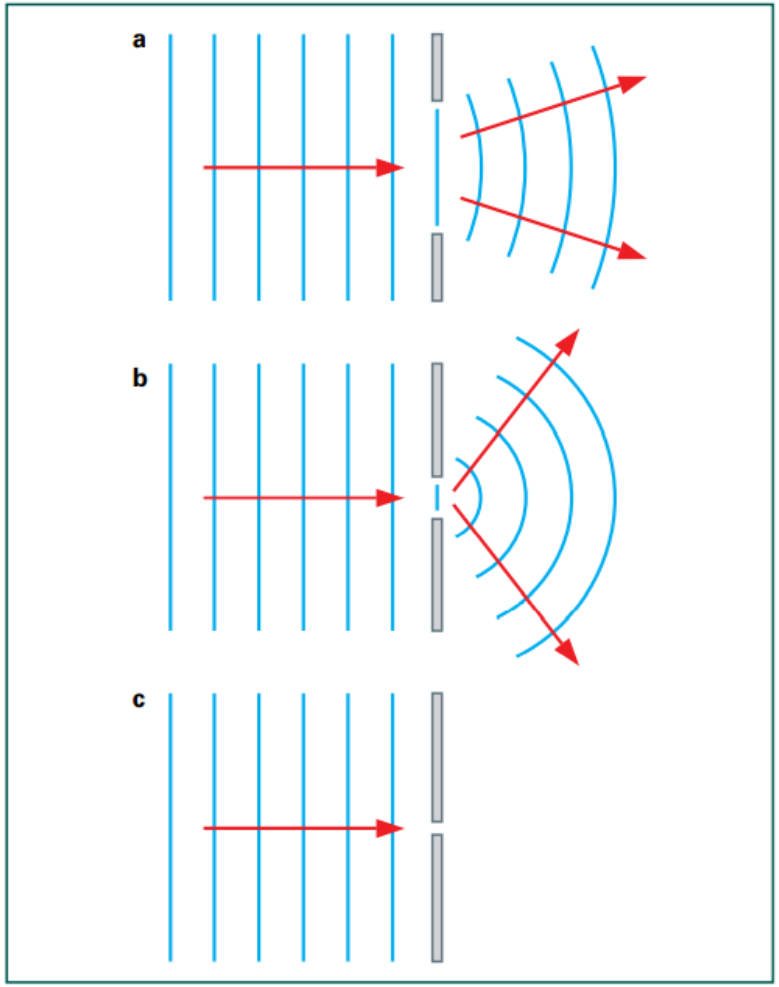


Figure 14.14 Diffraction is greatest when the width of the gap is equal to the wavelength of the waves being diffracted. When the gap is much smaller than the wavelength, the waves do not pass through at all.

Production of Sound Waves

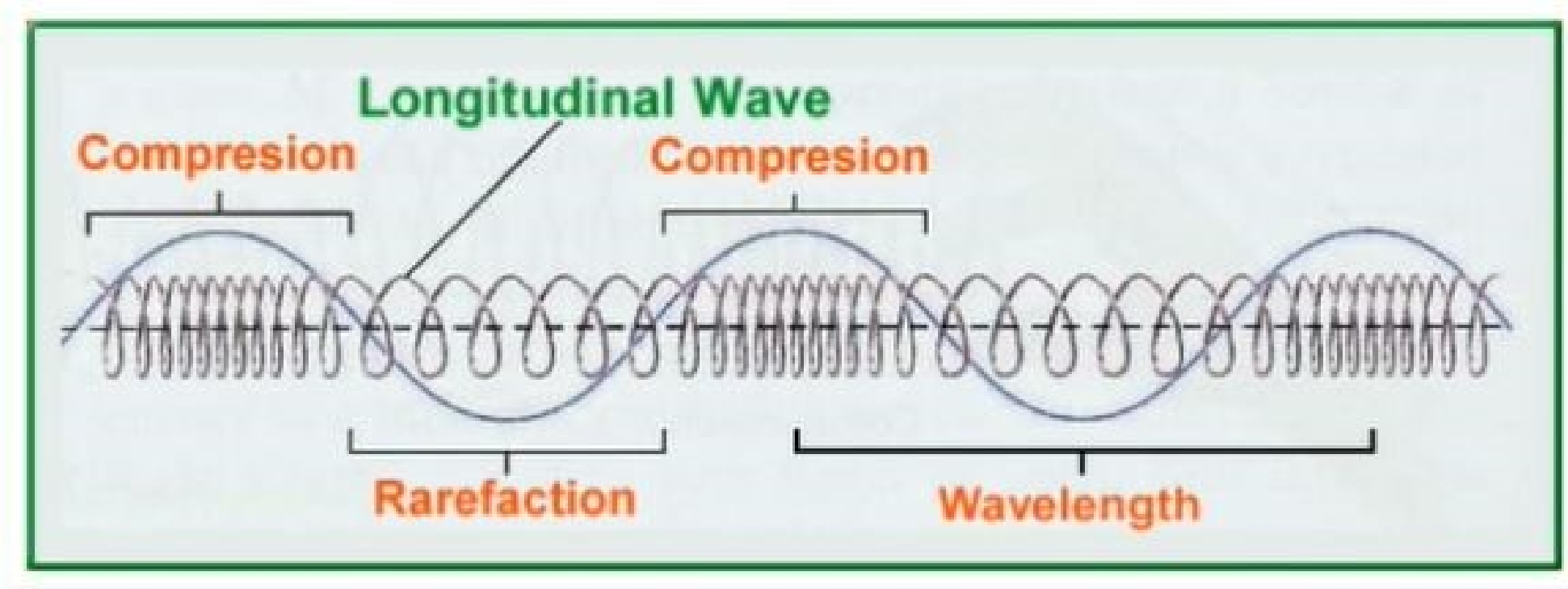
What is sound and how is sound produced?

Sound is produced when an object **vibrate**s, creating a **longitudinal** wave. This wave causes particles in the surrounding **medium** (air, water, or solid) to have **vibrational motion**. As the particles vibrate, they move nearby particles, transmitting the sound further through the medium.

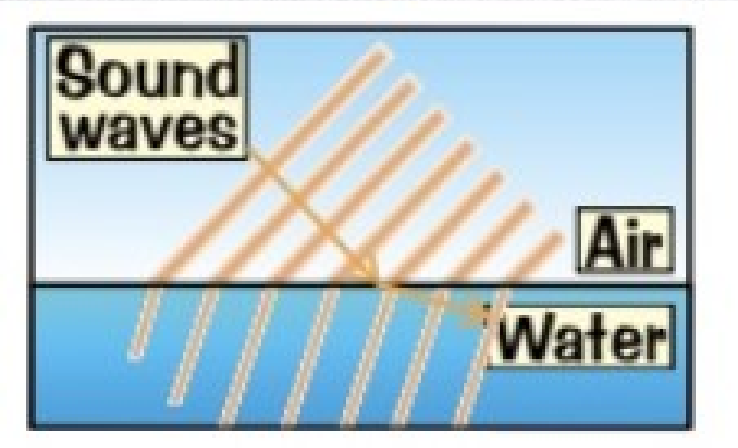
Production of Sound Waves

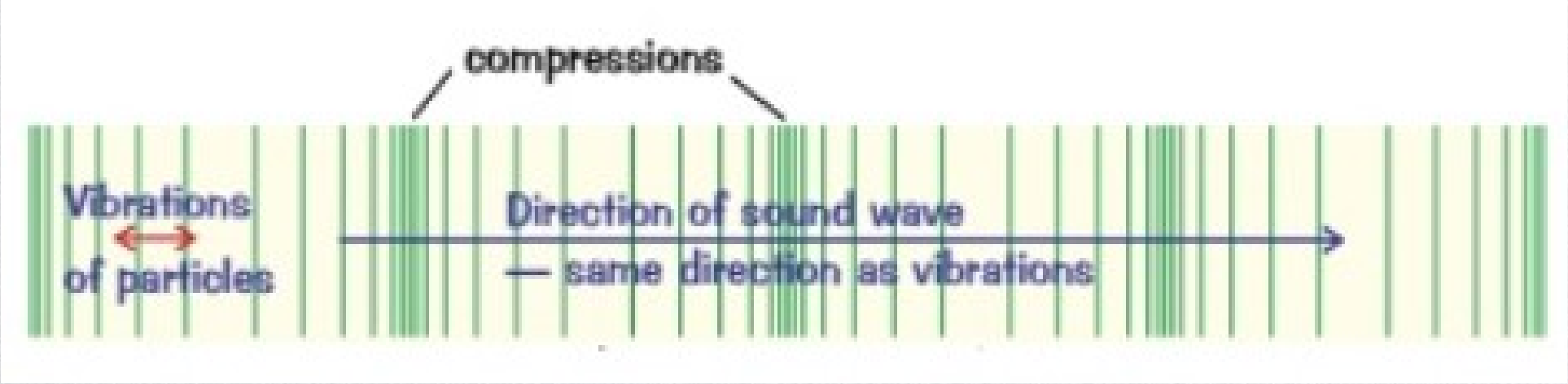
- Sound is a result of vibrating objects that cause a vibration of air molecules
- We hear sound when sound waves reach out ear which causes vibrations in our ear drums
- The human ear is capable of hearing sounds with frequencies between **20 Hz to 20 000 Hz**.
- All waves (including sound) have a frequency and amplitude
  - ✓ Frequency (Hz) is the number of waves that passes a fixed point per second
    - ❖ The higher the **frequency** the higher the **pitch**
  - ✓ The amplitude of wave is the maximum displacement of the vibration particles
    - ❖ The larger the **amplitude** the higher the **loudness**

Production of Sound Waves



Sound waves


Sound waves
Air
Water


compressions
Vibrations
of particles
Direction of sound wave
— same direction as vibrations

Sound waves

- Sound waves are **longitudinal** waves (with compressions and rarefactions) caused by **vibrating objects**. The vibrations are passed through the surrounding medium as a series of compressions.
- Since sound waves are caused by vibrating particles, in general **the denser the medium, the faster sound travels through it**. This also means it **can't travel through a vacuum**.
- Sound waves will be **reflect**ed by hard flat surfaces. Things like carpets and curtains act as **absorb**ing surfaces, which will absorb sounds rather than reflect them.
- Sound waves will also **refract** as they enter different media. As they enter denser material, they speed up (However, since sound waves are always spreading out so much, the change in direction is hard to spot under normal circumstances).

Ultrasound

- Ultrasound is defined as sound with a frequency **higher than 20 kHz**
- The uses of ultrasound in non-destructive testing of materials, medical scanning of soft tissue, and sonar including calculation of depth or distance from time and wave speed

Speed of Sound

- Sound cannot travel through **vacuum**
- Sound must be transmitted through vibrations of particles within a medium
- The closer the particles are within the medium, the faster sound will travel
  - ✓ Air particles are very spread out, so sound does not travel very fast
  - ✓ Metals on the other hand are usually solids, and particles are much closer together allowing quicker transmission of sound waves
  - ✓ Sound speed in air = 330 m/s (approximately 330–350 m / s)

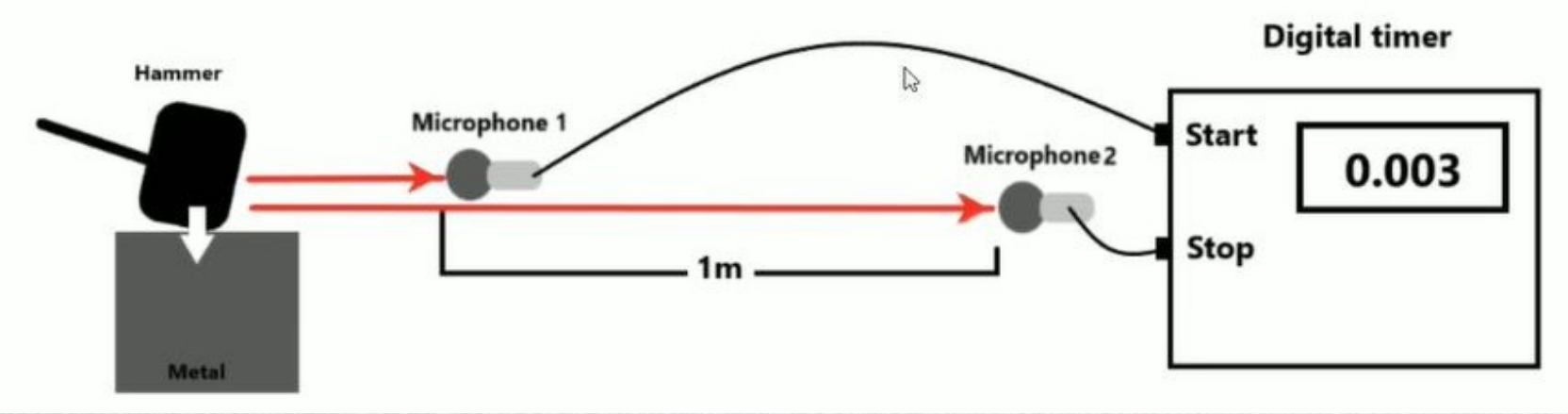
    Sound in water = 1500 m/s

    Sound in metals = 5000 m/s

Determining of Speed of Sound in Air

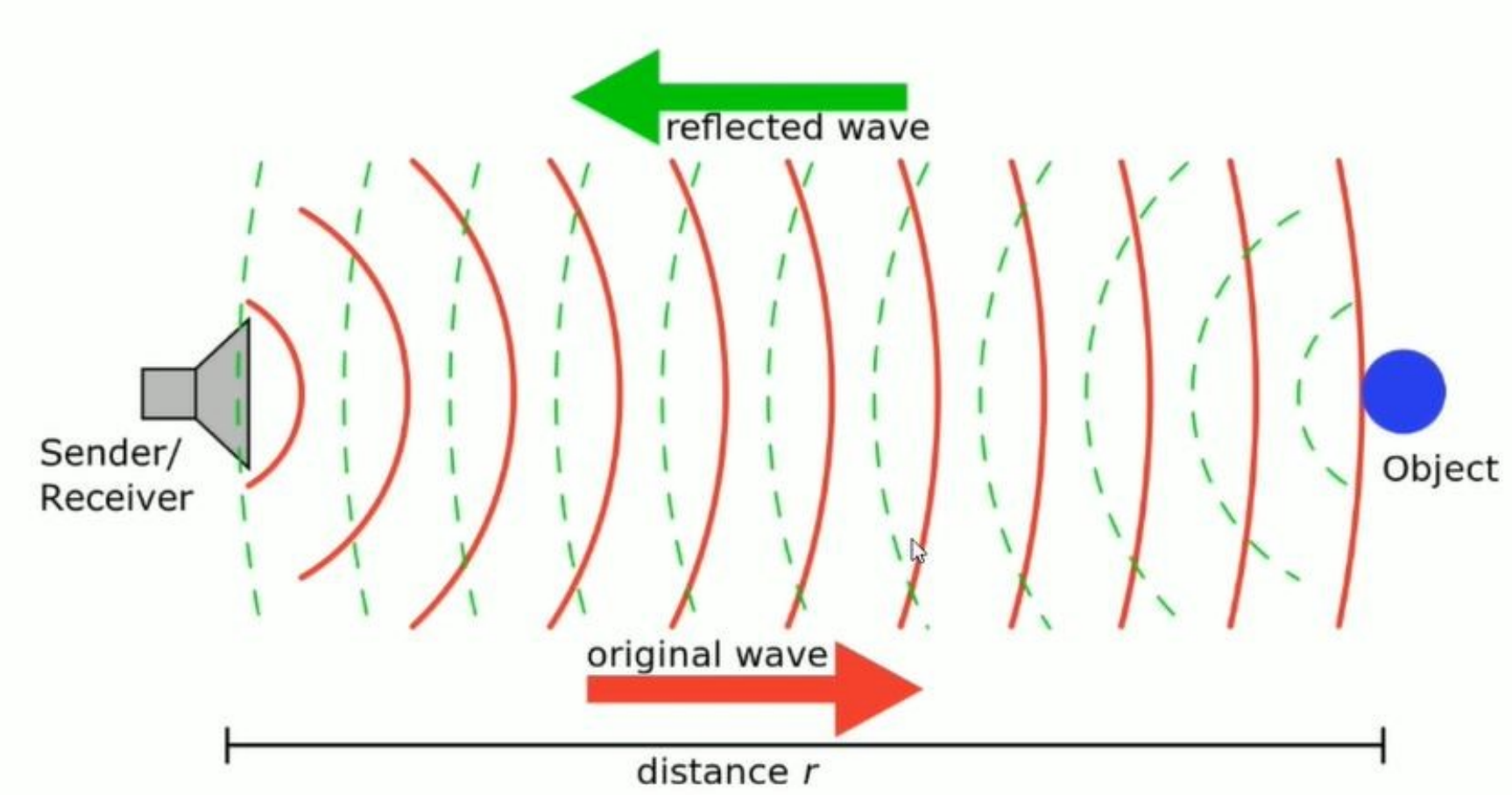
We can experimentally determine the speed of sound in air:

- 2 microphones are separated by exactly 1 m
- They are connected to a digital timer that starts when it gets signal from mic 1 and stops when it gets a signal from mic 2
- A hammer is used to hit a metal block to make sound
- The timer will record to travel between mic 1 and mic 2 the time taken from sound (i.e. 0.003 s)
- Speed = distance / time taken = 1/0.003 = 330 m/s



Echoes

When sound waves get reflected off a surface, it generates an echo



Sound waves

A group of students wants to determine the speed of sound in air.

Describe a method they can use. State the measurements they need to make.

.....

.....

.....

.....

.....

.....

.....

.....

..... [4]

[Total: 4]

Sound waves

Answer	Marks
for full marks the method described must work any **four** from: means of producing sharp sound use of suitable reflecting surface measure distance travelled by sound method for measurement of time for sound to travel measured distance use of speed = distance / time	**4**

EM Waves

The table shows 5 different types of electromagnetic wave.

In the blank column in the table, write the numbers 1 to 5 to show the order of wavelength. Write 1 for the wave with the shortest wavelength and 5 for the wave with the longest wavelength.

type of electromagnetic wave	order of wavelength
gamma rays	
light	
microwaves	
ultraviolet	
X-rays	

[2]

[Total: 2]

EM Waves

Answer	Marks	AO Element	Notes
(all five numbers correct from top to bottom =) 1, 4, 5, 3, 2	**2**		3 numbers correct = [1]