3 Waves

3.1 General properties of waves

Core

1 Know that waves transfer energy without transferring matter

2 Describe what is meant by wave motion as illustrated by vibrations in ropes and springs, and by experiments using water waves

3 Describe the features of a wave in terms of wavefront, wavelength, frequency, crest (peak), trough, amplitude and wave speed

4 Recall and use the equation for wave speed
$v = f\lambda$

5 Know that for a transverse wave, the direction of vibration is at right angles to the direction of propagation and understand that electromagnetic radiation, water waves and seismic S-waves (secondary) can be modelled as transverse

continued

Supplement

3.2.4 Dispersion of light

Core

1 Describe the dispersion of light as illustrated by the refraction of white light by a glass prism

2 Know the traditional seven colours of the visible spectrum in order of frequency and in order of wavelength

Supplement

3 Recall that visible light of a single frequency is described as monochromatic

3.1 General properties of waves continued

Core	Supplement
6 Know that for a longitudinal wave, the direction of vibration is parallel to the direction of propagation and understand that sound waves and seismic P-waves (primary) can be modelled as longitudinal	
7 Describe how waves can undergo: (a) reflection at a plane surface (b) refraction due to a change of speed (c) diffraction through a narrow gap	9 Describe how wavelength and gap size affects diffraction through a gap
8 Describe the use of a ripple tank to show: (a) reflection at a plane surface (b) refraction due to a change in speed caused by a change in depth (c) diffraction due to a gap (d) diffraction due to an edge	10 Describe how wavelength affects diffraction at an edge

3.2 Light

3.2.1 Reflection of light

Core	Supplement
1 Define and use the terms normal, angle of incidence and angle of reflection	
2 Describe the formation of an optical image by a plane mirror, and give its characteristics, i.e. same size, same distance from mirror, virtual	
3 State that for reflection, the angle of incidence is equal to the angle of reflection; recall and use this relationship	4 Use simple constructions, measurements and calculations for reflection by plane mirrors

3.2 Light continued

3.2.2 Refraction of light

Core

1 Define and use the terms normal, angle of incidence and angle of refraction

2 Describe an experiment to show refraction of light by transparent blocks of different shapes

3 Describe the passage of light through a transparent material (limited to the boundaries between two media only)

4 State the meaning of critical angle

5 Describe internal reflection and total internal reflection using both experimental and everyday examples

Supplement

6 Define refractive index, n, as the ratio of the speeds of a wave in two different regions

7 Recall and use the equation

$$n = \frac{\sin i}{\sin r}$$

8 Recall and use the equation

$$n = \frac{1}{\sin c}$$

9 Describe the use of optical fibres, particularly in telecommunications

3.2.3 Thin lenses

Core

1 Describe the action of thin converging and thin diverging lenses on a parallel beam of light

2 Define and use the terms focal length, principal axis and principal focus (focal point)

3 Draw and use ray diagrams for the formation of a real image by a converging lens

4 Describe the characteristics of an image using the terms enlarged/same size/diminished, upright/inverted and real/virtual

5 Know that a virtual image is formed when diverging rays are extrapolated backwards and does not form a visible projection on a screen

Supplement

6 Draw and use ray diagrams for the formation of a virtual image by a converging lens

7 Describe the use of a single lens as a magnifying glass

8 Describe the use of converging and diverging lenses to correct long-sightedness and short-sightedness

3.3 Electromagnetic spectrum

Core

1 Know the main regions of the electromagnetic spectrum in order of frequency and in order of wavelength

2 Know that all electromagnetic waves travel at the same high speed in a vacuum

3 Describe typical uses of the different regions of the electromagnetic spectrum including:

(a) radio waves; radio and television transmissions, astronomy, radio frequency identification (RFID)

(b) microwaves; satellite television, mobile phones (cell phones), microwave ovens

(c) infrared; electric grills, short range communications such as remote controllers for televisions, intruder alarms, thermal imaging, optical fibres

(d) visible light; vision, photography, illumination

(e) ultraviolet; security marking, detecting fake bank notes, sterilising water

(f) X-rays; medical scanning, security scanners

(g) gamma rays; sterilising food and medical equipment, detection of cancer and its treatment

4 Describe the harmful effects on people of excessive exposure to electromagnetic radiation, including:

(a) microwaves; internal heating of body cells

(b) infrared; skin burns

(c) ultraviolet; damage to surface cells and eyes, leading to skin cancer and eye conditions

(d) X-rays and gamma rays; mutation or damage to cells in the body

Supplement

6 Know that the speed of electromagnetic waves in a vacuum is 3.0×10^8 m / s and is approximately the same in air

3.3 Electromagnetic spectrum continued

Core

5 Know that communication with artificial satellites is mainly by microwaves:

(a) some satellite phones use low orbit artificial satellites

(b) some satellite phones and direct broadcast satellite television use geostationary satellites

Supplement

7 Know that many important systems of communications rely on electromagnetic radiation including:

(a) mobile phones (cell phones) and wireless internet use microwaves because microwaves can penetrate some walls and only require a short aerial for transmission and reception

(b) Bluetooth uses low energy radio waves or microwaves because they can pass through walls but the signal is weakened on doing so

(c) optical fibres (visible light or infrared) are used for cable television and high-speed broadband because glass is transparent to visible light and some infrared; visible light and short wavelength infrared can carry high rates of data

8 Know the difference between a digital and analogue signal

9 Know that a sound can be transmitted as a digital or analogue signal

10 Explain the benefits of digital signaling including increased rate of transmission of data and increased range due to accurate signal regeneration

3.4 Sound

Core

1 Describe the production of sound by vibrating sources

2 Describe the longitudinal nature of sound waves

3 State the approximate range of frequencies audible to humans as 20 Hz to 20 000 Hz

4 Know that a medium is needed to transmit sound waves

5 Know that the speed of sound in air is approximately 330–350 m/s

Supplement

10 Describe compression and rarefaction

11 Know that, in general, sound travels faster in solids than in liquids and faster in liquids than in gases

3.4 Sound continued

Core	Supplement
6 Describe a method involving a measurement of distance and time for determining the speed of sound in air	
7 Describe how changes in amplitude and frequency affect the loudness and pitch of sound waves	
8 Describe an echo as the reflection of sound waves	
9 Define ultrasound as sound with a frequency higher than 20 kHz	12 Describe the uses of ultrasound in non-destructive testing of materials, medical scanning of soft tissue and sonar including calculation of depth or distance from time and wave speed

CHAPTER – 3

WAVES

3.1 GENERAL PROPERTIES OF WAVE:

1. **Know that waves transfer energy without transferring matter?**

Here's how waves transfer energy without transferring matter:

1. Wave Motion:

- Waves are disturbances that travel through a medium

- The medium particles oscillate up and down (or back and forth)

- Each particle returns to its original position after the wave passes

2. Energy Transfer:

- Energy moves along with the wave from one point to another

- The particles themselves don't move along with the wave

- Only the wave pattern travels forward

3. Demonstration Example:

- Water waves in a pond: when a stone is dropped

  - Ripples move outward

  - Water molecules move up and down

  - A floating object bobs up and down but doesn't move horizontally

4. Types of Energy Transfer:

- Mechanical waves (sound, water waves)

- Electromagnetic waves (light, radio waves)

Both types transfer energy while the medium (if any) stays in place

This concept is fundamental to understanding wave behavior in physics and explains how energy can be transmitted across distances without physical matter moving along with it.

2. **Describe what is meant by wave motion as illustrated by vibrations in ropes and springs, and by experiments using water waves?**

Here's a description of wave motion using different examples:

1. Rope and Spring Waves:

- Created by moving one end back and forth
- The disturbance travels along the length
- Shows how energy moves through the medium

2. Water Waves:

- Form regular patterns of crests and troughs
- Can be straight or circular
- Can show diffraction when passing through gaps
- Speed and wavelength can be observed and measured

3. Wave Characteristics:

- Compressions (where parts are closer together)
- Rarefactions (where parts are further apart)
- Wave patterns show regular spacing between peaks

4. Wave Properties Demonstrated:

- Reflection (bouncing off surfaces)
- Refraction (changing direction)
- Diffraction (spreading out through gaps)
- Can be longitudinal or transverse

5. Energy Transfer:

- Waves carry energy from one point to another
- The medium (rope, spring, or water) oscillates but doesn't move forward
- The wave pattern moves through the medium

These demonstrations help visualize how waves transfer energy through different media without transferring matter.

3. **Describe the features of a wave in terms of wavefront, wavelength, frequency, crest (peak), trough, amplitude and wave speed?**

Here are the key features of a wave:

1. Wavefront:

- A line connecting points of the same phase in a wave

- Shows the direction of wave travel

- Can be straight or circular depending on the source

2. Wavelength (λ):

- Distance between successive crests or peaks

- Measured from one peak to the next

- Represented by the Greek letter λ (lambda)

3. Frequency (f):

- Number of complete waves generated per second

- Measured in hertz (Hz)

- One hertz = one wave per second

- Equal to the frequency of the wave source

4. Crest and Trough:

- Crest (peak) is the highest point of the wave

- Trough is the lowest point of the wave

5. Amplitude (a):

- Height of crest or depth of trough

- Measured from the undisturbed position

- Determines the energy carried by the wave

6. Wave Speed (v):

- Distance moved by a crest in one second

- Related to frequency and wavelength by the equation:

- $v = f\lambda$ (wave speed = frequency × wavelength)

4. Recall and use the equation for wave speed v = f λ?

Here's how to use the wave speed equation:

1. The Wave Speed Equation:

$v = f\lambda$ where:

- v = wave speed (in meters per second, m/s)

- f = frequency (in hertz, Hz)

- λ = wavelength (in meters, m)

2. Rearranging the Equation:

To find frequency: $f = \frac{v}{\lambda}$
To find wavelength: $\lambda = \frac{v}{f}$

3. Example Calculations:

If a wave has:

- Frequency = 5 Hz

- Wavelength = 2 m

Then:

$v = 5 \times 2 = 10$ m/s

4. Units Check:

- Speed must be in m/s

- Frequency must be in Hz (s^{-1})

- Wavelength must be in m

This ensures dimensional consistency

Remember: This equation applies to all types of waves, including water waves, sound waves, and electromagnetic waves.

5. **Know that for a transverse wave, the direction of vibration is at right angles to the direction of propagation and understand that electromagnetic radiation, water waves and seismic S-waves (secondary) can be modelled as transverse?**

In a transverse wave:

1. Direction of Vibration:

- The particles of the medium vibrate **perpendicularly** (at right angles) to the direction in which the wave propagates (travels) .

2. Examples of Transverse Waves:

- Electromagnetic Radiation: Light, radio waves, and X-rays are transverse waves where electric and magnetic fields oscillate perpendicular to the direction of wave travel.

- Water Waves: The water particles move up and down while the wave travels horizontally.

- Seismic S-Waves (Secondary Waves): These waves cause the ground to move perpendicular to the direction of wave propagation during an earthquake .

3. Key Features:

- Transverse waves have crests (peaks) and troughs.

- They can be represented graphically as sine waves, showing the perpendicular oscillations.

These examples illustrate how transverse waves transfer energy without transferring matter, with vibrations occurring at right angles to the wave's direction of travel.

6. **Know that for a longitudinal wave, the direction of vibration is parallel to the direction of propagation and understand that sound waves and seismic P-waves (primary) can be modelled as longitudinal?**

In a longitudinal wave:

1. Direction of Vibration:

- The particles of the medium vibrate **parallel** to the direction in which the wave propagates (travels) .

2. Examples of Longitudinal Waves:

- **Sound Waves:** Air molecules compress and expand as the wave travels, creating regions of compression and rarefaction.

- **Seismic P-Waves (Primary Waves):** These waves compress and expand the ground in the same direction as the wave's travel during an earthquake .

3. Key Features:

- **Compression:** Regions where particles are closer together.

- **Rarefaction:** Regions where particles are spread apart.

- Longitudinal waves do not have crests or troughs but instead have alternating compressions and rarefactions.

These waves demonstrate how energy is transferred through a medium with vibrations occurring in the same direction as the wave's travel.

7. **Describe how waves can undergo:**
    (a) reflection at a plane surface
    (b) refraction due to a change of speed
    (c) diffraction through a narrow gap?

(a) Reflection at a Plane Surface:

- When waves strike a plane surface, they bounce back into the same medium.

- The angle of incidence (angle between the incoming wave and the normal) is equal to the angle of reflection (angle between the reflected wave and the normal).

- Example: Water waves reflecting off a metal strip in a ripple tank .

(b) Refraction Due to a Change of Speed:

- When waves pass from one medium to another (or from deep to shallow water), their speed and wavelength change, causing the wave to bend.

- If the wave enters a slower medium, it bends **towards** the normal; if it enters a faster medium, it bends **away** from the normal.

- Example: Water waves in a ripple tank slow down and have shorter wavelengths in shallow water .

(c) Diffraction Through a Narrow Gap:

- When waves pass through a narrow gap, they spread out into circular wavefronts.

- The extent of diffraction depends on the gap size relative to the wavelength. Maximum diffraction occurs when the gap size is comparable to the wavelength.

- Example: Water waves spreading out after passing through a narrow gap in a ripple tank .

8. Describe the use of a ripple tank to show: (a) reflection at a plane surface (b) refraction due to a change in speed caused by a change in depth (c) diffraction due to a gap (d) diffraction due to an edge?

A **ripple tank** is a shallow tray of water used to study wave behavior. Here's how it can demonstrate different wave phenomena:

(a) Reflection at a Plane Surface:

- Place a **metal strip** in the ripple tank at an angle.

- Generate straight water waves using a vibrating bar.

- Observe that the waves reflect off the metal strip.

- The angle of incidence equals the angle of reflection, as shown by the wavefronts .

(b) Refraction Due to a Change in Speed Caused by a Change in Depth:

- Place a **glass plate** in the tank to create a shallow region.

- Generate straight waves.

- Observe that in the shallow region, the waves slow down and their wavelength decreases.

- If the waves enter the shallow region at an angle, they bend **towards the normal**, demonstrating refraction .

(c) Diffraction Due to a Gap:

- Place two obstacles in the tank to form a **narrow gap**.

- Generate straight waves.

- Observe that the waves spread out into circular wavefronts after passing through the gap.

- Maximum diffraction occurs when the gap size is comparable to the wavelength .

(d) Diffraction Due to an Edge:

- Place a **single obstacle** in the tank to create an edge.

- Generate straight waves.

- Observe that the waves curve around the edge, spreading into the region behind the obstacle.

- The curvature is more noticeable for longer wavelengths .

9. Describe how wavelength and gap size affects diffraction through a gap?

The extent of diffraction through a gap depends on the relationship between the **wavelength** of the wave and the **size of the gap**:

1. When the Gap Size is Comparable to the Wavelength:

- Maximum diffraction occurs.
- The waves spread out significantly into circular wavefronts beyond the gap.

2. When the Gap Size is Much Larger than the Wavelength:

- Diffraction is minimal.
- The waves pass through the gap with little spreading, remaining mostly straight.

3. When the Gap Size is Smaller than the Wavelength:

- The waves are mostly blocked, and only a small amount of energy passes through, spreading widely.

This principle applies to all types of waves, including water waves, sound waves, and light waves .

10. Describe how wavelength affects diffraction at an edge?

The extent of diffraction at an edge depends on the **wavelength** of the wave:

1. Longer Wavelengths:

- Diffraction is more noticeable.
- The wavefronts curve significantly around the edge, spreading into the region behind the obstacle.

2. Shorter Wavelengths:

- Diffraction is less noticeable.
- The wavefronts remain straighter, with only slight spreading around the edge.

This effect is why longer wavelengths, like radio waves, can bend around obstacles more effectively than shorter wavelengths, like light waves .

3.2 LIGHT

3.2.1 REFLECTION OF LIGHT

1. Define and use the terms normal, angle of incidence and angle of reflection?

1. Normal:

- A line that is **perpendicular** to a surface at the point where a wave (such as light) strikes it .

2. Angle of Incidence:

- The angle between the **incident ray** (incoming wave) and the **normal** .

3. Angle of Reflection:

- The angle between the **reflected ray** (outgoing wave) and the **normal** .

Key Relationship:

According to the **law of reflection**, the angle of incidence is always equal to the angle of reflection **.**

2. Describe the formation of an optical image by a plane mirror, and give its characteristics, i.e. same size, same distance from mirror, virtual?

A plane mirror forms an optical image through **reflection**. Here's how it happens and the characteristics of the image:

1. Formation:

- Light rays from a point on the object reflect off the mirror.

- These reflected rays appear to diverge from a point behind the mirror when extended backward.

- This point forms the **virtual image** of the object .

2. Characteristics of the Image:

- Same Size: The image is the same size as the object.

- Same Distance: The image appears as far behind the mirror as the object is in front of it.

- Virtual: The image cannot be projected onto a screen because the rays do not actually pass through the image point.

- Laterally Inverted: Left and right are reversed in the **image .**

3. State that for reflection, the angle of incidence is equal to the angle of reflection; recall and use this relationship?

For **reflection**, the **angle of incidence** is always equal to the **angle of reflection**. This is known as the **law of reflection**.

Mathematically:

$i = r$

where:

- i = angle of incidence (between the incident ray and the normal)

- r = angle of reflection (between the reflected ray and the normal)

This relationship can be used to predict the path of a reflected ray when the angle of incidence is known .

4. Use simple constructions, measurements and calculations for reflection by plane mirrors?

To perform simple constructions, measurements, and calculations for reflection by plane mirrors:

1. Drawing the Setup:

- Draw a **plane mirror** as a straight line.

- Mark the **normal** (a perpendicular line) at the point where the light ray strikes the mirror.

- Draw the **incident ray** approaching the mirror at a specific angle to the normal (angle of incidence, (i)).

2. Applying the Law of Reflection:

- Using the law of reflection (i = r), measure the angle of incidence.

- Draw the **reflected ray** at the same angle (\(r\)) on the opposite side of the normal.

3. Measuring and Calculating:

- Use a protractor to measure the angles of incidence and reflection.

- Verify that (i = r) through measurement.

- Extend the reflected ray if needed to determine the position of the virtual image behind the mirror.

4. Constructing the Image:

- Extend the reflected rays backward (dotted lines) to meet behind the mirror.

- The intersection point represents the **virtual image** of the object.

This method allows you to predict and verify the path of light rays and the position of the image formed by a plane mirror .

3.2.2 REFRACTION OF LIGHT

1. **Define and use the terms normal, angle of incidence and angle of refraction?**

1. Normal:

- A line that is **perpendicular** to the surface at the point where a light ray strikes or passes through it .

2. Angle of Incidence:

- The angle between the **incident ray** (incoming ray) and the **normal** .

3. Angle of Refraction:

- The angle between the **refracted ray** (bent ray) and the **normal** when light passes from one medium to another .

These terms are essential for understanding **reflection** and **refraction** phenomena.

2. Describe an experiment to show refraction of light by transparent blocks of different shapes?

Experiment to Show Refraction of Light Using Transparent Blocks:

1. Materials Needed:

- A ray box or laser pointer

- Transparent blocks of different shapes (e.g., rectangular, triangular, or semicircular)

- A protractor

- A ruler

- A sheet of white paper

2. Procedure:

- Place the transparent block on the white paper and trace its outline.

- Shine a single ray of light (from the ray box or laser) at an angle to one side of the block.

- Mark the points where the ray enters and exits the block.

- Remove the block and use a ruler to draw the **incident ray**, the **refracted ray** inside the block, and the **emergent ray**.

- Draw the **normal** at the points of incidence and emergence.

- Measure the **angle of incidence** (\(i\)) and the **angle of refraction** (\(r\)) using a protractor.

3. Observations:

- The light ray bends towards the normal when entering a denser medium (e.g., from air to glass).

- The light ray bends away from the normal when exiting to a less dense medium (e.g., from glass to air).

- For triangular blocks, dispersion may occur, separating the light into its spectrum.

4. Conclusion:

- The bending of light at the boundaries demonstrates **refraction**, and the amount of bending depends on the shape of the block and the refractive indices of the materials involved .

3. Describe the passage of light through a transparent material (limited to the boundaries between two media only)?

When light passes through a transparent material at the boundary between two media (e.g., air and glass), the following occurs:

1. At the First Boundary (Air to Glass):

- The light ray **slows down** as it enters the denser medium (glass).

- The ray bends **towards the normal** due to the change in speed. This bending is called **refraction**.

2. At the Second Boundary (Glass to Air):

- The light ray **speeds up** as it exits the denser medium into the less dense medium (air).

- The ray bends **away from the normal**.

The amount of bending depends on the **refractive index** of the materials and the **angle of incidence**. If the angle of incidence is 0° (ray perpendicular to the surface), the light passes straight through without bending .

4. State the meaning of critical angle?

The **critical angle** is the angle of incidence in a denser medium at which the refracted ray travels along the boundary between the two media, making an angle of 90° with the normal.

For angles of incidence greater than the critical angle, **total internal reflection** occurs, meaning all the light is reflected back into the denser medium instead of being refracted .

5. Describe internal reflection and total internal reflection using both experimental and everyday examples?

Internal Reflection:

When light passes from a denser medium (e.g., glass or water) to a less dense medium (e.g., air) at an angle of incidence less than the critical angle, part of the light is reflected back into the denser medium, and part is refracted into the less dense medium.

Total Internal Reflection (TIR):

When the angle of incidence exceeds the critical angle, all the light is reflected back into the denser medium. No refraction occurs in this case.

Experimental Example:

- **Setup**: Use a semicircular glass block and a laser beam.

- **Procedure**:

1. Direct the laser beam towards the flat side of the block at varying angles of incidence.

2. Observe the refracted ray as the angle increases.

3. At the critical angle, the refracted ray travels along the boundary.

4. Beyond the critical angle, the ray is completely reflected inside the block, demonstrating TIR.

Everyday Examples:

1. **Optical Fibres**: Light undergoes TIR within the fibre, allowing it to travel long distances without escaping.

2. **Mirages**: TIR occurs in layers of air with different temperatures, creating the illusion of water on roads.

3. **Diamond Sparkle**: Diamonds exhibit TIR due to their high refractive index, enhancing their brilliance .

6.Define refractive index, n, as the ratio of the speeds of a wave in two different regions?

The **refractive index** (n) is defined as the ratio of the speed of light in a vacuum (c) to the speed of light in a given medium (v):

$$n = \frac{c}{v}$$

It indicates how much the light slows down when entering a medium compared to its speed in a vacuum. A higher refractive index means the medium is optically denser .

7.Recall and use the equation?

$$n = \frac{\sin i}{\sin r}$$

The equation for the refractive index (n) in terms of the angles of incidence ((i)) and refraction ((r)) is:

$$n = \frac{\sin i}{\sin r}$$

Where:

- (n) is the refractive index of the medium.

-(i) is the angle of incidence (measured from the normal).

- (r) is the angle of refraction (measured from the normal).

This equation is derived from **Snell's Law** and is used to calculate the refractive index when light passes between two media .

8.Recall and use the equation?

$$n = \frac{1}{\sin c}$$

The equation

$$n = \frac{1}{\sin c}$$

relates the **refractive index ((n)) of a medium to its **critical angle** ((c)).

Where:

- (n): Refractive index of the medium.

- (c): Critical angle, which is the angle of incidence in the denser medium that causes the refracted ray to travel along the boundary (making an angle of 90° with the normal).

This equation is used to calculate the refractive index of a medium when the critical angle is known. It is derived from Snell's law by setting the angle of refraction to 90° at the critical angle.

9. Describe the use of optical fibres, particularly in telecommunications?

Optical fibres are widely used in telecommunications to transmit data as pulses of light over long distances. They are made of a core (glass or plastic) surrounded by a cladding, which ensures light remains within the core through **total internal reflection**.

Applications in Telecommunications:

1. Internet: Optical fibres carry high-speed broadband signals, enabling fast and reliable internet connectivity.

2. Telephone: They transmit voice data over long distances with minimal loss or interference.

3. Cable TV: Optical fibres deliver high-quality video and audio signals for television services.

Advantages

- High Bandwidth: Can carry large amounts of data, ideal for modern communication needs.

- Low Signal Loss: Signals can travel long distances without significant attenuation.

- Immunity to Electromagnetic Interference: Ensures reliable data transmission.

- Lightweight and Flexible: Easier to install compared to traditional copper cables.

- Enhanced Security: Difficult to tap into without detection, ensuring secure communication .

3.2.3 THIN LENSES

1. **Draw and use ray diagrams for the formation of a virtual image by a converging lens**

To draw and use a ray diagram for the formation of a **virtual image** by a **converging lens**, follow these steps:

Conditions for a Virtual Image:

- The object is placed **between the lens and its focal point (F)**.

Steps to Draw the Ray Diagram:

1. Draw the Lens: Represent the converging lens as a vertical line with the optical center (C), and mark the focal points (F) on both sides of the lens.

2. Place the Object: Draw the object (an arrow) upright and between (C) and (F).

3. Draw the Rays:

Ray 1: Draw a ray parallel to the principal axis from the top of the object. After passing through the lens, it refracts and appears to diverge from the focal point (F) on the same side.

Ray 2: Draw a ray passing through the optical center(C). This ray continues undeviated.

4. Extrapolate the Rays: Extend the refracted rays backward (as dotted lines) to meet behind the object. The point where they intersect gives the top of the virtual image.

5. Draw the Image: The virtual image is upright, larger than the object, and located on the same side of the lens as the object.

Characteristics of the Virtual Image:

-Upright: Same orientation as the object.

- Magnified: Larger than the object.

- Virtual: Cannot be projected onto a screen.

This setup is commonly used in magnifying glasses .

2. Describe the use of a single lens as a magnifying glass?

A single **converging lens** (convex lens) can be used as a **magnifying glass** to produce an enlarged, upright, and virtual image of an object.

How It Works:

1**. Object Placement**: The object is placed **between the lens and its focal point (F).

2**. Lens Action**: Light rays from the object pass through the lens and refract, appearing to diverge from a point behind the object.

3. **Virtual Image Formation:** The eye perceives these diverging rays as coming from a larger, upright image located on the same side of the lens as the object.

Characteristics of the Image:

- Virtual: Cannot be projected onto a screen.

- Upright: Same orientation as the object.

- Magnified: Larger than the actual object.

Practical Use:

-**Reading Small Text**: Magnifying glasses are used to enlarge text or small details for easier viewing.

- **Observation of Small Objects:** Useful in activities like examining stamps, jewelry, or biological samples.

The magnification depends on the curvature of the lens. A lens with a shorter focal length provides greater magnification but may distort the image if too curved .

3.Describe the use of converging and diverging lenses to correct long-sightedness and shortsightedness?

Correction of Long-Sightedness (Hyperopia):

- Problem: A long-sighted person can see distant objects clearly, but nearby objects appear blurred. This occurs because the eyeball is too short, or the eye lens is too weak, causing the image of a near object to focus **behind the retina**.

- Solution: A **converging lens** (convex lens) is used in spectacles or contact lenses.

- The converging lens bends the light rays **inward** before they enter the eye, so they focus correctly on the retina.

- This allows the person to see nearby objects clearly.

Correction of Short-Sightedness (Myopia):

- Problem: A short-sighted person can see nearby objects clearly, but distant objects appear blurred. This happens because the eyeball is too long, or the eye lens is too strong, causing the image of a distant object to focus **in front of the retina**.

- Solution: A **diverging lens** (concave lens) is used in spectacles or contact lenses.

- The diverging lens spreads the light rays **outward** before they enter the eye, so they focus correctly on the retina.

- This enables the person to see distant objects clearly.

Summary of Lenses Used:

- Long-Sightedness: Corrected with a **converging lens**.

- Short-Sightedness: Corrected with a **diverging lens** .

4.Describe the action of thin converging and thin diverging lenses on a parallel beam of light?

Action of a Thin Converging Lens (Convex Lens):

- A **converging lens** is thicker in the center and bends light rays **inward**.

- When a **parallel beam of light** passes through the lens:

  - The rays are refracted and converge to a single point on the other side of the lens.

  - This point is called the **principal focus (F)**.

- The principal focus is **real** because the rays physically meet at this point.

Action of a Thin Diverging Lens (Concave Lens):

- A **diverging lens** is thinner in the center and bends light rays **outward**.

- When a **parallel beam of light** passes through the lens:

  - The rays are refracted and appear to diverge from a point behind the lens.

  - This point is called the **virtual principal focus (F)** because the rays only appear to originate from it when traced backward.

Key Differences:

- Converging Lens: Brings light rays together to form a real focus.

- Diverging Lens: Spreads light rays outward, creating a virtual focus .

5.Define and use the terms focal length, principal axis and principal focus (focal point)?

1. Focal Length (f):

  - The distance between the **center of the lens** (optical center) and the **principal focus**.

  - It is measured along the **principal axis** and determines the lens's ability to converge or diverge light. A shorter focal length indicates a stronger lens.

2. Principal Axis:

  - A straight line that passes through the **optical center** of the lens and is perpendicular to its surface.

  - It serves as the reference line for measuring distances like the focal length.

3. Principal Focus (Focal Point):

- For a **converging lens**: The point on the principal axis where parallel rays of light converge after passing through the lens.

- For a **diverging lens**: The point on the principal axis from which parallel rays of light appear to diverge after passing through the lens (a virtual focus).

Usage:

- The **focal length** is used to calculate the lens's power and determine the nature of the image formed.

- The **principal axis** is essential for constructing ray diagrams and analyzing light paths.

- The **principal focus** helps in understanding how lenses bend light to form real or virtual images .

6.Draw and use ray diagrams for the formation of a real image by a converging lens?

Steps to Draw a Ray Diagram for a Real Image Formation by a Converging Lens**:

1. Draw the Lens and Principal Axis:

- Represent the **converging lens** as a vertical line.

- Draw the **principal axis** as a horizontal line passing through the center of the lens (optical center).

2. Mark the Focal Points:

- Mark the **principal focus (F)** on both sides of the lens at a distance equal to the **focal length (f)**.

3. Place the Object:

- Draw the object (an upright arrow) **beyond the focal point** on one side of the lens.

4. Draw the Rays:

- Ray 1: Draw a ray from the top of the object parallel to the principal axis. After passing through the lens, it refracts and passes through the **principal focus** on the other side.

- Ray 2: Draw a ray from the top of the object passing through the **optical center** of the lens. This ray continues in a straight line without deviation.

5. Locate the Image:

- The two refracted rays meet on the other side of the lens. The point where they intersect is the top of the **real image**.

- Draw the image (an inverted arrow) from the principal axis to the intersection point.

Characteristics of the Real Image:

- Inverted: The image is upside down compared to the object.

- Real: The image can be projected onto a screen.

- Size: The image may be magnified, diminished, or the same size, depending on the object's distance from the lens.

This method is commonly used in devices like projectors and cameras .

7.Describe the characteristics of an image using the terms enlarged/same size/diminished, upright/inverted and real/virtual?

Characteristics of an Image

1. Size:

- **Enlarged:** The image is larger than the object.
- **Same Size:** The image is equal in size to the object.
- **Diminished:** The image is smaller than the object.

2. Orientation:

- **Upright:** The image has the same orientation as the object (not flipped).
- **Inverted:** The image is flipped upside down compared to the object.

3. Type:

- **Real:** The image is formed by actual convergence of light rays and can be projected onto a screen.
- **Virtual:** The image is formed by the apparent divergence of light rays and cannot be projected onto a screen.

These characteristics depend on the lens type (converging or diverging), the object's position relative to the lens, and the focal length .

8. Know that a virtual image is formed when diverging rays are extrapolated backwards and does not form a visible projection on a screen?

A **virtual image** is formed when light rays **diverge** after passing through a lens or reflecting from a mirror. These rays do not actually meet but appear to originate from a point when extrapolated **backwards**.

Key Characteristics of a Virtual Image:

- **Formation:** Created by the apparent intersection of diverging rays when traced backward.

- **Projection:** Cannot be projected onto a screen because the rays do not physically converge.

- **Example:** The image seen in a plane mirror or through a diverging lens is virtual.

For instance, in a **diverging lens**, parallel rays of light spread outward after passing through the lens. When these rays are extended backward, they appear to originate from a point (the virtual focus) on the same side as the object .

3.2.4. DISPERSION OF LIGHT

1. Describe the dispersion of light as illustrated by the refraction of white light by a glass prism?

Dispersion of light occurs when white light is separated into its component colors as it passes through a glass prism. This happens due to **refraction** and the variation in the refractive index of the prism for different wavelengths of light.

Process of Dispersion:

1. Refraction at the First Surface:

- When white light enters the prism, it slows down and bends towards the normal due to the change in medium (air to glass).

- Different colors (wavelengths) of light bend by different amounts because the refractive index of glass is higher for shorter wavelengths (e.g., violet) and lower for longer wavelengths (e.g., red).

2. Refraction at the Second Surface:

- As the light exits the prism, it bends again, away from the normal (glass to air transition).

- The separation of colors becomes more pronounced, forming a spectrum.

3. Formation of the Spectrum:

- The colors of the spectrum appear in the following order:

  - **Violet, Indigo, Blue, Green, Yellow, Orange, Red** (VIBGYOR).

- Violet light has the shortest wavelength and is refracted the most, while red light has the longest wavelength and is refracted the least.

This phenomenon is why a prism can create a rainbow-like spectrum from white light .

2. **Know the traditional seven colours of the visible spectrum in order of frequency and in order of wavelength?**

The **traditional seven colors of the visible spectrum** are:

In Order of Frequency (Increasing):

1. Red
2. Orange
3. Yellow
4. Green
5. Blue
6. Indigo
7. Violet

In Order of Wavelength (Increasing):

1. Violet
2. Indigo
3. Blue
4. Green
5. Yellow
6. Orange
7. Red

- Note: Frequency and wavelength are inversely related. Violet has the **highest frequency** and **shortest wavelength**, while red has the **lowest frequency** and **longest wavelength** .

3.Recall that visible light of a single frequency is described as monochromatic?

Visible light of a **single frequency** is referred to as **monochromatic** light. This means it consists of only one color and does not split into a spectrum when passed through a prism. For example, light from a **laser** is typically monochromatic .

3.3 ELECTROMAGNETIC SPECTRUM

1. **Know that the speed of electromagnetic waves in a vacuum is 3.0 × 108m/s and is approximately the same in air?**

The speed of electromagnetic waves in a vacuum is **3.0 × 10^8 m/s**. This speed is also approximately the same when electromagnetic waves travel through air .

2. **Know that many important systems of communications rely on electromagnetic radiation including:**
   (a) mobile phones (cell phones) and wireless internet use microwaves because microwaves can penetrate some walls and only require a short aerial for transmission and reception
   (b) Bluetooth uses low energy radio waves or microwaves because they can pass through walls but the signal is weakened on doing so
   (c) optical fibres (visible light or infrared) are used for cable television and high-speed broadband because glass is transparent to visible light and some infrared; visible light and short wavelength infrared can carry high rates of data

Communication Systems and Electromagnetic Radiation:

1.Mobile Phones and Wireless Internet:

- **Use** microwaves.

- **Reason:** Microwaves can penetrate some walls and require only a **short aerial** for transmission and reception.

2. Bluetooth:

- **Uses** **low-energy radio waves** or **microwaves**.

- **Reason:** These waves can pass through walls, but the signal is **weakened** when doing so.

3. Optical Fibres:

- **Use** **visible light** or **infrared**.

- **Reason:** Glass is **transparent** to visible light and some infrared. These waves, especially **visible light** and **short-wavelength infrared**, can carry **high rates of data**, making them ideal for **cable television** and **high-speed broadband** .

3. **Know the difference between a digital and analogue signal?**

Difference Between Digital and Analogue Signals:

1. Analogue Signal:

- Varies **continuously** over time.

- Can take any value within a range.

- Examples: Sound waves, radio waves.

2. Digital Signal:

- Consists of **discrete values** (usually represented as 0s and 1s).

- Does not vary continuously but changes in steps.

- Examples: Data in computers, digital communication systems.

Digital signals are less prone to noise and interference compared to analogue signals, making them more reliable for modern communication systems .

4.Know that a sound can be transmitted as a digital or analogue signal?

A **sound** can be transmitted as either:

1. Analogue Signal:

- Represents sound as a **continuous wave**.

- The signal directly corresponds to the sound wave's amplitude and frequency.

2. Digital Signal:

- Represents sound as **discrete values** (binary code: 0s and 1s).

- The sound wave is sampled at intervals and converted into a digital format.

Digital signals are commonly used in modern communication systems because they are less affected by noise and can be easily compressed and stored **.**

5.Explain the benefits of digital signaling including increased rate of transmission of data and increased range due to accurate signal regeneration?

Benefits of Digital Signaling:

1. Increased Rate of Transmission:

- Digital signals can carry large amounts of data quickly because they are transmitted as discrete binary values (0s and 1s), which are easier to process and transmit at high speeds.

2. Increased Range with Accurate Signal Regeneration:

- Digital signals can be **regenerated** accurately at intervals during transmission, eliminating noise and distortion.

- This ensures the signal remains clear and intact over long distances, unlike analogue signals, which degrade progressively.

These features make digital signaling ideal for modern communication systems like the internet, mobile networks, and digital broadcasting .

6. Know the main regions of the electromagnetic spectrum in order of frequency and in order of wavelength?

Main Regions of the Electromagnetic Spectrum:

1. **In Order of Frequency (Lowest to Highest):**

- Radio waves
- Microwaves
- Infrared
- Visible light
- Ultraviolet
- X-rays
- Gamma rays

2. **In Order of Wavelength (Longest to Shortest):**

- Radio waves
- Microwaves
- Infrared
- Visible light
- Ultraviolet
- X-rays
- Gamma rays

Note: Frequency increases as wavelength decreases, and vice versa .

7.Know that all electromagnetic waves travel at the same high speed in a vacuum?

All electromagnetic waves travel at the same high speed of (300,000 km/s) in a vacuum. This speed is commonly referred to as the **speed of light** .

8.Describe typical uses of the different regions of the electromagnetic spectrum including:

(a) radio waves; radio and television transmissions, astronomy, radio frequency identification (RFID

) (b) microwaves; satellite television, mobile phones (cell phones), microwave ovens

(c) infrared; electric grills, short range communications such as remote controllers for televisions, intruder alarms, thermal imaging, optical fibres

(d) visible light; vision, photography, illumination

(e) ultraviolet; security marking, detecting fake bank notes, sterilising water

(f) X-rays; medical scanning, security scanners

(g) gamma rays; sterilising food and medical equipment, detection of cancer and its treatment

Uses of the Electromagnetic Spectrum:

(a) Radio Waves:

- **Radio and television transmissions:** Used to broadcast audio and video signals.
- **Astronomy:** Detects radio signals from stars and galaxies.
- **RFID (Radio Frequency Identification):** Tracks objects like parcels and passports using tags.

(b) Microwaves:

- **Satellite television:** Transmits signals via geostationary satellites.
- **Mobile phones**: Enables communication through microwave towers and satellites.
- **Microwave ovens**: Heats food by causing water molecules to vibrate.

(c) Infrared:

-Electric grills: Emits heat for cooking.

- Short-range communications: Used in remote controllers for TVs and other devices.

- Intruder alarms and thermal imaging: Detects heat signatures.

- Optical fibres: Transmits data in long-range communication systems.

(d) Visible Light:

- Vision: Enables humans to see.

- Photography: Captures images.

- Illumination: Provides light for visibility.

(e) Ultraviolet (UV):

- Security marking: Verifies invisible signatures or marks.

- Detecting fake banknotes: Identifies counterfeit currency.

- Sterilising water: Kills bacteria in water treatment plants.

(f) X-rays:

- **Medical scanning:** Detects fractures and internal injuries.

- **Security scanners**: Scans luggage and passengers at airports.

(g) Gamma Ray:

- Sterilising food and medical equipment: Kills harmful bacteria.

- Detection and treatment of cancer: Diagnoses and destroys cancerous cells .

9.Describe the harmful effects on people of excessive exposure to electromagnetic radiation, including:

(a) microwaves; internal heating of body cells

(b) infrared; skin burns

(c) ultraviolet; damage to surface cells and eyes, leading to skin cancer and eye conditions

(d) X-rays and gamma rays; mutation or damage to cells in the body ?

Harmful Effects of Excessive Exposure to Electromagnetic Radiation:

(a) Microwaves:

- Can cause **internal heating of body cells**, potentially leading to tissue damage.

(b) Infrared:

- Excessive exposure can result in **skin burns** due to the heat generated.

(c) Ultraviolet (UV):

- **Damage to surface cells**: Prolonged exposure can harm skin cells.

- **Eye damage**: Can lead to cataracts or other eye conditions.

- **Skin cancer**: UV radiation can cause mutations in skin cells, increasing the risk of cancer.

(d) X-rays and Gamma Rays:

- **Mutation or damage to cells**: High-energy radiation can ionize atoms in cells, leading to mutations or cell death.

- **Cancer risk**: Prolonged or high exposure increases the likelihood of developing cancer .

5.Know that communication with artificial satellites is mainly by microwaves: (a) some satellite phones use low orbit artificial satellites (b) some satellite phones and direct broadcast satellite television use geostationary satellites?

Communication with artificial satellites primarily uses **microwaves** due to their ability to penetrate the Earth's atmosphere effectively:

(a) Low Orbit Artificial Satellite:

- Used by some satellite phones.
- These satellites orbit closer to the Earth and require frequent adjustments due to atmospheric drag.

(b) Geostationary Satellites:

- Used by some satellite phones and direct broadcast satellite television.
- These satellites remain fixed above a specific point on the Earth's equator, making them ideal for continuous communication .

3.4 SOUND

1.Describe compression and rarefaction?

Compression and **rarefaction** are terms used to describe the behavior of particles in a **longitudinal wave**, such as sound waves:

- Compression:

This is the region where particles are **closer together** than normal, resulting in a **high-pressure** area.

- Rarefaction:

This is the region where particles are **further apart** than normal, resulting in a **low-pressure** area .

2. Know that, in general, sound travels faster in solids than in liquids and faster in liquids than in gases?

Sound travels faster in **solids** than in **liquids**, and faster in **liquids** than in **gases**, because the speed of sound depends on the **density** and **elasticity** of the medium. In solids, particles are tightly packed and can transmit vibrations more efficiently, while in gases, particles are far apart, making sound transmission slower .

3.Describe the uses of ultrasound in nondestructive testing of materials, medical scanning of soft tissue and sonar including calculation of depth or distance from time and wave speed?

Uses of Ultrasound:

1. Non-Destructive Testing (NDT):

- Ultrasound is used to detect flaws or cracks in materials without causing damage.

- High-frequency ultrasound waves are sent through the material, and reflections from defects (if any) are analyzed.

2. Medical Scanning of Soft Tissue:

- Ultrasound imaging is used to visualize internal organs, monitor fetal development, and diagnose medical conditions.

- The waves reflect off boundaries between tissues, creating detailed images of soft tissues (e.g., fetus, organs).

3. Sonar (Sound Navigation and Ranging):

- Used in ships and submarines to determine the depth of the seabed or locate objects underwater.

- Ultrasound waves are emitted, and the time taken for the echo to return is measured.

Calculation of Depth or Distance:

The depth or distance can be calculated using the formula:

$$d = \frac{v \cdot t}{2}$$

Where:

- (d) = depth or distance
- (v) = speed of sound in the medium
- (t) = total time taken for the ultrasound wave to travel to the object and back.

For example:

If the speed of sound in water is 1400 m/s and the time for the echo to return is 1.5 s:

$$d = \frac{1400 \cdot 1.5}{2} = 1050\,\mathrm{m}$$ s.

4.Define ultrasound as sound with a frequency higher than 20 kHz?

Ultrasound is defined as sound waves with a frequency higher than **20 kHz**, which is above the upper limit of human hearing .

5.Describe an echo as the reflection of sound waves?

An **echo** is the **reflection of sound waves** when they hit a hard surface, such as a wall or cliff, and bounce back to the listener. This reflected sound is heard after a short delay, depending on the distance of the reflecting surface .

6.Describe how changes in amplitude and frequency affect the loudness and pitch of sound waves

- Amplitude: Increasing the amplitude of a sound wave increases its **loudness**. A larger amplitude means more energy in the wave, resulting in a louder sound.

- Frequency: Increasing the frequency of a sound wave increases its **pitch**. A higher frequency corresponds to a higher-pitched sound, while a lower frequency results in a lower-pitched sound .

7.Describe a method involving a measurement of distance and time for determining the speed of sound in air?

To determine the speed of sound in air, you can use the **direct method**:

1. Setup:

- Place two microphones a known distance (\(d\)) apart (e.g., 1.2 m).

- Connect the microphones to a digital timer with millisecond accuracy.

2. Procedure:

- Produce a sharp sound (e.g., by striking a metal plate) near the first microphone.

- The timer starts when the sound reaches the first microphone and stops when it reaches the second microphone.

- Measure the time (\(t\)) taken for the sound to travel between the microphones.

3. Calculation:

- Use the formula:

$$\text{Speed of sound} = \frac{\text{distance}}{\text{time}}$$

For example, if (d = 1.2 , \text{m}) and (t = 3.6 , \text{ms}):

$$\text{Speed of sound} = \frac{1.2}{0.0036} = 333.3\,\text{m/s}.$$

8.Describe the production of sound by vibrating sources?

Sound is produced when a source vibrates, causing the surrounding medium (air, liquid, or solid) to vibrate as well. These vibrations create regions of **compression** (where particles are pushed closer together) and **rarefaction** (where particles are spread apart), forming a **longitudinal wave** that propagates through the medium. Examples include:

- **Vocal cords-** vibrating to produce speech.

- **Guitar strings**- vibrating to produce musical notes.

- **Loudspeakers-** vibrating to generate sound waves .

9.Describe the longitudinal nature of sound waves?

Sound waves are **longitudinal waves**, meaning the particles of the transmitting medium vibrate **back and forth** along the same direction as the wave's travel.

In a sound wave:

- Compressions are regions where particles are pushed closer together.

- Rarefactions are regions where particles are spread further apart.

These alternating compressions and rarefactions propagate through the medium, transferring energy without the particles themselves moving along with the wave .

10. Know that a medium is needed to transmit sound waves?

Sound waves require a **medium** (such as air, liquid, or solid) to travel because they are mechanical waves. They propagate through the vibration of particles in the medium. In a **vacuum**, where there are no particles to vibrate, sound cannot travel. This can be demonstrated by removing air from a jar containing a ringing bell; as the air is pumped out, the sound diminishes and eventually disappears .

11. Know that the speed of sound in air is approximately 330–350 m/s?

The speed of sound in air is approximately 330–350 m/s, depending on factors such as temperature. Higher temperatures increase the speed of sound, while at lower temperatures (e.g., at high altitudes), the speed decreases .

12. State the approximate range of frequencies audible to humans as 20 Hz to 20 000 Hz?

Humans can typically hear sounds within the frequency range of approximately **20 Hz to 20,000 Hz (20 kHz)**. Frequencies below 20 Hz are called **infrasound**, and those above 20,000 Hz are called **ultrasound**, both of which are inaudible to humans .