Year 9 Science Physical World: Part 1

Lesson 1 The Wave Model Sample resources

MATRIX EDUCATION

1. The wave model

☐ Wave motion

- A wave is a **disturbance or oscillation** that travels through space and matter and is accompanied by a **transfer of energy** from one point to another.
  - The photograph below shows a ripple of waves created when you dip your fingers in water.

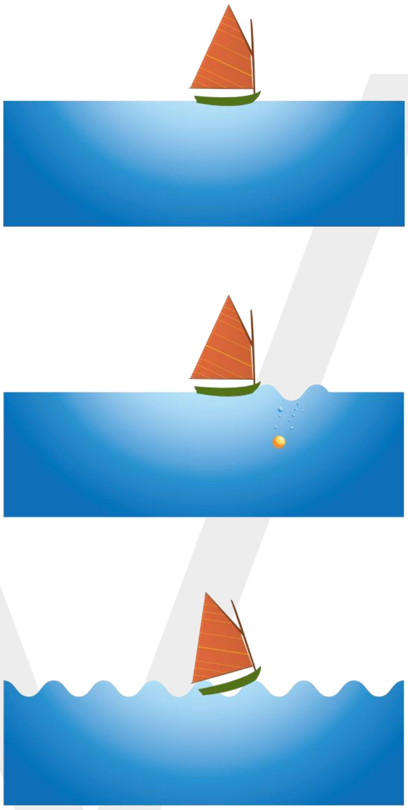
By Agustín Ruiz, [CC BY 2.0], via Wikimedia Commons

  - To create the waves, a disturbance to the water was provided. What is the disturbance in the photograph above?[1]

  - The wave causes the water to move up and down; it has kinetic energy while the wave moves through it.
  - The ripples represent **wave motion transferring energy** from one point to another.

☐ Waves are energy carriers

- Let's investigate the concept of a wave **transporting energy** by considering the following example.
- A golf ball is dropped into a body of water near a toy boat.
  - As a result, the surface of the water is disturbed. The disturbance travels through the water and thus waves are created.



  - When the waves pass by the boat, **the boat oscillates up and down.**
  - Energy is required to move an object. Where do you think the energy that causes the yacht to oscillate up and down came from?[2]

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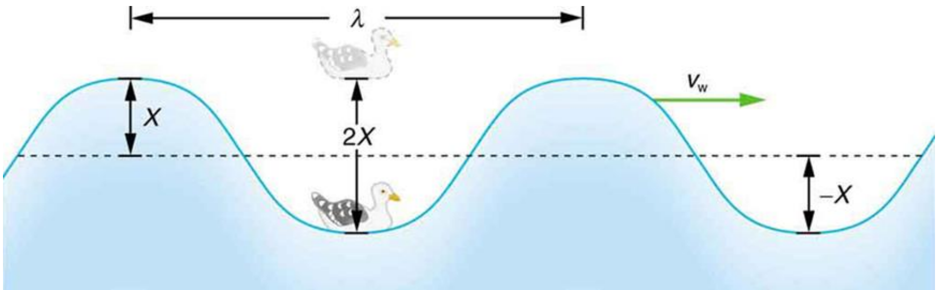
  - In this example, the golf ball caused a **disturbance in the water** which **created a wave** that **carried energy** to the yacht.

- A wave is a carrier of energy, not matter.
  - The diagram below show water waves passing a seagull floating on the water.



Source: Open Stax, openstax.org/books/college-physics-ap-courses)

  - As the wave passes under the seagull, the seagull bobs up and down.
  - **Comment** on the position of the seagull before and after the water waves have passed.[3]

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- The flowchart below outlines the process of energy transfer in wave motion.

Disturbance in medium

↓

Wave motion (disturbance propagates)

↓

Transfer of energy (not matter)

  - Can you name some other examples of wave motion?[4]

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☐ Energy carried by waves

- Waves can carry many forms of energy. The main forms of energy carried by waves are:
  - **Kinetic energy:** The energy an object possesses due to its motion.
  - **Gravitational potential energy:** The energy stored in an object as a result of its position above the ground.
  - **Electromagnetic energy:** The *energy carried by electromagnetic radiation.*

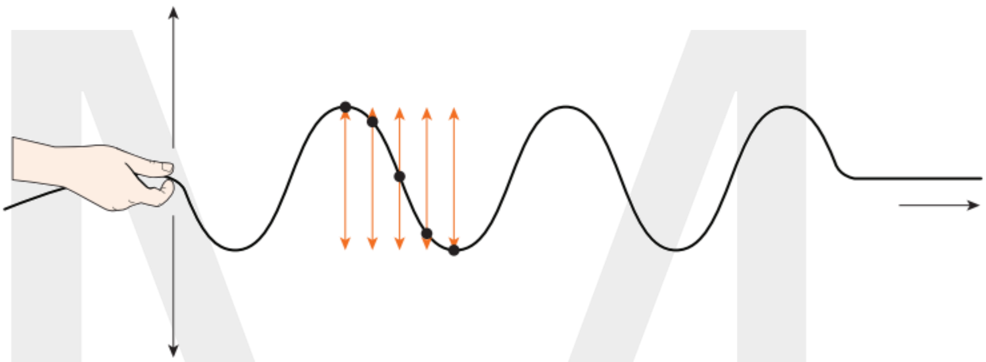
Note to students
Electromagnetic radiation covers a spectrum of waves including microwaves, radio waves, infrared, light waves, ultraviolet waves, x-rays and gamma rays. You will learn more about these in Lesson 3!

- Complete the following table. The types of energy carried by the waves are kinetic energy, potential energy and electromagnetic energy.

Wave	Type of energy carried or transferred
Sound wave[5]	
Water wave[6]	
Earthquake[7]	
Infrared wave[8]	
Wave in a taut string[9]	
Visible light wave[10]	
Radio wave[11]	

☐ Waves in different dimensions

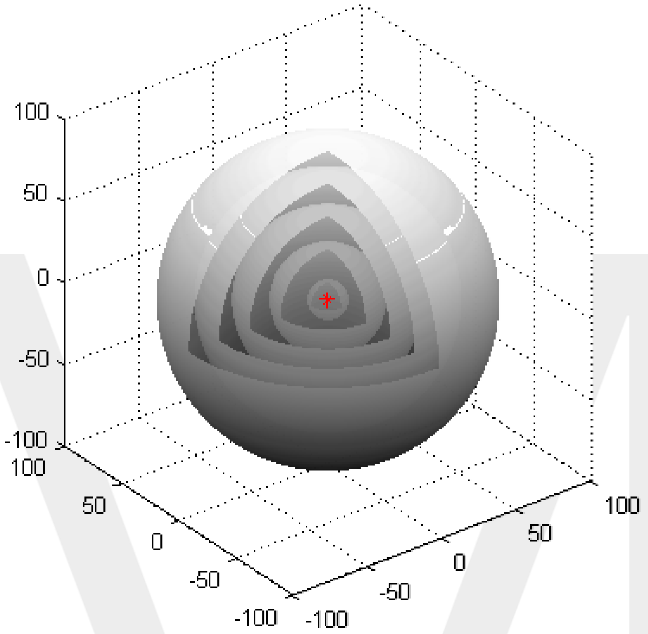
- Waves can exist in:
  - One dimension,
  - Two dimensions and
  - Three dimensions
- Examples of a **one-dimensional wave** are waves on a string or on a slinky.



  - Note that the wave moves along the string, but the individual sections of the string only move up and down.
- An example of a wave that moves in **two dimensions** is a water wave.
  - The photograph below shows water waves spreading out in two dimensions from a disturbance on the surface.

Source: Public domain

- Examples of waves that move in **three dimensions** are a light wave produced by a light bulb or sound waves. The picture below shows a representation of a wave spreading out in three dimensions from a source at the centre.



Source: Jonathan Papa [CC BY-SA 3.0], via Wikimedia Commons

2. Classification of waves

☐ Categories of waves

- There are two main ways of classifying waves:
  - The direction of oscillation of particles of the medium relative to the direction of the wave, or
  - The type of energy carried by the wave

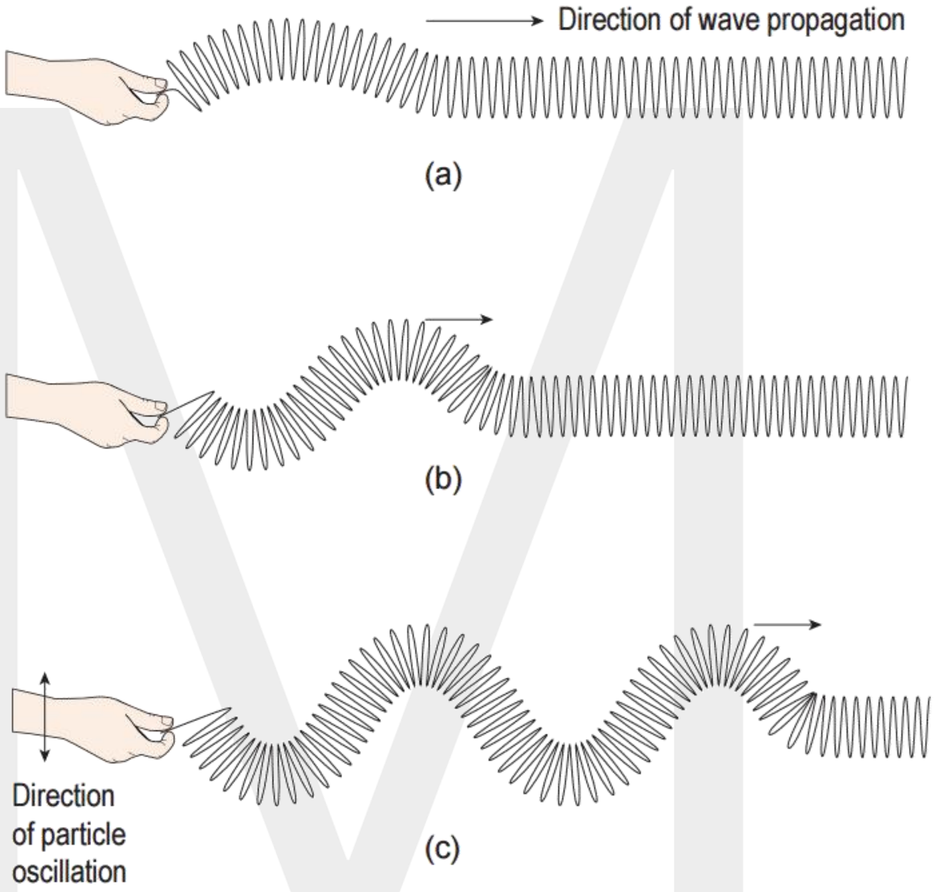
- Categorising waves on the basis of the **direction of movement of the individual particles** leads to two notable categories:
  - **Transverse** waves: particles oscillate perpendicular to wave direction
  - **Longitudinal** waves: particles oscillate parallel to wave direction

- VIDEO (Length: 0:07): Transverse and longitudinal waves in a slinky.

- Categorising waves on the basis of the **type of energy they carry** leads to two notable categories:
  - **Mechanical** waves (carry kinetic and potential energy, requires motion of the medium)
  - **Electromagnetic** waves (carry electromagnetic energy, stored in time-varying electric and magnetic field).

☐ Transverse waves

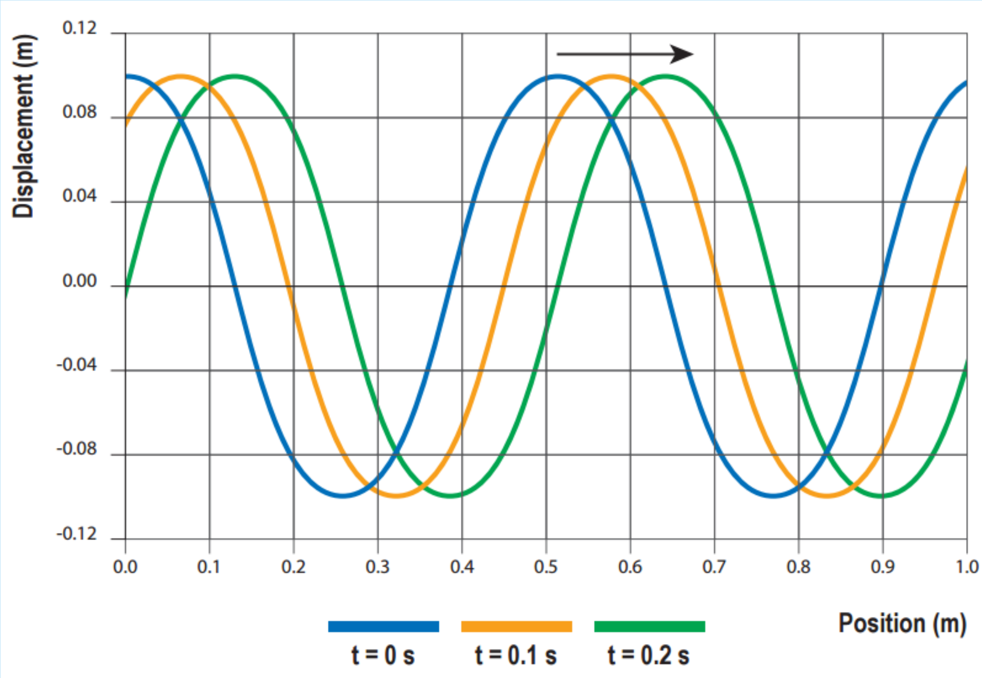
- In transverse waves, **particles oscillate** in simple harmonic motion (SHM) **perpendicular to** the direction of wave propagation.
  - The diagram below shows the relationship between the direction of disturbance and wave movement in a transverse wave in a slinky.



  - <u>**VIDEO (Length: 1:12):**</u> Transverse wave propagation on a slinky.

Note to students

Simple harmonic motion is a type of periodic motion. It involves repetitive movement back and forth through a central position (equilibrium position). This creates a waveform that looks the same at regular intervals. An example is given below. Three snapshots are taken of a periodic wave moving to the right.

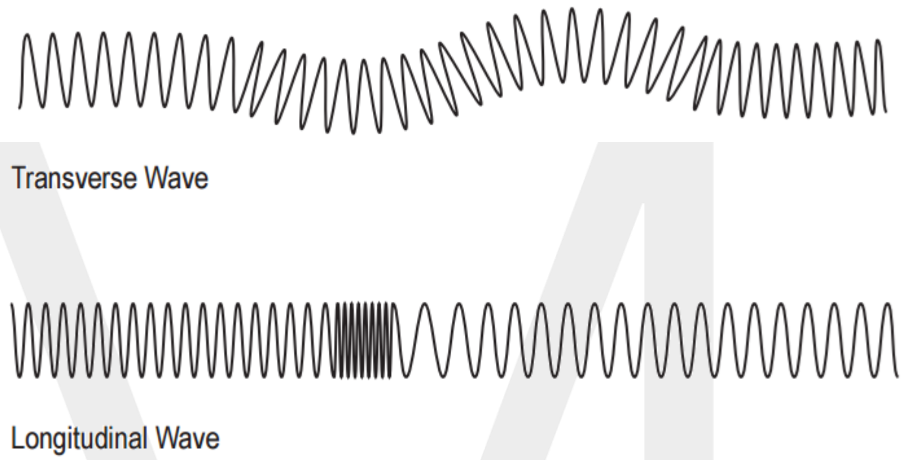


Watch **VIDEO 1 (Length 1:00)** and **VIDEO 2 (Length: 1:00):** Wave propagation – notice that particles move back and forth or up and down through a central position!

- Transverse waves can be either **mechanical** or **electromagnetic** in nature.
  - Do transverse waves require a medium to propagate?[12]
  - What are some examples of transverse waves?[13]

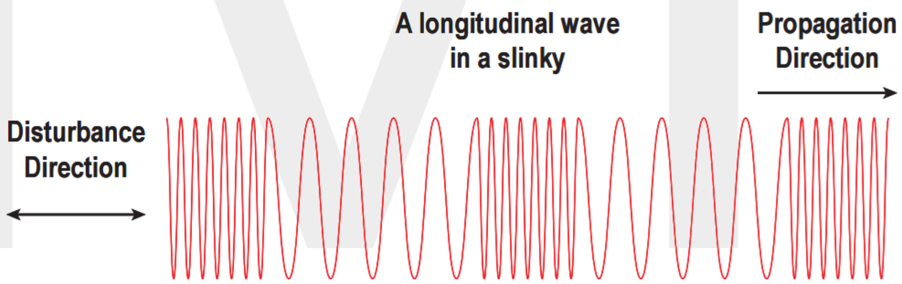
☐ Longitudinal waves

- In longitudinal waves, **particles oscillate parallel to** the direction of wave propagation.
  - The diagram below shows the motion of particles in a transverse wave and longitudinal wave.



  - <u>VIDEO (Length: 2:05):</u> Longitudinal wave propagation on a slinky.

- The diagram below shows the relationship between the direction of disturbance and wave movement in a longitudinal wave in a slinky.



  - Longitudinal waves are **mechanical** in nature. They cannot be electromagnetic.
  - Do longitudinal waves require a medium to propagate through?[14]

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  - What are some examples of transverse waves?[15]

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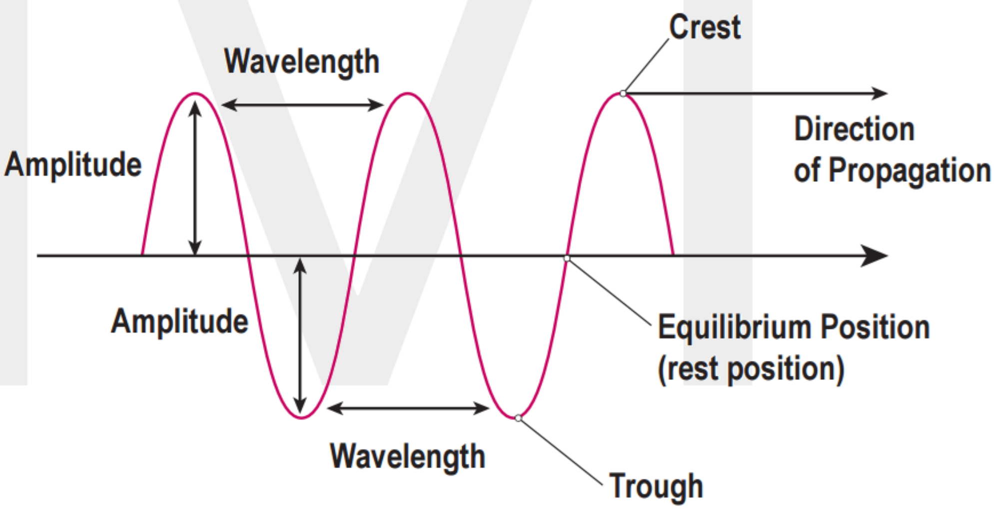
3. Wave characteristics

☐ Transverse wave characteristics

- All transverse waves have **common characteristics** which help us to describe a wave. The common characteristics are:
  - Wavelength
  - Frequency and period
  - Amplitude
  - Speed
- It is easiest to visualise these characteristics on a periodic transverse wave.

> **Note to students**
>
> Periodic transverse waves are sinusoidal. They look like sine/cosine waves!

- A snapshot of a **transverse wave** is shown below. Its characteristics have been labelled.



- The **crest** of a wave is the point on the medium which exhibits the maximum amount of positive or **upwards displacement** from the rest position.
- The **trough** of a wave is the point on the medium which exhibits the maximum amount of negative or **downwards displacement** from the rest position.

- The **amplitude (A)** of a wave refers to the maximum displacement of a particle on the medium from its equilibrium position. In other words, amplitude is the **distance from rest to crest or rest to trough**.
  - Amplitude is a measure of distance, so it is measured in **metres** (m).
- The **wavelength (λ)** (lambda) is the length of one complete wave cycle or the distance between adjacent crests or troughs.
  - Wavelength is a measure of distance, so it is measured in **metres** (m).
- The **frequency (f)** is the number of complete wave cycles (wavelengths) that pass a point per second.
  - Frequency is a measure of cycles per second (s^{-1}) and has the SI unit **Hertz** (Hz), after a scientist named Heinrich Hertz.
- The **period (T)** is the time taken for one complete wave cycle to pass a point.
  - Period is a measure of a time, so it is measured in **seconds** (s).

Note to students

A period of 1 second means it takes 1 second for 1 complete wave cycle to pass a point in space

  - The period is related to the frequency by the following relationship:

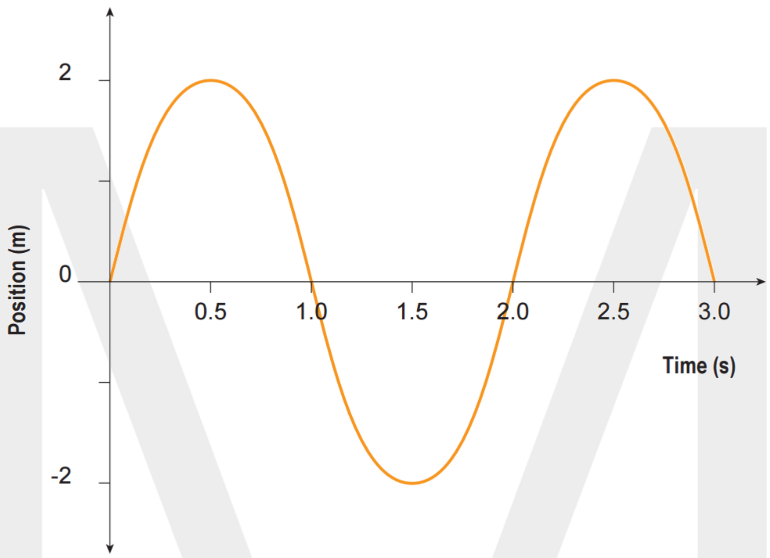
$$T = \frac{1}{f}$$

  - If a wave has a frequency of 50 Hz, what is its period?[21]

- The **speed** of a wave determines the distance through which each wave moves per second.

☐ Graphs for transverse wave motion

- Graphs can be used to **present and analyse the motion of particles** at fixed distances along a transverse wave.
- The graph below is a **position (displacement) vs. time graph** for a point in space as a periodic transverse wave passes by.



- Determine the following properties of the wave using the information provided in the graph above.
  - Amplitude[22]
  - Period[23]
  - Frequency[24]
- Can you calculate the wavelength of the wave using the graph shown above? [Hint: No, but why not?][25]

☐ Wave equation

- The **wave equation** is a formula that relates the speed, frequency and wavelength of a wave. It applies to all periodic waves, sinusoidal or not.

- Mathematically,

$$v = f\lambda$$

Where: v = speed of the wave (m/s or ms^{-1})
f = frequency of the wave (Hz, equivalent to s^{-1})
λ = wavelength of the wave (m)

- Using the wave equation, complete the table below.

Wave	Speed (m/s)	Wavelength (m)	Frequency (Hz)
Sound wave in air	340	2	
Gamma wave in vacuum			9.3×10^{19}

☐ Energy, amplitude and frequency

- The energy a wave carries depends on both the **amplitude** and the **frequency** of the wave.

- If either the amplitude or frequency is increased, the particles must be travelling faster, and carry more kinetic energy.
  - In a wave with a higher amplitude, particles oscillate larger distances (in the same amount of time, since the frequency is the same).
  - In a wave with a higher frequency, the particles oscillate up and down more times each second (over the same distance, since the amplitude is the same).

- Low frequency waves can have higher energy than high frequency waves if they have much larger amplitudes.

4. Lesson review questions

Concept Check 4.1

(a) What is a wave?[26] **1**

(b) What types of energy can waves transfer? Give examples.[27] **2**

Concept Check 4.2

(a) How can waves be classified?[28] **2**

(b) What is the difference between a transverse wave and a longitudinal wave? Give an example of each.[29] **2**

(c) What is the difference between a mechanical and an electromagnetic wave? Give an example of each.[30] **2**