Surfing

NSW PHYSICS 3&4

Module 3 Waves and Thermodynamics

Module 4 Electricity and Magnetism

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Module 3 Waves and Thermodynamics

Wave Properties

CONTENT FOCUS Conduct an investigation to create mechanical waves in a variety of situations to explain the role of the medium in the propagation of mechanical waves.

CONTENT FOCUS Conduct an investigation to create mechanical waves in a variety of situations to explain the transfer of energy involved in the propagation of mechanical waves.

CONTENT FOCUS Conduct investigations to explain and analyse differences between transverse and longitudinal waves.

CONTENT FOCUS Conduct investigations to explain and analyse differences between mechanical and electromagnetic waves.

CONTENT FOCUS Construct and/or interpret graphs of displacement versus time and displacement versus position of transverse and longitudinal waves and relate the features of these graphs to wave characteristics including velocity, frequency, period, wavelength, displacement and amplitude.

CONTENT FOCUS Solve problems and/or make predictions by modelling, deriving and applying the following relationships to a variety of situations: $v = f\lambda$ and $f = \frac{1}{T}$.

Wave Behaviour and the Ray Model Of Light

CONTENT FOCUS Explain the behaviour of waves in a variety of situations by investigating reflection.

CONTENT FOCUS Explain the behaviour of waves in a variety of situations by investigating refraction.

CONTENT FOCUS Quantitatively predict, using Snell's law and the concept of refractive index, the refraction and total internal reflection of light in a variety of situations including the use of $n_1 \sin i = n_2 \sin r$ and $\sin i_c = \frac{1}{n_x}$ for the critical angle i_c of medium x.

CONTENT FOCUS Conduct investigations to analyse qualitatively and quantitatively the refraction and total internal reflection of light including the use of $n_x = \frac{c}{v_x}$ for the refractive index of medium x, where v_x is the speed of light in the medium.

CONTENT FOCUS Explain the behaviour of waves in a variety of situations by investigating diffraction.

CONTENT FOCUS Conduct an investigation to distinguish between progressive and stationary waves.

CONTENT FOCUS Explain the behaviour of waves in a variety of situations by investigating wave superposition.

CONTENT FOCUS Conduct an investigation to explore resonance in mechanical systems and the relationships between the driving frequency, the natural frequency of the oscillating system, the amplitude of motion and the transfer/transformation of energy within the system.

CONTENT FOCUS Conduct an investigation to explain the formation of images in mirrors and lenses via reflection using the ray model of light.

CONTENT FOCUS Conduct an investigation to demonstrate and explain the phenomenon of the dispersion of light.

CONTENT FOCUS Conduct an investigation to demonstrate and relate the inverse square law, the intensity of light and the transfer of energy including the use of $I_1 r_1^2 = I_2 r_2^2$ to compare the intensity of light at two points, r_1 and r_2.
Investigate the relationship between distance and intensity of sound.

Soundwaves

CONTENT FOCUS Conduct an investigation to relate the pitch and loudness of a sound to its wave characteristics.
Model the behaviour of sound in air as a longitudinal wave.
Relate the displacement of air molecules to variations in pressure.

CONTENT FOCUS Conduct investigations to analyse the reflection of soundwaves.

CONTENT FOCUS Conduct investigations to analyse the diffraction of soundwaves.

CONTENT FOCUS Conduct investigations to analyse the resonance of soundwaves.

CONTENT FOCUS Investigate and model the behaviour of standing waves on strings to quantitatively relate the fundamental and harmonic frequencies of the waves produced to the physical properties (e.g. length, mass, tension, wave speed) of the medium.

CONTENT FOCUS Investigate and model the behaviour of standing waves in pipes to quantitatively relate the fundamental and harmonic frequencies of the waves produced to the physical properties (e.g. length, mass, tension, wave speed) of the medium.

CONTENT FOCUS Conduct investigations to analyse the superposition of soundwaves.
Analyse qualitatively and quantitatively, the relationships for the wave nature of sound to explain beats including $f_{beat} = f_2 - f_1$.

CONTENT FOCUS Analyse qualitatively and quantitatively, the relationships for the wave nature of sound to explain the Doppler effect: $f' = f\frac{v_{wave} \pm v_{observer}}{v_{wave} \mp v_{source}}$.

Thermodynamics

Module 4 Electricity and Magnetism

Electrostatics

Magnetism

CONTENT FOCUS

Investigate and describe qualitatively the force produced between magnetised and magnetic materials in the context of ferromagnetic materials.
Investigate and explain the process by which ferromagnetic materials become magnetised.

CONTENT FOCUS

Use magnetic field lines to model qualitatively the direction and strength of magnetic fields produced by magnets, current carrying wires and solenoids and relate these fields to their effect on magnetic materials that are placed within them.

CONTENT FOCUS

Apply models to qualitatively represent and quantitatively describe features of magnetic fields.

CONTENT FOCUS

Conduct investigations into and describe quantitatively the magnetic fields produced by wires, including $B = \frac{\mu_0 I}{2\pi r}$ or $B = \frac{kI}{d}$.

CONTENT FOCUS

Conduct investigations into and describe quantitatively the magnetic fields produced by solenoids, including $B = \frac{\mu_0 NI}{L}$.

Introduction

This book covers the Physics content specified in the NSW Physics Stage 6 Syllabus. Sample data has been included for suggested experiments to give you practice to reinforce practical work in class.

Each book in the *Surfing* series contains a summary, with occasional more detailed sections, of all the mandatory parts of the syllabus, along with questions and answers.

All types of questions – multiple choice, short response, structured response and free response – are provided. Questions are written in exam style so that you will become familiar with the concepts of the topic and answering questions in the required way.

Answers to all questions are included.

A topic test at the end of the book contains an extensive set of summary questions. These cover every aspect of the topic, and are useful for revision and exam practice.

Words To Watch

account, account for State reasons for, report on, give an account of, narrate a series of events or transactions.

analyse Interpret data to reach conclusions.

annotate Add brief notes to a diagram or graph.

apply Put to use in a particular situation.

assess Make a judgement about the value of something.

calculate Find a numerical answer.

clarify Make clear or plain.

classify Arrange into classes, groups or categories.

comment Give a judgement based on a given statement or result of a calculation.

compare Estimate, measure or note how things are similar or different.

construct Represent or develop in graphical form.

contrast Show how things are different or opposite.

create Originate or bring into existence.

deduce Reach a conclusion from given information.

define Give the precise meaning of a word, phrase or physical quantity.

demonstrate Show by example.

derive Manipulate a mathematical relationship(s) to give a new equation or relationship.

describe Give a detailed account.

design Produce a plan, simulation or model.

determine Find the only possible answer.

discuss Talk or write about a topic, taking into account different issues or ideas.

distinguish Give differences between two or more different items.

draw Represent by means of pencil lines.

estimate Find an approximate value for an unknown quantity.

evaluate Assess the implications and limitations.

examine Inquire into.

explain Make something clear or easy to understand.

extract Choose relevant and/or appropriate details.

extrapolate Infer from what is known.

hypothesise Suggest an explanation for a group of facts or phenomena.

identify Recognise and name.

interpret Draw meaning from.

investigate Plan, inquire into and draw conclusions about.

justify Support an argument or conclusion.

label Add labels to a diagram.

list Give a sequence of names or other brief answers.

measure Find a value for a quantity.

outline Give a brief account or summary.

plan Use strategies to develop a series of steps or processes.

predict Give an expected result.

propose Put forward a plan or suggestion for consideration or action.

recall Present remembered ideas, facts or experiences.

relate Tell or report about happenings, events or circumstances.

represent Use words, images or symbols to convey meaning.

select Choose in preference to another or others.

sequence Arrange in order.

show Give the steps in a calculation or derivation.

sketch Make a quick, rough drawing of something.

solve Work out the answer to a problem.

state Give a specific name, value or other brief answer.

suggest Put forward an idea for consideration.

summarise Give a brief statement of the main points.

synthesise Combine various elements to make a whole.

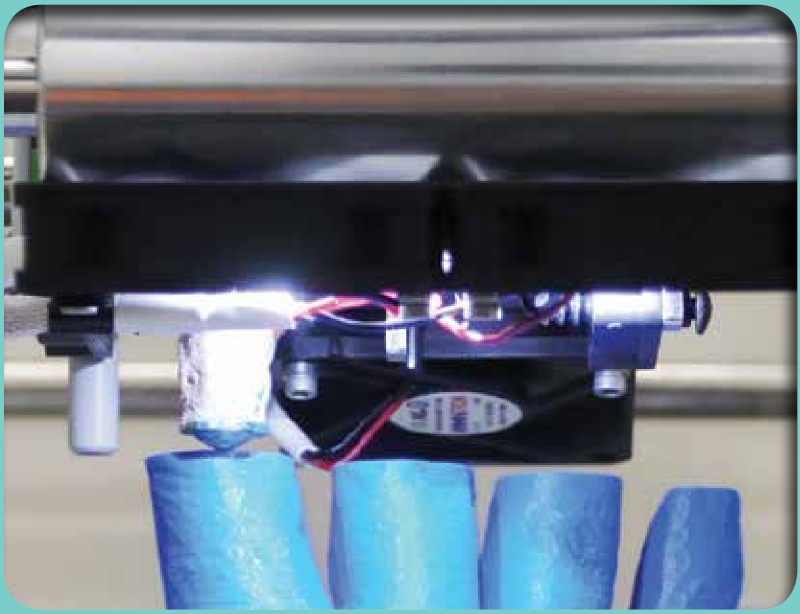
Surfing

NSW PHYSICS 3&4

Module 3

Waves and Thermodynamics

Content Focus



In this module you will:

- Investigate that wave motion involves the transfer of energy without the transfer of matter.
- Explore the properties of wave motion and examine the characteristics of wavelength, frequency, period, velocity and amplitude.
- Demonstrate how waves can be reflected, refracted, diffracted and superposed (interfered).
- Understand that not all waves require a medium to travel through.
- Examine mechanical waves and electromagnetic waves and the differences between their similarities and differences in properties.
- Understand that energy can be transferred in the form of heat from one place to another.
- Study thermodynamics to examine the relationship between energy, temperature and matter.
- Develop an understanding of how thermodynamics provides an appreciation of particle motion within objects.
- Examine how hot objects lose energy in three ways: by conduction and convection – which both involve the motion of particles; and emission of electromagnetic radiation.

CONTENT FOCUS

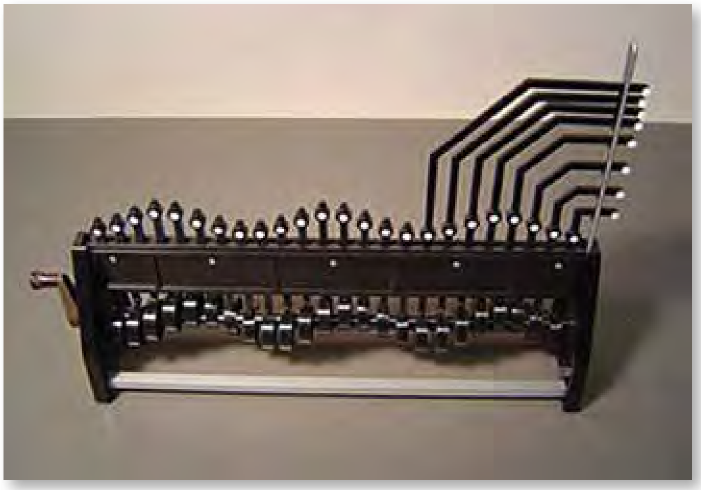
Conduct an investigation to create mechanical waves in a variety of situations to explain the role of the medium in the propagation of mechanical waves.

1 The Role Of the Medium Carrying a Wave

We can observe mechanical waves in the laboratory using ‘wave machines’.

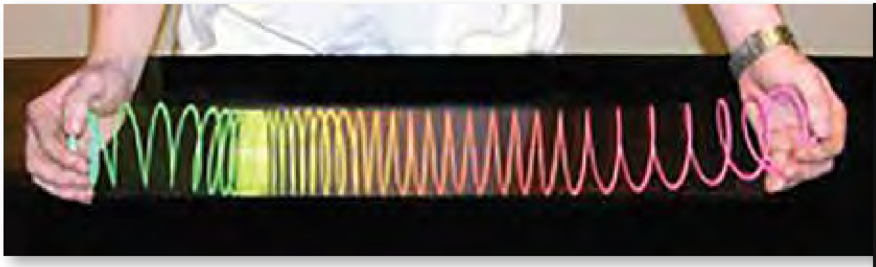
These machines also allow us to model the motion of the particles in the medium that carries the wave as well as the progression of the wave through the medium carrying it.

For example, when the handle on the wave machine (shown) is turned, the cam shaft at the bottom turns and the white balls at the top of the vertical risers and the horizontal arms move up and down and side to side (respectively) to simulate the particle movement in transverse and longitudinal waves.



On the particle level, these oscillations result in the transfer of energy from one particle to the next and transfer the energy through the medium.

Transverse and longitudinal waves can also be produced in a slinky spring and the movement of the individual coils in the slinky models the motion of the particles in a medium such as air for those waves.



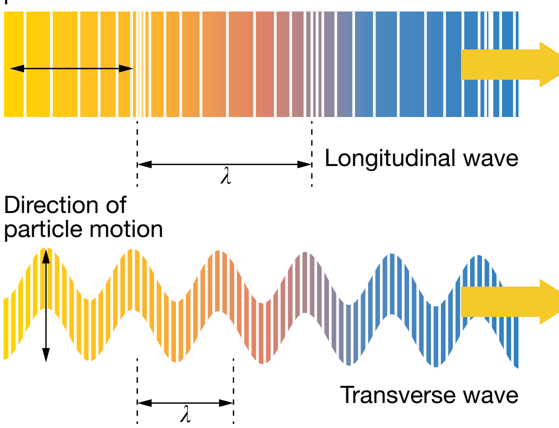
In these ways we can model the nature of the particle movement in the medium carrying either a transverse wave or a longitudinal wave.

Conclusions from modelling experiments

The diagrams show the conclusions we can draw from these modelling experiments.

Particle motion in a medium carrying a **longitudinal wave** is oscillation back and forth in the same plane as the direction of propagation of the energy.

Particle motion in a medium carrying a **transverse wave** is oscillation at 90° to the direction of propagation of the energy.



Conduct an investigation to create mechanical waves in a variety of situations to explain the transfer of energy involved in the propagation of mechanical waves.

2 Transfer Of Energy By Mechanical Waves

QUESTIONS

For each photo identify the type of mechanical wave involved and the evidence or implied evidence it presents to show that energy is or has been carried by that wave.

A

B

C

D

E

F

G

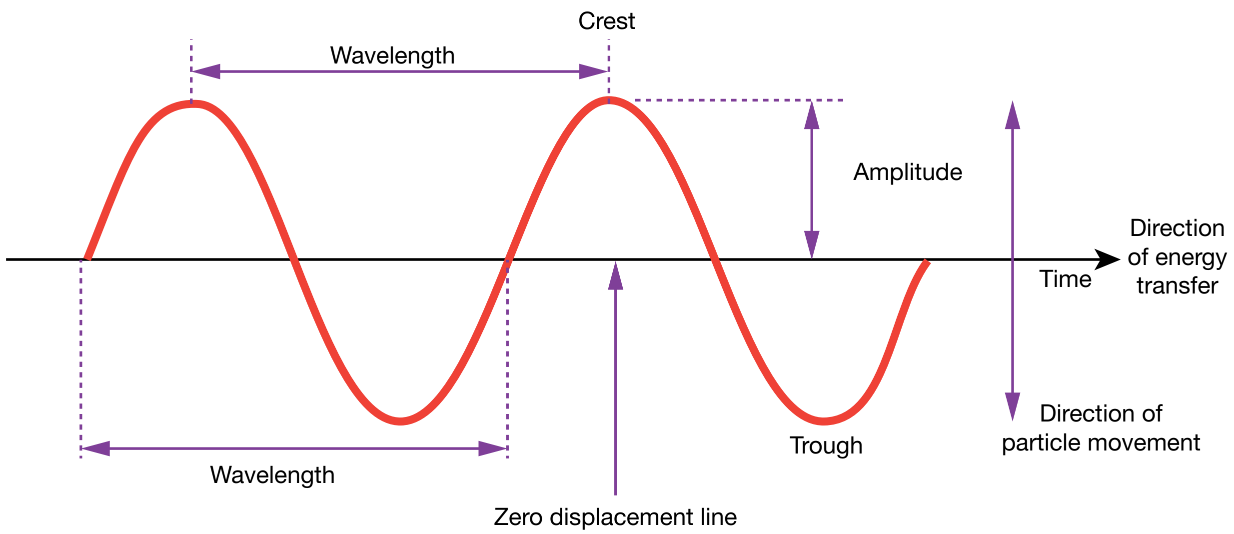
Conduct investigations to explain and analyse differences between transverse and longitudinal waves.

3 Transverse Matter Waves

Matter waves need a medium in which to travel. Matter waves transfer energy through the movement and collisions of the particles of the matter through which they are travelling. Matter waves are also known as **mechanical waves**. They include water, sound and earthquake waves and waves in ropes and springs.

A **matter wave** can be thought of as a disturbance in a medium – such as air, water and rock – that transfers energy from place to place. Waves transfer energy without transferring the matter of the medium with the energy. The amount of energy carried is represented by the amplitude of the wave.

Matter waves are also classified how the particles move in the medium as energy passes through it. In **transverse waves** the particles oscillate at right angles to the direction of energy transfer. We represent transverse waves using a sine/cosine curve.

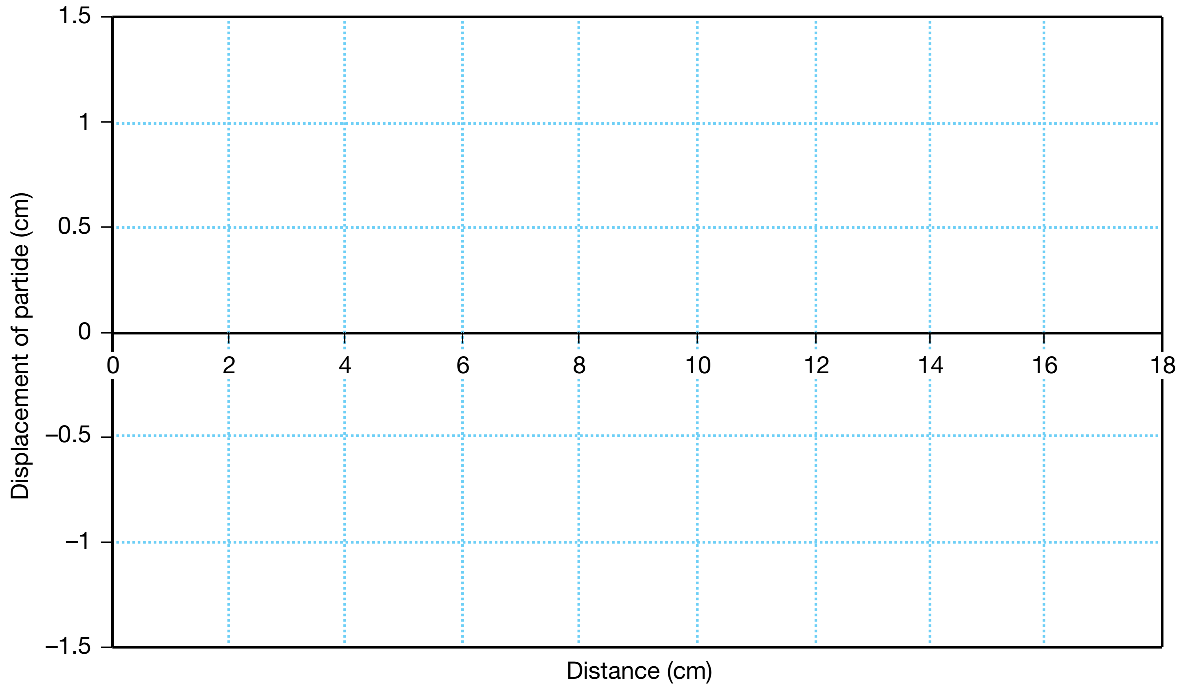


Typical transverse matter waves include a water wave, a wave in a skipping rope, or a violin string as it is bowed. These, as well as all electromagnetic waves, have the following properties (among others).

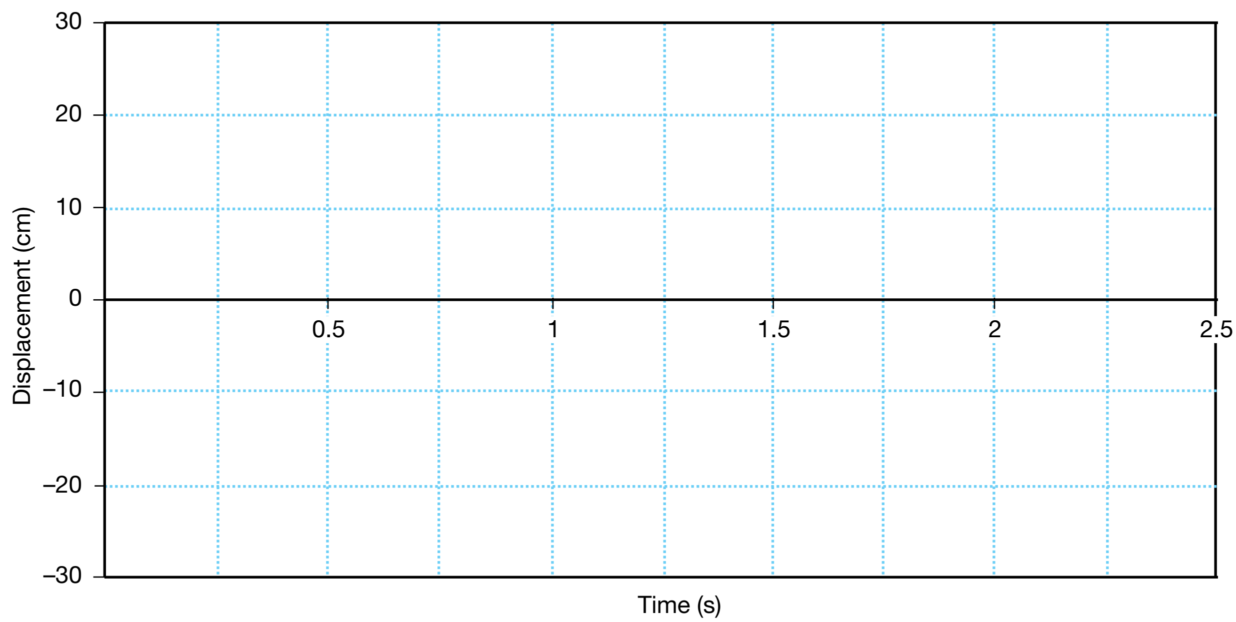
- The **wavelength** of a wave is the distance from one point on the wave to the next identical point on the wave. This is measured in centimetres or metres.
- The **period** of a wave is the time it takes one wave to pass a point, measured, e.g. in seconds or milliseconds.
- The **frequency** of a wave is the number of wavelengths that pass a point each second. Frequency is measured in hertz (Hz).
- The **energy** carried by a wave depends on its frequency and amplitude. The higher the frequency and the larger the amplitude, the more energy the wave carries.
- The **amplitude** of a wave is the distance from the zero displacement position of the matter particles to a maximum displacement position (a crest or trough). It is measured in centimetres or metres.
- The **zero displacement position** indicates where the particles would be if no energy was being transferred through the medium.
- A **crest** is a position of maximum upward displacement of a particle – the 'top of the wave'.
- A **trough** is a position of maximum downward displacement of a particle – the 'bottom of the wave'.

QUESTIONS

1. (a) On the grid below, draw, in red pen, two wavelengths of a wave which has an amplitude of 10 mm and a wavelength of 8 cm.
   (b) On the same axes draw three wavelengths of another graph (in blue) which has an amplitude of 12.5 mm and a wavelength of 5.0 cm.



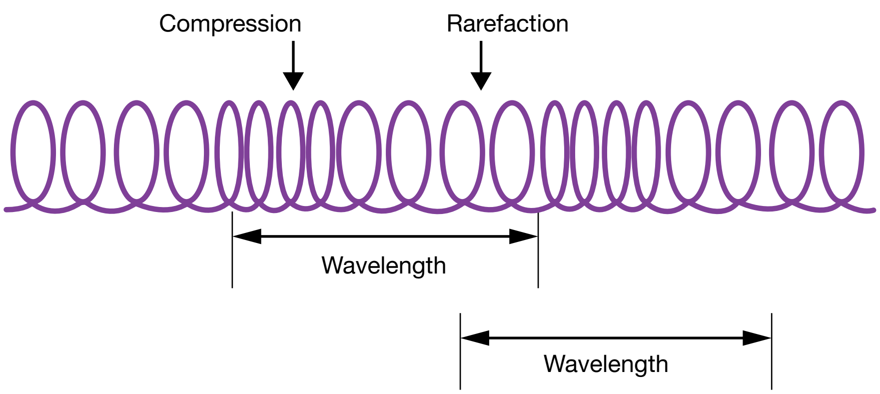
2. (a) On the grid below, draw, in blue pen, four wavelengths of a wave which has an amplitude of 20 mm and a frequency of 2.0 Hz.
   (b) On the same axes draw six wavelengths of another graph (in red) which has an amplitude of 25 mm and a frequency of 0.5 Hz.

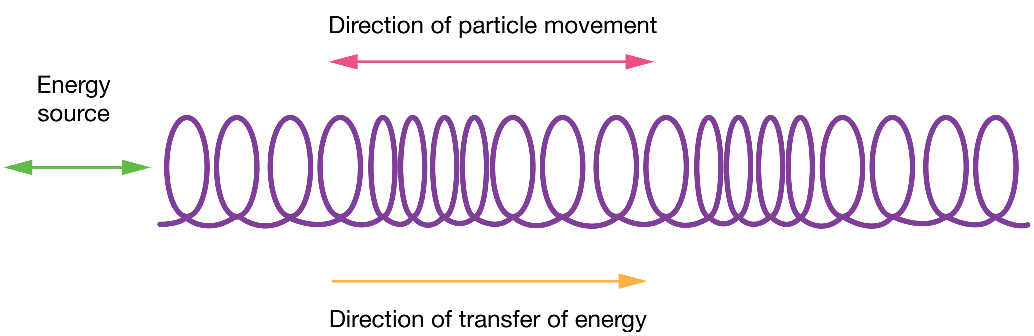


4 Longitudinal Matter Waves

Typical longitudinal matter waves include a soundwave in the air, the ‘shock wave’ produced when a plane breaks the sound barrier and some earthquake waves. They have the following properties.

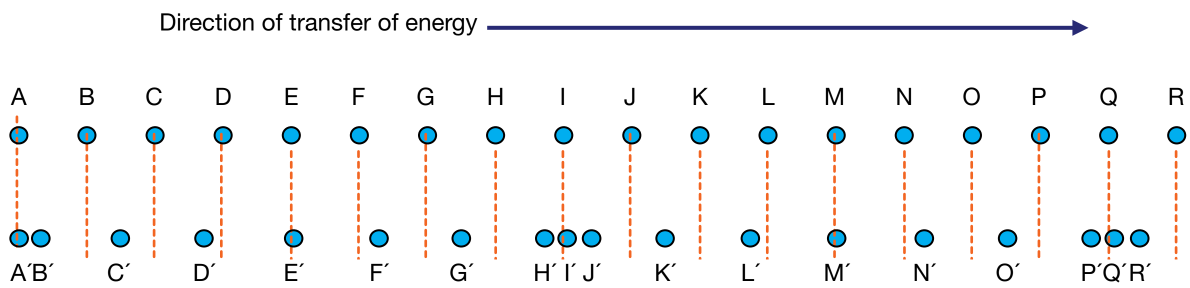
- The **wavelength** of a wave is the distance from one point on the wave to the next identical point on the wave. It is measured in centimetres or metres.
- The **period** of a wave is the time it takes one wave to pass a point.
- The **frequency** of a wave is the number of wavelengths that pass a point each second.
- The **energy** carried by a wave depends on its frequency and amplitude. The higher the frequency and the larger the amplitude, the more energy the wave carries.
- The **amplitude** of a wave is the distance from the zero displacement position of the matter particles to a maximum displacement position. It is measured in centimetres or metres.
- The **zero displacement position** indicates where the particles would be if no energy was being transferred through the medium.
- Both **rarefactions** and **compressions** are positions of zero displacement in a longitudinal wave.
- In a longitudinal wave, the direction of the movement of particles in matter is back and forth along the direction of the transfer of energy.
- When longitudinal waves pass through a solid medium, then the energy transfers through high and low pressure regions within the medium.
- Because longitudinal waves are also very difficult to draw using typical ‘dotty’ diagrams where each dot represents a particle of the medium, we often represent them as transverse wave diagrams too.



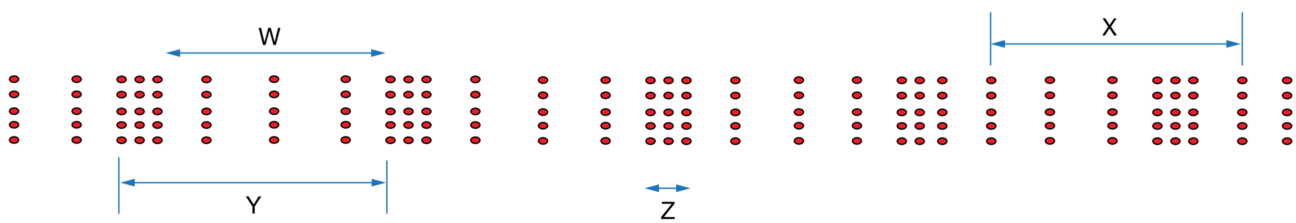


QUESTIONS

1. Distinguish between a *compression* and a *rarefaction* in a longitudinal wave in a spring and in a longitudinal wave in a solid material like the crust of the Earth.
2. Contrast the direction of movement of the matter particles in a longitudinal wave and the direction the energy is carried.
3. (a) Define amplitude for a longitudinal wave.
   (b) How can you determine the amplitude in a longitudinal wave?
4. The diagram shows the undisturbed positions of the matter particles in a medium (first row of dots labelled A to R), and their positions when a longitudinal wave is passing through the medium (second row of dots, labelled A´ to R´). Vertical orange lines have also been provided to mark the zero displacement positions of each particle in the medium.



   On the diagram label:
   (a) Two wavelengths.
   (b) A compression.
   (c) A rarefaction.
   (d) Two particles at maximum displacement from their zero position.
   (e) Two particles with zero displacement.
5. The diagram represents a soundwave. Identify each labelled part of the diagram.



6. Which choice correctly defines the amplitude of a matter wave?
   (A) The distance between successive wave pulses.
   (B) The distance between two adjacent crests or troughs.
   (C) The distance from the top of a crest to the bottom of a trough.
   (D) The distance from zero displacement to a position of maximum displacement.
7. Which choice correctly describes how the particles of the medium carrying a soundwave move?
   (A) Oscillate up and down.
   (B) Oscillate left and right.
   (C) Oscillate in the same direction as energy is transferred.
   (D) Oscillate at right angles to the direction of energy transfer.

Conduct investigations to explain and analyse differences between mechanical and electromagnetic waves.

5 Electromagnetic Waves

The wave model of light was accepted by scientists for over 200 years because it was able to explain all the observed properties of light. The only weakness of the wave theory at the time was that light waves, like soundwaves, would need a medium for transmission.

The existence of the hypothetical substance *luminiferous aether* proposed by **Christiaan Huygens** in 1678 held up the development of the knowledge of the nature of light for many years.

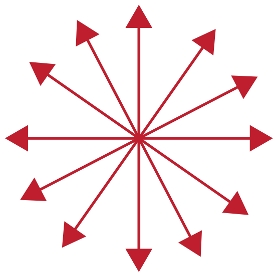
Michael Faraday (1791-1867).

The electromagnetic theory

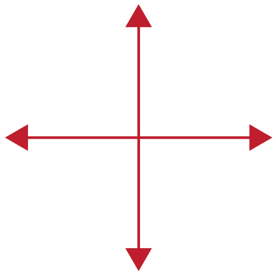
In 1845, **Michael Faraday** discovered that light was affected by magnetic fields. This was the first evidence that light was related to electromagnetism. In 1847 Faraday proposed that light was a high-frequency electromagnetic vibration, which could propagate even in the absence of a medium such as the aether.

Faraday's work inspired **James Clerk Maxwell** to study electromagnetic radiation and light. Maxwell discovered, while working on mathematical equations to describe electrical phenomena, that self-propagating electromagnetic waves would travel through space at a constant speed, which happened to be equal to the previously measured speed of light. From this, Maxwell supported Faraday's idea, proposing, in 1873, that light was a form of electromagnetic radiation.

A light wave is known to have pairs of fields oscillating at all angles.



For simplicity, we consider electromagnetic waves as fields oscillating only in the vertical and horizontal planes.

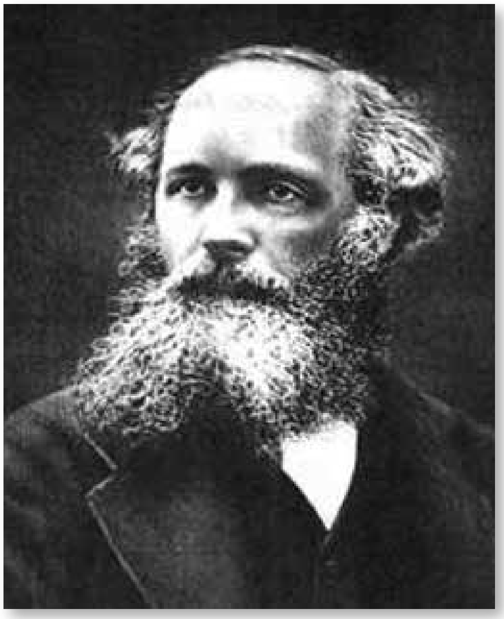


In 1887, **Heinrich Hertz** confirmed Maxwell's idea of additional electromagnetic waves experimentally by generating and detecting what we now know as radio waves and demonstrating that they had the same properties as light.

The electromagnetic model for light was the first one able to explain **polarisation**.

Polarisation is a property of waves that can oscillate with more than one orientation.

In the electromagnetic model for light, light is considered to have many pairs of electric and magnetic fields oscillating at right angles to each other.

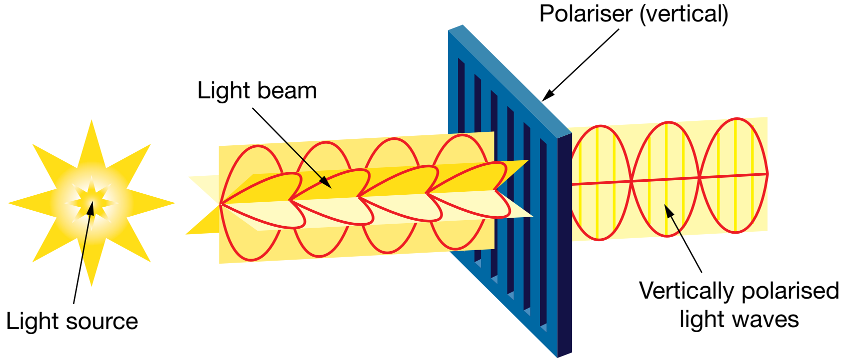


James Clerk Maxwell (1831-1879).

We would refer to a light wave like this as being **unpolarised**. When a light wave is passed through a **polariser**, all the sets of field pairs are cut from the beam except those in one plane. The light is now **polarised**.

Polarisation reduces the intensity of the light beam which is why it is useful in sunglasses.

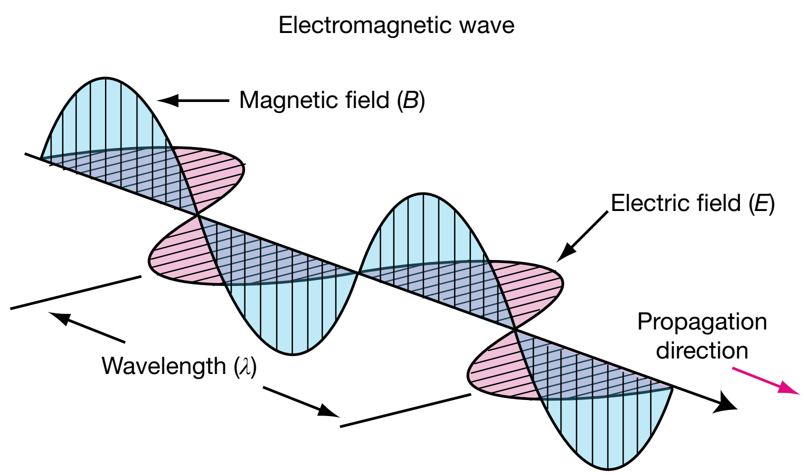
While Maxwell's theory and Hertz's work led directly to the development of modern radio, radar, television, electromagnetic imaging, and wireless communications, it was unable to explain spectral lines and the threshold frequency in the photoelectric effect which Hertz also observed, but did not study further.



Properties of electromagnetic waves

Electromagnetic transverse waves are different from transverse matter waves in that they have the following properties.

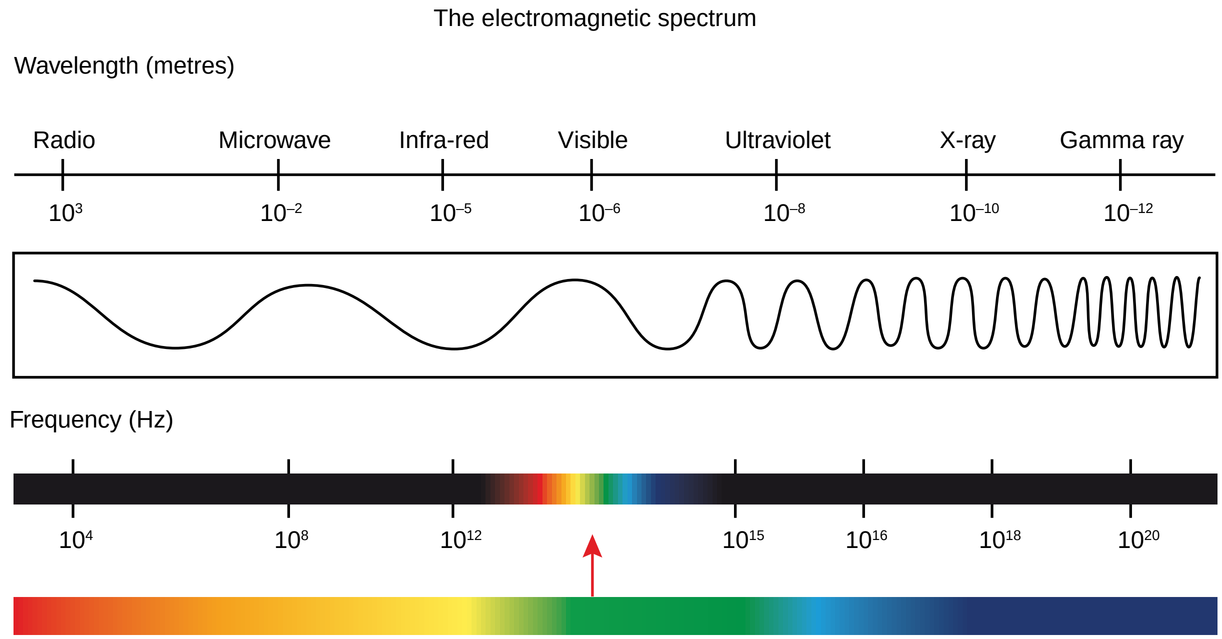
- Electromagnetic waves can travel through a vacuum.
- They all travel at the speed of light (3×10^8 m s^{-1}) in a vacuum – they slow down a little in other media.
- Electromagnetic waves are proposed to be **self-propagating alternating electric and magnetic fields**.
- Because the motion of the changing magnetic and electric fields are at right angles to the direction in which they carry energy, electromagnetic waves are also classified as transverse waves.
- Because electromagnetic waves are really hard to draw, we usually draw them as transverse matter waves. The flaw in doing this is that the energy carried by a transverse wave is indicated by the amplitude of the wave but this is not the case with electromagnetic waves.
- In electromagnetic waves, the energy is directly proportional to the frequency of the photons which constitute the radiation as given by Planck's quantum theory equation, $E = hf$, which you shall learn about later.
- The **wavelength** of an electromagnetic wave is the distance between the peaks of successive magnetic or electric field pulses.
- We usually refer to the **intensity** of an electromagnetic wave rather than to its amplitude. The intensity of an electromagnetic wave depends on the number of photons in the beam. Each photon will have energy dependent on its frequency.
- The **period** of an electromagnetic wave is the time for one wavelength to pass a given point.
- The **frequency** of an electromagnetic wave is the number of wavelengths that pass a point each second. Frequency is measured in hertz (Hz).



Transverse waves

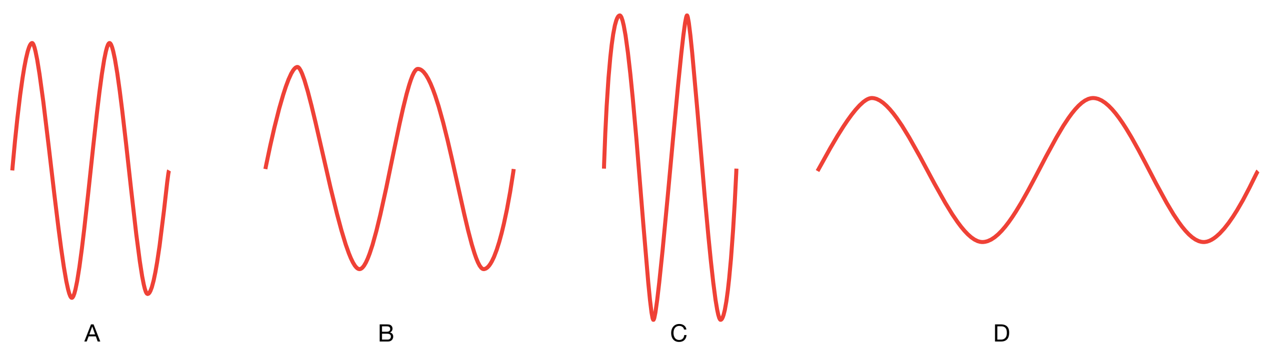
Electromagnetic waves are often referred to as being transverse electromagnetic waves. This is because the shape of the growth and decay of the alternating electric and magnetic fields that produces them follows a sinusoidal pattern, and the oscillation of those fields are both at right angles to the direction of propagation of the energy.

However, they *are not* correctly drawn using the transverse waves that we usually use when we want to represent them on paper. These are used for simplicity and for ease of understanding, and the analysis of them gives the correct results.

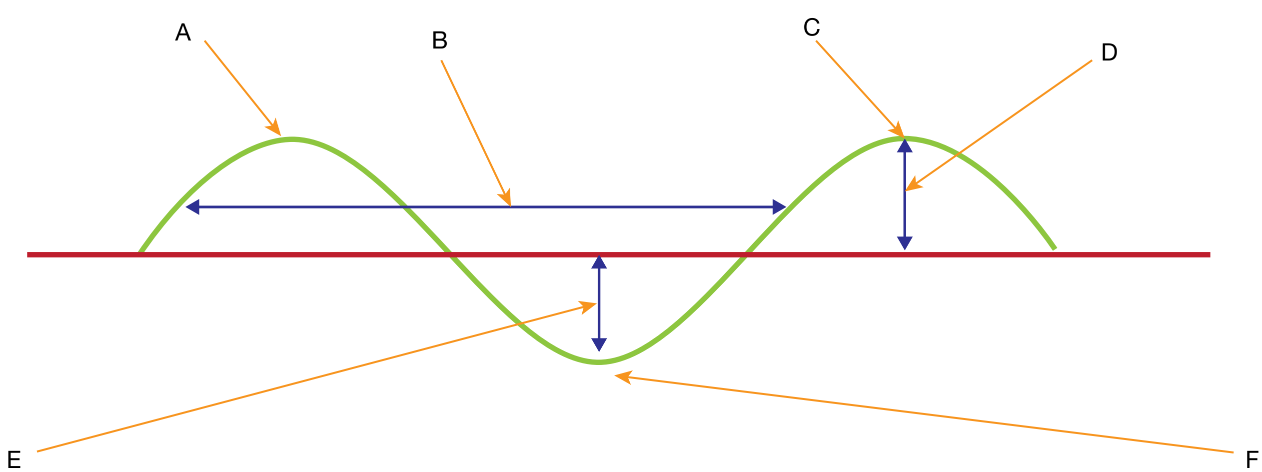


QUESTIONS

1. (a) The waves shown below all represent electromagnetic waves travelling for the same interval of time. List them in order of increasing wavelength, amplitude, and then in order of increasing frequency.
   (b) Measure the wavelength and amplitude of each wave.



2. Using the definitions you have from Question 1, identify each of the labelled parts of the wave shown.



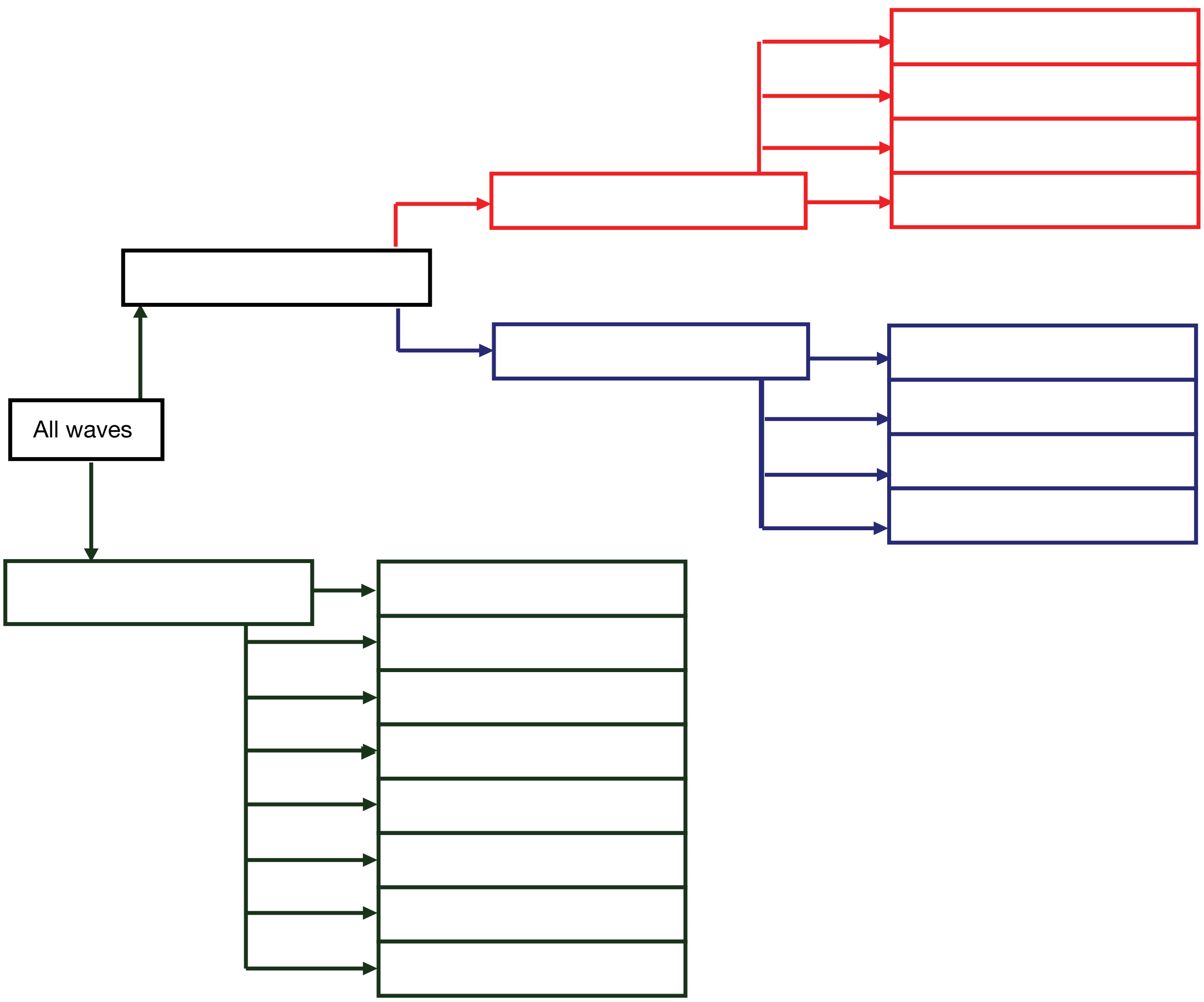
3. Examine the diagram of the electromagnetic spectrum on the previous page.
   (a) Which visible light photons (the particles that carry electromagnetic energy) would carry more energy, green photons or yellow photons. Justify your choice of answer.
   (b) On the basis of this information, would you say that the energy carried by electromagnetic photons is proportional to their wavelength, frequency or amplitude? Justify your answer.
   (c) An electromagnetic photon has a wavelength of 1.0 m. What type of ray is it?
   (d) An electromagnetic photon has a wavelength of 1.0 cm. What type of ray is it?
   (e) An electromagnetic photon has a wavelength of 1.0 mm. What type of ray is it?
   (f) An electromagnetic photon has a wavelength of 1.0 μm. What type of ray is it?
   (g) An electromagnetic photon has a wavelength of 1.0 nm. What type of ray is it?
4. (a) What is the distinguishing property of all electromagnetic waves?
   (b) Microwaves, rather than radio waves are used to communicate with satellites and the space station. Suggest a reason for this.
   (c) Most of the data collected by astronomers in their study of celestial objects from the Earth's surface, is obtained from visible light, radio and microwaves. Explain why this data is from such a small section of the electromagnetic spectrum.
5. (a) In terms of particle movement, define a transverse wave.
   (b) In terms of particle movement, define a longitudinal wave.
   (c) Given that electromagnetic waves do not involve the oscillation of particles, explain how they can be classified as transverse waves.
6. A logical thinking puzzle. Use the clues to arrange electromagnetic waves (represented by the letters B, E, G, H, J, K, L) in order of increasing wavelength, and then use the diagram of the electromagnetic spectrum on the previous page to identify the radiation each letter represents. You may choose to use the grid to help you solve this problem.
   - L has a shorter wavelength than E.
   - L doesn't have the shortest wavelength.
   - G is more energetic than H.
   - G does not have the shortest wavelength.
   - J represents infra-red radiation.
   - H is not visible light and L is not microwave radiation.
   - G has a longer wavelength than E.
   - K lies between E and J on the electromagnetic spectrum.

	⟶ Increasing wavelength ⟶						
	λ	X	UV	Vis	IR	M	R/TV
B							
E							
G							
H							
J							
K							
L							

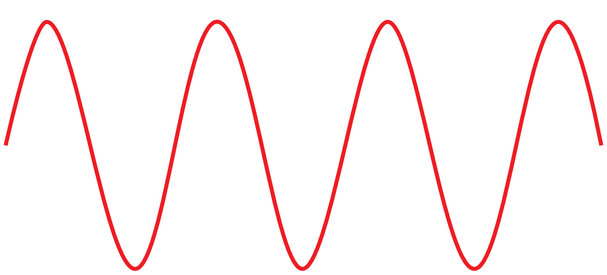
6 Some General Wave Questions

QUESTIONS

1. Complete the diagram below to summarise the classification of waves.

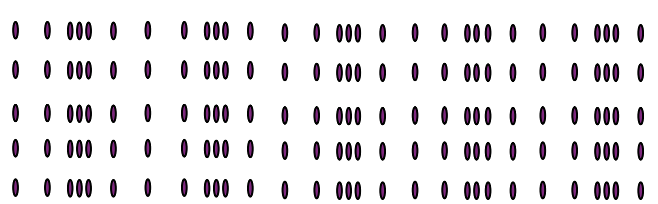


2. Consider the following diagram which represents 0.28 seconds of time.



Determine:
(a) The wavelength of the wave (λ).
(b) The amplitude of the wave (A).
(c) The period of the wave (T).
(d) The frequency of the wave (f).
(e) The velocity of the wave. (*Note:* $v = f\lambda$.)

3. Consider the following diagram which represents 0.15 seconds of time. It has been drawn to a scale where 1 cm = 10^{-6} m.



Determine:
(a) The wavelength of the wave.
(b) The period of the wave.
(c) The frequency of the wave.
(d) The velocity of the wave.

Construct and/or interpret graphs of displacement versus time and displacement versus position of transverse and longitudinal waves and relate the features of these graphs to wave characteristics including velocity, frequency, period, wavelength, displacement and amplitude.

7 Analysing Wave Graphs 1

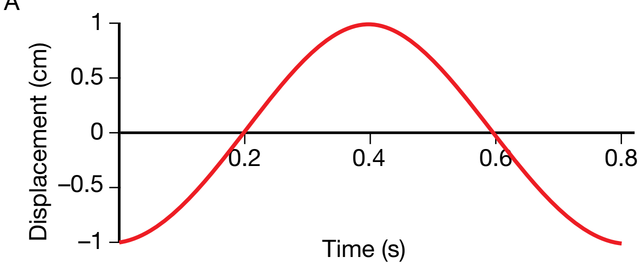
Displacement-time and displacement-displacement graphs

We often represent wave motion graphically. Rather than draw the wave, we graph the displacement of a medium particle against time (which is the same thing for a transverse wave, but longitudinal waves also appear as sine/cosine curves in these situations), or we graph displacement of the particle against distance the energy has travelled. The graphs below (travelling left to right) show various examples of this. Analyse them to answer the questions.

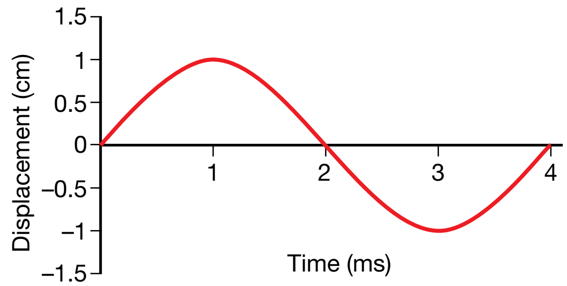
QUESTIONS

1. The graphs shows the displacement of a particle in a wave of wavelength 4.0 m.

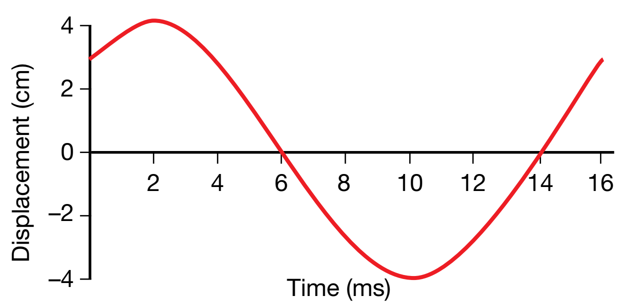
A



B



C

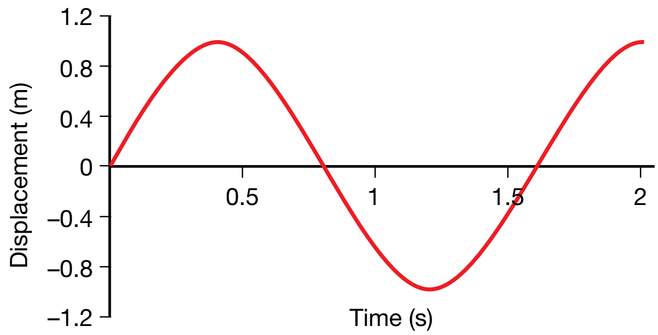


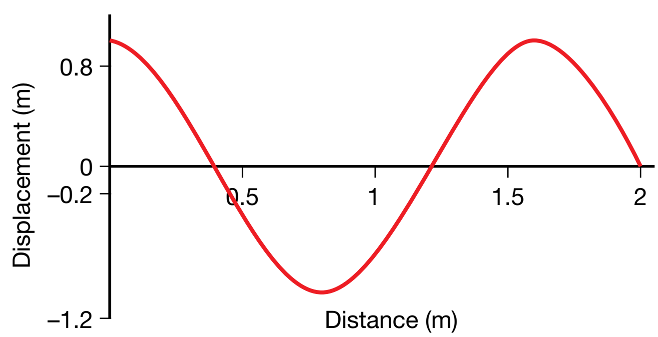
Determine the:

(a) Period. (b) Frequency.

(c) Amplitude. (d) Speed of the wave.

2. The graphs show the displacement of a water particle plotted against the distance the wave travels and time.





Analyse these graphs to determine the wavelength, period, frequency, amplitude and speed of the water wave.

Answers

Module 3 Waves and Thermodynamics

1 The Role Of the Medium Carrying a Wave

No questions.

2 Transfer Of Energy By Mechanical Waves

A Soundwaves produced by the musical instruments transfer sound energy to the audience.

B Plane flying at high speed compresses the air in front of it, forming a barrier which, when it exceeds the speed of sound in air, it breaks through and travels faster than sound. The noise of the plane flying overhead trails behind the plane itself.

C Under ocean earthquakes produce high amplitude, high energy water waves that can cause significant destruction to natural and man-made structures on land.

D Energy carries by earthquake waves through the Earth's crust can distort the crust.

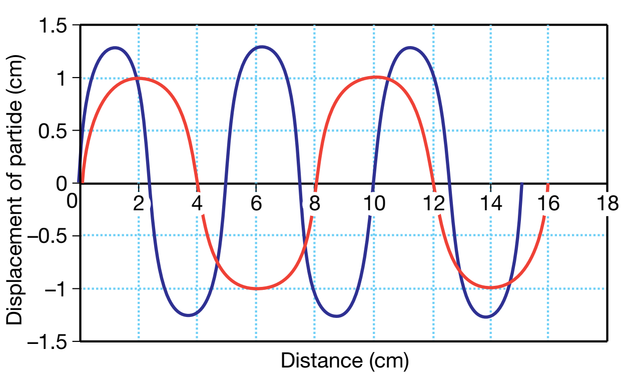
E Energy carried by water waves slowly erodes the rocks on the coastline.

F An ultrasound (very high frequency) image of a baby in its mother's womb. The sound has energy to penetrate different densities of different tissues by varying amounts and then reflecting back to a receiver which records the reflected intensities to produce the image.

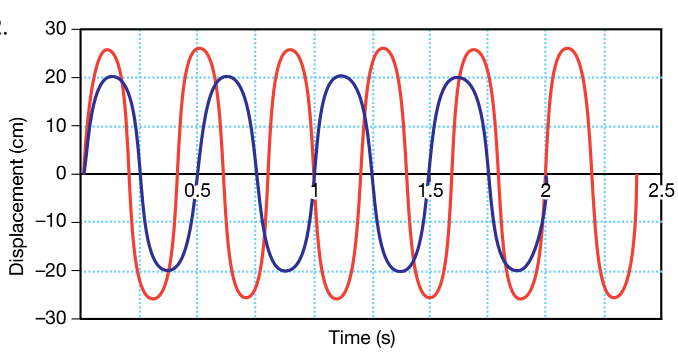
G Provided the singer can produce a sound with sufficient amplitude, for long enough, and at the natural frequency of the molecular vibrations of the glass, energy will transfer to the bonds within the glass and cause it to break.

3 Transverse Matter Waves

1.

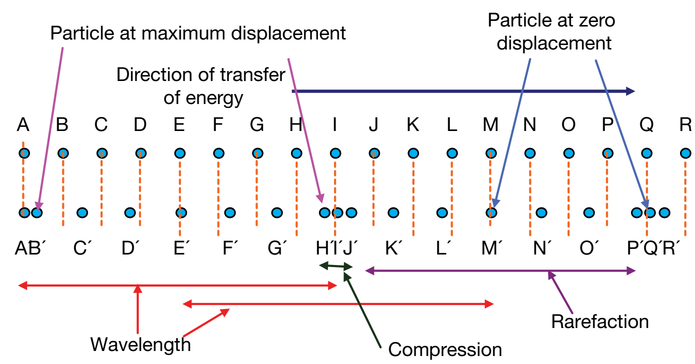


2.



4 Longitudinal Matter Waves

1. A compression is a region in a longitudinal wave where the particles are closer together than in the medium at rest. A rarefaction is a region where the particles are further apart than normal. In a solid material, the compression indicates a region of higher pressure, the rarefaction a region of lower pressure.
2. Particle movement is back and forth in the same plane as the direction of energy transfer.
3. (a) Amplitude is the maximum displacement of a particle from its rest position.
   (b) For a longitudinal wave, we would need to know the rest positions of the particles (as we also need to with transverse waves), and then measure the maximum displacement.
4. Answers will vary, for example:



5. W = rarefaction
   X = wavelength
   Y = wavelength
   Z = compression
6. D
7. C

5 Electromagnetic Waves

1. (a) Wavelength = CABD
   Amplitude = DBAC
   Frequencies are equal (See the question – 'same interval of time'.)
   (b)

Wave	Wavelength (mm)	Amplitude (mm)
A	10	16
B	16	13
C	8.5	15
D	28	8

2. A = crest
   B = wavelength
   C = crest
   D = amplitude
   E = amplitude
   F = trough
3. (a) Green photons. Green is closer to the high frequency end of the visible spectrum, and energy carried by photons depends on their frequency, or, alternatively, general knowledge tells us that gamma rays are most dangerous, so we could infer that the gamma ray end of the spectrum is the high energy end, and green is closer to this.
   (b) Because energy increases as frequency increases and as wavelength decreases, then energy is more likely to be proportional to the frequency (inversely proportional to the wavelength).
   Note that amplitude is a property of transverse matter waves and we use these only to represent electromagnetic waves because the magnetic/electric field diagrams are too difficult to draw.
   (c) Radio wave.
   (d) Microwave.
   (e) Short wavelength microwave or long wavelength infra-red (they overlap and the name depends on what we use them for).
   (f) Visible light.
   (g) Short wavelength ultraviolet or long wavelength X-rays.

4. (a) They all travel at the speed of light = 3×10^8 m s^{-1} in vacuum.
(b) Microwaves are used as their small wavelength allows the use of small antennas and dishes. Microwaves are also more directional than radio waves, and their higher frequency means they can carry more information.
(c) These are the frequencies that pass through the atmosphere. Others are absorbed and do not make it to the surface.

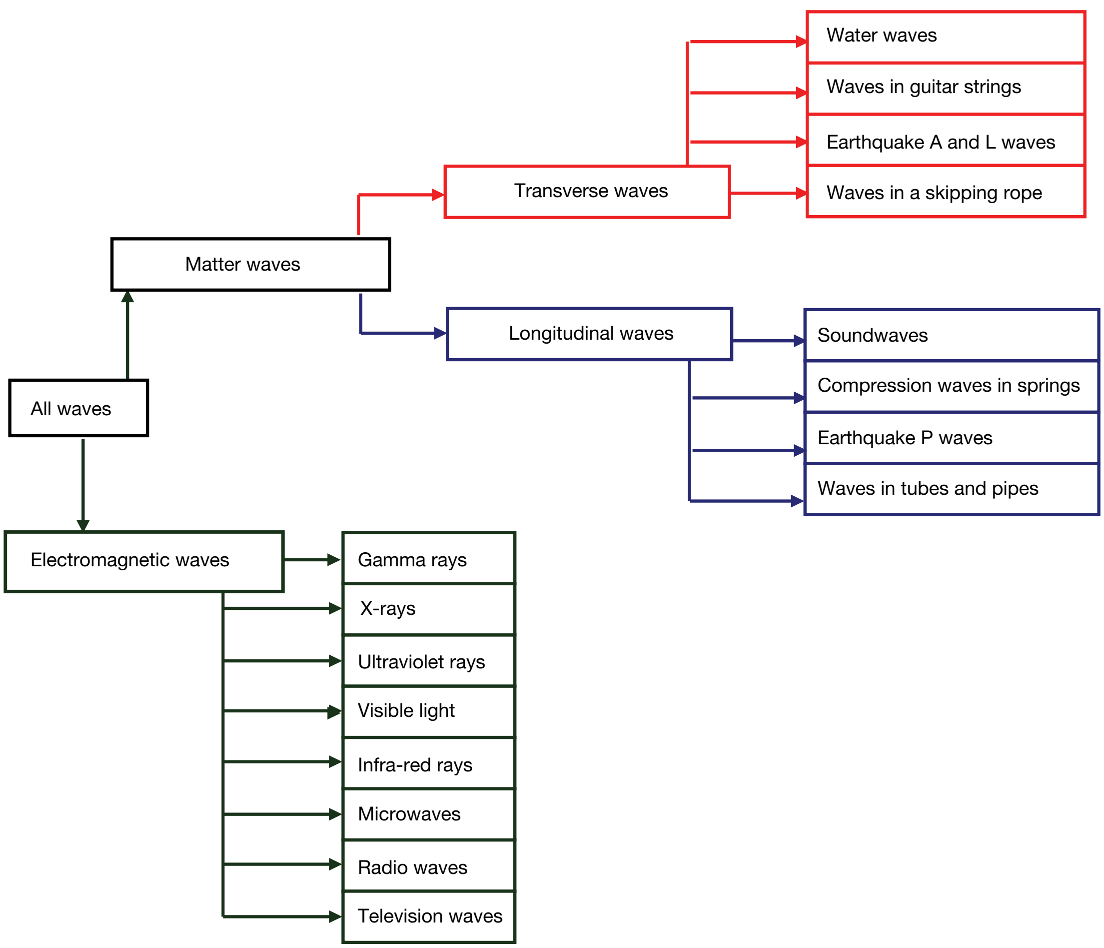
5. (a) Particle oscillation is at right angles to the direction of energy transfer.
(b) Particle oscillation is back and forth in the same plane as energy transfer.
(c) The mechanism by which electromagnetic waves propagate, the alternating electric and magnetic fields are at right angles to the direction of energy transfer.

6.

	Increasing wavelength →						
	γ	X	UV	Vis	IR	M	R/TV
B	●						
E			●				
G						●	
H							●
J					●		
K				●			
L		●					

6 Some General Wave Questions

1.



2. (a) About 22 mm.
(b) About 2 cm.
(c) 0.08 s
(d) $f = \frac{1}{T} = \frac{1}{0.8} = 12.5$ Hz
(e) About 27.5 cm s^{-1}

3. (a) About 19 mm
(b) 0.03 s
(c) $f = \frac{1}{T} = \frac{1}{0.03} = 33.3$ Hz
(d) $v = f\lambda = 33.3 \times 1.9 \times 10^{-6} = 63.6 \times 10^{-6}$ m s^{-1} = 56.6 cm s^{-1}

7 Analysing Wave Graphs 1

1. A (a) $T = 0.8$ s
(b) $f = \frac{1}{T} = \frac{1}{0.8} = 1.25$ Hz
(c) $A = 1.0$ m
(d) $v = f\lambda = 1.25 \times 4 = 5$ m s^{-1}

B (a) $T = 4 \times 10^{-3}$ s
(b) $f = \frac{1}{4 \times 10^{-3}} = 250$ Hz
(c) $A = 1.0$ cm
(d) $v = 250 \times 4 = 1000$ m s^{-1}

C (a) $T = 16$ ms $= 1.6 \times 10^{-2}$ s
(b) $f = \frac{1}{1.6 \times 10^{-2}} = 62.5$ Hz
(c) $A = 4$ cm
(d) $v = 62.5 \times 4 = 250$ m s^{-1}

2. $\lambda = 2 - 0.4 = 1.6$ m (from distance graph)
$T = 1.6$ s (from time graph)
$f = 0.63$ Hz
$A = 1.0$ m
$v = 1.0$ m s^{-1}