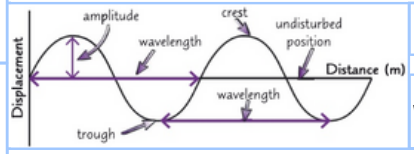
WAVES - PART 1 -

- When waves travel through a medium, the particles of the medium oscillate and transfer energy between each other
- Overall the particles stay in the same place, only energy is transferred

- **Amplitude:** maximum displacement of point on a wave from its undisturbed position
- **Wavelength:** distance between same point on two adjacent waves (eg between two troughs)
- **Frequency:** number of complete waves passing a certain point per second, 1Hz = 1 wave/sec
- **Period** of a wave is how long it takes for a full cycle of a wave
- **Wave speed:** speed at which energy is being transferred

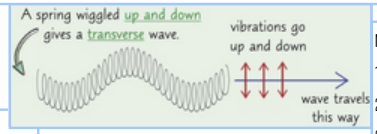


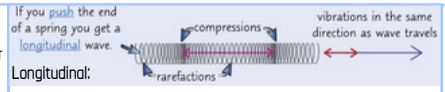
T = 1/F
PERIOD(S) = 1/FREQUENCY(HZ)

V = Fλ
WAVE SPEED(M/S) = FREQUENCY(HZ) X WAVELENGTH(M)

TYPES OF WAVE

Transverse:
- Oscillations are perpendicular to direction of energy transfer
- Most waves are transverse
- EM waves, ripples & waves in water, wave on string

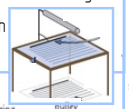




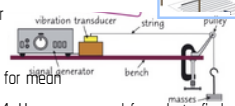
Longitudinal:
- Oscillations are parallel to direction of energy transfer
- Sound waves in air eg ultrasound, shock waves eg seismic wavs

EXPERIMENTS

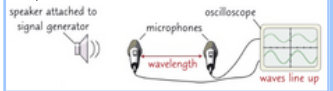
Measuring speed of water ripples:
1 Signal generator makes rod create water waves at a set frequency
2 Strobe light used to see wave crests on paper underneath tank
3 Increase frequency of strobe light until wave pattern on paper 'freezes' -> strobe light frequency = wave frequency
4 Measure distance between shadow lines that are 10 wavelengths apart then divide by 10 to find average wavelength
5 Use wave speed formula to calculate speed



Measuring waves on strings:
1. Set up, turn on signal generator & vibration transducer
2. Adjust frequency until there is a clear wave on string
3. Measure 4 or 5 half wavelengths then divide by 4/5 for mean half-wavelength then double to get full-wavelength
4. Use wave speed formula to find speed



Measuring speed of sound:
1 Set up oscilloscopes so detected waves at microphones are shown as separate waves
2 Start with both microphones next to speaker, then slowly move one away until the two waves are aligned on display but are one wavelength apart
3 Measure distance between microphones to find one wavelength
4 Use wave speed formula to find speed of sound waves (frequency is whatever you set signal generator to, eg 1kHz)
5 Speed of sound in air is around 330m/s



wave properties

TRANSFER OF ENERGY

X-Rays & Gamma Rays:
- Radiographers take X-Ray 'photographs' to look for broken bones -> X-rays pass easily through flesh but not through bones
- Radiotherapy used to treat cancer as high doses of x-rays & gamma rays kills living cells
- Gamma radiation used as medical tracers

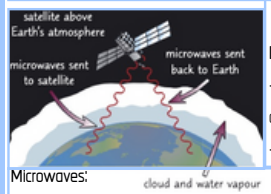
DANGERS

Ultraviolet Radiation:
- Fluorescence -> UVR absorbed & visible light emitted
- Fluorescent lights generate UVR which is absorbed & re-emitted as light by layer of phosphorus
- Security pens (invisible ink)
- UV produced by Sun -> UV lamps used to give suntans

Infrared Radiation:
- Increase/monitor temperature
- Infrared cameras detect IR & turns it into electrical signal which is displayed on screen, hotter = brighter it appears
- Food cooked by IR -> absorbing IR increases temperature
- Electric heaters contain wire that heats up when current flows which emits IR which is absorbed by objects & air, energy transferred to thermal energy stores which increases temperature

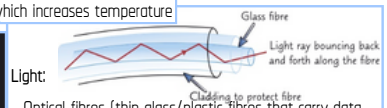
uses & dangers of EM waves

USES



Microwaves:
- Satellite communication
- Satellite TV -> signal transmitted into space & picked up by satellite receiver dish orbiting above Earth which transmits signal back to Earth in different direction & is received by satellite dish on ground
- There is slight time delay due to long distance

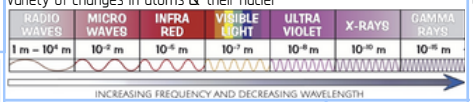
- Microwave ovens -> different wavelength used in satellite communication
- Microwaves penetrate few cms into food, are absorbed, transfer energy they are carrying to water molecules in food which heats it up, water molecules transfer energy to rest of food by heating



Light:
- Optical fibres (thin glass/plastic fibres that carry data over long distance as pulses of visible light)
- Light rays reflected back & forth until they reach end

EM waves

- All EM waves are transverse & transfer energy from a source to an absorber
- All EM waves travel at same speed through air or a vacuum (space)
- They form a continuous spectrum over a range of frequencies, and they are grouped into 7 basic types based on wavelength & frequency
- There is a large range of frequencies because they are generated by a variety of changes in atoms & their nuclei



REFLECTION

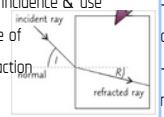
reflection & refraction

When waves arrive at boundary between two different materials three things can happen:
- Waves absorbed by material which transfers energy to material's energy stores
- Waves transmitted through material which often leads to refraction
- Waves reflected

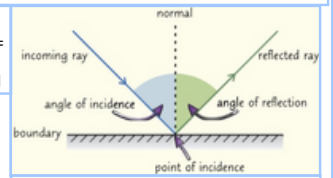
INVESTIGATING LIGHT

- **Angle of incidence:** angle between incoming wave and normal
- **Angle of reflection:** angle between reflected wave and normal
- **Normal:** imaginary line that is perpendicular to surface at point of incidence, normally shown as dotted line

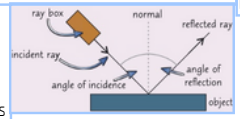
Investigating refraction with transparent materials:
1 Place transparent rectangular block on paper & use ray box/laser to shine ray at middle of side of block
2 Trace incident ray & mark emerging light ray
3 Remove block & join up incident ray with emerging point to show path of refracted ray
4 Draw normal at point of incidence & use protractor to measure angle of incidence and angle of refraction
5 Repeat using blocks of different materials, keep incident angle the same
Angle of refraction should change for different materials as they have different optical densities

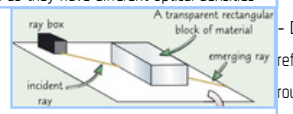


ANGLE OF INCIDENCE = ANGLE OF REFLECTION

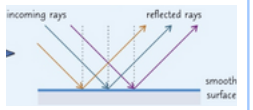


Investigating materials that reflect light by different amounts:
1 Draw straight line on paper & place object so one side lines up with it
2 Shine ray of light at object & trace incoming & reflected light beams
3 Draw normal at point of incidence & use protractor to measure angle of incidence & angle of reflection
4 Repeat with different objects, make note of width & brightness of reflected light ray
Smooth surfaces = thin & bright ray

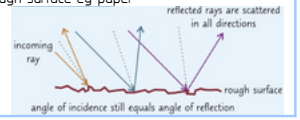




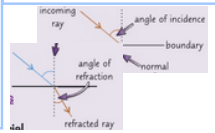
- Reflection can be specular or diffuse
- Waves are reflected at different boundaries in different ways
- Specular reflection happens when wave is reflected in a single direction by a smooth surface eg mirror



- Diffuse reflection happens when wave is reflected in lots of different directions by a rough surface eg paper



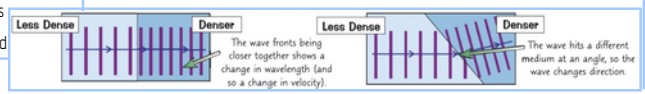
Constructing ray diagram for refracted light ray:
1 Draw boundary between materials & normal which is 90° to boundary, then draw incident ray meeting normal (angle between them is angle of incidence)
2 Draw refracted ray on other side of boundary. If second material is optically denser than first, refracted ray bends towards the normal so angle of refraction is smaller than angle of incidence. If second material is less optically dense, angle of refraction is larger than angle of incidence



- **Optical density:** measure of how quickly light travels through a material
- Higher optical density = slower speed of light rays

- When wave crosses boundary between materials at an angle it changes direction -> it is refracted
- How much it is refracted by depends on how much the wave's speed changes, which depends on the density of the two materials
- Higher density = slower speed of wave
- If wave slows down = bends towards normal
- If wave speeds up = bends away from normal

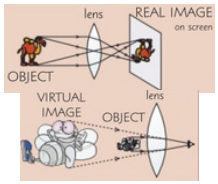
- The wavelength changes when a wave is refracted but frequency stays same
- If wave is travelling along normal it changes speed but is not refracted



WAVES – PART 2 –

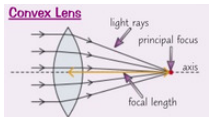
LENSES

- Real image: light from object comes together to form image on a 'screen' eg retina
- Virtual image: light from object appears to come from completely different place eg
  - when looking in mirror face appears to be behind mirror
  - when looking through magnifying lens image looks bigger than it actually is

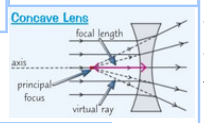


- Form images by refracting light & changing its direction
- Two main types:
  - -Convex
  - -Concave

Convex lenses:
- Bulge outwards
- Causes rays of light parallel to axis to be brought together (converge) at principal focus



Concave lenses:
- Curves inwards
- Parallel rays of light spread out (diverge)



- Axis: line passing through middle of lens
- Principal focus-
  - For convex: where rays meet
  - For concave: where rays 'come from'
- One on each side of lens
- Focal length: distance from centre of lens to principal focus

Refraction in convex lenses:
- Incident ray parallel to axis refracts through lens and passes through principal focus
- Incident ray passing through principal focus refracts through lens and travels parallel to axis
- Incident ray passing through centre of lens carries on in same direction

Refraction in concave lenses:
- Incident ray parallel to axis refracts through lens and travels in line with principal focus
- Incident ray passing through lens towards principal focus refracts through lens and travels parallel to axis
- Incident ray passing through centre of lens carries on in same direction

- Convex lenses can create real and virtual images
- Concave lenses only create virtual images

IMAGES

To describe image:
- Size
- Upright or inverted
- Real or virtual

VISIBLE LIGHT

- Waves have different properties depending on the material they are travelling through

When wave arrives at a boundary it can be:
- Completely/partially reflected
- Continue in same direction at different speed
- Refracted
- Absorbed

EARTHQUAKES

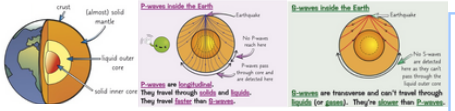
- Earthquakes produce seismic waves which travel through the Earth and are detected using seismometers
- Seismologists work out the time it takes for waves to reach seismometer and also note which parts of the Earth don't receive the waves at all
- When seismic waves reach a boundary between different layers of material inside the Earth, some waves will be absorbed or refracted
- If they are refracted they change speed gradually, resulting in a curved path
- When the properties change suddenly the wave speed changes abruptly and the path has a kink

There are two different types of seismic waves (p-waves and s-waves

P-WAVES & S-WAVES

exploring structures using waves

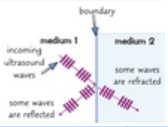
- By observing how seismic waves are absorbed/refracted, scientists can work out where the properties of the Earth dramatically change



- When wave passes from one medium to another, some of the wave is reflected off the boundary and some is transmitted (and refracted) -> partial reflection
- You can point a pulse of ultrasound at an object, and wherever there are boundaries between one substance and another, some of the ultrasound gets reflected back
- Time it takes for the reflections to reach a detector can be used to measure how far away the boundary is

ULTRASOUND

- Electrical devices can be made which produce electrical oscillations over a range of frequencies
- These can easily be converted into mechanical vibrations to produce sound waves above 20kHz
- This is called ultrasound

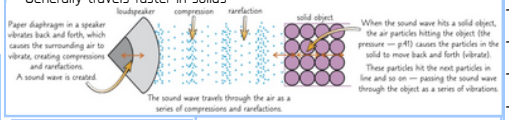


Used in:
- Medical imaging eg prenatal scanning of foetus
- Industrial imaging eg finding flaws in materials

- Echo sounding uses high frequency sound waves (including ultrasound) -> boats use this to find out depth of water or to locate objects in deep water

sound waves

- Sound waves are caused by vibrating objects
- Vibrations passed through surrounding medium as series of compressions & rarefactions (longitudinal)
- Generally travels faster in solids



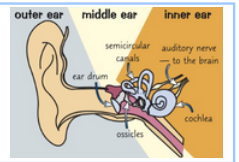
SOUND WAVES

- Sound cannot travel in space because it is mostly a vacuum (no particles to move/vibrate)

HEARING SOUND

- Sound waves are reflected by hard flat surfaces (echoes are reflected sound waves)
- Can also refract as they enter different media
- Denser material = speed up
- When entering medium, wavelength changes but frequency stays same so speed must change

- Sound waves reach ear drum, making it vibrate
- Vibrations passed on to tiny bones (ossicles), through semicircular canals and to the cochlea
- Cochlea turns vibrations into electrical signals which are sent to brain via auditory nerve, allowing you to sense (hear) the sound



- Different materials convert different frequencies into vibrations eg humans hear sound in range of 20Hz-20kHz
- Human hearing is limited by size and shape of ear drum, as well as structure of parts in ear that vibrate to transfer energy from sound wave

radiation

INFRARED RADIATION

- All objects are continuously emitting and absorbing infrared radiation
- Infrared radiation is emitted from the surface of an object
- Hotter object = more radiation

- An object hotter than its surroundings emits more IR than it absorbs as it cools down
- An object cooler than its surroundings absorbs more IR than it emits as it warms up

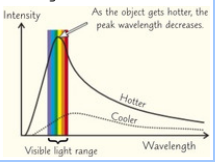
- Object at constant temperature emits and absorbs IR at same rate
- Some colours/surfaces emit IR better than others eg
- Black is better than white
- Matt is better than shiny

BLACKBODY RADIATION

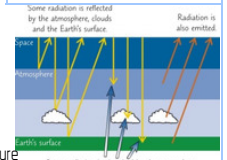
Leslie cubes are used to investigate IR emission:
- Hollow watertight metal cube, 4 different surfaces (matt black, matt white, shiny metal, dull metal)

1 place empty cube on heatproof mat
2 boil water in kettle and fill cube with boiling water
3 hold thermometer against each side (should be same temperature)
4 hold IR detector at set distance from each side
5 record amount of IR it detects
6 black and matt should emit most IR

- A perfect black body is an object that absorbs all radiation hitting it (none is reflected or transmitted)
- All objects emit EM radiation due to energy in their thermal energy stores
- This is not just IR; it covers a range of wavelengths & frequencies
- Intensity & distribution of wavelengths emitted by object depends on object's temperature
- Intensity is power per unit area ie how much energy transferred to a given area in a certain time
- As temperature of object increases, intensity of every emitted wavelength increases
- Intensity increases more rapidly for shorter wavelengths, which causes peak wavelength (with highest intensity) to decrease

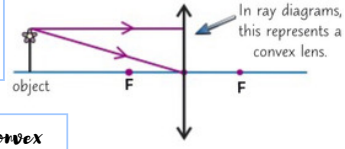


- Overall temperature of Earth depends on the amount of radiation it reflects, absorbs &emits
- Daytime: lots of radiation (light) transferred to earth and absorbed, causing an increase in local temperature
- Nighttime: less radiation absorbed than being emitted, causing a decrease in local temperature
- Overall, temperature of earth stays fairly constant
- Changes to atmosphere = change to Earth's overall temperature
- If atmosphere absorbs more radiation without emitting same amount, overall temperature will rise until absorption and emission are equal (global warming)



RAY DIAGRAMS

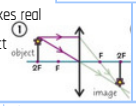
1 Pick point on top of object
2 Draw ray from object to lens parallel to axis
3 Draw another rat from top of object through middle of lens
4 Incident ray parallel to axis is refracted through principal focus on other side of lens
5 Draw refracted ray passing through principal focus
6 Ray passing through middle doesn't bend
7 Mark where rays meet->top of image
8 Repeat for bottom of object
9 If bottom is on axis, bottom of image is on axis too

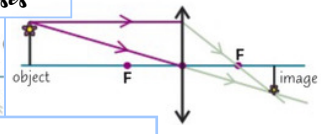


Distance from lens affects image:

1 Object at 2F produces real inverted image same size as object at 2F
2 Object between F and 2F makes real inverted image bigger than object beyond 2F
3 Object near F makes virtual upright image bigger than object on same side of lens

for convex lenses

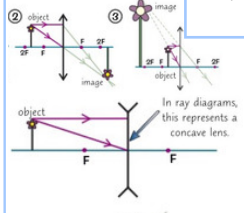


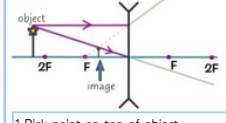


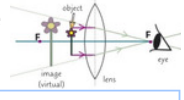
magnification

- Magnifying glasses create a magnified virtual image
- Object being magnified must be closer to lens than focal length
- Image produced is virtual so light rays don't actually come from place where image appears to be
- Ratio so no units

for concave lenses





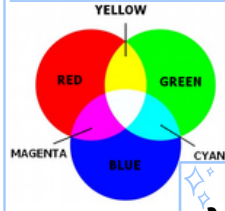


1 Pick point on top of object
2 Draw ray from object to lens parallel to axis
3 Draw another ray from top through middle of lens
4 Incident ray parallel to axis is refracted so appears to have come from principal focus
6 Draw ray from principal focus-make dotted before it reaches lens
7 Ray passing through middle does not bend
8 Mark where refracted rays meet->top of image
9 Repeat for bottom
10 If bottom is on axis, bottom of image is on axis too

WAVES PART 2

VISIBLE LIGHT

- Visible light spectrum are the only EM waves we can see
- Range of wavelengths that we see as colours
- Each colour has own narrow range of wavelengths
- Violets 400nm to reds 700nm
- Colours mix to create other colours
- Cannot mix to create primary colours-red green blue
- Red green blue = white
- Specular reflection-reflection from smooth surface in single direction
- Diffuse reflection-reflection from rough surface scattering light



colour & transparency

- Objects absorb, transmit & reflect different wavelengths in different ways

Opaque objects:

- Do not transmit light
- Visible light hits them => some wavelengths absorbed others reflected
- Colour of object depends on which wavelengths are most strongly reflected

For opaque objects not primary colours:

- May be reflecting colour's wavelength or colours that mix to make that colours wavelengths
- Yellow object = yellow light or red and green light

- Used to filter out different wavelengths of light so only certain wavelengths are transmitted - rest are absorbed

colour filters

Primary colour filter:
- Only transmits that colour
- Eg white light shone at blue filter => only blue light let through, rest absorbed
- Looking at blue object through blue filter it will look blue
- Looking at red object through blue filter it will look black - all light reflected by object is absorbed by filter

White objects:
- Reflect all wavelengths equally

Black objects:
- Absorb all wavelengths
- Lack of visible light

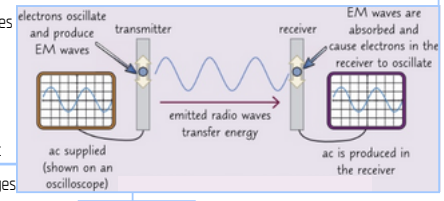
Transparent and translucent objects:
- Transmit light ie some light passes through
- Some wavelengths may be absorbed or reflected
- Colour is related to wavelengths transmitted and reflected

Non primary colour filter:
- Let through that colour's wavelength and primary colour wavelengths that mix for that colour

WAVES PART 2

RADIO WAVES

- EM waves are made up of oscillating electric & magnetic fields
- Alternating currents are made up of oscillating charges which produce oscillating electric & magnetic fields ie EM waves
- Frequency of waves = frequency of AC
- Radio waves produced using AC in electrical circuit

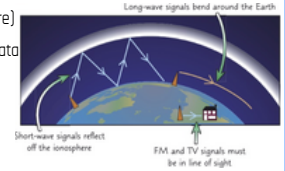


oscillating charges

- The object in which charges (electrons) oscillate to create radio waves is called a transmitter
- When transmitted radio waves reach receiver they are absorbed
- Energy carried by waves is transferred to electrons in material of receiver which causes them to oscillate and generate an AC -> this has same frequency as radio wave

uses

- Radio waves have wavelengths longer than about 10cm
- Long-wave radio (wavelengths of 1-10km) can be transmitted and received halfway round the world
- This is because long wavelengths diffract (bend) around curved surface of Earth
- This makes it possible for radio signals to be received even if the receiver is not in line of sight of transmitter



- Short-wave radio signals (wavelengths 10-100m can be received at long distances from transmitter
- This is because they are reflected from the ionosphere (electrically charged layer in Earth's upper atmosphere)
- Bluetooth uses short-wave radio waves to send data over short distances between devices without wires
- Medium-wave signals reflect from the ionosphere, depending on atmospheric conditions & time of day
- Radio waves used for TV & FM radio transmissions have very short wavelengths -> to get reception you need to be directly in sight of transmitter

WAVES PART 1

Dangers of EM waves ->

- Some EM radiation can be harmful to people
- Low frequency waves eg radio do not transfer much energy so mostly pass through soft tissue without being absorbed
- High frequency waves eg UV, X-Rays & gamma rays transfer lots of energy so cause lots of damage
- UV radiation damages surface cells -> sunburn, skin ages prematurely, blindness, increased risk of skin cancer
- X-rays & gamma rays are ionising -> gene mutation or cell destruction, cancer

- Radiation dose: measure of risk of harm from body being exposed to radiation in sieverts (Sv), not a measure of total amount of radiation absorbed
- Risk depends on total amount of radiation absorbed and how harmful the type of radiation is
- Risk can be different for different parts of the body