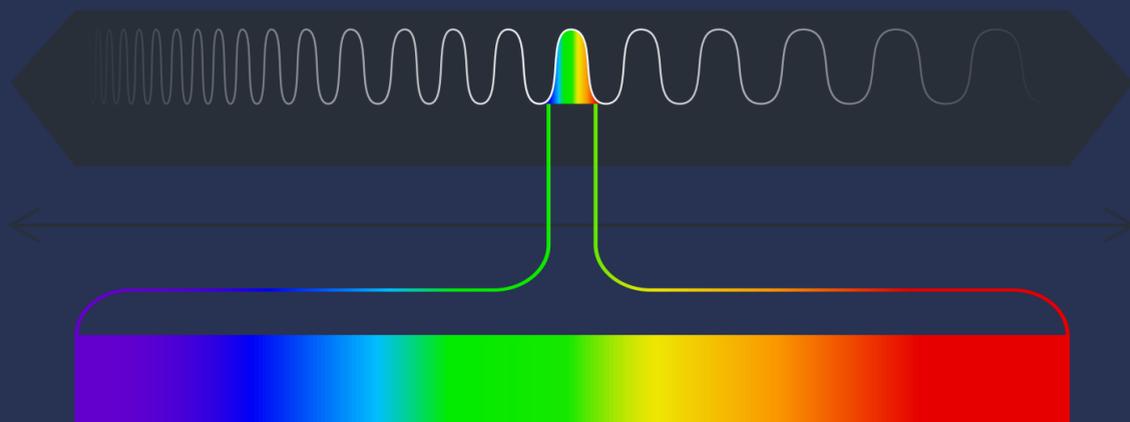


GCSE PHYSICS

WAVES



CHECKLIST

4.6.1 Waves in Air, Fluids and Solids

Topic	Success Criteria	Progress		
Transverse and Longitudinal Waves	I can name the two types of wave.			
	I know whether ripples on a water surface are transverse or longitudinal.			
	I know whether sound waves are transverse or longitudinal.			
	I can identify the two different areas of a longitudinal wave.			
	I can describe the differences between longitudinal and transverse waves.			
	I can describe evidence that, for ripples on a water surface, it is the wave and not the water itself that moves.			
	I can describe evidence that, for sound waves in air, it is the wave and not the air particles that move.			

CHECKLIST

Topic	Success Criteria	Progress		
Properties of Waves	I can describe wave motion in terms of their amplitude, wavelength, frequency and period.			
	I can describe what is meant by the amplitude of a wave.			
	I can describe what is meant by the wavelength of a wave.			
	I can identify amplitude and wavelength from given diagrams.			
	I can describe what is meant by the frequency of a wave.			
	I can calculate the period of a wave by applying the correct equation from the physics equation sheet.			
	I can rearrange the equation linking the frequency and period to calculate the frequency of a wave.			
	I can describe what is meant by the wave speed.			
	I can recall and apply the correct equation to calculate the wave speed.			
	I can rearrange the equation linking frequency, wavelength and wave speed to calculate the frequency or wavelength of a wave.			
	I can describe a method to measure the speed of sound waves in air.			
	I can describe a method to measure the speed of ripples on a water surface.			
	I can show how changes in velocity, frequency and wavelength, in transmission of sound waves from one medium to another, are interrelated.			
	I can make observations to identify the suitability of apparatus to measure the frequency, wavelength and speed of waves in a ripple tank and waves in a solid (required practical activity 8).			
I can take appropriate measurements to calculate frequency, wavelength and speed of waves in a ripple tank and waves in a solid (required practical activity 8).				

CHECKLIST

Topic	Success Criteria	Progress		
Reflection of Waves	I can name three things that can happen to a wave at the boundary between two different materials.			
	I can construct ray diagrams to illustrate the reflection of a wave at a surface.			
	I can describe the effect of the reflection of waves at the boundary between two materials.			
	I can describe the effect of the transmission of waves at the boundary between two materials.			
	I can describe the effect of absorption of waves at the boundary between two materials.			
	I can describe a method to investigate the reflection of light by different types of surface (required practical activity 9).			
	I can describe a method to investigate the refraction of light by different substances (required practical activity 9).			
Sound Waves (HT Only)	I can describe what happens when a sound wave travels through a solid.			
	I can explain how sound waves in the ear cause the sensation of sound.			
	I can describe, with examples, processes which convert wave disturbances between sound waves and vibrations in solids.			
	I can explain why processes that convert wave disturbances only work over a limited frequency range and the relevance of this to human hearing.			
	I can state the normal range of human hearing.			

CHECKLIST

Topic	Success Criteria	Progress		
Reflection of Waves	I can name three things that can happen to a wave at the boundary between two different materials.			
	I can construct ray diagrams to illustrate the reflection of a wave at a surface.			
	I can describe the effect of the reflection of waves at the boundary between two materials.			
	I can describe the effect of the transmission of waves at the boundary between two materials.			
	I can describe the effect of absorption of waves at the boundary between two materials.			
	I can describe a method to investigate the reflection of light by different types of surface (required practical activity 9).			
	I can describe a method to investigate the refraction of light by different substances (required practical activity 9).			
Sound Waves (HT Only)	I can describe what happens when a sound wave travels through a solid.			
	I can explain how sound waves in the ear cause the sensation of sound.			
	I can describe, with examples, processes which convert wave disturbances between sound waves and vibrations in solids.			
	I can explain why processes that convert wave disturbances only work over a limited frequency range and the relevance of this to human hearing.			
	I can state the normal range of human hearing.			

CHECKLIST

Topic	Success Criteria	Progress		
Waves for Detection and Exploration (HT Only)	I can explain in qualitative terms, how the differences in velocity, absorption and reflection between different types of wave in solids and liquids can be used for both detection and exploration of structures which are hidden from direct observation.			
	I can explain why ultrasound waves can be used to determine how far away a boundary is.			
	I can name two uses of ultrasound waves.			
	I know what causes seismic waves.			
	I can describe the difference between P-waves and S-waves.			
	I can explain how P-waves and S-waves led to discoveries about parts of the Earth which are not directly observable.			
	I can explain how echo sounding is used to: <ul style="list-style-type: none"> • detect objects in deep water; • measure water depth. 			

CHECKLIST

4.6.2 Electromagnetic Waves			
Topic	Success Criteria	Progress	
Types of Electromagnetic Waves	I can describe what an electromagnetic wave is.		
	I know whether electromagnetic waves are transverse or longitudinal.		
	I can compare the velocity of all types of electromagnetic wave through a vacuum or air.		
	I can name the groups of electromagnetic waves in order of wavelength and frequency.		
	I can name the type of electromagnetic wave that our eyes can detect.		
	I can give examples that illustrate the transfer of energy by electromagnetic waves.		
Properties of Electromagnetic Waves 1	(HT only) I can name four ways that electromagnetic waves interact with substances in ways that vary with wavelength.		
	(HT only) I can explain how the velocity of waves in different substances determines some effects, for example, refraction.		
	I can construct ray diagrams to illustrate the refraction of a wave at the boundary between two different media.		
	(HT only) I can use wave front diagrams to explain refraction in terms of the change of speed that happens when a wave travels from one medium to a different medium.		
	I can describe a method to investigate how the amount of infrared radiation absorbed or radiated by a surface depends on the nature of that surface (required practical activity 10).		

CHECKLIST

Topic	Success Criteria	Progress		
Properties of Electromagnetic Waves 2	(HT only) I can explain how radio waves can be produced.			
	(HT only) I can explain how radio waves can induce oscillations in an electrical circuit.			
	I can explain how changes in atoms and the nuclei of atoms can result in electromagnetic waves being generated or absorbed over a wide frequency range.			
	I can explain how gamma rays originate.			
	I can name the groups of electromagnetic waves that can have hazardous effects on human body tissue.			
	I can describe the factors that determine the effects of electromagnetic waves on human body tissue.			
	I can give a definition for radiation dose.			
	I can draw conclusions from data about the risks and consequences of exposure to radiation.			
	I can describe the impact of ultraviolet waves on skin.			
	I can explain the hazardous effects of X-rays and gamma rays.			
Uses and Application of Electromagnetic Waves	I can name two practical applications of radio waves.			
	I can name two practical applications of microwaves.			
	I can name three practical applications of infrared.			
	I can name a practical application of visible light.			
	I can name two practical applications of ultraviolet.			
	I can name two practical applications of X-rays and gamma rays.			
	(HT only) I can explain briefly why each type of electromagnetic wave is suitable for its practical application.			

CHECKLIST

Topic	Success Criteria	Progress		
Lenses	I can explain how a lens forms an image.			
	I can explain what the principal focus is.			
	I can explain what the focal length is.			
	I can state what type of images are produced by a convex lens.			
	I can state what type of images are produced by a concave lens.			
	I can construct ray diagrams to illustrate the similarities and differences between convex and concave lenses.			
	I can calculate the magnification produced by a lens by applying the correct equation from the physics equation sheet.			
	I can identify a convex lens in a ray diagram.			
	I can identify a concave lens in a ray diagram.			
Visible Light	I can explain which properties of each colour within the visible light spectrum vary.			
	I can explain what is meant by specular reflection.			
	I can explain what is meant by diffuse reflection.			
	I can explain how colour filters work.			
	I can explain how the colour of an object is related to the differential absorption, transmission and reflection of different wavelengths of light by the object.			
	I can explain the effect of viewing objects through filters or the effect on light of passing through filters.			
	I can explain why an opaque object has a particular colour.			
	I can explain what is meant by the terms transparent and translucent.			

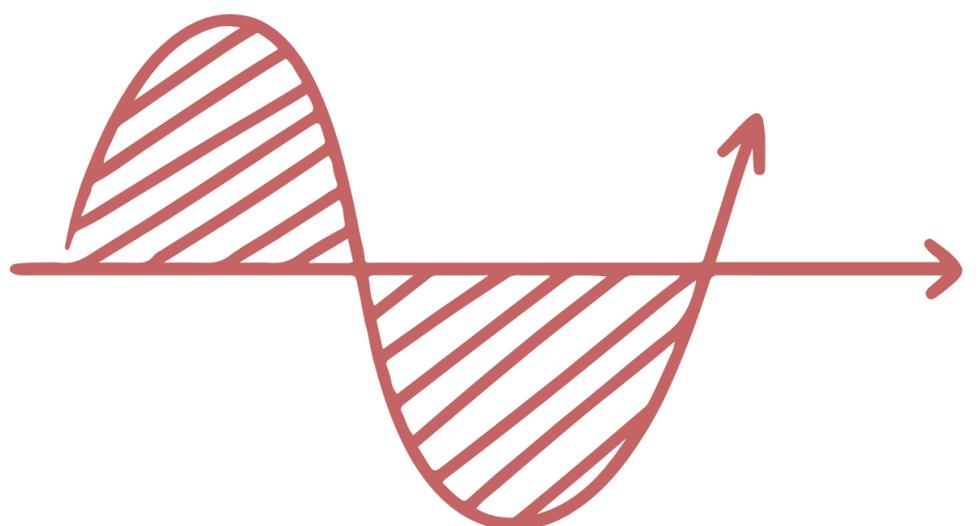
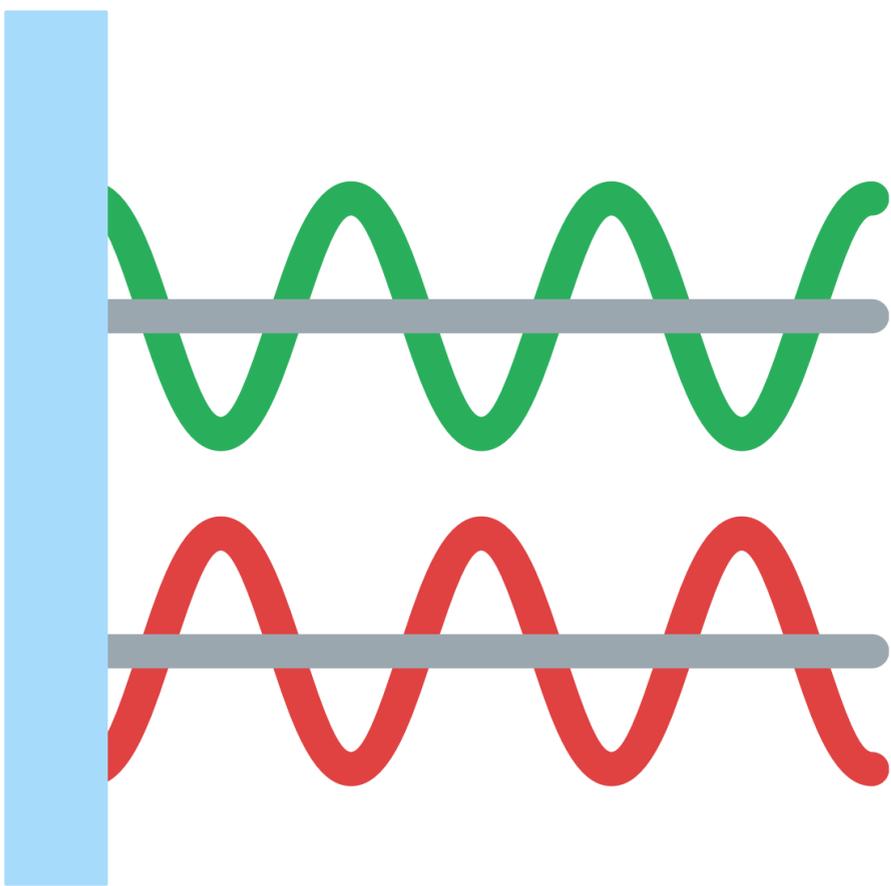
CHECKLIST

4.6.3 Black Body Radiation			
Topic	Success Criteria	Progress	
Emission and Absorption of Infrared Radiation	I can describe how the temperature of an object relates to the amount of infrared radiation it radiates in a given time.		
	I can describe what is meant by a perfect black body in terms of absorption and emission of radiation.		
Perfect Black Bodies and Radiation	I can explain that all bodies (objects) emit radiation.		
	I can explain that the intensity and wavelength distribution of any emission depends on the temperature of the body.		
	(HT only) I can describe how the rate of absorption of radiation compares to the rate of emission of radiation in a body at a constant temperature.		
	(HT only) I can explain what happens to the temperature of a body when it absorbs radiation faster than it emits radiation.		
	(HT only) I can describe some factors that affect the temperature of the Earth.		
	(HT only) I can explain how the temperature of a body is related to the balance between incoming radiation absorbed and radiation emitted, using everyday examples to illustrate this balance.		
	(HT only) I can use information, or draw/interpret diagrams to show how radiation affects the temperature of the Earth's surface and atmosphere.		

WAVES

A wave is a way of **transferring energy** from one place to another without transferring matter. When a wave passes through a medium, the particles of the medium vibrate about their fixed positions but return to their original positions once the wave has passed. This is why waves can travel large distances without carrying material with them.

- Energy is transferred, not particles
- Particles oscillate around equilibrium positions
- Mechanical waves require a medium



TRANSVERSE WAVES

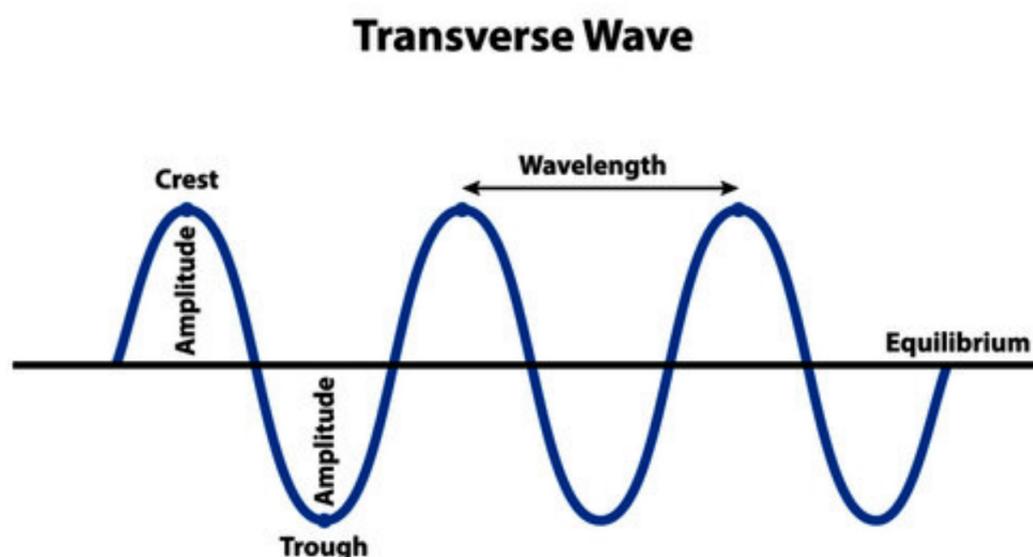
In transverse waves, the vibrations of the particles are perpendicular to the direction in which the wave travels. As the wave moves forwards, the particles move up and down, forming crests and troughs.

This type of wave can only exist when the medium can support sideways vibrations.

- Vibrations \perp direction of wave travel
- Have crests (peaks) and troughs
- Energy moves forward, particles move up and down

Examples

- Water surface waves
- Waves on ropes and strings
- All electromagnetic waves (e.g. light, X-rays)



LONGITUDINAL WAVES

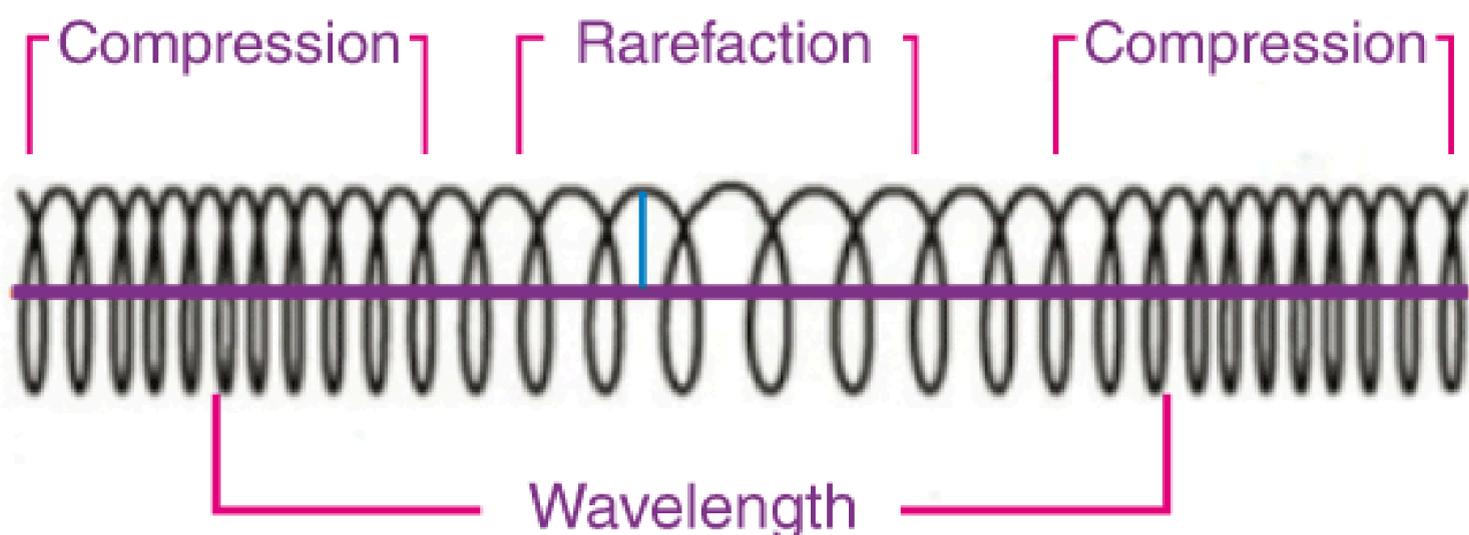
In longitudinal waves, the vibrations of the particles are parallel to the direction of wave travel. The particles move back and forth, creating regions where particles are close together (compressions) and regions where they are spread out (rarefactions).

These pressure changes move through the medium, transferring energy.

- Vibrations // direction of wave travel
- Consist of compressions and rarefactions
- Cannot travel in a vacuum

Example

- Sound waves
- Seismic P-waves



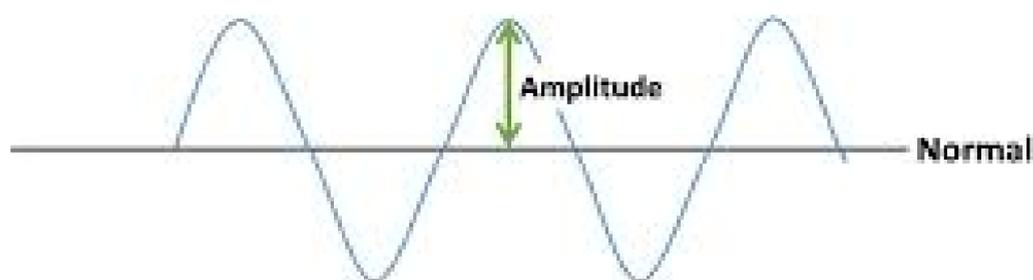
AMPLITUDE

Amplitude is the maximum displacement of a particle from its equilibrium (rest) position. It shows how far the particles vibrate when a wave passes through a medium. A larger amplitude means the wave carries more energy.

- Maximum displacement from the rest position
- Measured vertically from the centre line to the crest or trough
- Greater amplitude means greater energy transfer
- Does not affect wave speed in the same medium

Examples

- Loud sounds are produced by sound waves with large amplitude
- Bright light is produced by light waves with large amplitude



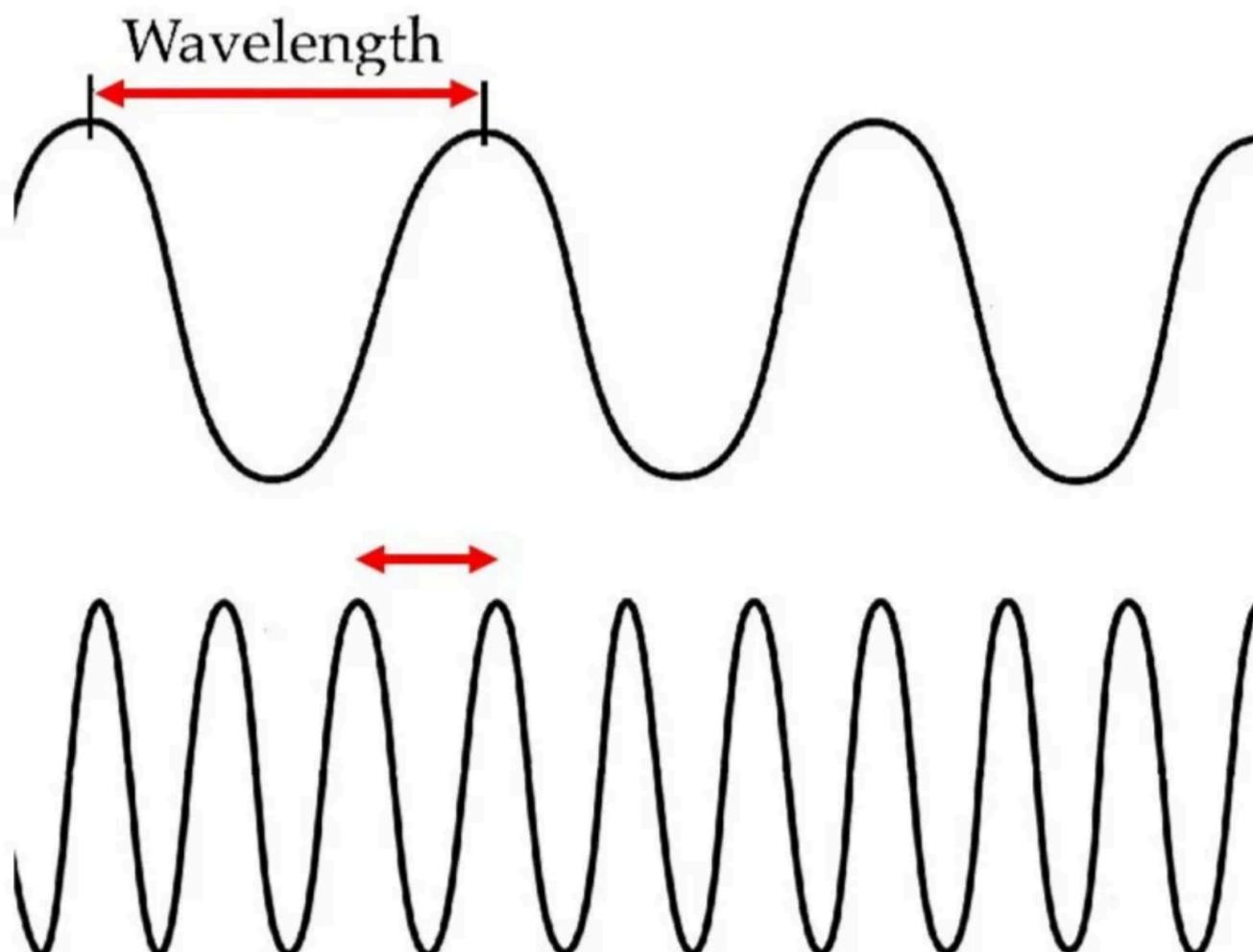
WAVELENGTH

Wavelength is the distance between two identical points on consecutive waves, measured along the direction of wave travel. It represents the length of one complete wave cycle.

- Distance between two corresponding points on adjacent waves
- Measured from crest to crest or trough to trough (transverse waves)
- Measured from compression to compression (longitudinal waves)
- Measured in metres (m)

Examples:

- Low-pitched sounds have long wavelengths
- High-frequency waves have short wavelengths



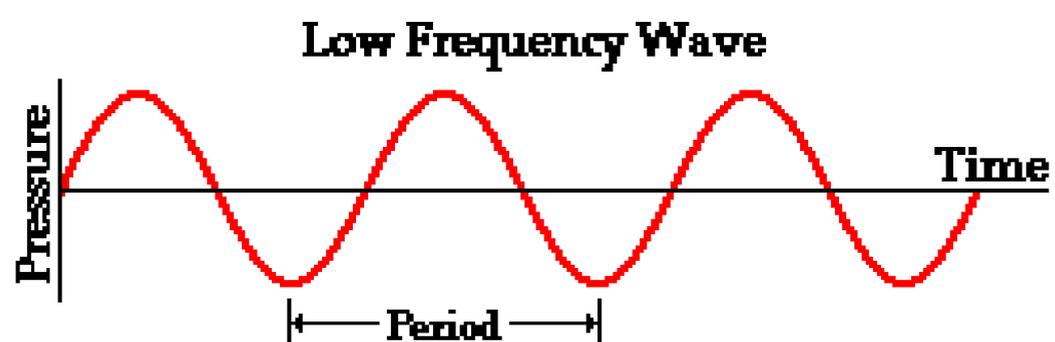
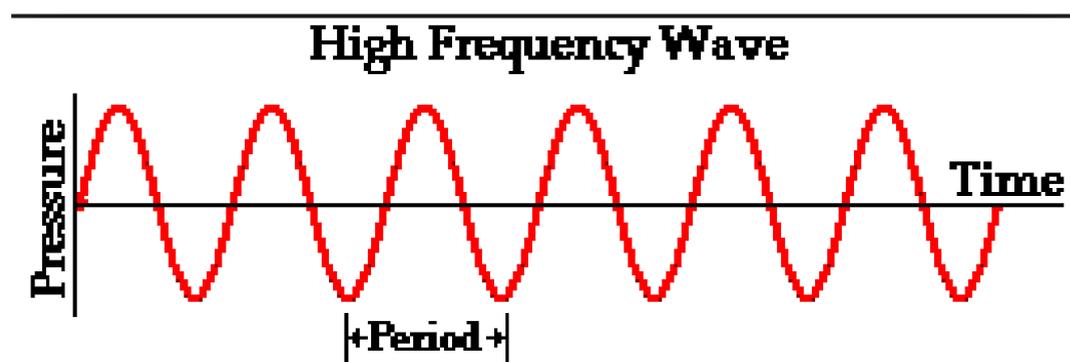
FREQUENCY

Frequency is the number of complete waves passing a fixed point per second. It shows how often particles vibrate in a wave.

- Number of waves passing a point each second
- Measured in hertz (Hz)
- Higher frequency means more energy is transferred
- Inversely related to time period

Examples:

- High-frequency sound waves produce high-pitched sounds
- Radio waves can have very high frequencies



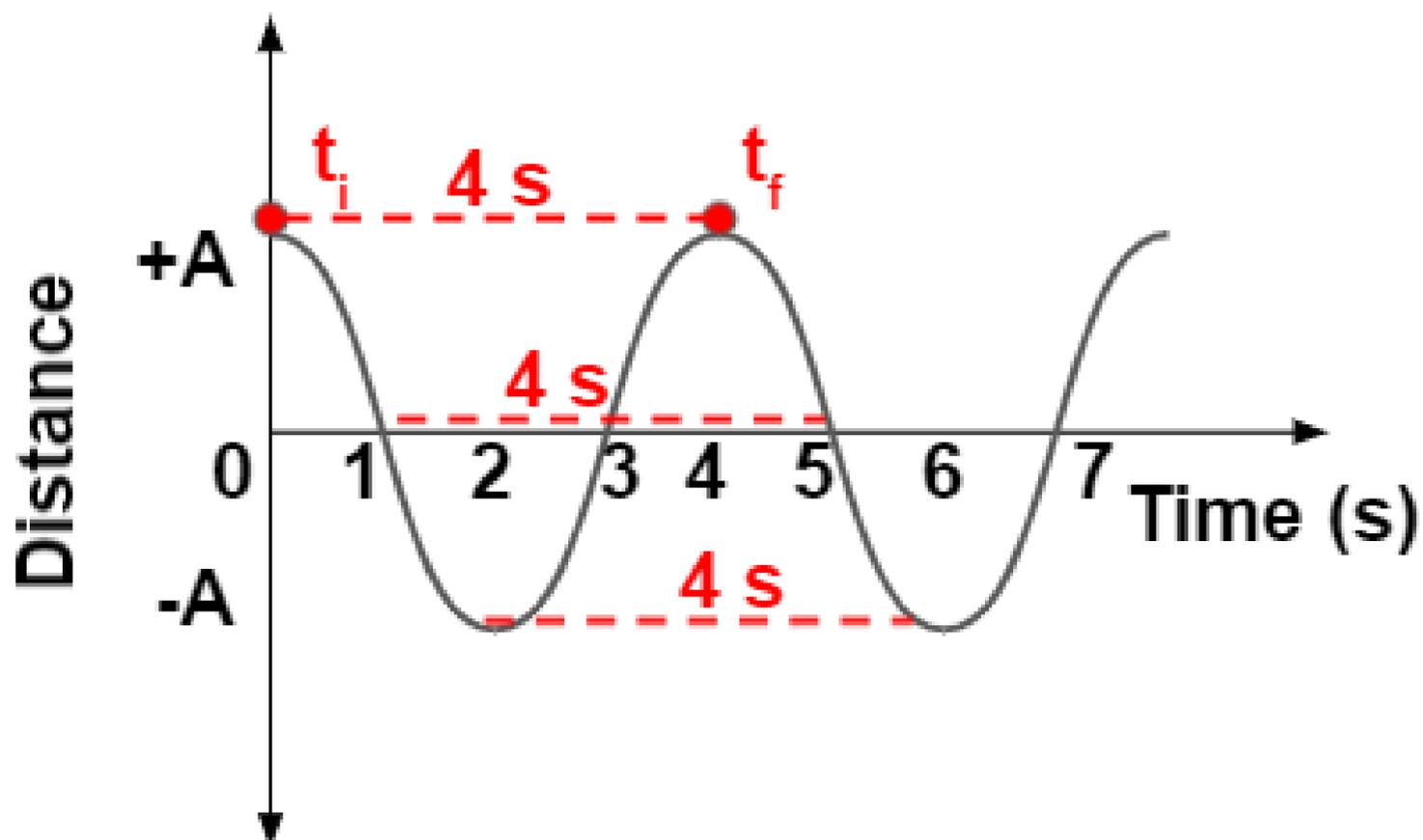
TIME PERIOD

Time period is the time taken for one complete wave to pass a fixed point. It is the inverse of frequency.

- Time taken for one full wave cycle
- Measured in seconds (s)
- $T=1/f$
- Decreases when frequency increases

Example:

- A wave with frequency 2 Hz has a time period of 0.5 seconds
- Slow vibrations have a longer time period



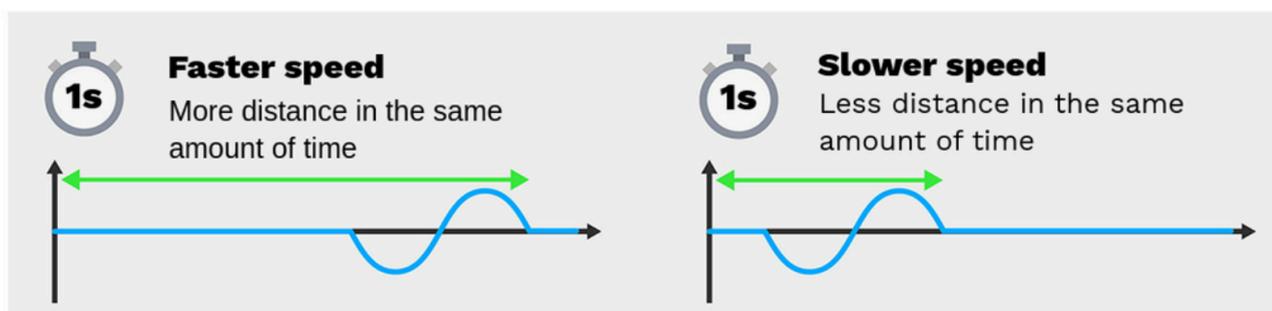
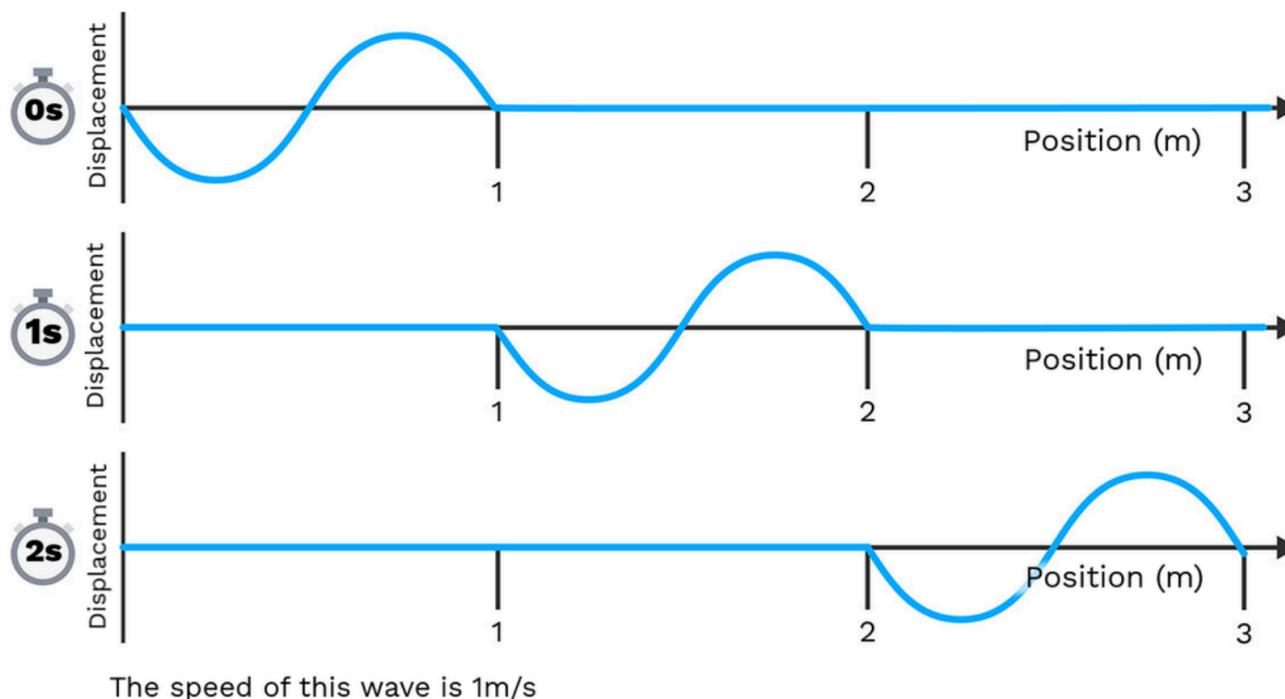
WAVE SPEED

Wave speed is the speed at which energy is transferred through a medium. It depends on the properties of the medium.

- Given by the formula $v=f\lambda$
- Measured in metres per second (m/s)
- Frequency remains constant when entering a new medium
- Wavelength changes if speed changes

Examples:

- Sound travels faster in solids than in gases
- Light travels slower in water than in air



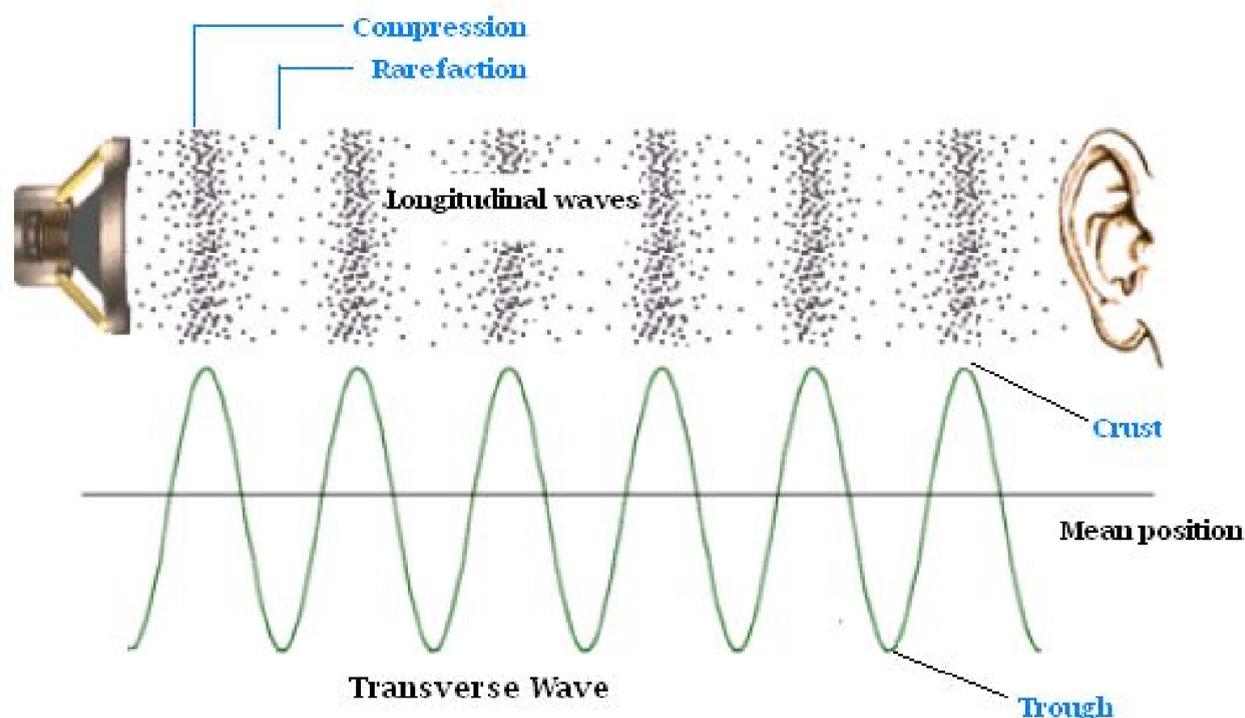
SOUND WAVES

Sound waves are longitudinal waves that transfer energy through vibrations of particles. They require a medium to travel.

- Vibrations are parallel to wave direction
- Consist of compressions and rarefactions
- Cannot travel through a vacuum
- Speed depends on temperature and medium

Examples:

- Speech is produced by vibrating vocal cords
- Thunder is caused by rapid expansion of air



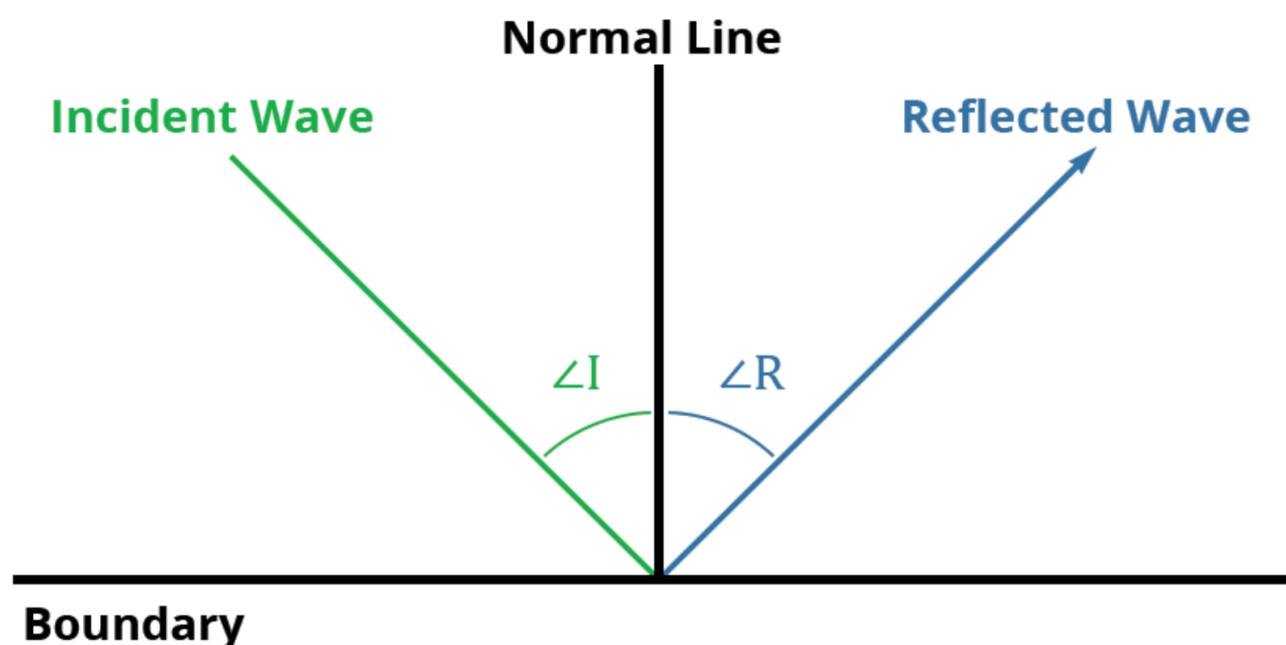
REFLECTION OF WAVES

Reflection occurs when waves bounce off a boundary and remain in the same medium.

- Angle of incidence equals angle of reflection
- Measured from the normal
- Occurs at smooth, hard surfaces
- Frequency remains unchanged

Examples:

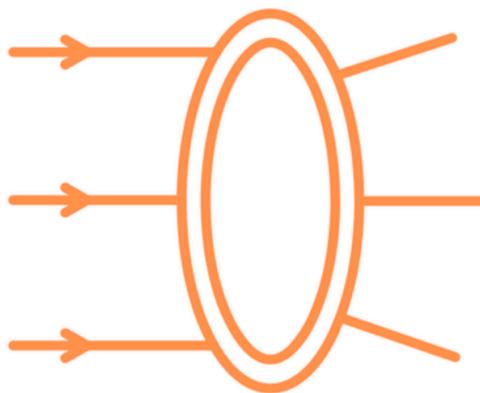
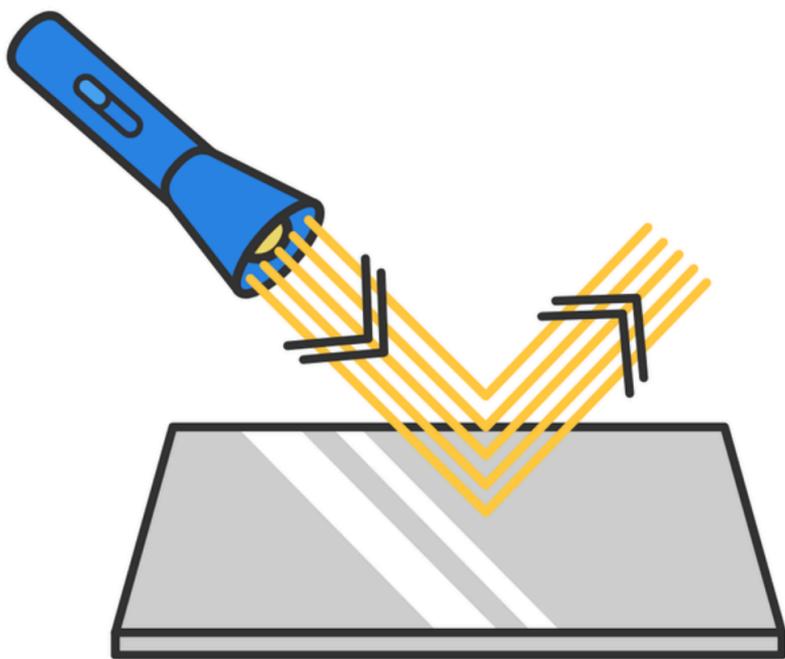
- Echoes are produced by reflection of sound waves
- Light reflecting from a mirror



REFLECTION AND REFRACTION OF WAVES

Reflection and refraction both occur when waves meet a boundary. Reflection happens when a wave bounces off a surface and stays in the same medium. Refraction happens when a wave enters a different medium and changes direction because its speed changes.

Reflection and Refraction



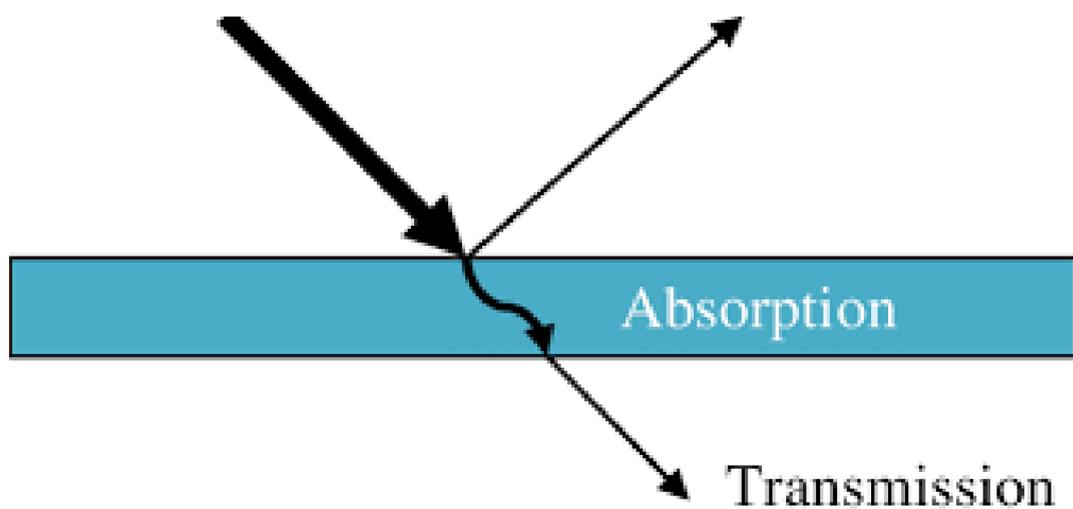
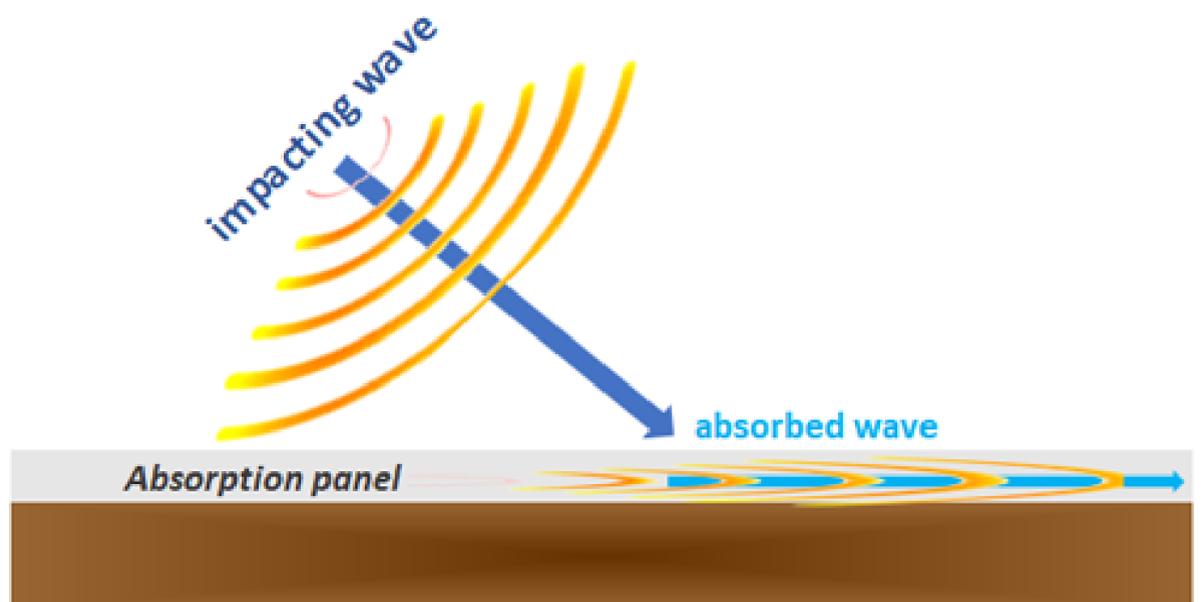
ABSORPTION

Absorption occurs when wave energy is transferred to a material, usually increasing its internal energy.

- Reduces amplitude of the wave
- Converts wave energy into heat
- Occurs more in soft and porous materials
- Does not reflect much energy

Example:

- Carpets absorb sound in a room
- Foam panels reduce echoes



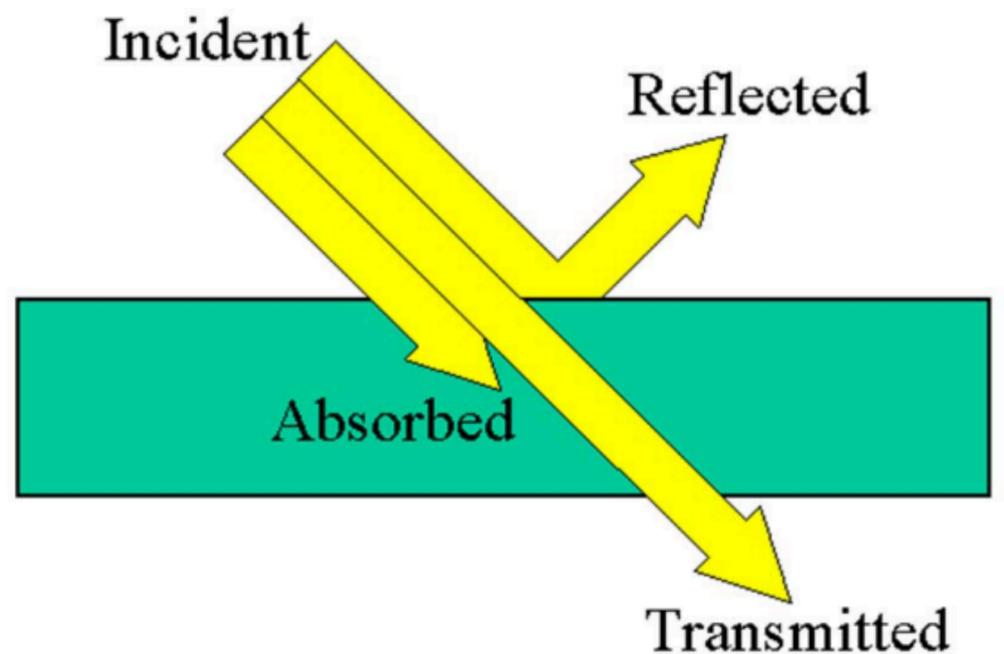
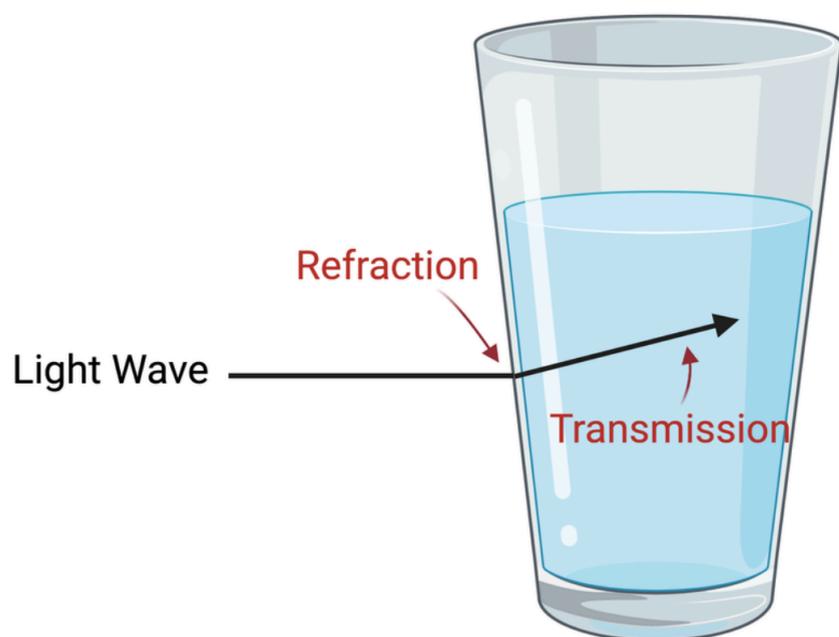
TRANSMISSION

Transmission occurs when a wave passes through a material.

- Wave continues into another medium
- Some energy may be lost
- Frequency remains constant
- Speed may change in new medium

Examples:

- Light passing through glass
- Sound passing through a wall



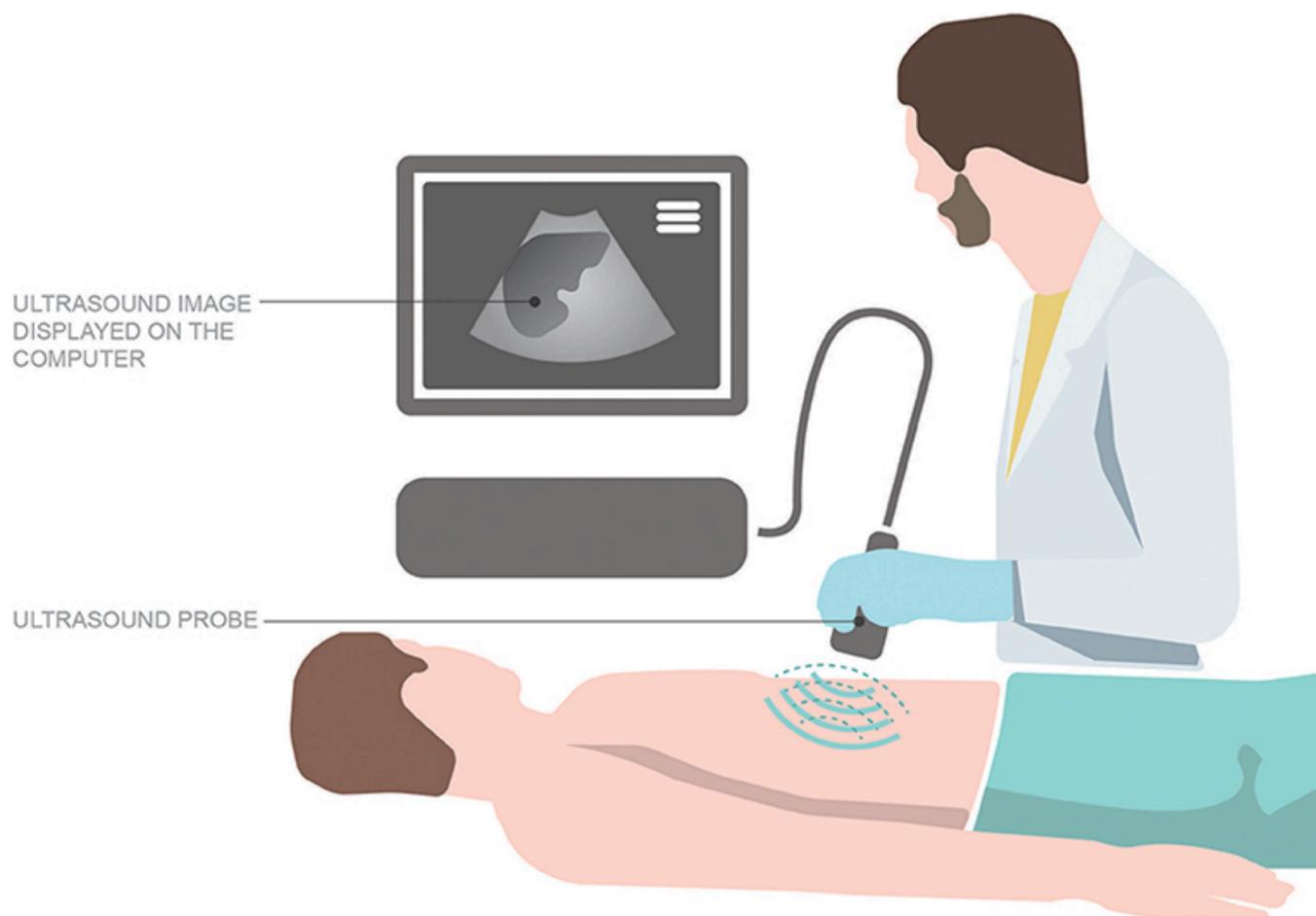
ULTRASOUND

Ultrasound refers to sound waves with frequencies above 20,000 Hz, which humans cannot hear.

- Very high frequency sound waves
- Partially reflected at boundaries
- Used to detect internal structures
- Produces detailed images

Example:

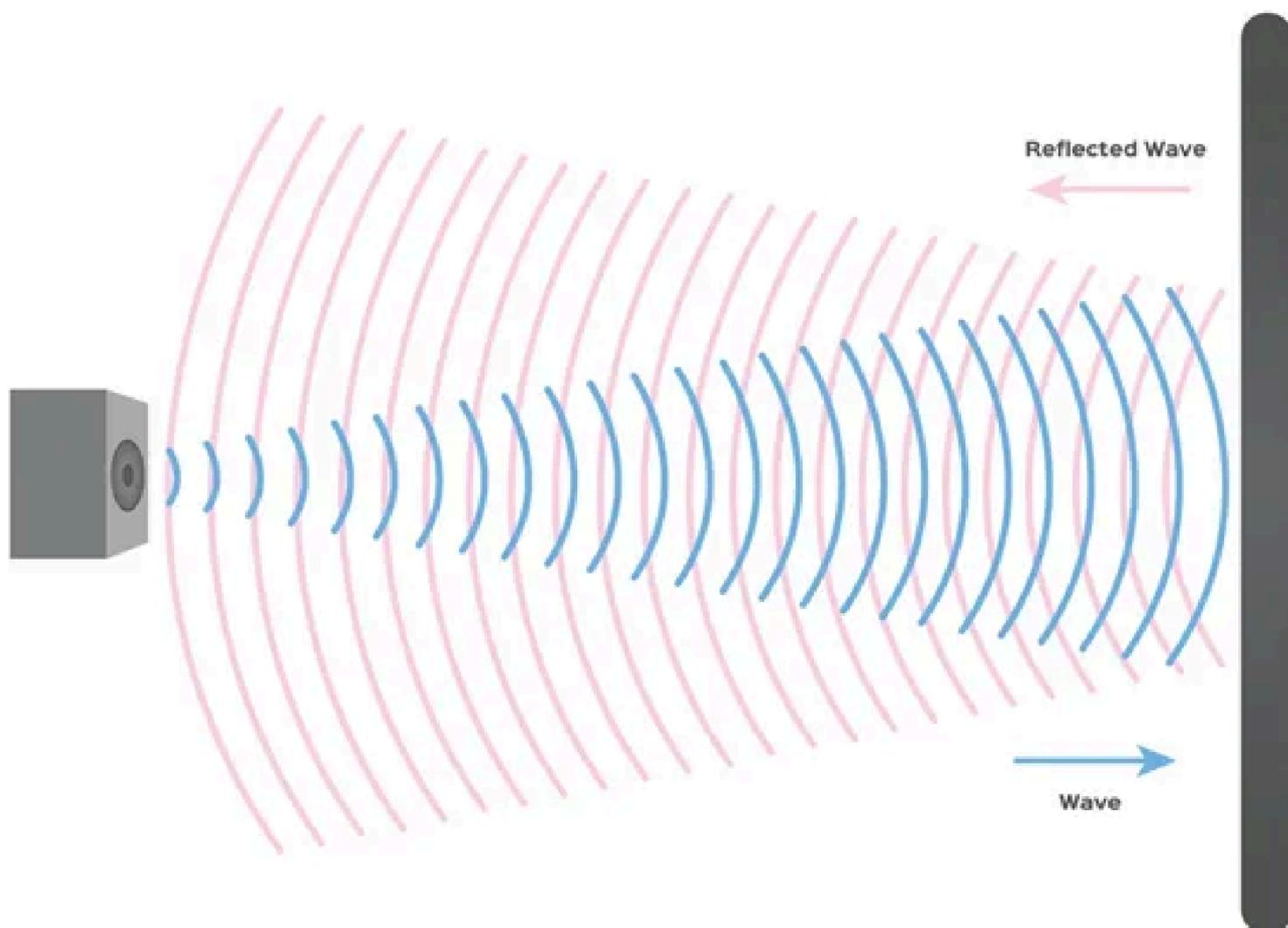
- Medical scans of unborn babies
- Detecting cracks in metal



ECHO SOUNDING

Echo sounding uses reflected sound waves to measure distance or depth.

- Uses ultrasound pulses
- Measures time taken for echo to return
- Distance calculated using $\text{distance} = vt/2$
- Divided by 2 because wave travels to object and back



SEISMIC WAVES

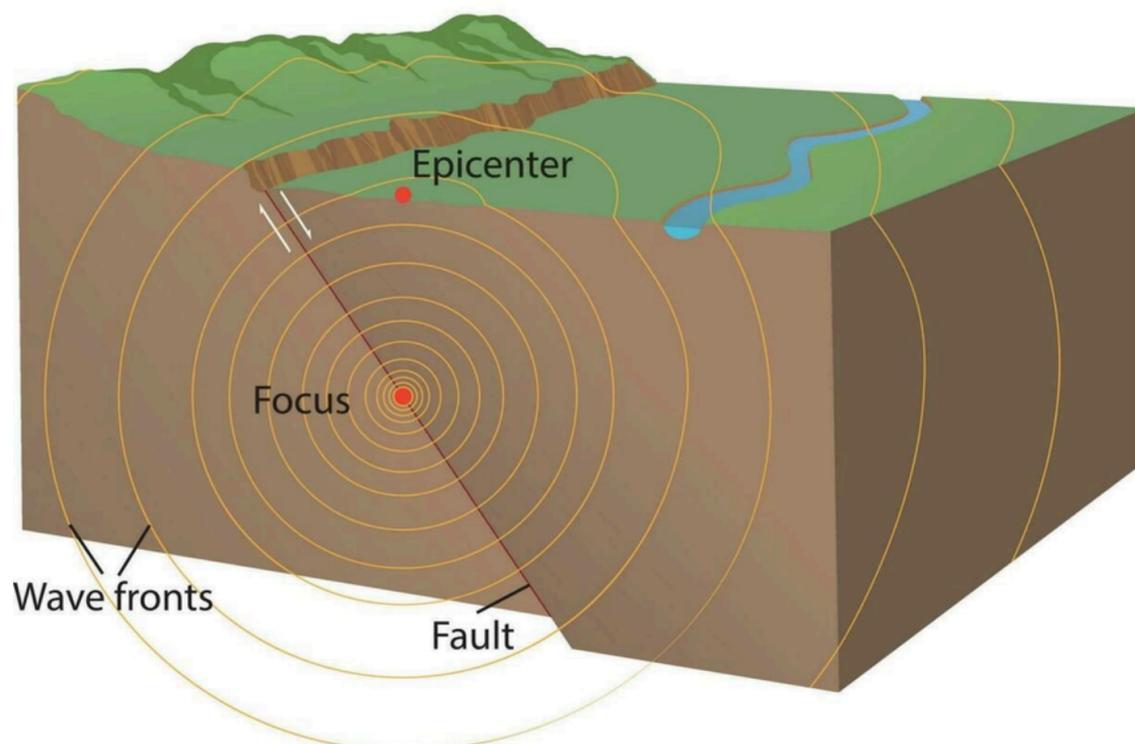
Seismic waves are waves of energy that travel through the Earth, usually as a result of earthquakes or volcanic activity. They transfer energy through the Earth's layers and can be detected using special instruments.

- Produced by sudden movements in the Earth's crust
- Travel through the Earth and along its surface
- Can be detected using seismometers
- Help scientists study the internal structure of the Earth

Examples:

- Earthquakes generate seismic waves
- Volcanic eruptions can also produce seismic waves

SEISMIC WAVES



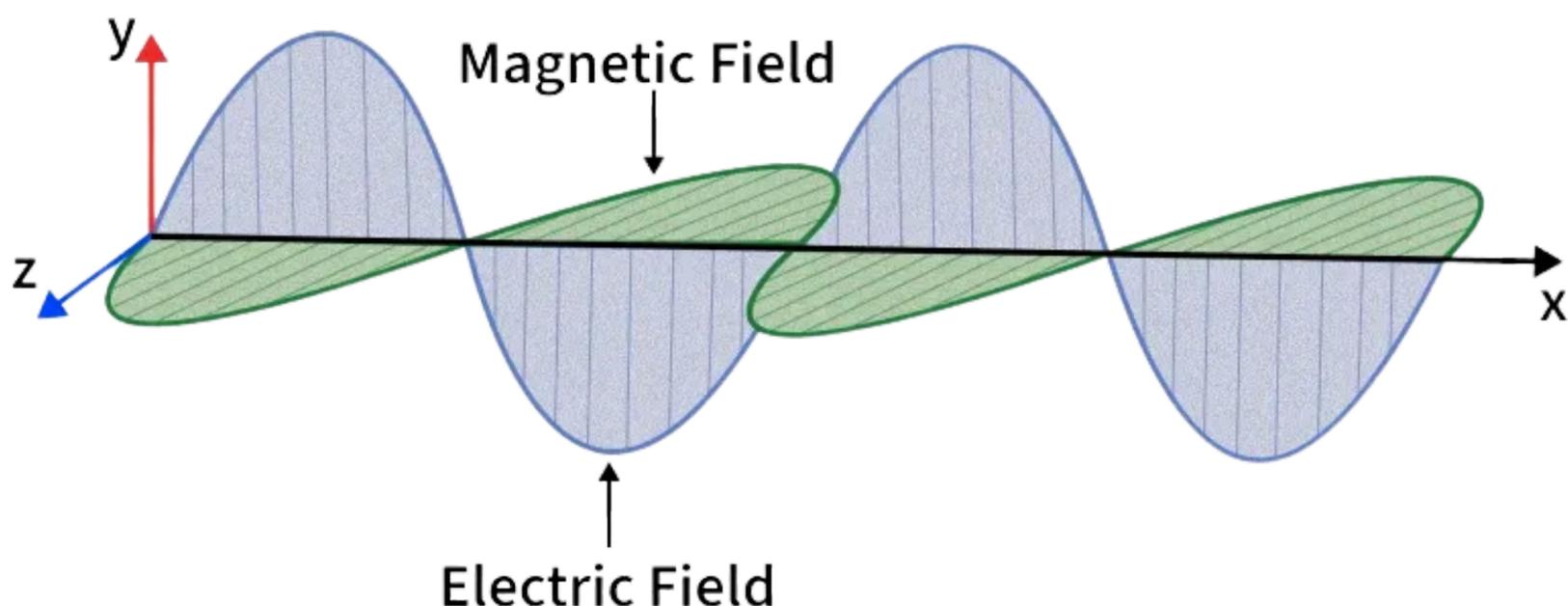
ELECTROMAGNETIC (EM) WAVES

Electromagnetic waves are transverse waves that transfer energy from a source to an absorber. They do not require a medium and can travel through a vacuum.

- All electromagnetic waves are transverse
- They can travel through a vacuum
- They all travel at the same speed in a vacuum
- They form a continuous spectrum
- Energy increases as frequency increases

Examples:

- Light from the Sun reaching Earth
- Radio signals travelling through space



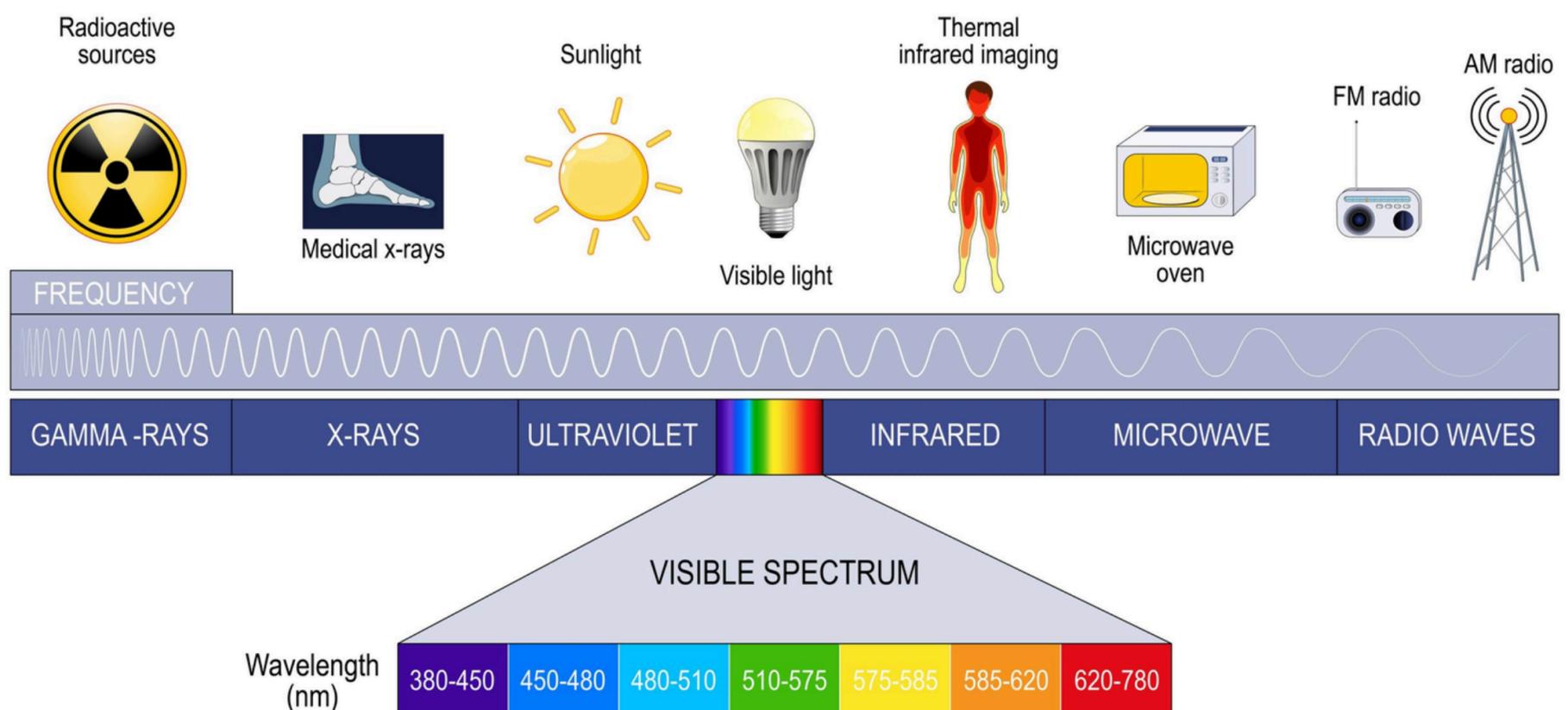
THE ELECTROMAGNETIC SPECTRUM

The electromagnetic spectrum is the complete range of electromagnetic waves arranged in order of wavelength or frequency.

- Arranged from long wavelength to short wavelength
- Long wavelength means low frequency and low energy
- Short wavelength means high frequency and high energy
- Higher frequency waves are more ionising
- Includes seven main types of waves

Examples:

- Radio waves have long wavelengths
- Gamma rays have very short wavelengths



VISIBLE LIGHT

Visible light is the part of the electromagnetic spectrum that can be detected by the human eye. It forms only a small part of the entire spectrum.

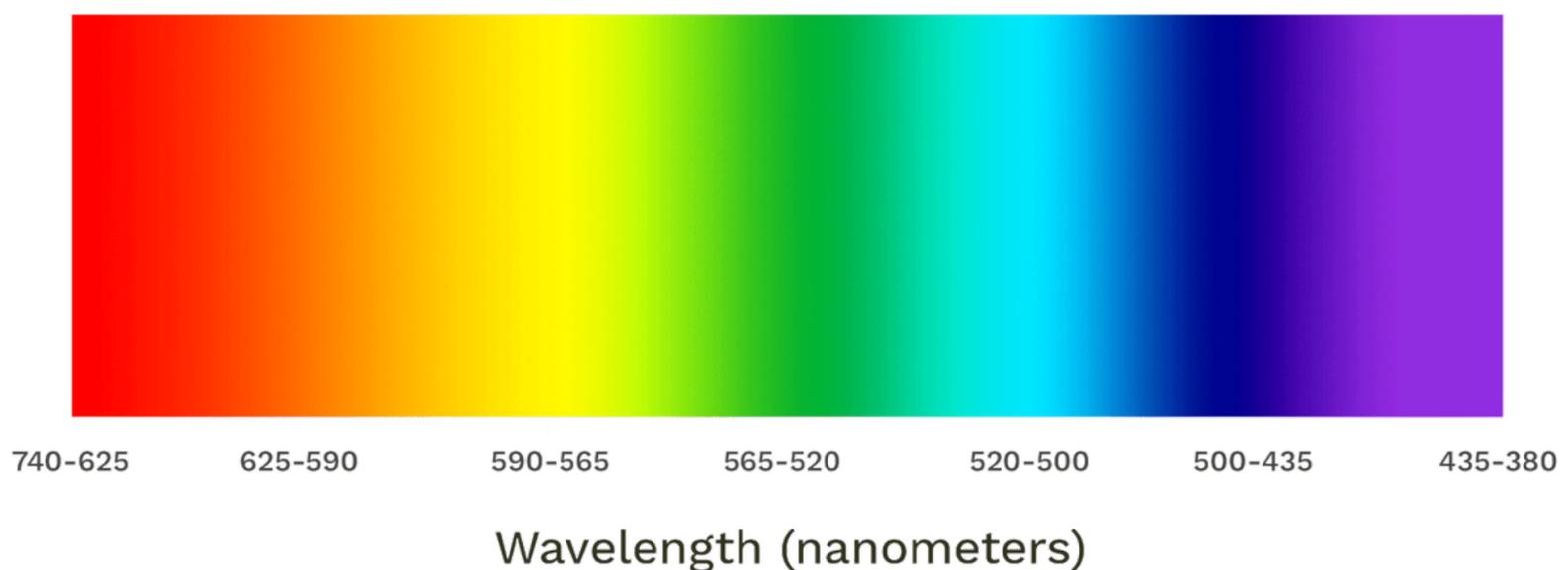
- Only part of the spectrum visible to humans
- Red light has the longest wavelength
- Violet light has the shortest wavelength
- Different colours correspond to different frequencies
- Higher frequency visible light has higher energy

Examples:

- Red light has lower energy than violet light
- Rainbows show the visible spectrum

The Visible Light Spectrum

The visible light spectrum is the section of the electromagnetic radiation spectrum that is visible to the human eye.



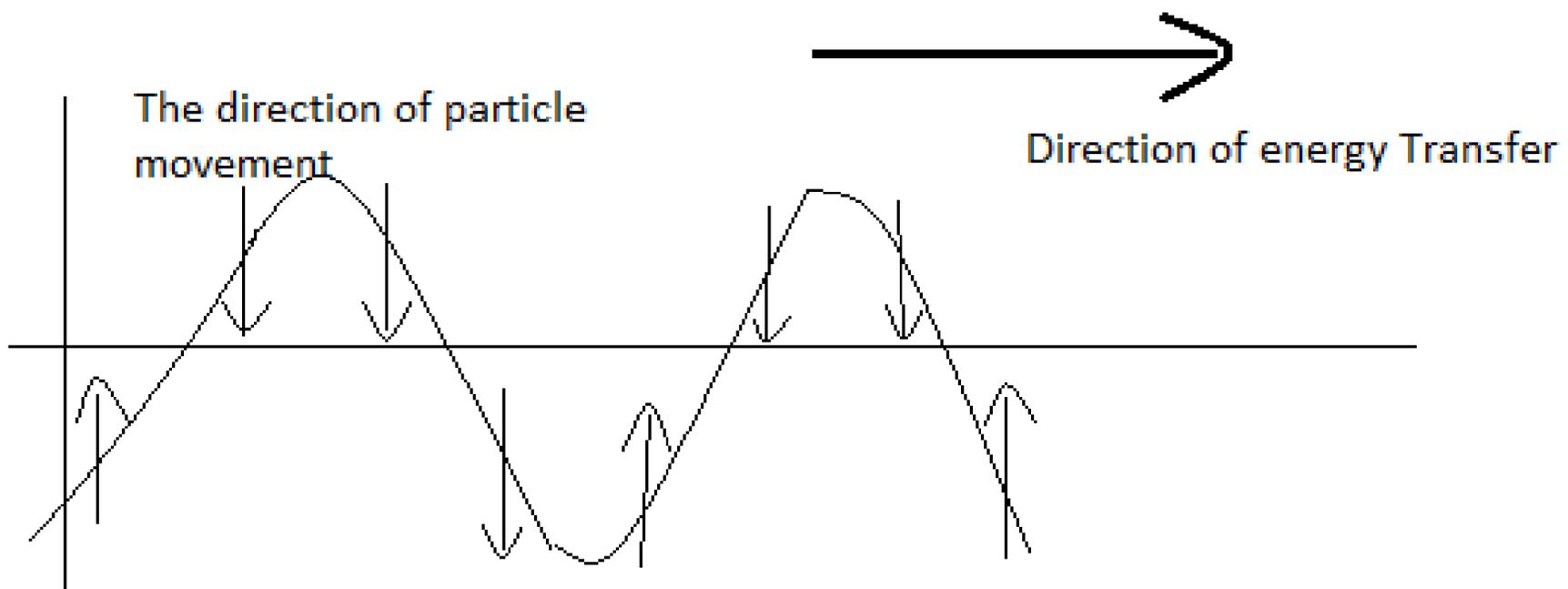
TRANSFER OF ENERGY BY EM WAVES

Electromagnetic waves transfer energy from one place to another through radiation. The amount of energy depends on the frequency of the wave.

- EM waves transfer energy by radiation
- Shorter wavelengths carry more energy
- Higher energy waves are more dangerous
- Energy can be absorbed by materials

Examples:

- Microwaves heat food by transferring energy to water molecules
- Infrared radiation warms objects



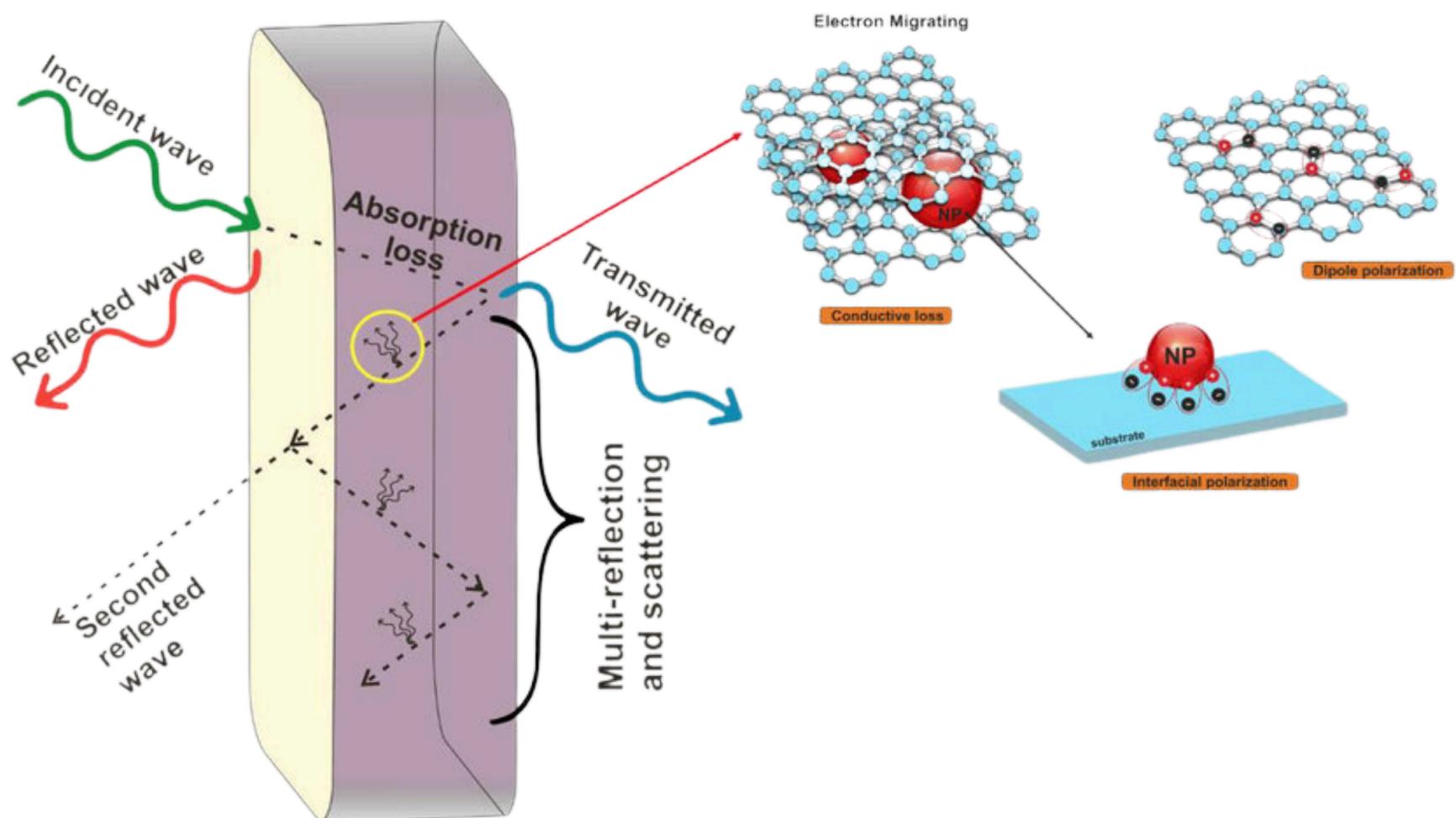
INTERACTION OF EM WAVES WITH MATTER

When electromagnetic waves meet a material, they can interact in different ways depending on the wavelength and the material.

- Waves may be transmitted
- Waves may be absorbed
- Waves may be reflected
- Waves may be refracted
- The interaction depends on wavelength and material

Examples:

- Glass transmits visible light
- Glass absorbs ultraviolet radiation



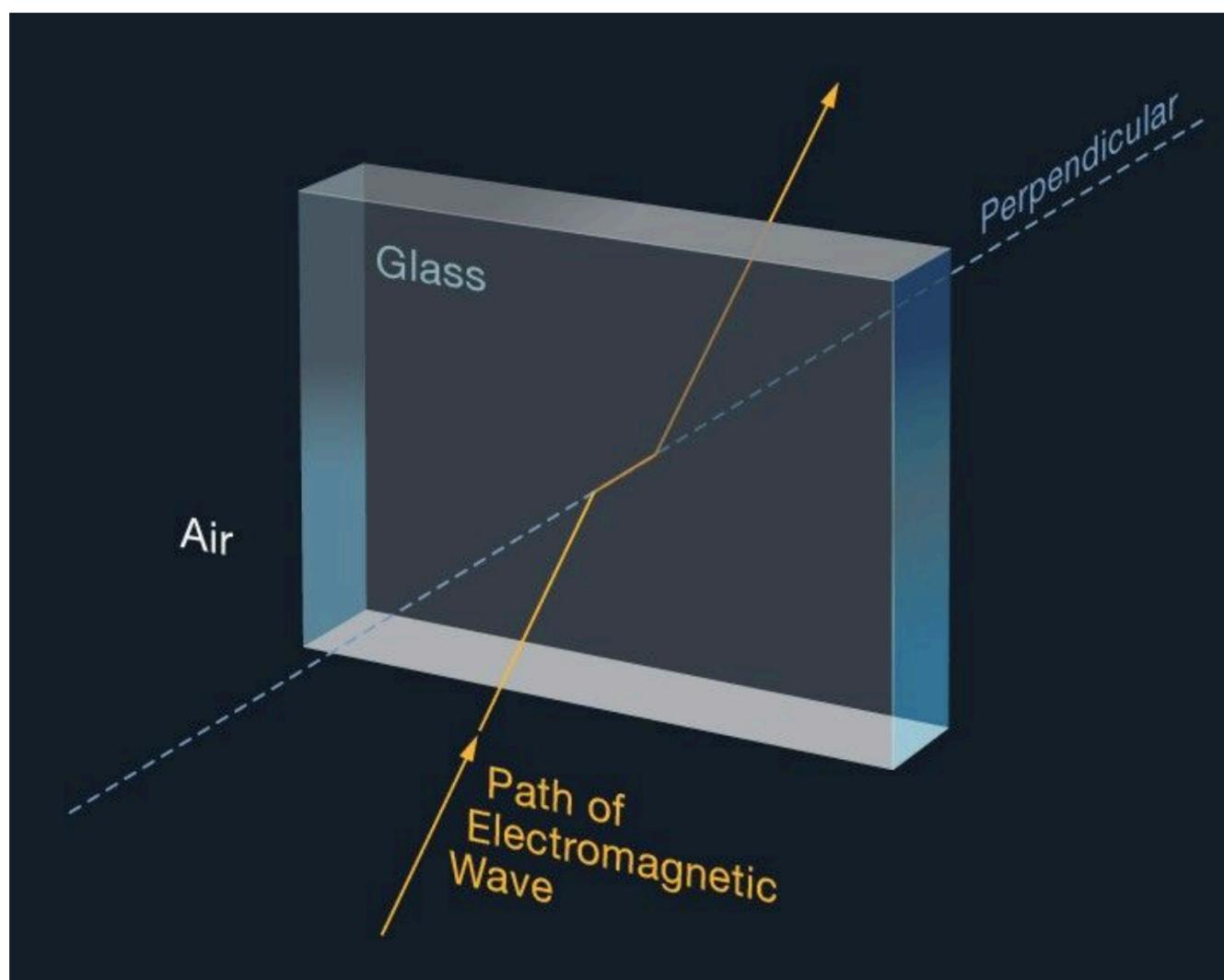
REFRACTION OF EM WAVES

Refraction occurs when electromagnetic waves change direction due to a change in speed when entering a different medium.

- Occurs when waves enter a new medium
- Speed changes in different materials
- Wavelength changes during refraction
- Frequency remains constant
- Waves bend towards the normal when slowing down

Examples:

- Light bending when entering a glass block
- Light bending when entering water



EM WAVES & ATOMS

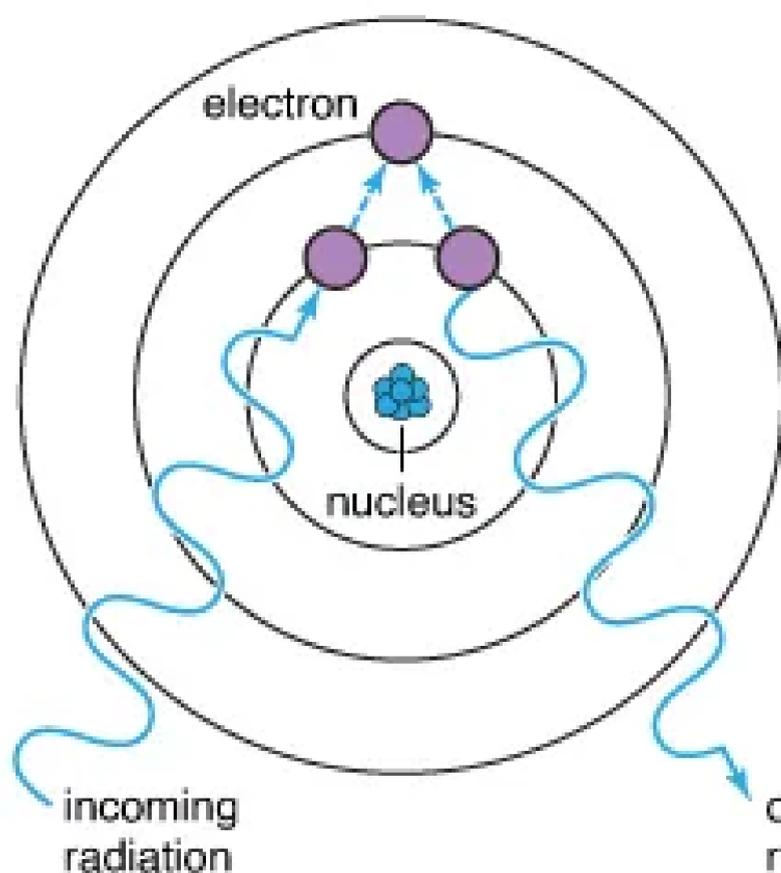
Atoms can absorb and emit electromagnetic waves when electrons move between energy levels.

- Electrons absorb energy and move to higher levels
- Electrons emit energy when falling to lower levels
- Visible and UV radiation often involve electron transitions
- Gamma rays involve nuclear changes

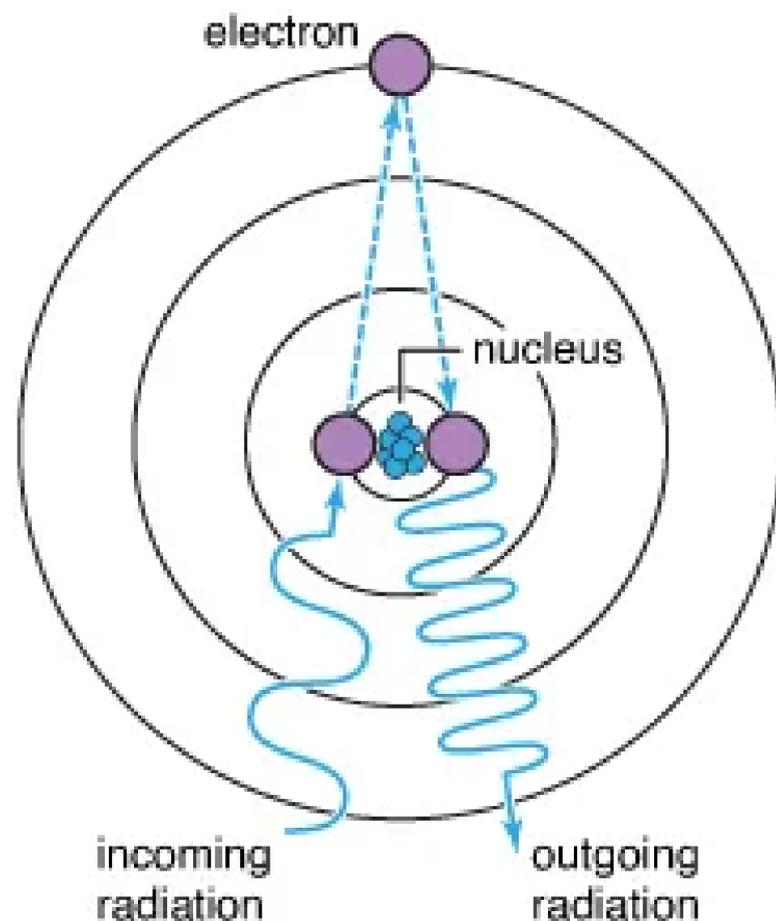
Examples:

- Neon lights emit visible light
- X-rays are produced by high-energy electron interactions

Radiation from electrons within atoms



An electron leap to a nearby orbit



An electron leap to a distant orbit

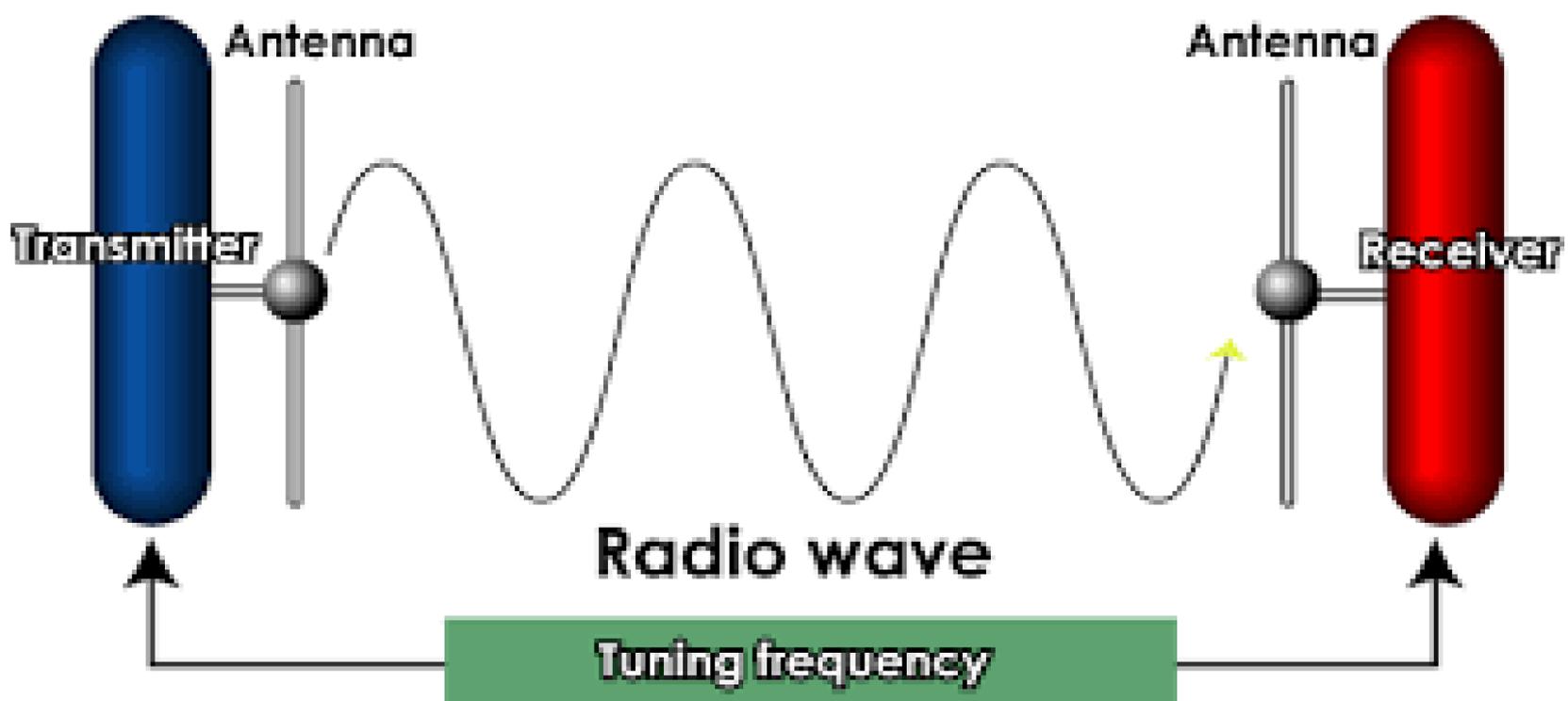
RADIO WAVES

Radio waves are produced by oscillating charges in an alternating current circuit. They are used mainly for communication.

- Produced by high-frequency alternating currents
- Transmitted by antennas
- Received by aerials
- Induce currents in receiving circuits

Examples:

- Radio broadcasting
- Television signals



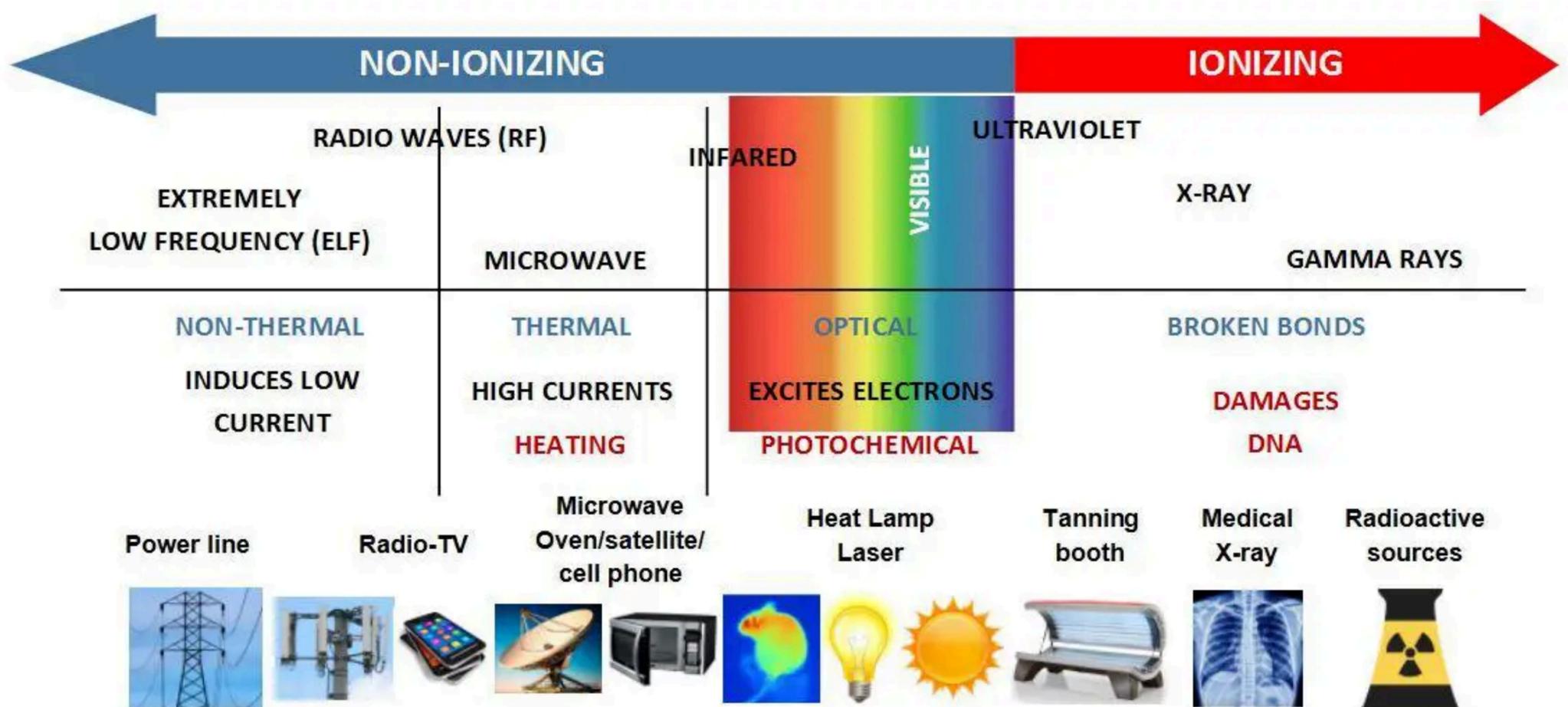
DANGERS OF HIGH-ENERGY EM WAVES

As frequency increases, electromagnetic waves become more energetic and more ionising. Ionising radiation can damage cells and cause mutations.

- Shorter wavelength means higher energy
- Ionising radiation removes electrons from atoms
- UV, X-rays and gamma rays are ionising
- Can cause cell damage and cancer
- Risk depends on dose and exposure time

Examples:

- Excess UV exposure can cause skin cancer
- X-rays can damage body tissues



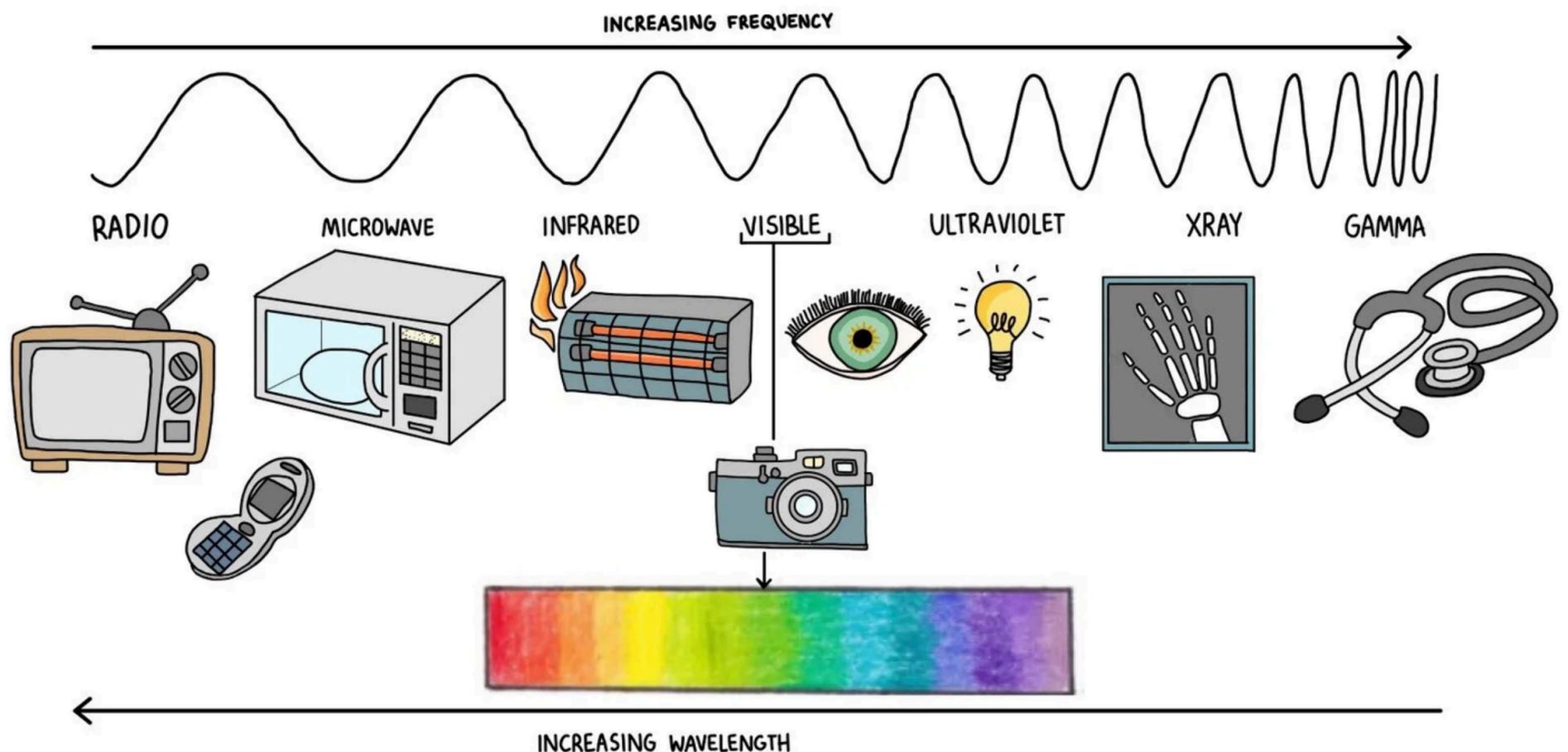
APPLICATIONS OF EM WAVES

Different electromagnetic waves are suited for different uses based on their properties.

- Suitability depends on energy and penetrating ability
- Low-energy waves are used for communication
- High-energy waves are used for medical imaging
- Some waves are used for heating

Examples:

- Microwaves are used in ovens
- X-rays are used to detect bone fractures



CONVEX & CONCAVE LENSES

A lens is a transparent object that forms an image by refracting light. There are two main types of lenses: convex (converging) lenses and concave (diverging) lenses.

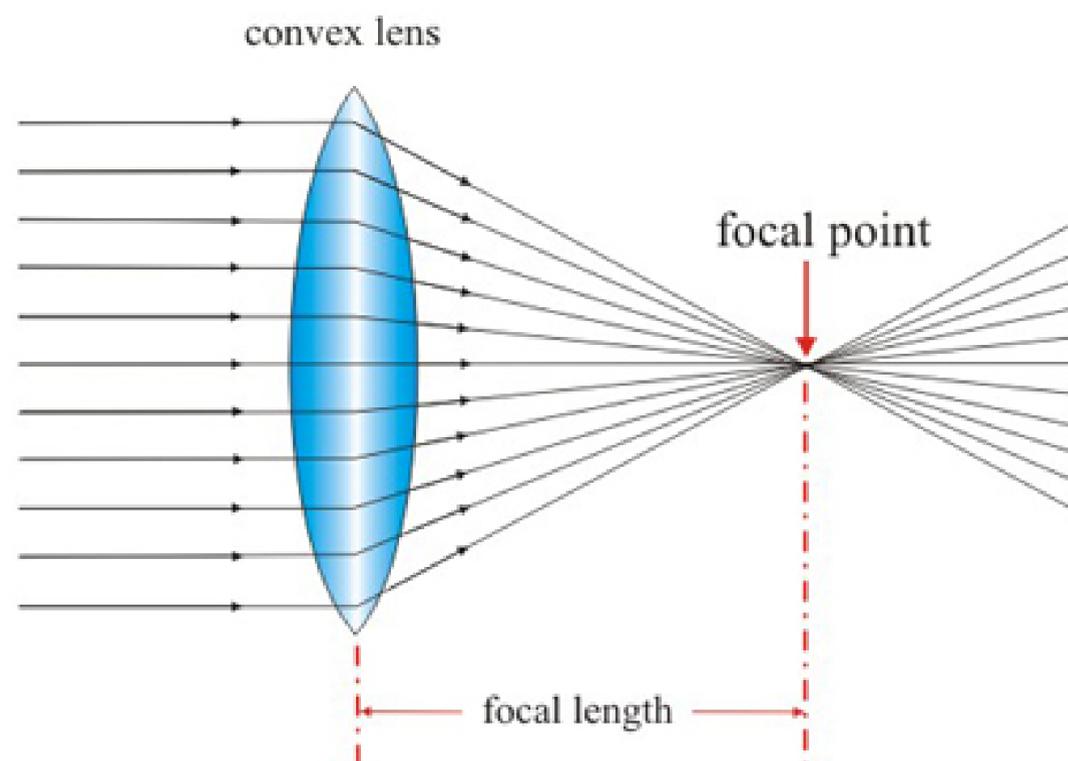
CONVEX LENS (CONVERGING LENS)

A convex lens brings parallel rays of light together to a single point called the principal focus.

- A convex lens converges parallel light rays to a focus.
- The point where the rays meet is called the **principal focus**.
- The distance from the lens to the principal focus is called the focal length.
- A more curved lens has a shorter focal length.
- A convex lens can produce real or virtual images depending on object position.

Examples:

- Magnifying glass
- Camera lens
- Human eye lens



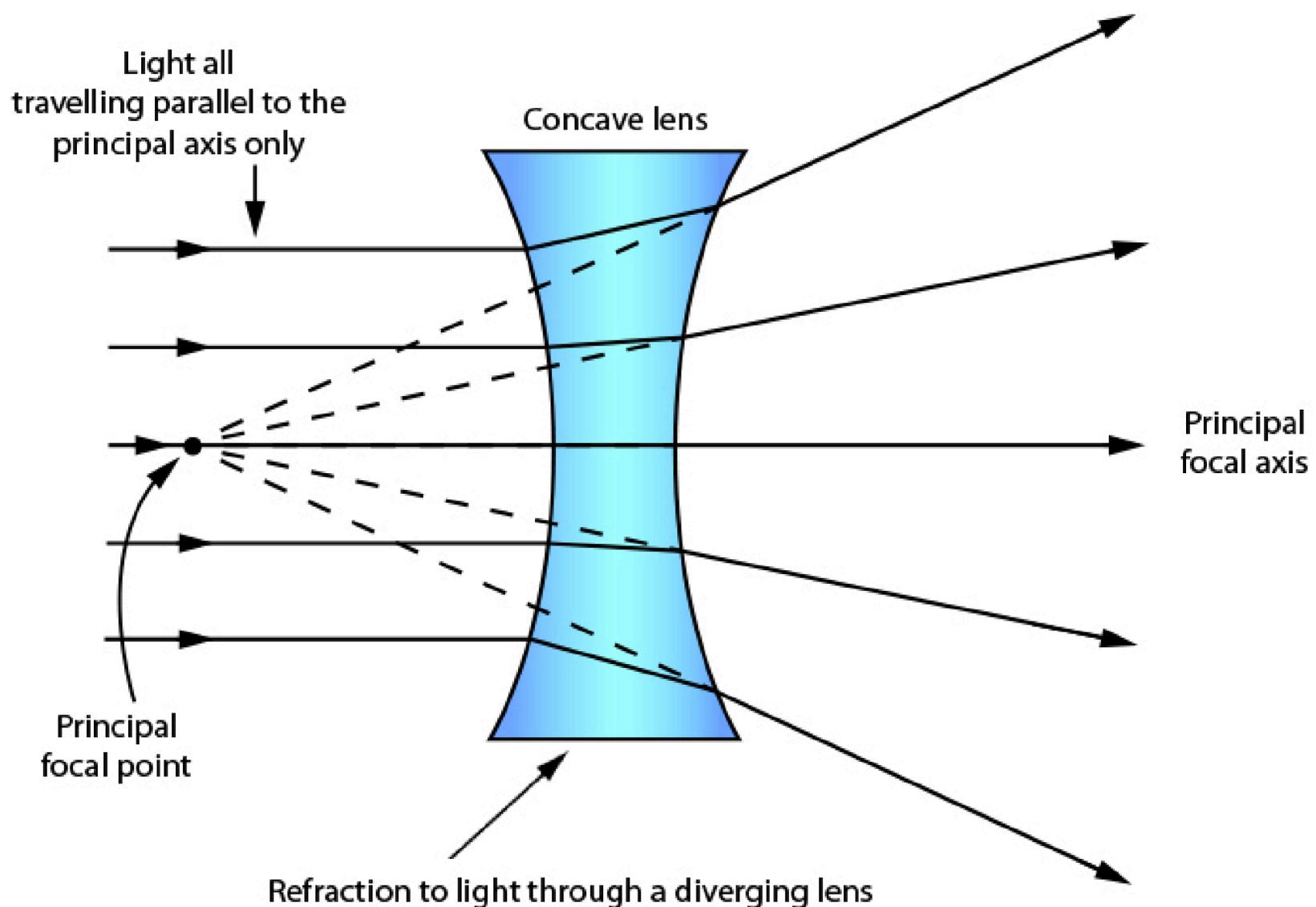
CONCAVE LENS (DIVERGING LENS)

A concave lens spreads parallel rays of light outwards so they appear to come from a focal point.

- A concave lens causes parallel rays to diverge.
- The principal focus is the point from which rays appear to spread out.
- A concave lens always forms a virtual image.
- The image formed is always upright and diminished.

Examples:

- Glasses for short-sightedness
- Door viewers (peepholes)



REAL & VIRTUAL IMAGES

Real Images

A real image is formed when light rays actually meet after refraction.

- A real image is formed by converging rays.
- A real image can be projected onto a screen.
- A real image is always inverted.
- In ray diagrams, real images are formed where solid rays meet.

Example:

- Image formed on a cinema screen

Virtual Images

A virtual image is formed when light rays appear to meet but do not actually meet.

- A virtual image cannot be projected onto a screen.
- A virtual image is always upright.
- It is formed by diverging rays.
- In ray diagrams, virtual images are formed where dashed lines meet.

Example:

- Reflection in a mirror

MAGNIFICATION

Magnification describes how much larger or smaller an image is compared to the object.

- Magnification is the ratio of image height to object height.
- Magnification has no units because it is a ratio.
- If magnification is greater than 1, the image is magnified.
- If magnification equals 1, the image is the same size.
- If magnification is less than 1, the image is diminished.

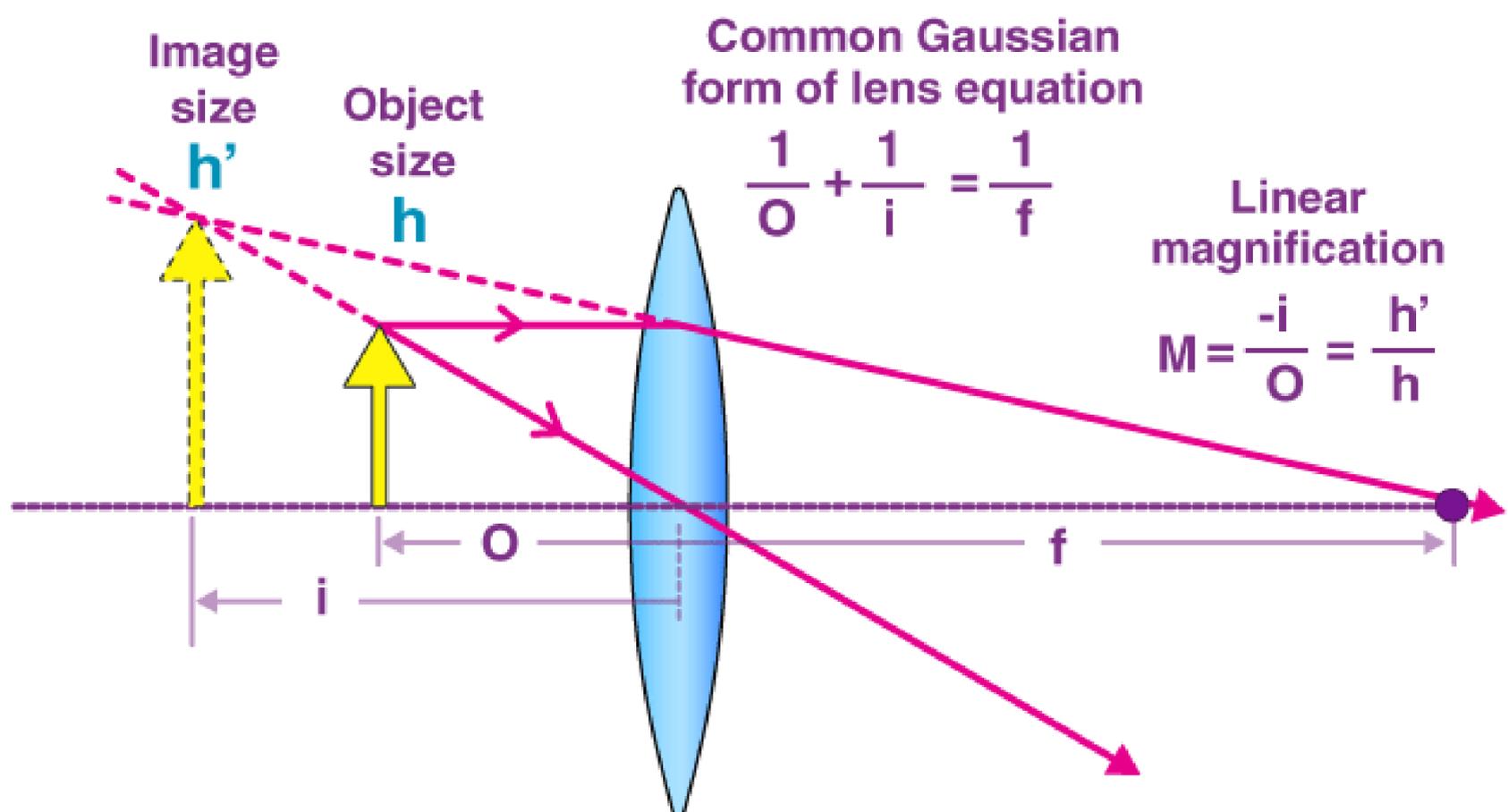
Formula:

Magnification = Image height \div Object height

Example:

If the object is 10 cm and the image is 20 cm:

Magnification = $20 \div 10 = 2$



VISIBLE LIGHT SPECTRUM

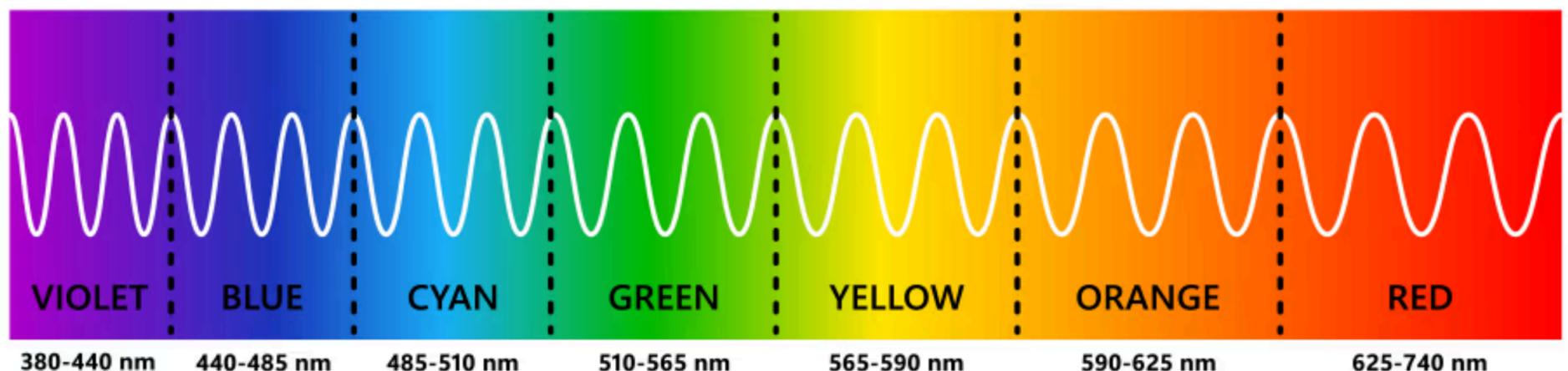
The visible spectrum is the small part of the electromagnetic spectrum that the human eye can detect.

- Each colour corresponds to a specific wavelength and frequency.
- Red has the longest wavelength and lowest frequency.
- Violet has the shortest wavelength and highest frequency.
- Wavelength and frequency are inversely proportional.
- As wavelength increases, frequency decreases.

Order (longest to shortest wavelength):

Red → Orange → Yellow → Green → Blue → Indigo → Violet

VISIBLE SPECTRUM



SPECULAR & DIFFUSE REFLECTION

Specular Reflection

Specular reflection occurs when light reflects from a smooth surface.

- Light reflects in one clear direction.
- A clear image is formed.
- The angle of incidence equals the angle of reflection.

Example:

- Reflection from a mirror

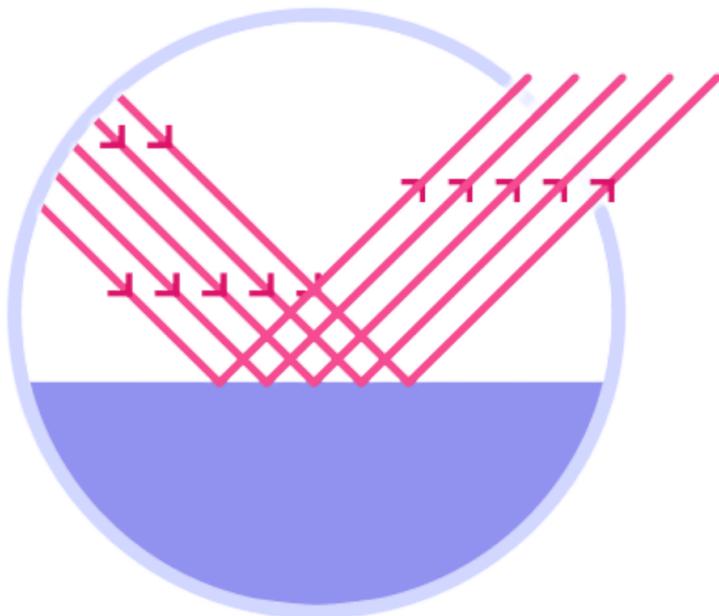
Diffuse Reflection

Diffuse reflection occurs when light reflects from a rough surface.

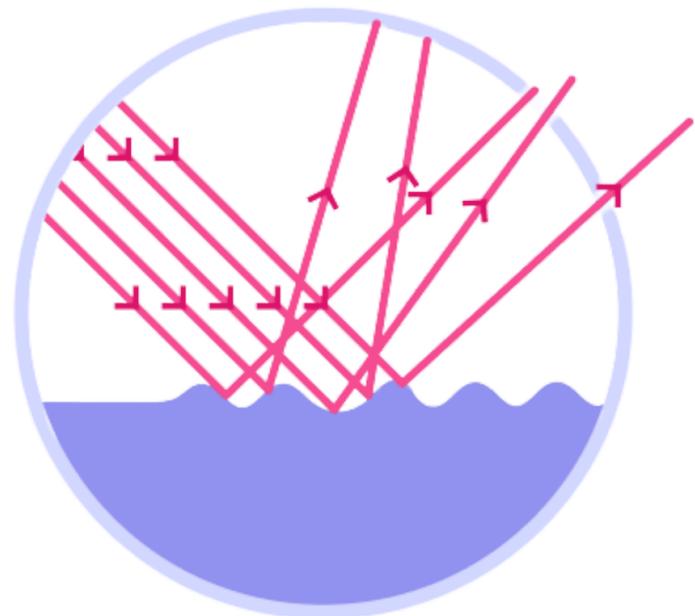
- Light is scattered in many directions.
- No clear image is formed.
- Most everyday surfaces produce diffuse reflection.

Example:

- Light reflecting from a table or wall



Specular reflection



Diffuse reflection

COLOUR & REFLECTION OF LIGHT

The colour of objects depends on which wavelengths are reflected, absorbed or transmitted.

White Light & Prism

White light contains all colours of the visible spectrum.

- White light can be separated into colours using a prism.
- This separation occurs due to refraction.
- Violet light bends the most.
- Red light bends the least.

Example:

- Formation of a rainbow

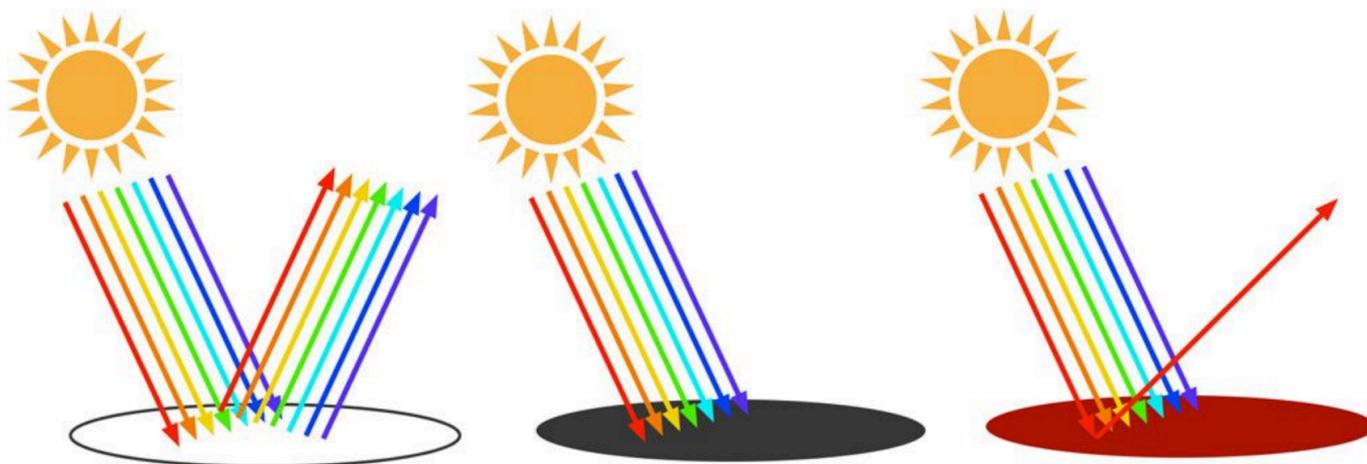
Colour Filters

Colour filters transmit certain wavelengths and absorb others.

- A filter allows its own colour to pass through.
- Other colours are absorbed.
- The transmitted colour matches the filter colour.

Example:

- A red filter transmits red light and absorbs all other colours



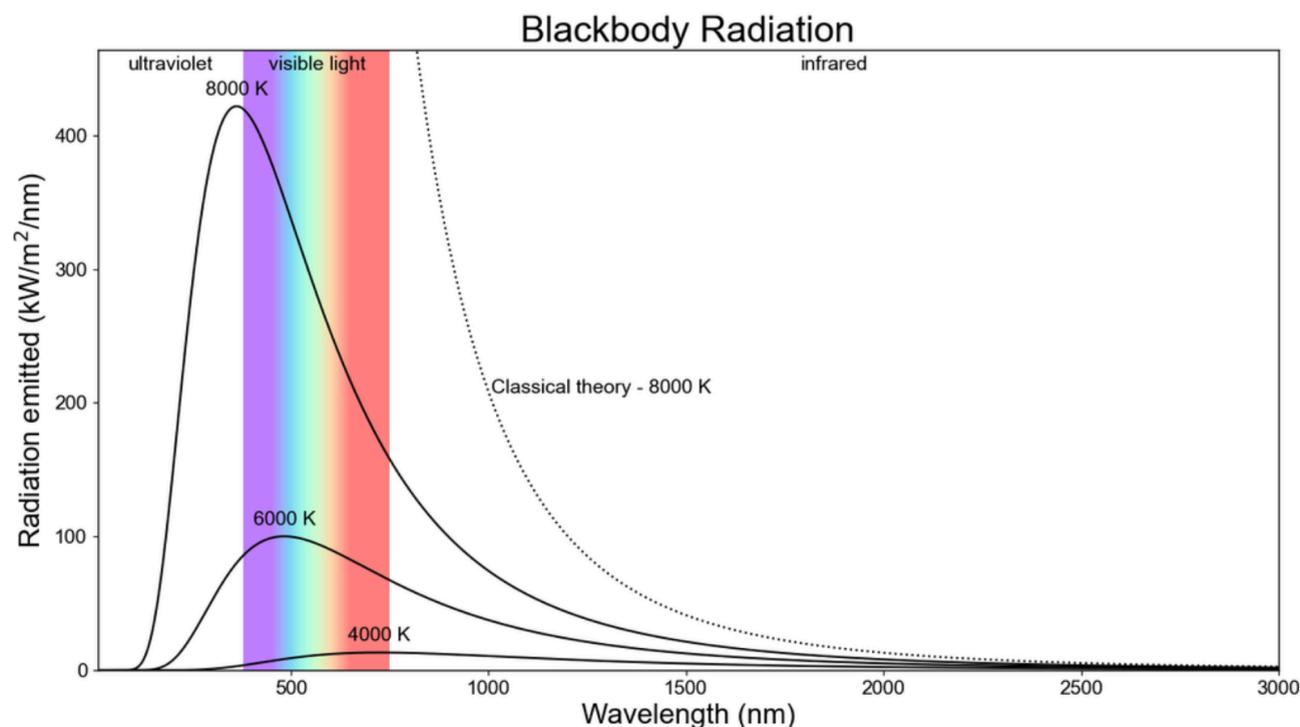
BLACK BODY RADIATION

Black body radiation is the thermal radiation emitted by all objects.

- Emitted as electromagnetic waves (mainly infrared at normal temperatures).
- The hotter the object, the more radiation it emits.
- As temperature increases, wavelength decreases and intensity increases.
- A perfect black body absorbs all incident radiation and reflects none.
- A good absorber is also a good emitter.
- At about 6000 °C (like the Sun), objects emit white/blue light and some ultraviolet radiation.

Examples:

- The Sun
- Infrared cameras
- Heated metal glowing red



TEMPERATURE BALANCE & RADIATION

Temperature balance occurs when the rate of absorption equals the rate of emission.

- An object heats up if it absorbs radiation faster than it emits.
- An object cools down if it emits radiation faster than it absorbs.
- At equilibrium, temperature remains constant.
- Dark, matt surfaces are good absorbers and emitters.
- Light, shiny surfaces are poor absorbers and emitters.
- Greenhouse gases trap infrared radiation and keep the Earth warm (Greenhouse Effect).

Examples:

- Shiny emergency blankets
- The Greenhouse Effect on the Earth

