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Wave Characteristics

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3.1 Role Of the Medium Carrying Wave Energy

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.
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.

Role of the medium carrying wave energy

- Mechanical waves (water, wind, waves in ropes and strings and springs, soundwaves and those in all musical instruments) all occur because the particles in the medium oscillate and transfer energy from one particle to the next.
- 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.

All waves need an input source of energy to form in any medium.

Sample Questions

1. (a) Give five other examples of mechanical waves travelling through different mediums.
   (b) For each example, indicate how we can demonstrate that this wave carries energy.
   (c) For each example state the source of energy forming the wave.
2. Soundwaves travel more efficiently through wood than they do through air. Suggest a reason for this.
3. Mechanical waves will not travel through space. Why not?

Making waves in heavy ropes can use a lot of energy in a training session.

During an earthquake, the ground can transmit energy as the waves go through it.

Sand sprinkled on a drum skin shows the waves formed when it vibrates.

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3.3 Transverse and Longitudinal Matter Waves

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

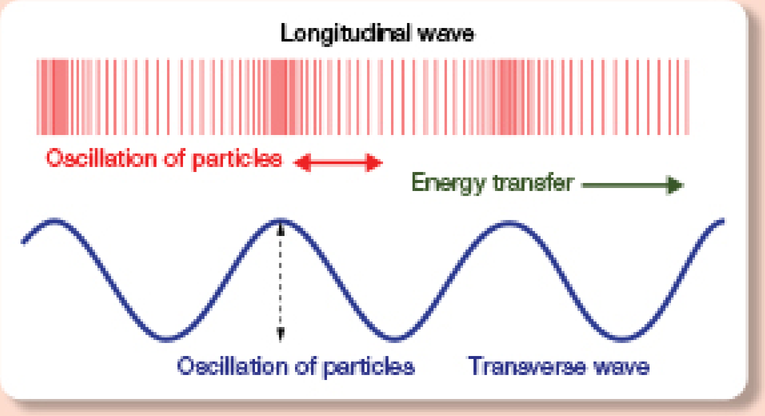
Transverse and longitudinal matter waves

Transverse matter waves

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

Longitudinal matter waves

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.



General properties of waves

- 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 wavelength of the wave to pass a point, usually measured in seconds.
- The **frequency** of a wave is the number of wavelengths that pass a point each second. Frequency is measured in hertz (Hz) where 1 Hz = 1 oscillation per 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 (a **crest** or **trough**). Measured in m or cm.

Transverse waves only

- 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** – position of maximum downward displacement of a particle of the medium carrying the wave – the 'bottom of the wave'.
- In a transverse wave, the direction of the oscillation of particles in matter is at 90° to the direction of the transfer of energy.

Longitudinal waves only

- Rarefactions – position in a longitudinal wave where particles are closer together than when undisturbed – higher pressure region.
- Compressions – position in a longitudinal wave where particles are further apart than when undisturbed – lower pressure region.
- The centre positions of both **rarefactions** and **compressions** are positions of zero displacement in a longitudinal wave.
- In a longitudinal wave, the direction of oscillation of particles in matter is back and forth along the direction of the transfer of energy.

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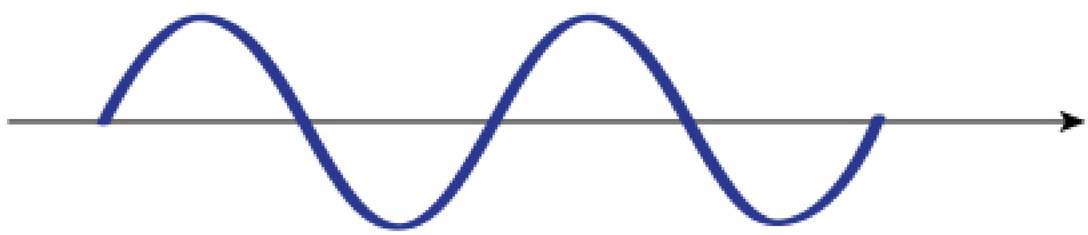
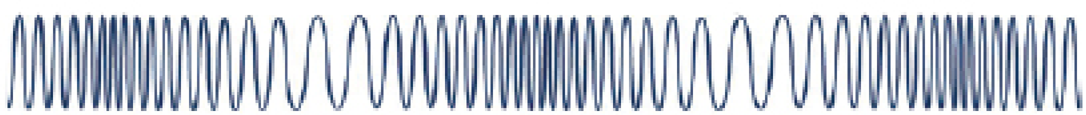
Sample Questions

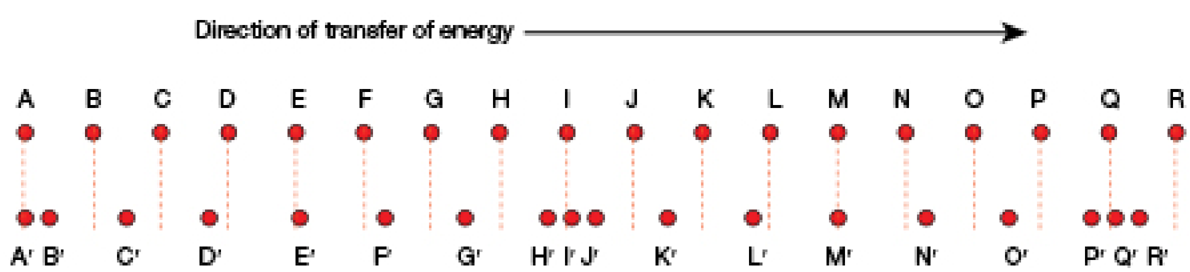
1. Label the features of the transverse wave below. Label two different wavelengths.



2. Label the features of the longitudinal wave below. Label two different wavelengths.



3. The diagram shows the undisturbed positions of the particles in a medium (first row of dots A to R), and their positions when a longitudinal wave passes through the medium (second row of dots, A′ to R′). Vertical lines 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.

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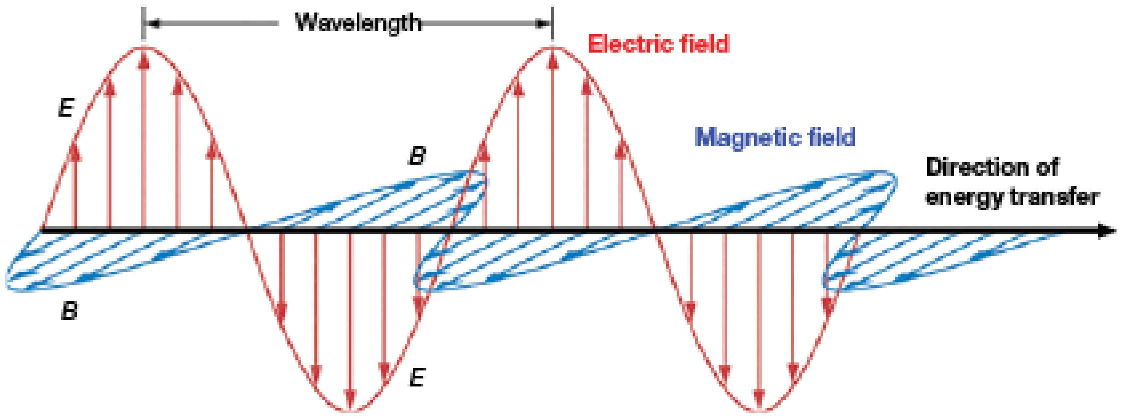
3.4 Electromagnetic Waves

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

Electromagnetic waves

Electromagnetic transverse waves are different from transverse matter waves in that they:

- Can travel through a vacuum.
- 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 **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 classified as transverse waves.
- In electromagnetic waves, the energy is directly proportional to the frequency of the **photons** (the particles which make up EMR) 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 is the number of wavelengths that pass a point each second. Frequency is measured in hertz (Hz).
- 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.
- The best known electromagnetic waves are gamma rays, X-rays, ultraviolet rays, visible light rays, infra-red, microwaves, radio waves (which include TV waves).
- The shortest wavelength, highest frequency, most energetic rays are the gamma rays.



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Sample Questions

Note: The wavelength and frequency data in this diagram is approximate only. It will vary slightly to that in other resources.

1. Research information to identify the labels in the diagram.

2. From this diagram of the electromagnetic spectrum:

(a) Which visible light photons would carry more energy, orange photons or blue photons? Justify your choice of answer.

(b) Is the energy carried by electromagnetic photons proportional to their wavelength, frequency or amplitude?

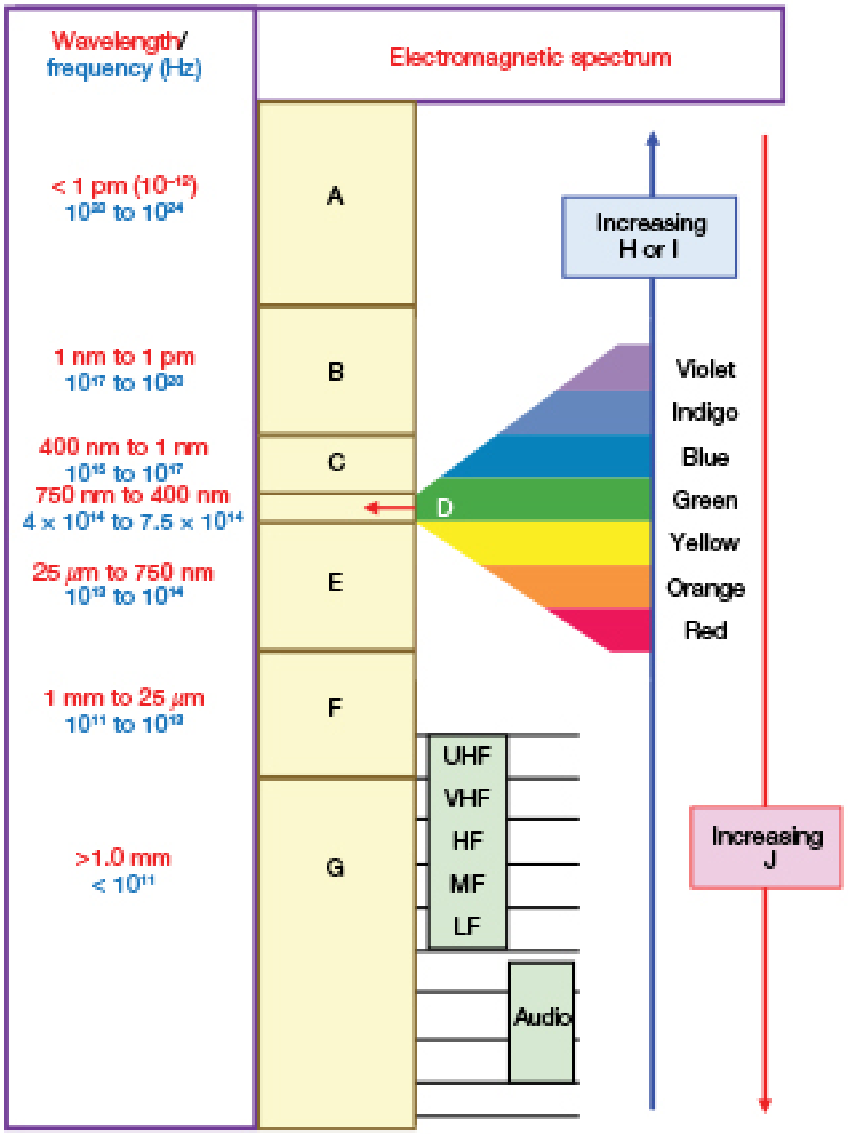
(c) An electromagnetic photon has a wavelength of 5.0 m. What type of ray is it?

(d) An electromagnetic photon has a wavelength of 5.0 cm. What type of ray is it?

(e) An electromagnetic photon has a wavelength of 5.0 mm. What type of ray is it?

(f) An electromagnetic photon has a wavelength of 5.0 μm. What type of ray is it?

(g) An electromagnetic photon has a wavelength of 5.0 nm. What type of ray is it?



3. (a) Which electromagnetic waves have the highest frequencies?

(b) Which electromagnetic radiation has the shortest wavelength?

(c) What is the same for all EMR in a vacuum?

(d) What is the relationship between the wavelength (λ), and frequency (f), of an EMR?

(e) Which electromagnetic radiation has the longest wavelength?

(f) What rays do police use in speed detection devices?

(g) Name three electromagnetic radiations which have a higher frequency than visible light

(h) How does visible EMR from the Sun differ from the non-visible EMR from the Sun?

(i) State a property that is shared by infra-red waves and ultraviolet waves?

(j) Which electromagnetic radiation has the lowest frequency?

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