Year 11

Physics

5.1 Wave Model

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Subtopic 5.1: Wave Model

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<tr><th>Science Understanding</th><th>Possible contexts</th></tr>
<tr><td rowspan="3">Waves are periodic oscillations that transfer energy from one point to another.
In longitudinal waves, the direction of oscillation is parallel to the direction of travel of the wave.
In transverse waves, the direction of oscillation is perpendicular to the direction of travel of the wave.
• Represent transverse waves graphically and analyze the graphs.
• Describe waves in terms of measurable quantities, including amplitude, wavelength (λ), frequency (f), period (T), and velocity (v).
• Solve problems using:
◆ $f = 1/T$
◆ $v = f\lambda$.</td><td>This connects to the concept of waves used in Stage 2 subtopics 3.1: Wave behaviour of light and 3.2: Wave–particle duality.
Show longitudinal and transverse waves in a slinky spring or wave machine.
Discuss longitudinal waves in terms of compressions and rarefactions.
Demonstrate and explain the Doppler effect and the formation of sonic booms at supersonic speeds.
Use PhET, ‘Sound and Waves’, simulations:
https://phet.colorado.edu/en/simulations/category/physics/sound-and-waves.
Discuss the difference in time between seeing lightning and hearing thunder.</td></tr>
<tr><td>Investigate sound and vibrations (e.g. tuning fork in water, speaker cone).
Analyze wave representations using technology, such as oscilloscopes or smartphone apps.
Measure sound levels and relate them to the amplitude of the waves.
Explore the relationships between the frequency and period of oscillators (such as pendulums and springs) and investigate factors that affect these quantities (such as string length).
Investigate the velocity of various waves (sound, seismic, light) in various media (air, water, solids).</td></tr>
<tr><td>Ascertain the economic, social, and environmental impacts of applications of the Doppler effect.
Examples include:
• detecting red-shirt and blue-shift stars
• radar guns
• Doppler radar
• reading weather patterns (e.g. to map a moving storm system using a stationary transmitter)
• using sound waves to produce images of the heart (Doppler echocardiogram).</td></tr>
</table>

1 Waves

- The motion of the disturbance in the medium (or in free space) is called a wave disturbance or generally a wave.
- A wave is a disturbance that travels through a medium from the source to the detector without any movement of matter. Waves therefore transfer energy without any net movement of particles.
- The disturbance which carries energy and momentum from one point in space to another point in space without the transfer of the medium is known as a wave.

When a small rock is thrown into the centre of a still pond, the kinetic energy of the rock is transferred to the water as it enters. This energy is carried through the water in the form of evenly spaced ripples, which are small waves. If there are objects on the surface of the water such as twigs or lily pads, they move up and down rather than being carried along with the waves. It is the energy that is travelling from the centre of the pond out to the edges in the form of the waves through the water, not the water itself.

In this way, the disturbance travels, but the medium stays where it is.

2 Characteristics of Wave motion

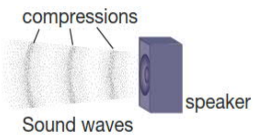
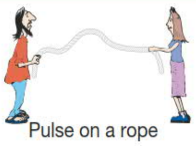
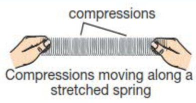
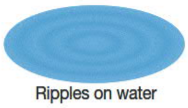
- For the propagation of the waves, the medium must possess both inertia and elasticity, which decide the velocity of the wave in that medium.
- In a given medium, the velocity of a wave is a constant whereas the constituent particles in that medium move with different velocities at different positions. Velocity is maximum at their mean position and zero at extreme positions.
- Waves undergo reflections, refraction, interference, diffraction, and polarization.

3 Classification of Waves

3.1 Mechanical Waves

The waves which require elastic medium for their transmission are called mechanical waves. Such a wave propagates due to the elastic properties of the medium. All these waves have the characteristics that they are governed by Newton’s laws.

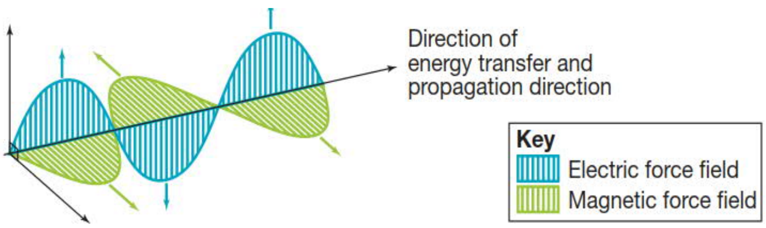
For example, waves on a string, ripples on the water suface, sound waves and seismic waves.

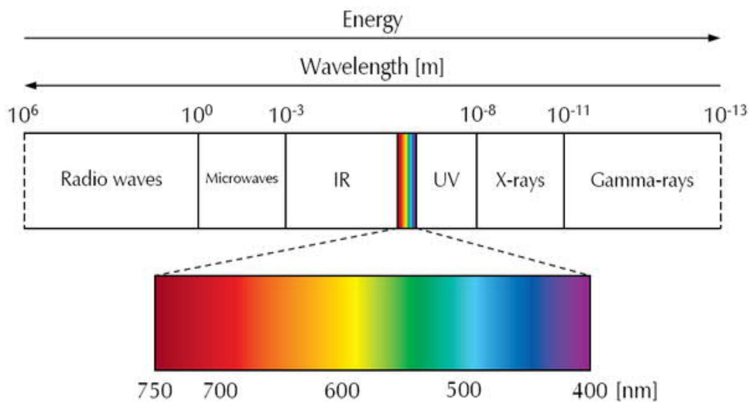
Wave	Source		Medium	Detector	Disturbance
Sound	Push/pull of a loudspeaker		Air	Ear	Increase and decrease in air pressure
Rope	Upward flick of hand		Rope	Person at other end	Section of rope is lifted and falls back
Stretched spring	Push of hand		Coils in the spring	Person at other end	Bunching of coils
Water	Dropped stone		Water	Bobbing cork	Water surface is lifted and drops back

3.2 Electromagnetic Waves

For the propagation of electromagnetic waves no material medium is essential. They can propagate in the vacuum also. In this types of waves the disturbance in the electric and magnetic fields that propagates. Here, instead of particles, the vectors of the electric and magnetic field intensities are oscillating.

Light waves, radio waves, microwave, X-ray etc. are the examples of the electromagnetic waves.

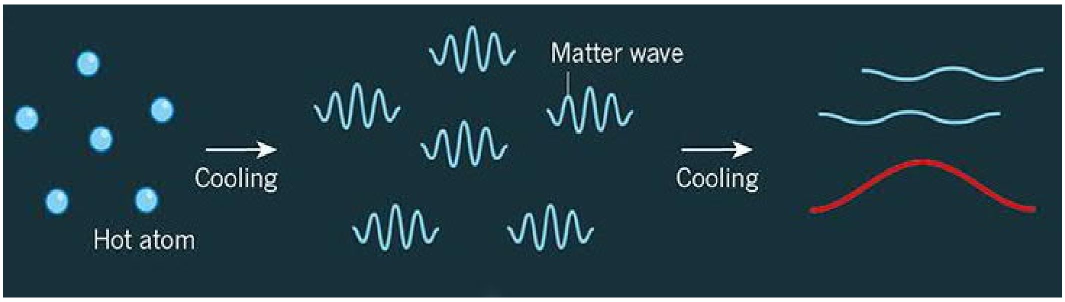




3.3 Matter Waves

Matter waves are associated with moving electrons, protons, neutrons and other fundamental particles and even atoms and molecules. These particles constituting matter, therefore, such waves are called matter waves.

The matter waves associated with electron are employed in the electron microscope.



Year 11

Physics

5.3 Light

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Subtopic 5.3: Light

Science Understanding	Possible contexts
Light is the visible part of the electromagnetic spectrum — a spectrum that also includes radio waves, microwaves, infrared and ultraviolet radiations, X-rays, and gamma rays. Electromagnetic waves can be modelled as a transverse wave that can travel through a vacuum. Refraction is the change in direction of propagation of a wave as its speed changes. Diffraction is the bending/spreading of waves as they pass through an aperture or past a sharp edge. The plane of polarisation of an electromagnetic wave is the plane defined by the direction of travel and the oscillating electric field. • Describe reflection and refraction, using the ray model of light. • Explain a range of light-related phenomena, including reflection, refraction, total internal reflection, diffraction, and polarisation, using the wave model. Undertake experiments to investigate reflection or refraction of light using different media.	This connects to the concept of waves used in Stage 2 subtopics 3.1: Wave behaviour of light and 3.2: Wave–particle duality. Demonstrate transmission of a mobile phone signal into an evacuated bell jar. Observe spectra of various light sources through a spectrometer or prism. Refer to PhET, 'Light and Radiation', at: https://phet.colorado.edu/en/simulations/category/physics/light-and-radiation. Use Snell's Law to quantitatively describe refraction of light, using: $\frac{\sin i}{\sin r}=\frac{v_1}{v_2}=\frac{\lambda_1}{\lambda_2}=\frac{n_2}{n_1}$. Demonstrate transmission of light through optical fibres.
	Use a light box or laser to investigate reflection, refraction, total internal reflection, and the optics of concave and convex lenses and curved and flat mirrors. Investigate polarisation of light, using filters.
	Analyse the interaction between science and technology with advances in: • optics of camera lenses, telescopes, and binoculars • optometry (spectacles and corrective laser surgery) • the uses of optic fibres in medicine and communication • applications of polarisation (e.g. 3D glasses and sunglasses) • the uses of radio waves and microwaves in communication (e.g. Wi-Fi, mobile phones, and space communication)
	• heating using microwaves • the uses of X-rays and gamma rays in diagnostic and therapeutic medicine • laser airborne depth sounder (LADS). Assess the economic and health impacts of ultraviolet radiation exposure.

1 Electromagnetic Waves.

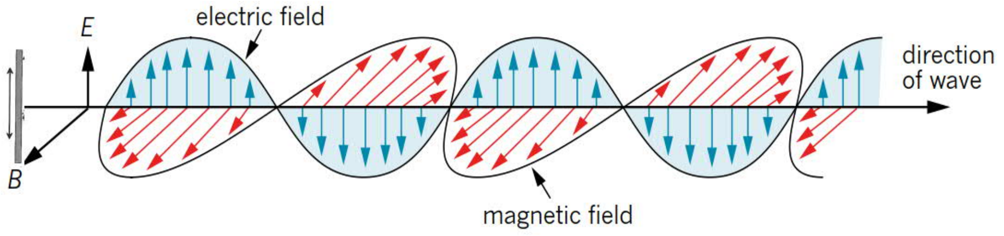
1.1 Introduction

For the propagation of electromagnetic waves no material medium is essential. They can propagate in the vacuum also. In this types of waves the disturbance in the electric and magnetic fields that propagates. Here, instead of particles, the vectors of the electric and magnetic field intensities are oscillating.

Light waves, radio waves, microwave, X-ray etc. are the examples of the electromagnetic waves.

As in earlier chapters, electric current can be used to produce a magnetic field, and a changing magnetic field can be used to generate an electromotive force (EMF) or voltage. Maxwell proposed that if a changing electric field is produced, then this changing electric field will produce a changing magnetic field at right angles to it.

The changing magnetic field would, in turn, produce a changing electric field and the cycle would be repeated. In effect, this would produce two mutually propagating fields and the electromagnetic radiation would be self-propagating, i.e. it could extend outwards into space. Both the electric and magnetic fields would oscillate at the same frequency: the frequency of the oscillation.



When a small rock is thrown into the centre of a still pond, the kinetic energy of the rock is transferred to the water as it enters. This energy is carried through the water in the form of evenly spaced ripples, which are small waves. If there are objects on the surface of the water such as twigs or lily pads, they move up and down rather than being carried along with the waves. It is the energy that is travelling from the centre of the pond out to the edges in the form of the waves through the water, not the water itself.

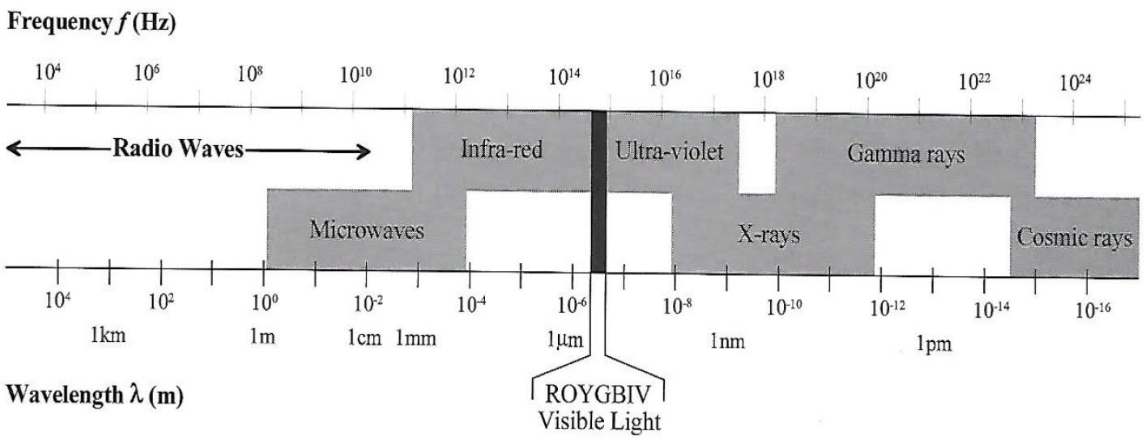
In this way, the disturbance travels, but the medium stays where it is.

1.2 Summary of EM Waves

- An accelerating charged particle radiates an electromagnetic wave.
- Electromagnetic waves travel through space because a changing magnetic field produces a changing electric field and a changing electric field produces a changing magnetic field. Thus these two fields create and recreate each other giving existence to the electromagnetic wave.
- Electromagnetic waves in a vacuum consist of oscillating electric and magnetic field strength vectors, E and B, which oscillate in mutually perpendicular directions.
- The electric and magnetic field strength vectors oscillate at right angles to the direction of travel of the electromagnetic wave. Therefore electromagnetic waves are transverse waves.
- The frequency of the radiated electromagnetic wave is the same as the frequency of oscillation of the charges, which produces it.
- They differ in frequency 'f' and wavelength 'λ' but all travel at the speed of light in the vacuum.

2 Electromagnetic Spectrum

The electromagnetic spectrum represents the range of energy from low energy, low frequency radio waves with long wavelengths up to high energy, high frequency gamma waves with small wavelengths.

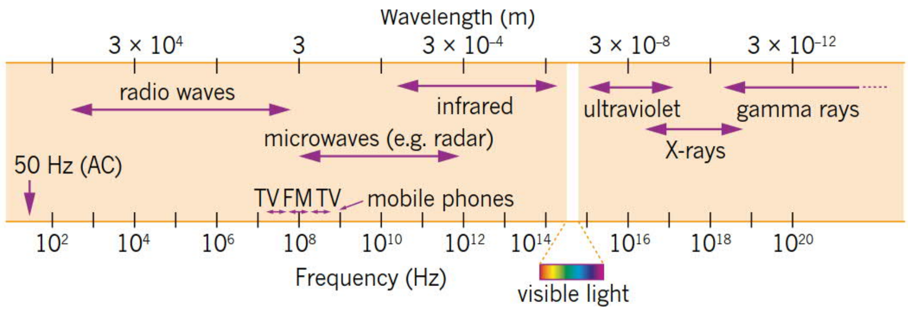


Changing the frequency and wavelength of the waves changes the properties of the electromagnetic radiation, and so the electromagnetic spectrum is divided into 'bands' according to how the particular types of EMR are used.

The shorter the wavelength of the EM wave, the greater its penetrating power. This means that waves with extremely short wavelength, such as X-rays, can pass through some materials (e.g. skin), revealing the structures inside (e.g. bone).

On the other hand, long wavelength waves such as AM radio waves have such low penetrating power that they cannot even escape Earth's atmosphere, and can be used to 'bounce' radio signals around to the other side of the world.

Compares the characteristics of different waves in the electromagnetic spectrum.



2.1 Types of EM Waves

Different types of electromagnetic waves are produced by charges oscillating in different situations. The frequency of the EM waves is same as the frequency of the oscillation of the charges in their sources.

Power frequencies

These waves are produced by electric generators, which are transmitting alternating electric currents. (Wavelength 1000 to 100 km).

Radio & TV waves

They are produced by charges accelerating (oscillating) through conducting wires. Radio waves cover a broad band of the spectrum with wavelength from 10 km to few mm. One of the most revolutionary applications of EMR is the use of radio waves to transmit information from one point to another over long distances.

Microwaves

They are generated by charges oscillating in special vacuum tubes called klystrons. Microwaves are used in radar systems, communications as well as in microwave ovens. In microwave ovens, the waves cause water molecules to vibrate faster and therefore become hotter, heating up all foods. (Wavelength 1 m to 0.1 mm)