### 6.1 WAVES

**What is waves?**

Process of transferring energy from one location to another which is produced by an oscillating or vibrating motion.

**Examples of waves**

- **Light waves** are produced as a result of vibrations of electrons in an atom.
- **Sound waves** are produced by vibrating mechanical bodies such as a guitar strings or a tuning fork.
- **Water waves** are produced by a disturbance on a still water surface.

**How do waves transfer energy?**

When energy is transferred by a wave from a vibrating source to a distant receiver, there is no transfer of matter between the two points.

When the string is shaken up and down, a disturbance moves along the length of the string. It is the disturbance that moves along the length of the string, not parts of the string itself.

Drop a stone in a quite pond. It will produce a wave that moves out from the center in expanding circles. It is the disturbance that moves, not the water. After the disturbance passes, the water is where it was before the wave was produced.

The energy transferred from a vibrating source to a receiver is carried by a disturbance in a medium, not by matter moving from one place to another within the medium.

**What is Transverse Wave?**

A **transverse wave** is a wave in which the vibration of particles in the medium is at right angle to the direction of propagation of the wave.
The spring is moved sideways. The motion of the particles medium (spring) is at right angles to the direction in which the wave travels. 

Examples: water waves, light waves

<table>
<thead>
<tr>
<th>What is Longitudinal Waves?</th>
</tr>
</thead>
<tbody>
<tr>
<td>A <strong>longitudinal wave</strong> is a wave which the <strong>vibration of particles</strong> in the medium is <strong>along</strong> (parallel to) the <strong>direction of propagation</strong> of the wave.</td>
</tr>
</tbody>
</table>

The slinky spring moves backwards and forwards to produce a transverse wave. The particles of the medium (spring) move **along the direction** of the wave. The wave that travels along the spring consists of a series of **compression** and **rarefaction**.

Examples: sounds waves.
What is a ripple tank?

The phenomenon of water waves can be investigated using a ripple tank. The water waves are produced by a vibrating bar on the water surface.

The tank is leveled so that the depth of water in the tank is uniform to ensure water waves propagate with uniform speed.

The water acts as a lens to produce a pattern of bright and dark regions on a piece of white paper placed under the tank when light passes through it. Water waves have crests and troughs.

A crest is the highest position of the wave acts as a convex lens, whereas a trough is the lowest position acts as a concave lens.

Light rays from the lamp on top will focus onto the white screen below. The bright lines correspond to the crests, and the dark lines correspond to the troughs.
What is meant by a wavefront?

Lines joining all the points of the same phase are called wavefronts.

The wavefronts of a transverse wave and longitudinal wave are perpendicular to the direction of propagation of the waves.

Describing Waves

<table>
<thead>
<tr>
<th>Vibration/Oscillation</th>
<th>Amplitude ((a))</th>
</tr>
</thead>
<tbody>
<tr>
<td>The movement from one extreme position to the other and back to the same position.</td>
<td>The maximum displacement from its equilibrium position. Amplitude relates to loudness in sound and brightness in light. SI unit: meter, m</td>
</tr>
</tbody>
</table>

Wavelength (\(\lambda\))

The distance between two adjacent points of the same phase on a wave.

The distance between two successive crests or two successive troughs. The distance between two successive compressions or two successive rarefactions in a sound wave.
**Period (T)**
The time taken for an oscillation to complete one cycle.
SI unit is second (s).

**Frequency, f**
The number of waves produced in one second.
SI unit is Hertz (Hz)

**Relation between frequency and period:**
\[ f = \frac{1}{T} \]

**Wave Speed (v)**
The speed of a wave is the measurement of how fast a crest is moving from a fixed point.
SI unit is \( \text{ms}^{-1} \).

**The relationship between speed, wavelength and frequency**

\[ \text{Velocity} = \text{wavelength} \times \text{frequency} \]
\[ v = f\lambda \]

**Displacement-time graph**

**Displacement-distance graph**

**Velocity, \( v = f\lambda \)**

**Example 1**
From the graph, calculate:
(a) Amplitude
(b) Period,
(c) Frequency
Example 2  

displacement/cm

A graph shows a wave produced by a slinky spring vibrating at frequency 8 Hz. What is:  
(a) amplitude  
(b) wavelength  
(c) wave speed  

What is damping?  

Damping is the decrease in the amplitude of an oscillating system when its energy is drained out as heat energy. The amplitude of an oscillating system will gradually decrease and become zero when the oscillation stops.

What causes damping?  

1. **External damping** of the system is the loss of energy to overcome frictional forces or air resistance.  
2. **Internal damping** is the loss of energy due to the extension and compression of the molecules in the system.

A graph to show damping

<table>
<thead>
<tr>
<th>Displacement</th>
</tr>
</thead>
<tbody>
<tr>
<td>time</td>
</tr>
</tbody>
</table>

**External Force**  

➢ To enable an oscillating system to go on continuously, an **external force** must be applied to the system.

➢ The external force supplies energy to the system. Such a motion is called a **forced oscillation**

**Natural frequency**  

➢ The frequency of a system which oscillates freely without the action of an external force is called the **natural frequency**.
<table>
<thead>
<tr>
<th>Resonance</th>
<th>Resonance occurs when a system is made to oscillate at a frequency equivalent to its natural frequency by an external force. The resonating system oscillates at its maximum amplitude.</th>
</tr>
</thead>
</table>
| Experiment in Barton’s pendulum | The frequency of a simple pendulum depends on the length of the pendulum.  
In Barton’s pendulum experiment, there are many pendulums tied to the rope. Two of the pendulum are of the same length  
When pendulum B oscillates, all the other pendulums are forced to oscillate.  
But pendulum D oscillates with the largest amplitude, ie, pendulum D resonates |
| How does resonance occur in the two pendulum of equal length? | Pendulum B and pendulum D are of the same length.  
Frequency B = Frequency D  
Therefore, pendulum B causes pendulum D to oscillate at its natural frequency.  
1. The tuner in a radio or television enables us to select the programmes we are interested. The circuit in the tuner is adjusted until resonance is achieved, at the frequency transmitted by a particular station selected. Hence a strong electrical signal is produced.  
2. The loudness of music produced by musical instruments such as the trumpet and flute is the result of resonance in the air.  
3. A bridge can collapse when the amplitude of its vibration increases as a result of resonance. |
### 6.2 REFLECTION OF WAVES

<table>
<thead>
<tr>
<th>Reflection of wave</th>
<th>Occurs when a wave strikes an obstacle.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The wave undergoes a change in direction of propagation when it is reflected.</td>
</tr>
<tr>
<td></td>
<td>The value of frequency (f), wavelength (λ) and speed (v) remain the same after reflection.</td>
</tr>
</tbody>
</table>

**Incident wave**: the wave before it strikes the obstacle

**Reflected wave**: the wave which has undergone a change in direction of propagation after reflection.

\[ i = \text{angle of incident} - \text{the angle between the direction of propagation of incident wave and the normal} \]

\[ r = \text{angle of reflection} - \text{the angle between the direction of propagation of reflected wave and the normal}. \]

**Law of Reflection:**

The angle of incidence, \( i \) is equal to the angle of reflection, \( r \).

**Reflection of plane water waves in a ripple tank**

1. Set up a ripple tank.
2. Switch on the motor to set the vibrating. Increase the frequency of the waves by increasing the voltage power supply to the motor.
3. Observe the reflected wave by using a stroboscope.

Draw a diagram to show reflection of waves.

![Diagram of reflection](image)

![Diagram of ripple tank](image)
6.3 REFRACTION OF WAVES

<table>
<thead>
<tr>
<th>What is Refraction of waves?</th>
<th>Refraction of waves is a change in its direction as the waves pass from one medium to another. It occurs when there is a difference in the speed of the wave at the boundary of two mediums.</th>
</tr>
</thead>
<tbody>
<tr>
<td>What happens to frequency, speed, wavelength &amp; direction?</td>
<td>After refraction, the wave has the same frequency, but a different speed, wavelength and direction of propagation.</td>
</tr>
<tr>
<td><img src="image1" alt="Diagram" /></td>
<td><img src="image2" alt="Diagram" /></td>
</tr>
<tr>
<td>The relationship between $v$ and $\lambda$ of a water wave in deep and shallow water:</td>
<td>$v = f \lambda$ $f$ is constant $\therefore v \propto \lambda$ $v$ is directly proportional to $\lambda$ $f = \frac{v}{\lambda} = \text{const} \tan \theta \therefore \frac{v_1}{\lambda_1} = \frac{v_2}{\lambda_2}$</td>
</tr>
<tr>
<td>Use the words, ‘increase’, ‘decrease’ or ‘unchanged’</td>
<td>Characteristics</td>
</tr>
<tr>
<td>Speed</td>
<td>Decrease</td>
</tr>
<tr>
<td>Wavelength</td>
<td>Decrease</td>
</tr>
<tr>
<td>Frequency</td>
<td>unchanged</td>
</tr>
<tr>
<td>How does the direction of waves change when:</td>
<td>Water passing from the deep region to the shallow region, the water wave is refracted toward the normal.</td>
</tr>
</tbody>
</table>
Example 1
A plane wave has a wavelength of 2 cm and a velocity of 8 cm s\(^{-1}\) as it moves over the surface of shallow water. When the plane wave moves into an area of greater depth, its velocity becomes 12 cm s\(^{-1}\). What is

(a) the wavelength

(b) the frequency of the wave in the area of greater depth?
Example 2
The diagram shows a plane water wave moving from one area P to another area Q of different depth.

If the speed of water wave in P is 18 cm s\(^{-1}\), what is the speed of water wave in Q?

6.4 DIFFRACTION OF WAVES

<table>
<thead>
<tr>
<th>What is diffraction of waves?</th>
<th>Diffraction of waves is a phenomenon in which waves spread out as they pass through a gap or round a small obstacle.</th>
</tr>
</thead>
</table>
| What are Characteristics of diffracted waves? | 1. Frequency, wavelength and speed of waves do not change.  
2. Changes in the direction of propagation and the pattern of the waves.  
3. The amplitude of the diffraction wave decreases so its energy decrease. |
| What are the factors that influence the effect of diffraction? | The effect of diffraction is obvious if:  
1. the size of the gap or obstacle is small enough  
2. the wavelength is large enough.  

The effect of diffraction is obvious if the shape of the diffracted waves more spread out or more circular. |
**Diffraction of sound**

Sound diffracting around corners so allowing us to hear others who are speaking to us from adjacent rooms.

**Diffraction of light**

Light is diffracted if it passes through a narrow slit comparable in size to its wavelength. However, the effect is not obvious as the size of the slit increases. This is because the wavelengths of light are very short.

We can hear the sound of a radio placed nearby a corner of a wall but we cannot see the radio. Why?

Sound waves are more easily diffracted in comparison to light waves because the wavelength of sound waves is much longer than the wavelength of light waves.

**Procedure**

- A ripple tank is filled with water and set up as shown.
- Switch on the power pack.
- Use a barrier to block the incident straight water waves. Observe the wave pattern beyond the barrier.
- Send a straight water waves to pass through a gap. Observe the pattern of diffracted waves beyond the gap.
- Send straight water waves towards a small gap. Observe the wave pattern beyond the small gap.
| Observation |
|-------------|-------------|
| (a) Wide gap | (b) Narrow gap |

The waves are bend only at the edges after passing through the gap. The effect of diffraction is not obvious.

The waves are circular and appear to originated from the small gap. The effect of diffraction is obvious.

Straight water wave propagate towards an obstacle.

As the size of the gap or obstacle is smaller, the effect of diffraction becomes obvious.
### 6.5 INTERFERENCE OF WAVES

<table>
<thead>
<tr>
<th>State the Principle of superposition of Waves</th>
<th>When two waves interfered, the resulting displacement of the medium at any location is the algebraic sum of the displacements of the individual waves.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Superposition of two crests</td>
<td><strong>Constructive Interference</strong></td>
</tr>
<tr>
<td><img src="image1.png" alt="Diagram" /></td>
<td><img src="image2.png" alt="Diagram" /></td>
</tr>
<tr>
<td>(b) Superposition of two troughs</td>
<td><strong>Constructive Interference</strong></td>
</tr>
<tr>
<td><img src="image3.png" alt="Diagram" /></td>
<td><img src="image4.png" alt="Diagram" /></td>
</tr>
<tr>
<td>(c) Superposition of a crest and a trough</td>
<td><strong>Destructive Interference</strong></td>
</tr>
<tr>
<td><img src="image5.png" alt="Diagram" /></td>
<td><img src="image6.png" alt="Diagram" /></td>
</tr>
<tr>
<td>What is Interference of Waves?</td>
<td><em>Interference is the superposition of two waves originating from two coherent sources.</em></td>
</tr>
<tr>
<td>What is coherent sources?</td>
<td><em>The waves from coherent sources have the same frequency (f), same wavelength and constant phase difference.</em></td>
</tr>
<tr>
<td>How does interference occur?</td>
<td><em>Wave interference occurs when two waves meet while propagating along the same medium. When the two waves are superposed, interference will occur either constructive interference or destructive interference.</em></td>
</tr>
</tbody>
</table>
Constructive Interference

- Occurs when the crests or troughs of both waves coincide to produce a wave with crests and troughs of maximum amplitude.

Destructive interference

- Occurs when crest of one wave coincide with the trough of the other wave, thus canceling each other with the result that the resultant amplitude is zero.

The occurrence of constructive interference and destructive interference

- A point where constructive interference occurs
- A point where destructive interference occurs.

Keys:

- Maximum crest wave (2 crests meet)
- Zero amplitude (trough meets crest)
- Maximum trough wave (2 troughs meet)
Young’s formula

The relationship between $\lambda$, $a$, $x$ and $D$

$\lambda = \frac{ax}{D}$

Factors affecting the interference pattern

The interference pattern depend on the value of $x$

When $x$ changes, the interference pattern also changes

$x = \frac{\lambda D}{a}$

1. $x \propto \frac{1}{a}$

The distance between 2 consecutive lines, $x$ is inversely proportional to the distance between 2 sources, $a$

As $a$ becomes larger, $x$ becomes smaller

As $a$ becomes smaller, $x$ becomes larger
2. \( x \propto \lambda \)

where \( a \) \& \( D \) are constant

The distance between two consecutive node lines or antinode lines, \( x \) increases is directly proportional to the wavelength of the wave, \( \lambda \)

![Graph showing \( x = D/\lambda \)]

As \( \lambda \) increases, \( x \) increases

Low frequency (large \( \lambda \))

High frequency (small \( \lambda \))

As \( \lambda \) decreases, \( x \) also decreases.

3. \( x \propto D \)

\( x \) directly proportional to \( D \)

where \( a \) \& \( \lambda \) are constant

The distance between two consecutive node lines or antinode lines, \( x \) is directly proportional to the distance from the two sources to the point of measurement of \( x, D \)

![Graph showing \( x = \lambda D/a \)]

Interference of lights

Occurs when an incident light wave passes through a double slit. An interference pattern is produced as a result of the superposition of two emerging light waves from the double slit.

Young’s double-slit experiment

- Use monochromatic light (light which has one colour and one wavelength)
- The double slit must be very narrow (about 0.5 mm) to produce a clear interference pattern because the wavelength of light is very small.
- When light from monochromatic source passes through a double slit, two sources of coherent light are produced.
The interference pattern consists of alternate bright and dark fringes that can be seen on a distant screen.

- Bright fringes: constructive interference
- Dark fringes: destructive interference.

\[ \lambda = \frac{ax}{D} \]

### Interference of Sound Waves

Occurs when two coherent sound waves interact on the basis of the principle of superposition to produce a pattern of

- \( a \) = Distance between the two loudspeakers
- \( D \) = Distance between the loudspeakers and the path along which interference can be detected
- \( \lambda \) = The wavelength of sound waves is

The two loudspeakers are the sources of the two coherent sound waves as they are connected to the same audio signal generator.

A student is requested to walk in a straight path at a distance of \( D \) from the loudspeakers.

The student hears alternating loud and soft sounds as he walks along the straight path.
The alternating loud and soft sounds is caused by interference of the sound waves.  
The loud sound: constructive interference  
The soft sound: destructive interference.
\[ \lambda = \frac{ax}{D} \]

<table>
<thead>
<tr>
<th>Water wave</th>
<th>Sound wave</th>
<th>Light wave</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Water wave diagram" /></td>
<td><img src="image" alt="Sound wave diagram" /></td>
<td><img src="image" alt="Light wave diagram" /></td>
</tr>
<tr>
<td>( \lambda )</td>
<td>The wavelength of water waves is influenced by the frequency of the vibrator</td>
<td>The wavelength of sound waves is influenced by the frequency of the audio signal generator.</td>
</tr>
<tr>
<td>( D )</td>
<td>Distance between the spherical dippers and the position marked ( x ) is measured</td>
<td>Distance between the loudspeakers and the path along which interference can be detected</td>
</tr>
<tr>
<td>( a )</td>
<td>Distance between the two spherical dippers</td>
<td>Distance between the two loudspeakers</td>
</tr>
<tr>
<td>( x )</td>
<td>Distance between two consecutive antinode lines or two consecutive node lines</td>
<td>Distance between two consecutive positions where loud sound is heard</td>
</tr>
<tr>
<td>High amplitude of water</td>
<td>Loud sound</td>
<td>Bright fringes</td>
</tr>
<tr>
<td>Calm water</td>
<td>Soft sound</td>
<td>Dark fringes</td>
</tr>
<tr>
<td>Example 1</td>
<td>Example 2</td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>-----------</td>
<td></td>
</tr>
<tr>
<td>In the interference of two coherent sources of waves, the separation between two spherical dippers is 3 cm and the distance between two consecutive node lines is 4 cm measured at a distance of 15 cm from the two coherent sources of waves. Calculate the wavelength of the water waves originating from the sources.</td>
<td>In a Young’s double slit experiment, the distance between the double slit and the screen is 4.0 m and the separation of the two slits is 0.5 mm. Calculate the distance between two consecutive bright fringes for violet light with a wavelength of $4.0 \times 10^{-7}$ m</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Example 3</th>
<th>Example 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>The wavelength of light can be determined with a double-slit plate. The diagram shows the pattern of interference fringes obtained in a Young’s double-slit experiment. The separation of distance of the two slits is 0.25 mm and the distance between the screen and the double slit plate is 3.0 m. Calculate the wavelength of light used in the experiment.</td>
<td>In an experiment on the interference of waves, two loudspeakers are placed at a distance of 1.5 m from each other. They are connected to an audio signal generator to produce coherent sound waves at a frequency of 0.5 kHz. Calculate</td>
</tr>
<tr>
<td>(a) the wavelength of the sound wave if the speed of sound is 300 ms$^{-1}$</td>
<td>(b) the distance between two consecutive soft sounds at a perpendicular distance of 5 m from the source of the sound.</td>
</tr>
</tbody>
</table>
## 6.6 ANALYSING SOUND WAVES

<table>
<thead>
<tr>
<th>What is sound waves?</th>
<th>Sound is a form of energy propagated as waves that make our eardrums vibrate. Sound waves are caused by vibrating objects. Sound waves are longitudinal waves.</th>
</tr>
</thead>
</table>
| How is sound produced by a vibrating objects? | • Sound waves are produced when a vibrating object causes the air molecules around it to vibrate.  

![Diagram](image)

• When a tuning fork vibrates, layers of air vibrate and the sound energy is propagated through the air around it in the form of waves.  
• When the tuning fork moves forwards, the air is compressed.  
• When the tuning fork moves backwards, the air layers are pulled apart and cause a rarefaction.  
• Therefore, a series of compression and rarefactions will produce sound. |
| Why does sound waves is a longitudinal waves? | • The air particles vibrate backward and forward in the direction parallel to the direction of propagation of the sound wave.  
• Wavelength of sound, \( \lambda \) = the distance between two successive regions of compression or two successive regions of rarefaction. |
| Explain how the loudness relates to amplitude? | • The loudness of the sound depends on its amplitude.  
• If the amplitude is increased, the loudness increases. |
| Explain how | • A high pitch sound corresponds to a high frequency and |
The pitch relates to frequency

<table>
<thead>
<tr>
<th>Wave form</th>
<th>Amplitude of sound wave</th>
<th>Loudness of sound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The relation between the pitch and the frequency of sound

The audio signal is switched on and the frequency of the sound is varied from low to high gradually. The pitch of the sound that is heard and the form of the wave displayed on the screen of the oscilloscope is observed.

Write: low / medium / high

<table>
<thead>
<tr>
<th>Wave form</th>
<th>Frequency of sound wave</th>
<th>Pitch of sound</th>
</tr>
</thead>
</table>
describe applications of reflection of sound waves.

Ultrasound in medicine

The reflection of sound is called echoes.

<table>
<thead>
<tr>
<th>Infrasound</th>
<th>Normal audible range</th>
<th>Ultrasound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 20 Hz</td>
<td>20 Hz to 20 000 Hz</td>
<td>Higher than 20 000 Hz</td>
</tr>
</tbody>
</table>

- Ultrasound waves is used to scan and capture the image of a fetus in a mother’s womb and the image of internal organ in a body.
- Transmitter P emits ultrasound downwards to the fetus.
- Detector R receives the ultrasound (echoes) reflected by the various parts of the fetus.
- The soft tissues of the fetus absorb most of the incident ultrasound, reflect very little. The bony parts will absorb very little, but reflect most of the ultrasound. The reflected ultrasound will produce an image of contrasting brightness.

- Sonar is the technique of using ultrasound to locate underwater objects or to measure the depth of a seabed.
- Ultrasound signal is sent out from a transmitter.
- Its echo from the seabed is detected by a receiver which is connected to an electrical recording circuit.
- The time interval, $t$ between the sending and receiving of the ultrasound signal after reflection from the seabed is measured.
A bat can navigate in darkness

- The depth of the seabed, \( d = \frac{v \times t}{2} \) where \( v \) is the velocity of sound in water.

- When ultrasonic waves emitted by the bat hit an object, they are reflected back and received by the bat.

- The time between the emission of the sound waves and reception of the reflected waves enables the bat to estimate the position of the object accurately.

- This enables the bat to adjust its direction to avoid knocking at the object.

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### Calculate distances using the reflection of sound waves.

An ultrasonic wave is used to determine the depth of a seabed. A pulse of ultrasound is generated and travels to the seabed and reflected by it. The time taken by a pulse of ultrasonic wave to travel to and fro the seabed is 0.28 s. If the speed of sound in the water is 1 500 ms\(^{-1}\), calculate the depth of the seabed.
## Describe the electromagnetic spectrum

### Radio waves

<table>
<thead>
<tr>
<th>Radio waves</th>
<th>Medium waves</th>
<th>Short waves</th>
<th>VHF</th>
<th>UHF</th>
<th>Microwaves</th>
<th>Infrared</th>
<th>Light</th>
<th>Ultraviolet</th>
<th>X-rays</th>
<th>Gamma rays</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000 m</td>
<td>1 m</td>
<td>1 mm</td>
<td>1 x 10^{-3} mm</td>
<td>1 x 10^{-6} mm</td>
<td>1 x 10^{-9} mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**What is electromagnetic wave?**

- It consists of a group of waves with similar natures.
- The members of the electromagnetic spectrum arranged in increasing frequencies and decreasing wavelengths are: radio waves, microwaves, infrared rays, visible light, ultraviolet rays, X-rays, and gamma rays.
- Radio waves have the longest wavelength but are of low frequency waves. They carry very little energy.
- Gamma rays have the shortest wavelength but are of high frequency waves. They carry very high energy.

**What is the electromagnetic spectrum?**

- It is produced when electric and magnetic field vibrate at right angle to each other.
- The direction of propagation of the wave is perpendicular to both fields.
State the visible light is a part of the electromagnetic spectrum

- Visible light waves are the only electromagnetic waves we can see. Light can be seen as the colours of rainbow.
- Each colour has a different wavelength.
- Red has the longest wavelength and violet the shortest.
- When all the waves are seen together, they make **white light**.
- When white light shines through a prism, the white light is broken apart into the **seven** colours of the visible light **spectrum**.
- Red, orange, yellow, green, blue, indigo and violet.

Describe the properties of electromagnetic waves

1. They transfer **energy** from one point to another.
2. They are **transverse** waves.
3. They can travel through **vacuum**.
4. They travel at the same speed through vacuum, i.e at the speed of light, \( c = 3 \times 10^8 \, \text{ms}^{-1} \).
5. They all show wave properties such as **reflection**, **refraction**, **diffraction** and **interference**.
6. They obey the wave equation, \( v = f\lambda \).

List sources of electromagnetic waves and the applications.

<table>
<thead>
<tr>
<th>Electromagnetic wave</th>
<th>Sources</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamma Rays</td>
<td>Radioactive substances</td>
<td>• Engineering – to detect leakages in underground pipes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Medicine – cancer treatment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Food sterilisation</td>
</tr>
<tr>
<td>Radiation Type</td>
<td>Source/Device</td>
<td>Applications</td>
</tr>
<tr>
<td>---------------------</td>
<td>----------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| X-rays              | X-ray tube                             | Medicine  
  i. X-ray photograph of the internal organs of the body, e.g. to locate bone fracture.  
  ii. Cancer treatment  
  Engineering – to detect cracks in metal  
  Checking of luggage at airports |
| Ultraviolet rays    | The sun, mercury vapour lamp.           | Cause sunburn  
  Stimulation of the formation of vitamin D needed for assimilation of calcium and the prevention of rickets.  
  Detect fake notes  
  Fluorescent lamp  
  Sterilization of surgical tools and plant seedlings. |
| Visible light       | Flames, lamps, the sun                  | Visual communication  
  Photography  
  Photosynthesis |
| Infrared radiation  | Hot objects such as flames, the human body, the sun | A sensation of warmth is felt when IR falls on the skin.  
  Thermal imaging and physiotherapy  
  Infrared binoculars for night time vision. IR radiation emitted by a living thing can be detected.  
  Remote control for TV / VCR |
| Microwaves          | Radar transmitter  
  Microwaves oven | Communication system with satellites  
  Used in radar system  
  Cooking  
  Cellular (mobile) phone service |
| Radio waves         | Electrons oscillating in aerials  
  Radio/television | For broadcasting and wireless communication  
  UHF (ultra high frequency) radio waves – television and hand phones |
Describe the detrimental effects of excessive exposure to certain components of the electromagnetic spectrum.

<table>
<thead>
<tr>
<th>Component</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radio waves</td>
<td>No evidence of hazard</td>
</tr>
<tr>
<td>Microwaves</td>
<td>Internal heating of body tissues when they enter our body. Long exposure to mobile phones can cause brain tumor and inner ear complications in children. Just SMS.</td>
</tr>
<tr>
<td>Infrared</td>
<td>Skin burns</td>
</tr>
<tr>
<td>Visible light</td>
<td>No evidence of hazard</td>
</tr>
<tr>
<td>Ultraviolet</td>
<td>Damage to the surface cells (including skin cancer) and blindness</td>
</tr>
<tr>
<td>X-rays</td>
<td>Damage to cells. Cancer, mutation The mutated cells may result in the abnormal growth of cancer cells. Pregnant mothers who are exposed to X-rays and radiations too frequently may cause abnormalities in new born babies.</td>
</tr>
<tr>
<td>Gamma rays</td>
<td></td>
</tr>
</tbody>
</table>