Physics Year 11 Prelim Notes

Module 1: Kinematics

Describe uniform straight-line (rectilinear) motion and uniformly accelerated motion through:
- Qualitative descriptions
- The use of scalar and vector quantities

Scalar quantities

Scalars are quantities having only a magnitude (size) but not a direction
Examples include:

- Distance
- Speed
- Volume
- Mass
- Time

Speed

Speed is a scalar quantity that refers to how fast an object is moving
It is the rate at which an object is covering distance

- An object that covers a large amount of distance is faster than an object covering a smaller amount of distance in the same time

It is mathematically expressed as:

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

The SI units for speed is m/s or ms^{-1}
An object that is stationary is said to have zero speed

Distance

Distance is defined as the length traversed by an object over a period of time
By rearranging the formula speed, distance can be found using the formula
Distance=speed * time
The SI unit for distance is metre (m)

Vectors

Vector quantities unlike scalar quantities have both a magnitude and a direction
The vector counterpart to speed is known as velocity. The velocity of an object refers to both its speed as well as its direction it is moving

- It is represented by the symbol $\vec{v}$

An object with negative velocity means that it is moving backwards
The vector counterpart to distance is displacement

- It is represented by the symbol $\vec{s}$

Displacement refers to an object's overall change in position
It does not consider what route the object took to change position, only where it started and where it ended
Directions are usually given in terms of angles or compass directions like 'north'

Velocity is expressed mathematically as:

Velocity=$\frac{\Delta displacement}{time}$

Acceleration

Acceleration is defined as an object's rate of change of velocity, and is expressed mathematically as:

Acceleration=$\frac{\Delta velocity}{time}$

It is expressed as $\vec{a}$ and is represented by the SI unit ms^{-2}

A net force must act on a body if it undergoes acceleration

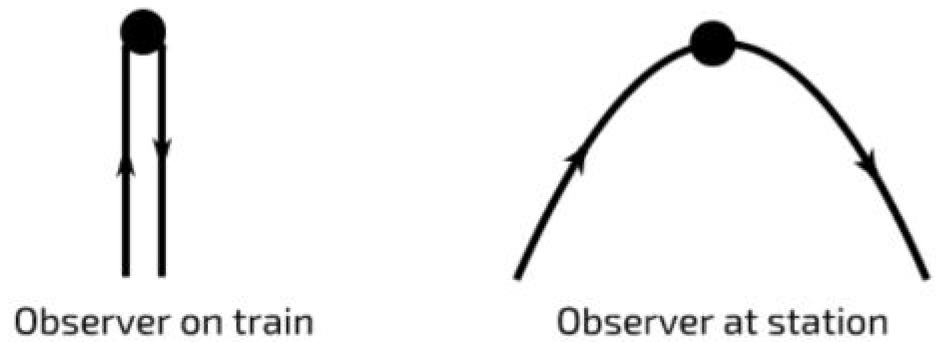
Calculate the relative velocity of two objects moving along the same line using vector analysis

Frame of reference

If a observer a moving train where to throw a ball vertically upwards on a moving train

For observers on the train, they observe the ball to be going vertically up, and then falling back down vertically

However, for an observer outside the train (either stationary or a slower velocity), would observe the ball follow a parabolic path as the train passes them, with the constant horizontal component of velocity equal to the velocity of the train



In the above scenario, the frame of references are the train and the station, and thus the motion of the ball is different for observers on different frames of reference

Relative Velocity

Relative velocity is the velocity of an object as measured from a certain frame of reference

For example, consider two cars, A and B, travelling at 60 and 80 km/hr respectively in the same direction

- The relative velocity of A as measured from B is 80-60=20km/hr

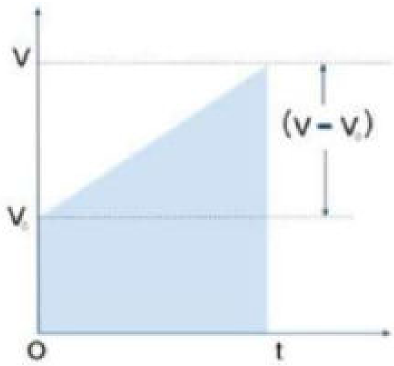
The velocity of A relative to B ($\vec{V}_{AB}$) is given by the formula:

$\vec{V}_{AB}=\vec{V}_A-\vec{V}_B$

Using mathematical modelling and graphs, selected from a range of technologies, to analyse and derive relationships between time, distance, displacement, speed, velocity and acceleration in rectilinear motion, including:

$s=ut+\frac{1}{2}at^2$
$v=u+at$
$v^2=u^2+2as$

Acceleration is change in velocity over change in time
$A=\frac{\Delta v}{t}=\frac{v-u}{t}$
Where v is the final velocity and u is the initial velocity. Rearranging this equation gives:
$v=u+at$
Now consider a typical velocity vs time graph. This displacement is equal to the area under the curve
The area can be found by breaking it up into a rectangle and a triangle
The area of the rectangle is ut and the area of the triangle is $\frac{1}{2}(v-u)t$
After substituting v-u=at, the result is derived
$s=ut+\frac{1}{2}(v-u)t=ut+\frac{1}{2}at^2$



To derive the final equation, we eliminate t by using the first and second equation
From the equation, $t\frac{v-u}{a}$. Substituting this into the second equation, we obtain:
$S=\frac{u(v-u)}{a}+\frac{1}{2}a(\frac{v-u}{a})^2$
$2as=2u(v-u)+(v-u)^2$
$2as=2uv-2u^2+v^2-2uv+u^2$
$\therefore v^2=u^2+2as$

Basic *suvat* Questions

1. A particle is accelerated uniformly from rest, so that after 10 seconds it has achieved a speed of 15 m/s. Find its acceleration and the distance it has covered?

2. A car accelerates uniformly from rest and after 12 seconds has covered 40m. What are its acceleration and its final velocity?

3. A train is uniformly accelerated from 35m/s to 21m/s over a distance of 350m. Calculate the accelerated and the time taken to come to rest from the 35m/s.

4. A particle is accelerated from 1m/s to 5m/s over a distance of 15m. Find the acceleration and the time taken.

5. A car accelerates uniformly from 5m/s to 15m/s taking 7.5 seconds. How far did it travel during this period.

6. A particle moves with uniform acceleration 0.5m/s^2 in a horizontal line ABC. The speed of the particle at C is 80m/s and the times taken from A to B and from B to C are 40 and 30 seconds respectively. Calculate

(a) Speed at A

(b) Distance BC

7. Initial velocity 5m/s, final velocity 36km/hr, acceleration 1.25m/s/s. Distance?

8. A car accelerates from rest with acceleration 0.8m/s^2 for 5 seconds. Find the final velocity

9. A train starts from rest and accelerates uniformly at 1.5m/s^2 until it attains a speed of 30m/s. Find the time taken and the distance travelled.

10. A train travels along a straight piece of track between 2 stations A and B. The train starts from rest at A and accelerates at 1.25m/s^2 until it reaches a speed of 20m/s. It then travels at this speed for a distance of 1560m and then decelerates at 2m/s^2 to come to rest at B. Find

(a) Distance from A to B

(b) Total time taken for the journey

(c) Average speed for the journey

11. A car is being driven along a road at 25m/s when the driver suddenly notices that there is a fallen tree blocking the road 65m ahead. The driver immediately applies the brakes giving the car a constant acceleration of 5m/s^2. How far in front of the tree does the car come to rest?

12. In travelling the 70cm along a rifle barrel, a bullet uniformly accelerates from rest to a velocity of 210m/s. Find the acceleration involved and the time taken for which the bullet is in the barrel.

Answer to SUVAT Questions

1) 1.5 ms^{-2} 75m

2) 0.55 ms^{-2} 6.67 ms^{-1}

3) -1.12 ms^{-2} 31.25 secs

4) 5 secs 0.8 ms^{-2}

5) 75m

6) 45 ms^{-1} 2175m

7) 30m

8) 4ms^{-1}

9) 300m 20secs

10) (a) 1820 (b) 104 secs (c) 17.5ms^{-1}

11) 2.5m before the tree

12) 31500 ms^{-2} 0.0067 secs

Analyse vectors in one and two dimensions to:

- Resolve a vector into two perpendicular components

- Add two perpendicular vector components to obtain a single vector

Represent the distance and displacement of objects moving on a horizontal plane using:

- Vector addition

- Resolution of component vectors

Describe and analyse algebraically, graphically and with vector diagrams, the ways in which the motion of object changes, including:

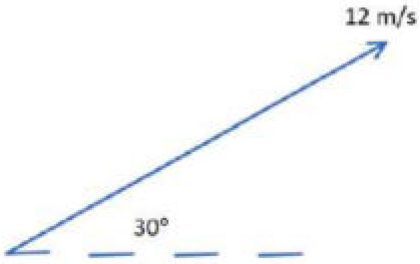
- Velocity

- Displacement

A vector has both a magnitude and a direction

Vectors can be represented graphically using arrows, whereby the length of the arrow corresponds to the magnitude of the vector whilst the head corresponds to the direction. This is known as a vector diagram

For example, a velocity of 12m/s at 30 degrees above the horizontal is shown below



Given any vector, with magnitude V and angle θ above the horizontal, it can be resolved to its perpendicular (horizontal and vertical) vector components using trigonometry

$V_x = V\cos\theta$

$V_y = V\sin\theta$

For example, for the velocity vector above the horizontal component is $12\cos30 \approx 10.4ms^{-1}$ and it vertical component is $12\sin30 = 6ms^{-1}$

Two perpendicular vectors can also be added together to obtain a resultant vector

To find the magnitude of the resultant vector, the Pythagoras theorem is used, and to find the angle (direction), inverse tan is used

For example, a block was moved 3m to the right, the n 4m up. Its displacement is the resultant vector of two perpendicular vectors

Using Pythagoras theorem, the magnitude of displacement is

$s = \sqrt{3^2 + 4^2} = \sqrt{25} = 5m$

And its direction is

$\Theta = \tan^{-1}(\frac{4}{3}) = 53°$ above the horizontal

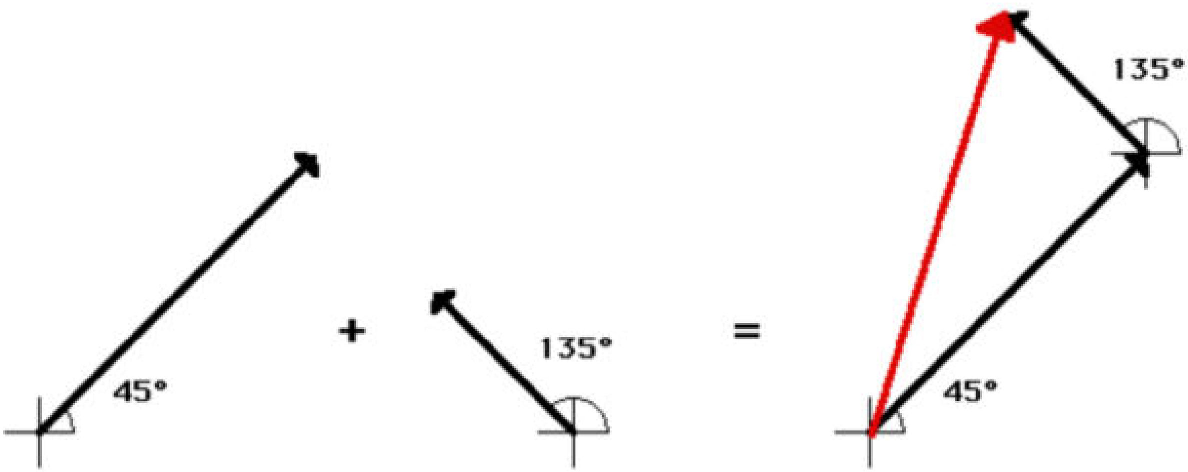
To add multiple vectors, a method known as head to tail method is used

- First draw the vectors one after another placing the tail of the successor vector at the head of the previous vector
- Then draw the resultant vector from the tail of the first vector to the head of the last vector

To determine the magnitude and angle of the resultant vector:

- Break all vectors into their component vectors(horizontal and vertical)
- Add all the horizontal vectors to obtain a resultant horizontal vector. Add up all the vertical vectors to obtain a resultant vertical vector
- Use Pythagoras theorem on the two vectors to determine the magnitude of the resultant and use inverse tan to determine the direction of the resultant

For example, a object moves 5m at 45° above the horizontal and then 2.5m at 135° above the horizontal



Breaking up each vector and adding their horizontal and vertical components,

d_x=5cos45-2.5cos45≈ 1.77m

d_y=5 sin 45 + 2.5 sin 45 ≈ 5.3m

is obtained

To find the resultant, two vectors are added together using Pythagoras theorem and inverse tan:

D$\sqrt{1.77^2+5.3^2} \approx 5.99m$ at $\tan^{-1}\frac{5.3}{1.77}$= 71.6°

Describe and analyse, using vector analysis, the relative positions and motions of one object relative to another object on a plane

Analyse the relative motion of objects in in two dimensions in a variety of situations, for example:

- A boat on a flowing river relative to the bank

- Two moving cars

- An aeroplane in a crosswind relative to the ground

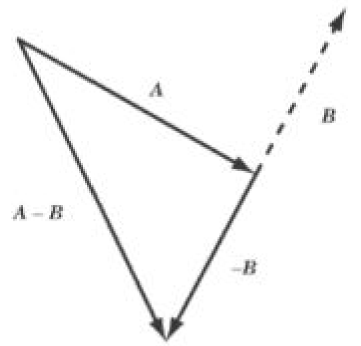
Relative velocity of an object is the velocity of the object as measured from a specific frame of reference

The velocity of A as measured from B is

$\vec{V}_{AB}=\vec{V}_A-\vec{V}_B$

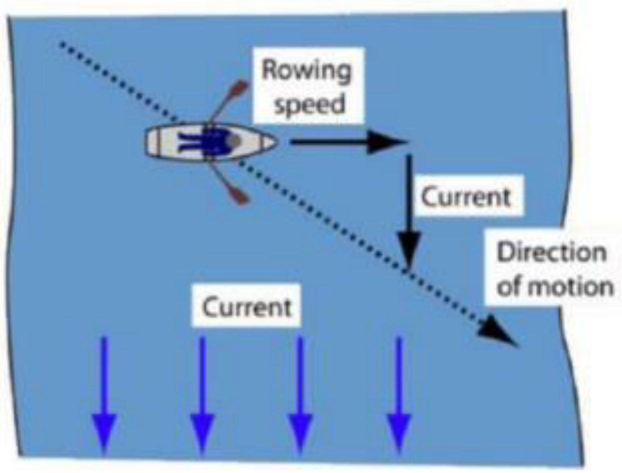
To find relative motions, subtracting the vectors is equivalent to adding the negative vector

$\vec{a}-\vec{b}=\vec{a}+(-\vec{b})$



A boat on a flowing river relative to the bank

A boats motion on a river is not always straight, as its motion is affected by the effects of the current



To find the velocity of the boat relative to the earth, we add the velocity of the boat relative to the water with the velocity of the water (relative to the earth):

$\vec{V}_{BE}=\vec{V}_{BW}+\vec{V}_{WE}$

This is equivalent, as expanding (using the relative velocity formula) the RHS gives the LHS:

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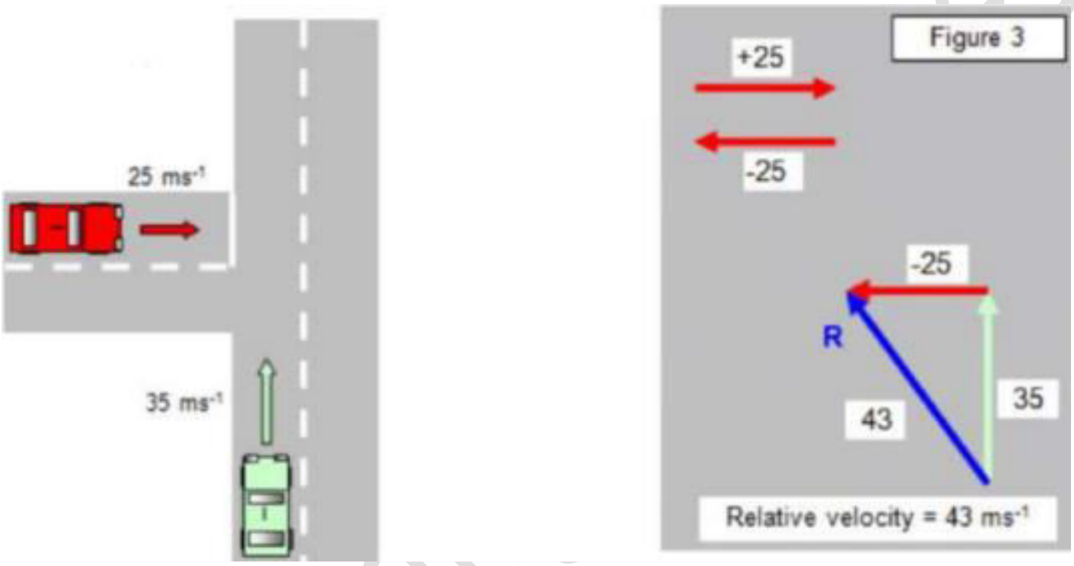
$\vec{V}_{BW}+\vec{V}_{WE}=\vec{V}_{B}-\vec{V}_{W}+\vec{V}_{W}-\vec{V}_{E}=\vec{V}_{B}-\vec{V}_{E}=\vec{V}_{BE}$

Two moving cars

To find the velocity of a car as measured from a different car, the relative motion formula is used

For example, consider two cars approaching the intersection

- Let the velocity of the red car be v_r and the green car be v_g



Using the relative motion formula, the velocity of the green car relative to the red car is:

$v_{gr}=v_g-v_r$

Using Pythagoras theorem and inverse tan once completing the vector diagram, v_{gr} is obtained to be 43ms^{-1} at 325°T

Plane crosswinds

This scenario is identical to the boat on a river scenario. The plane can be thought of as the boat and the crosswinds can be though of as the water current

Therefore the velocity of the plane (with respect to the ground) is the vector sum of the velocity of the plane (with respect to the air) and the velocity of the air (with respect to the ground):

$\vec{V}_{PG}=\vec{V}_{PA}+\vec{V}_{AG}$

Module 2: Dynamics

Using Newton's Laws of Motion, describe static and dynamic interactions between two or more objects and the changes that result from:
- A contact force
- A force mediated by fields

- Pushing on a box, horizontally and on an incline
- Interactions between magnets
- Interactions between charges
- Interactions between masses

A force is a push, pull, or a twist on an object due to its interaction with another object
This interaction can be either direct or indirect

Force is a vector quantity and is measured in Newtons (N)

Net force refers to the sum of all forces acting on a body
The forces acting on a body is balanced if the net force is equal to zero
If the resultant force is non-zero, then we say that it is unbalanced

There are two types of force:
Contact force requires two objects to physically touch each other, for example friction
Non-Contact forces are force mediated by fields, for example gravity

Newton's Laws of Motion

Newton's First Law

This is known as the law of inertia, it states that an object will remain at rest will remain at rest or in uniform motion in a straight line unless acted upon by an external unbalanced force
For example, if you throw a ball in space it will continue to travel at the same velocity forever, until acted upon by an external unbalanced force
However if you were to roll the ball on a surface on earth, it will eventually come to a complete stop
This is due to an unbalanced force, friction, which acts on the ball
Friction is a contact force that is created when two objects move or try to move against each other
Friction always acts in the opposite direction of the object's motion

Newton's Second Law

This law states that an object will only accelerate when subjected to a net unbalanced force. This is given by the equation:
$\Sigma F=ma$
Where the sum of forces is equal to the mass multiplied by its acceleration
The force of friction can again be analysed using Newton's Second Law. As friction opposes an object, it essentially causes it to decelerate and thus making come to a complete stop.

Gravity (a non-contact force can also be explained using this law, any object in Earth's gravitational field will accelerate toward the centre of the Earth at $9.8ms^{-2}$

Newton's Third Law

Newton's Third Law states that for every action, there is an equal and opposite reaction force.
For example, consider what happens when you sit on a chair. You exert a downwards force on the chair (due to your weight) and the chair pushes back on you with an equal upwards force such that the net force is balanced

- This force is known as a normal force and it is a type of static contact force. It always acts perpendicular to the surface that the object is in contact with
- Another common type of a contact force is tension. It is the force that is transmitted through a rope, string or wire when it is pulled tightly from each side
- It pulls equally on the objects on the opposite ends of the wire

Explore the concept of net force and equilibrium in one-dimension and simple two-dimensional contexts using:

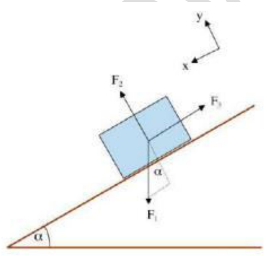
- Algebraic addition
- Vector addition
- Vector addition by resolution into components

Solve problems or make quantitative predictions about resultant and component forces by applying the following relationships:
- $\vec{F}_{AB} = -\vec{F}_{BA}$
- $F_x = F \cos \theta$, $F_y = F \sin \theta$

When a net force of zero acts on an object, we say that it is in an equilibrium

- This means that it has zero acceleration according to Newton's First Law

To solve physics problems, an analysis of all forces acting upon an object is transferred to a free-body diagram (which is an example of a vector diagram).
In a free-body diagram the magnitude of the is represented by the size of the arrow and the direction by the direction of the arrow.
The arrows are always drawn from the centre of the object.
To solve a problem, all forces must be identified and represented in a free body diagram



1. Find the x- and y- components of each vector.
2. Add the x- and y- components of each vector.
3. Draw a resultant vector.
4. Determine the magnitude of the resultant with the Pythagorean Theorem.
5. Calculate the angle of the displacement using Inverse Tangent.
6. Write a statement describing the magnitude with units, and direction with angle, of the displacement.

Conduct a practical investigation to explain and predict the motion of objects on inclined plane

Aim:
- To determine the acceleration of a trolley down a ramp due to its weight

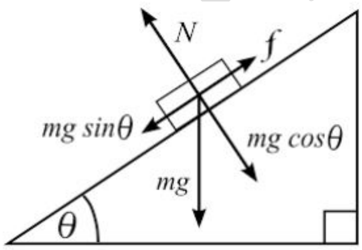
Equipment:
- Motion Sensor, interface and computer
- Dynamics trolley
- Runway
- Protractor
- Wooden Block

Method:
1. The runway was propped up at 45° angle of inclination
2. A wooden block was set up at the bottom of the ramp
3. A motion sensor was set up with a computer at the top of the ramp facing down the incline
4. The trolley was released from the top of the ramp and the data was recorded
5. Data logging software was configured to plot the trolley's velocity vs. time
6. The experiment was repeated five times

Results:
- The acceleration of the trolley was then found by taking the gradient of the graph
- This acceleration was due to the trolley's weight force parallel to the plane:

$$a = \frac{\Sigma F}{m} = \frac{mg\sin\theta - F_{friction}}{m}$$

- The force due to friction can also be calculated using the above expression



Apply Newton's first two laws of motion to a variety of everyday situations, including both static and dynamic examples, and include the role of friction $\vec{f}_{friction} = \mu \vec{F}_N$

Investigate, describe and analyse the acceleration of a single object subjected to a constant net force and relate the motion of the object to Newton's Second Law of motion using:

- Qualitative descriptions
- Graphs and vectors
- Deriving relationships from graphical representations including $\vec{F}_{net} = m\vec{a}$ and relations of uniformly accelerated motion

Newton's First Law states that an object will remain at rest or in constant uniform velocity in a straight line unless acted upon by an external unbalanced force.

Newton's First Law can be utilised to solve problems that involve objects at equilibrium

- This means, if an object is stationary/moving with a constant velocity even though there are many forces acting upon it the total of those forces must be equal to zero

Newton's Second Law states that a net force applied on an object causes it to accelerate according to the equation:

$\Sigma F = ma$

This law is usually used to solve problems that do not involve object at equilibrium and can be used to determine their acceleration.

Newton's First and Second Laws are usually associated with problems that involve friction.

Friction

Friction is created whenever two objects move or try to move against each other.

Friction always opposes the motion or the attempted motion of an object.

The formula for friction is given as:

$\vec{F}_{friction} = \mu \vec{F}_N$

Where μ is a non-dimensional number known as the coefficient of friction and F_N is the normal reaction force acting on the object.

As seen by the equation, the friction acting on an object is proportional to the magnitude of the contact force pushing the two surfaces together.

The coefficient of friction is dependent on the nature of the surface and is usually obtained experimentally.

- μ always has a value between 0 and 1 and the rougher the surface is, the higher the value.

There are two types of friction static and kinetic friction.

Static friction is the type of force that keeps an object at rest. It must be overcome before the object can move.

For example:

A block is being pushed that is initially stationary on a rough surface

- Initially the static friction is zero
- Once you start pushing it, the static friction increases
- Eventually the friction will reach a maximum value and once you exert a push greater the maximum value the block will start to move.

- It is given by the formula
    - $F_f \leq \mu_s N$

  μ_s increases with the applied force to keep the object at rest, until the applied force exceeds the maximum value of $\mu_s N$

Once the object is in motion, kinetic friction acts upon it to oppose the motion. It is given by the formula:

$F_k = \mu_k N$

Note that μ_k is different to μ_s, $\mu_k \leq \mu_s$

Acceleration

Acceleration of an object is its rate of change of velocity:

$a = \frac{\Delta v}{t}$

We can represent acceleration diagrammatically as the gradient of a velocity vs time graph

- The steeper the gradient, the larger the acceleration

Acceleration can also be represented using Newtons Second Law:

$\Sigma F = ma$

Apply the special case of conservation of mechanical energy to the quantitative analysis of motion involving:

- Work done and change in the kinetic energy of an object undergoing accelerated rectilinear motion in one dimension $W = F_{||}s = Fs \cos \theta$

- Changes in gravitational potential energy of an object in a uniform field $\Delta U = mg\Delta h$

In physics, energy is the capacity to do work

- It is a scalar quantity and is measured in Joules (J)

There are many forms of energy such as light, sound, heat, etc

The Law of Conservation of Energy

- Energy can neither be created nor destroyed; rather, it can be transformed or transferred from one form to another
- This means the total energy in the universe is always constant

There are two main types of energy kinetic and potential energy

Kinetic energy is the energy involved when an object is at motion. The faster the object is moving the heavier it is, the more kinetic energy it has, it is given by the formula:

$KE=\frac{1}{2}mv^2$

Potential energy is the energy that is stored in an object. For example, an object at a very high altitude will store more gravitational potential energy compared to an object at sea level

The mechanical energy of an object is the sum of its kinetic and potential energy

Work

In physics, work is the mechanical energy transferred to or from an object when it is moved over a distance by an external force

It is given by the formula:

$W=F_S$

Where the direction of the displacement and the force are the same

If the object moves at an angle of Θ to the direction of the force, then we use the formula

$W=F_S \cos \Theta$

That is, only the part parallel to the force matters

Work is measured in Joules (J) and although it is a scalar quantity, it is possible to have negative quantity

An important theorem is the work-energy theorem, which states that the work done on an object is equal to its change in kinetic energy:

$W= \Delta KE = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

Gravitational potential energy

When lifting an object, work is done to it by applying a force against the force of gravity

As work is the transfer of energy, this extra energy is stored in the object as gravitational potential energy (GPE)

The magnitude of GPE the object gains can be calculated using the formula for work:

$W = F_s = mas = mg\Delta h = \Delta U$

Thus, the higher the object, the more GPE it has

The law of conservation of mechanical energy states that the total mechanical energy in a system remains constant if the only forces acting are conservative forces:

$K_i+U_i=K_f+U_f$

Conduct investigations over a range of mechanical processes to analyse qualitatively and quantitatively the concept of average power $P=\frac{\Delta E}{\Delta t}$, $P=F_{||v}=F_V\cos\theta$ including but not limited to:

- Uniformly accelerated rectilinear motion
- Objects raised against the force of gravity
- Work done against air resistance, rolling resistance and friction

In physics, power is defined as the rate at which energy is transferred or transformed

It is given by the formula:

$$P = \frac{\Delta E}{\Delta t}$$

It is measured in watts (W) which is equal to J/s

In the case where only mechanical energy is involved, we can substitute W into ΔE to give:

$$P= \frac{W}{\Delta t} = F(\frac{s}{\Delta t})= F_v$$

The above formulae can used to solve problems involving power.

Module 3: Waves and Thermodynamics

Conduct a practical investigation involving the creation of mechanical waves in a variety of situations in order to explain:

- The role of medium in the propagation of mechanical waves

- The transfer of energy involved in the propagation of mechanical waves

Conduct practical investigations to explain and analyse the differences between

- Transverse and longitudinal waves

- Mechanical and electromagnetic waves

A wave is a form of oscillation accompanied by the transfer of energy

- It transfers energy without transfers energy without transferring mass

Some waves may require a medium to propagate while others do not

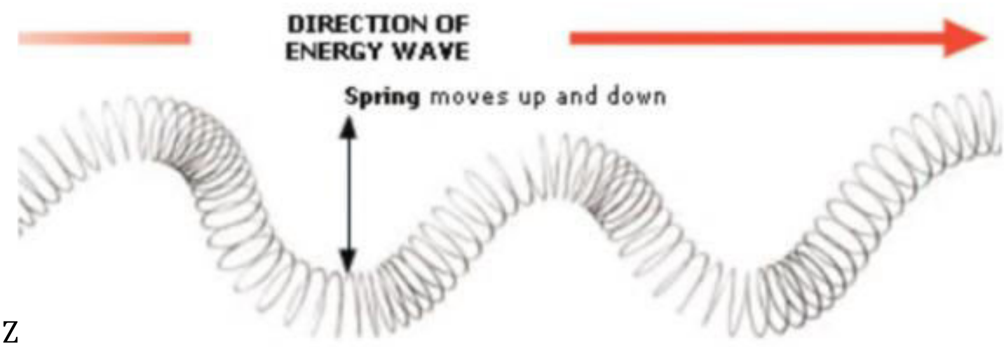
- Waves that require a medium are known as mechanical waves
- Waves that do not require a medium to transfer energy are known as non-mechanical waves

Mechanical waves can be further classified into transverse and longitudinal waves

In a transverse wave, the particles of the medium are displaced at right angles to the direction of the energy transfer (wave propagation)

For example, consider moving a slinky up and down

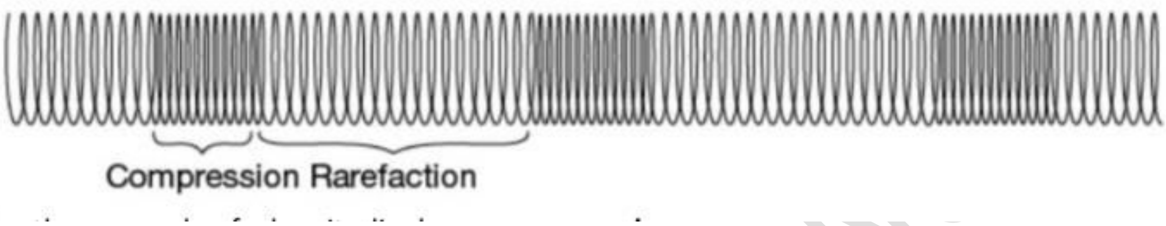
- The direction of energy transfer is away from you, however the actual slinky vibrates perpendicular to this (up and down)
- Hence it is called a transverse wave



In a longitudinal wave is one in which the particles of the medium are displaced in the same direction as energy transfer

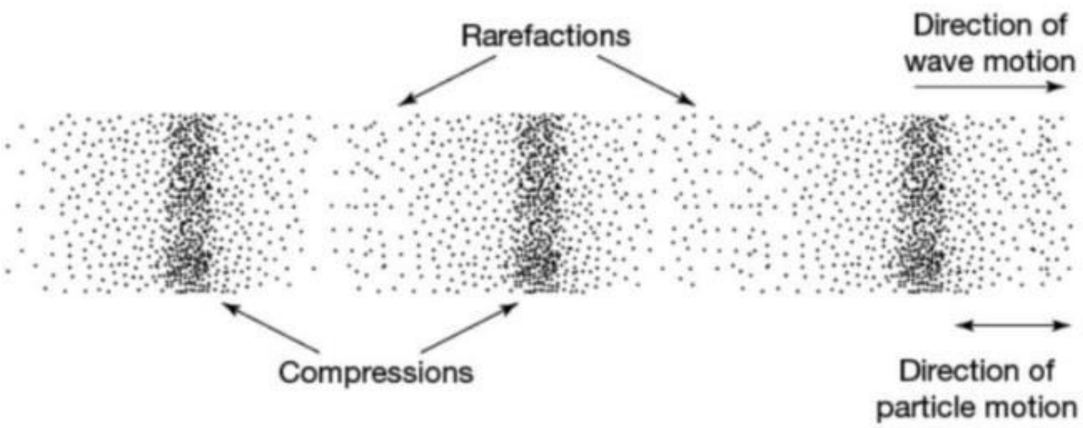
- As the particles move and forth parallel to the wave propagation, there will be areas with a high density of particles. This is known as compression
- Areas with low density of particles are known as rarefaction

For example, consider a slinky moving back and forth will produce a longitudinal wave



Another example of a longitudinal wave are sound waves

- Sound waves are when sound energy is transferred through the vibration of particles
- This is also why sound cannot travel through vacuum as there are no particles (medium) to transfer the energy

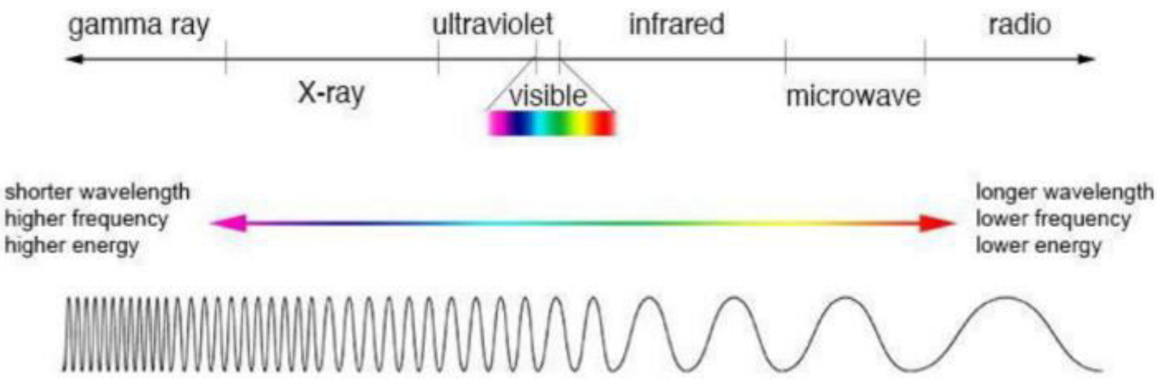


Note that in all mechanical waves, the particles of the medium have a net displacement of zero, as they return to their equilibrium position once the disturbance has passed

Electromagnetic waves are an example of non-mechanical waves, as they do not require a medium to transfer energy

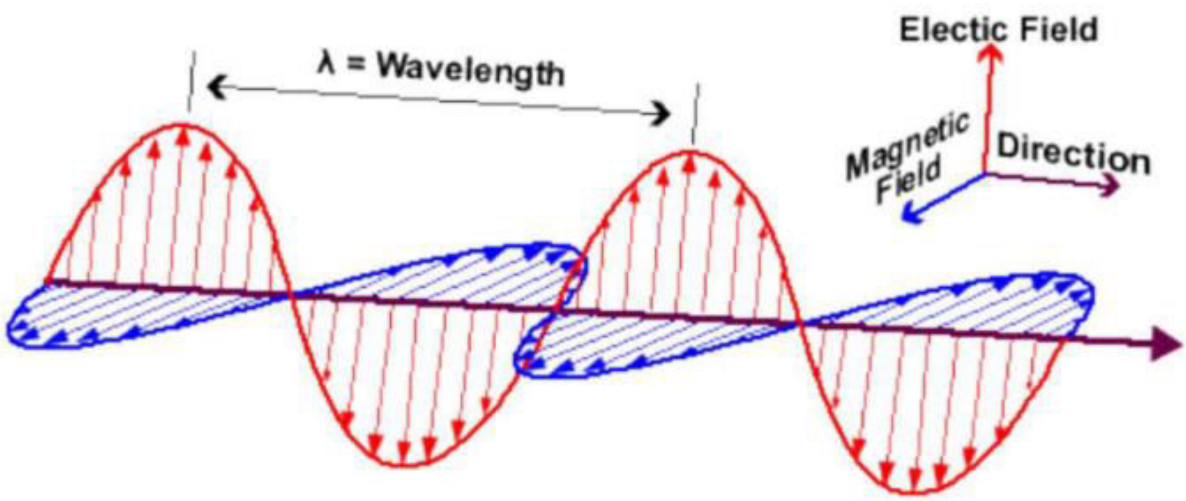
- Examples of EMR include the visible spectrum of light, UV radiation, radio waves, etc

- All EMR waves can travel through a vacuum



All EMR waves are composed of oscillating electric and magnetic fields (hence their name)

The electric field, magnetic field and the direction of propagation are all perpendicular to one another



All EMR waves travel at c ($3*10^8 ms^{-1}$) in a vacuum

While mechanical waves are generated from the vibration or disturbance in a medium, EMR waves are generated from the accelerated motion of charged particles

Summary of difference between EMR and mechanical waves

Mechanical	Electromagnetic
Longitudinal or transverse	Transverse
Requires a medium	Does not require a medium
Slower (sound in air ~340m/s)	Travels at c in a vacuum
Initiated a disturbance in a medium	Initiated by an accelerated charged particle
Faster in solids	Fastest in a vacuum

solve problems and/or make predictions by modelling and applying the following relationships to a variety of situations:

– $v=f\lambda$

– $f= 1/T$

– $k= 2\pi/\lambda$

construct and/or interpret graphs of displacement as a function of time and as a function of position of transverse and longitudinal waves, and relate the features of those graphs to the following wave characteristics:

– velocity

– frequency

– period

– wavelength

– wave number

– displacement and amplitude

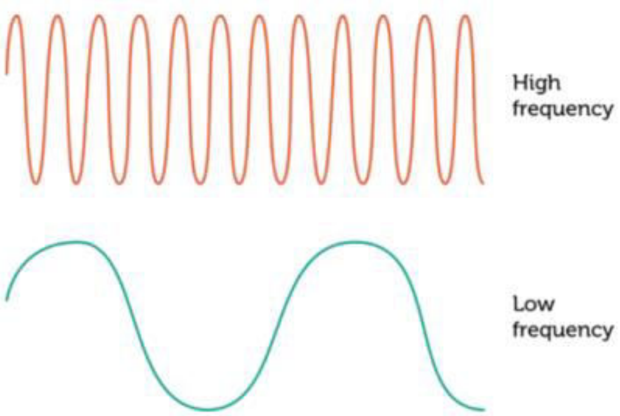
Crest are maximum positive displacement on a transverse wave while troughs are maximum negative distance on a transvers wave

The period of the wave is time for the wave to pass a fixed point

- It is easily calculated by determining the time difference between two successive crests/trough on a time vs displacement graph
- It is represented by the symbol T and is measured in second (s)

The frequency of a wave is a measure of the number of waves passing a fixed point per second

- It is represented by the symbol f and is measured in Hertz ($Hz=s^{-1}$)
- Higher frequency sound waves have a higher pitch
- Period and Frequency are calculated through the equation:
- $T=\frac{1}{f}$



The wavelength of a wave is the distance between two successive points on wave

- It is determined by measuring the distance between two successive crests/troughs on a position vs displacement graph
- It is represented by lambda (λ) and is measured in metres (m)

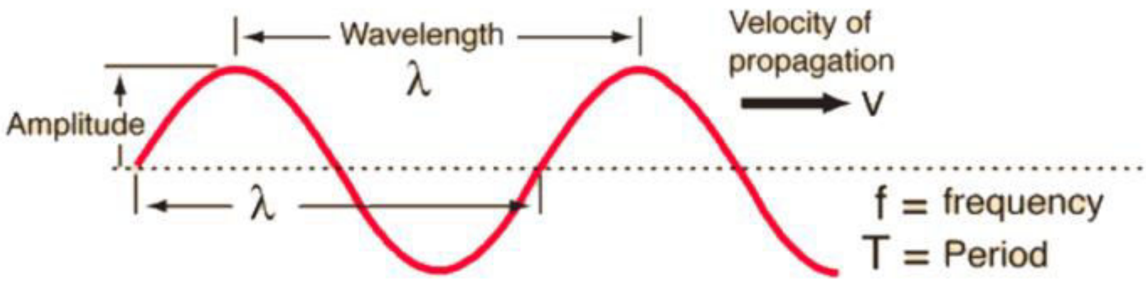
The amplitude of a wave is the difference the maximum displacement and the equilibrium (rest) point of a wave

- It is represented by the symbol A and is measured in metres
- The higher the amplitude of a sound wave, the louder they are

The velocity of a wave is related by its wavelength and its frequency and is therefore given by the equation:

$v = f\lambda$

- Velocity is represented by v and is measured in m/s
- As all EMR waves travel at the speed c, the frequency of EMR is inversely proportional to their wavelength
- $F = \frac{c}{\lambda}$



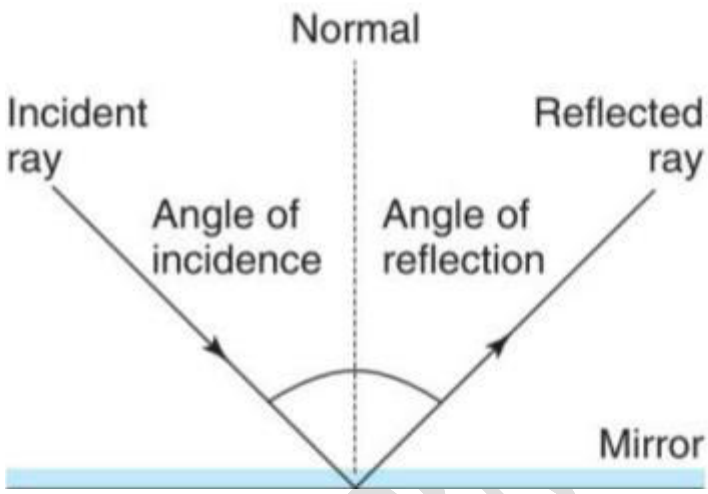
Explain the behaviour of waves in a variety of situation by investigating the phenomena of:

- Reflection
- Refraction
- Diffraction
- Wave superposition

Reflection

Reflection is the phenomena when a wave encounters a wall or a boundary and gets bounced back

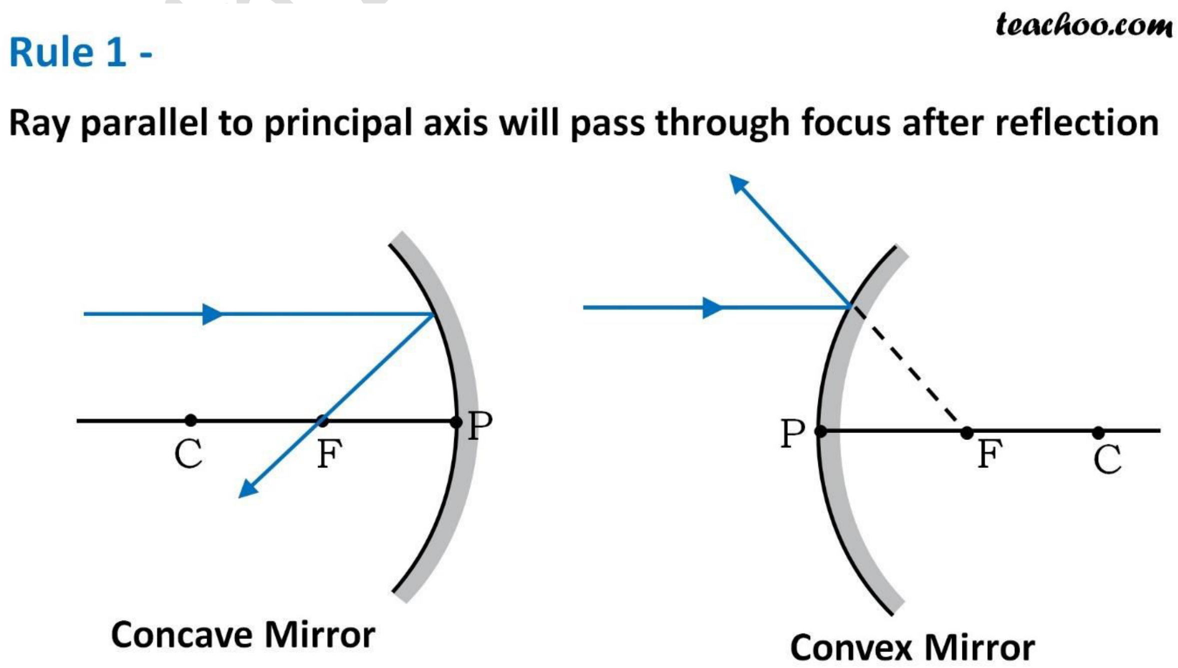
- All waves follow the law of reflection, which states that the angle of incidence (angle between the incidence ray and the normal) is equal to the angle of reflection (angle between the reflected ray and the normal)
- $\Theta_i = \theta_r$



Properties such as velocity, frequency etc remain constant after being reflected

Mirrors of different shapes can utilise reflection for many purposes

- For example, convex mirrors reflects and diverges the light. Hence it can be used to see 'around corners'
- A concave mirror, or converging mirror, has a reflecting surface that is recessed inward (away from the incident light). Concave mirrors reflect light inward to one focal point. They are used to focus light.

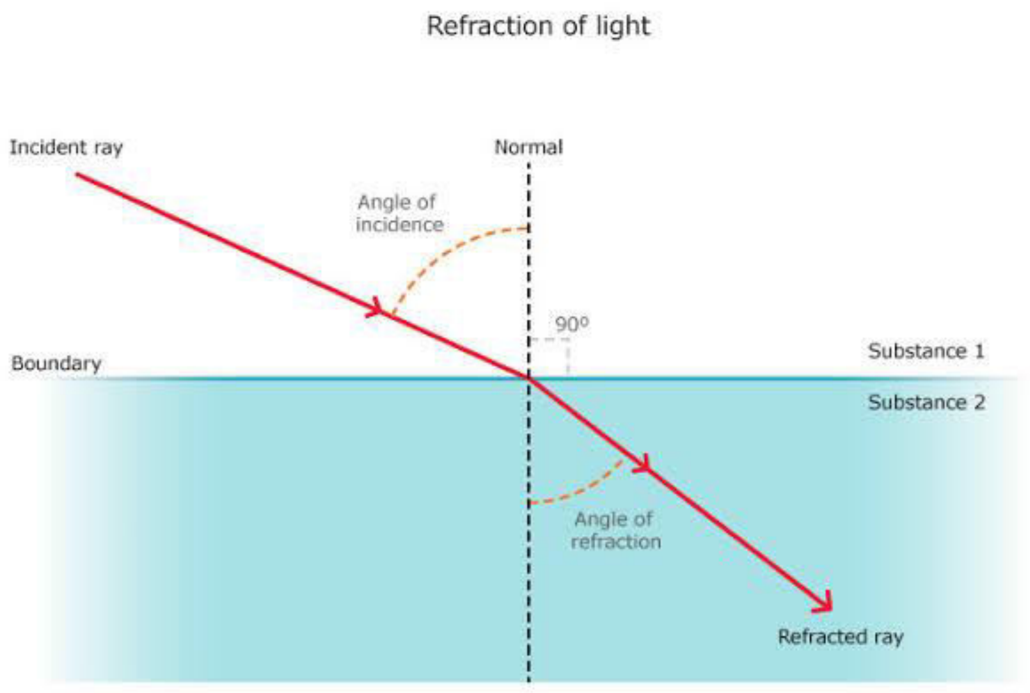


Refraction

When a wave encounters a barrier, it may also pass through the medium of the barrier, this is known as refraction

As the wave enters the new medium, its velocity changes due to the changes in the medium's density

- This change in velocity causes a change in direction of the wave, and thus causing it to bend

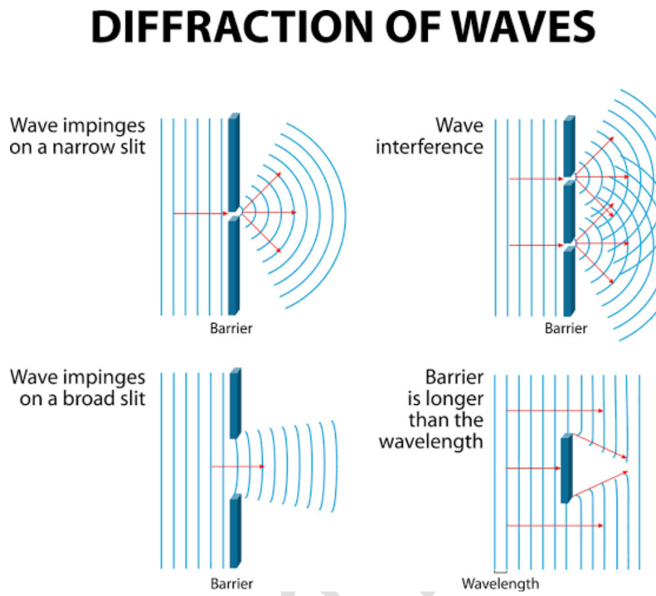


- Refraction is the reason why some objects in water appear to be disjointed or bent at the interface between air and water

Diffraction

Diffraction occurs when the waves pass through an opening or meet an obstruction and seemingly ‘bend’ or change direction

- The larger the wave the wavelength relative to the obstruction, the larger the diffraction



Wave superposition

When two or more waves meet, they interference with each other, producing a net resultant wave

This interference is known as superposition and the principle of superposition states that if two or more waves of the same type pass through the same medium at the same time, the displacement of any point is the sum od the individual displacement of each wave(adding the amplitudes)

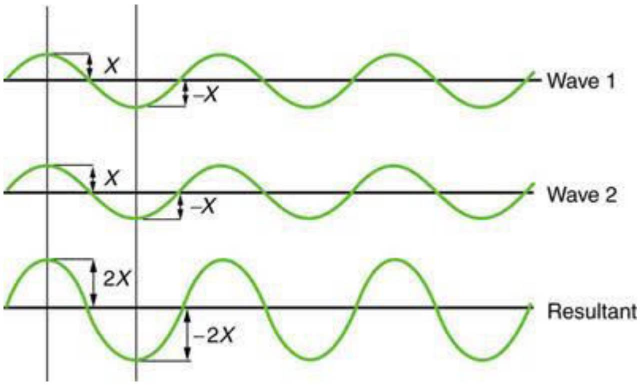
- To find the net resultant wave, add the individual amplitudes of the interfering waves:

  ### Constructive Interference

  Then two waves with the same frequency and amplitude travelling in the same direction superimpose in phase, the resulting wave will have twice the amplitude

  This is known as constructive interference

  - Constructive interference of sound will produce louder sound

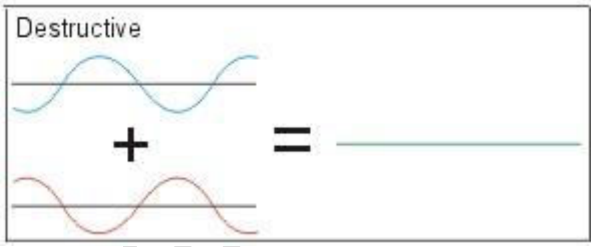


Destructive Interference

When two waves with same frequency and amplitude superimpose when 180 degrees out of phase, they cancel out resulting in 0 amplitude

This is known as destructive interference

- Destructive interference of sound will produce no sound



Conduct an investigation to distinguish between progressive and standing waves

Progressive waves are waves that move freely through the medium until an interface is met

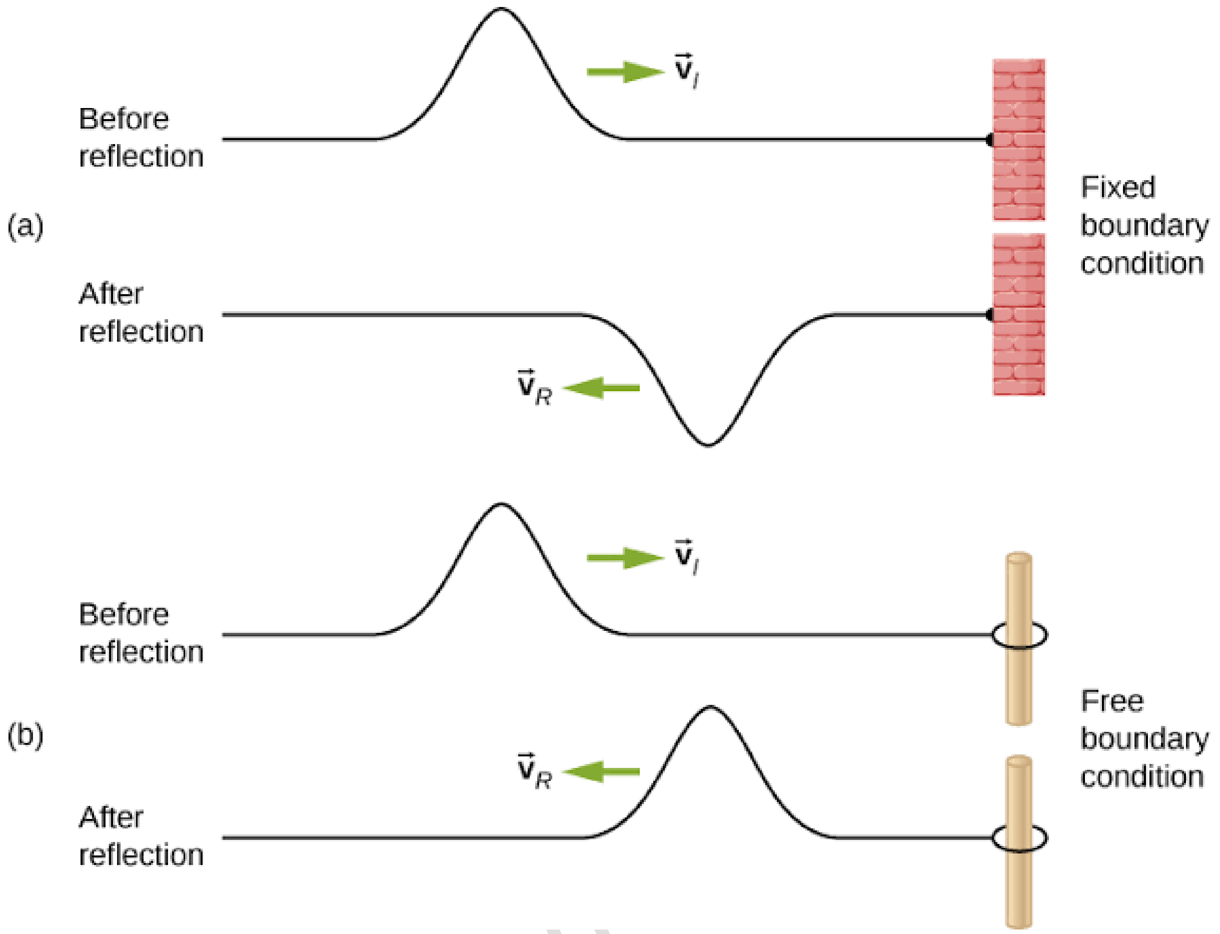
However, in certain conditions, some waves may appear to be stationary or still, these are known as standing waves

If a wave is reflected at some fixed end, the wave is inverted with respect to the incidence wave

- This is known as fixed boundary condition

If a wave is reflected at some free end the reflected wave is not inverted with respect to the incidence wave

- This is known as free boundary condition



Standing Waves

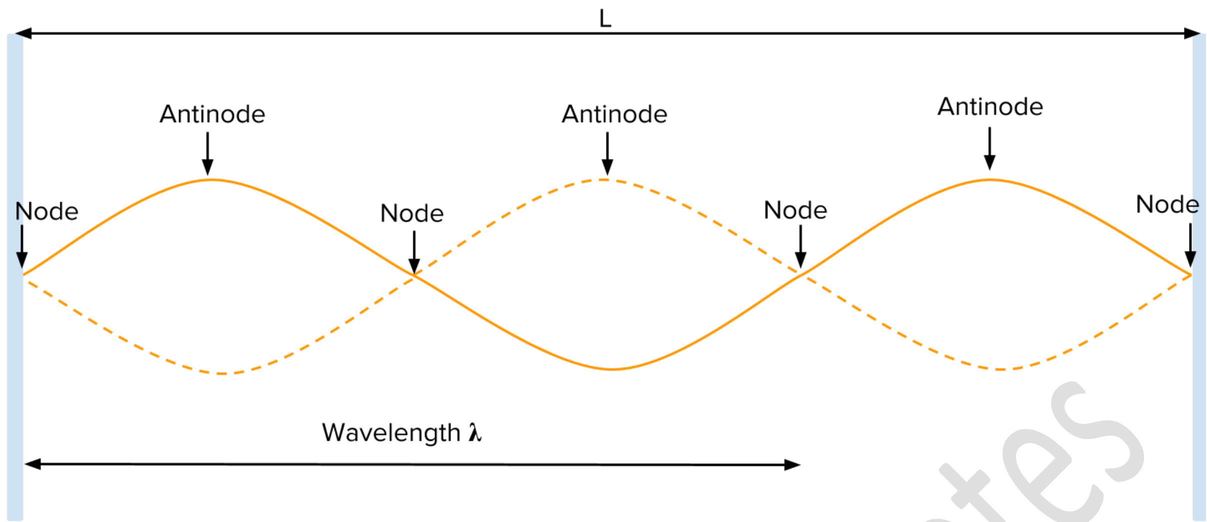
When a wave gets reflected off some boundary, the interference between the incident and the reflect ray may produce a wave that seems to be stationary

For a certain wavelength, the resultant wave will have constructive and destructive interference evenly placed

- This interference results in the superimposed wave to appearing fixed in position and hence they are known as standing wave
- The max amplitude of the wave at any point in space is constant with time

The points where destructive interference takes place, (zero amplitude) is known as nodes

The points where constructive interference takes place, that is, (maximum amplitude) is known as anti-nodes



The nodes and anti-nodes occur at evenly spaced, fixed intervals and the distance between them is half of the wavelength

$L=\frac{\lambda}{2}$

The anti-nodes can either be observed crests or troughs as the point is continually moving up and down with time

Conduct an investigation to explore resonance in mechanical systems and the relationships between:

- Driving frequency
- Natural frequency of the oscillating system
- Amplitude of motion
- Transfer/transformation of energy within the system

When an object is hit, disturbed, etc, the object tends to vibrate at a particular frequency

- This frequency which an object tends to vibrate with when disturbed is known as natural frequency

If the amplitude of the vibrations is large enough and if the natural frequency is within the human frequency range, then the vibrating object will produce sound waves that are audible

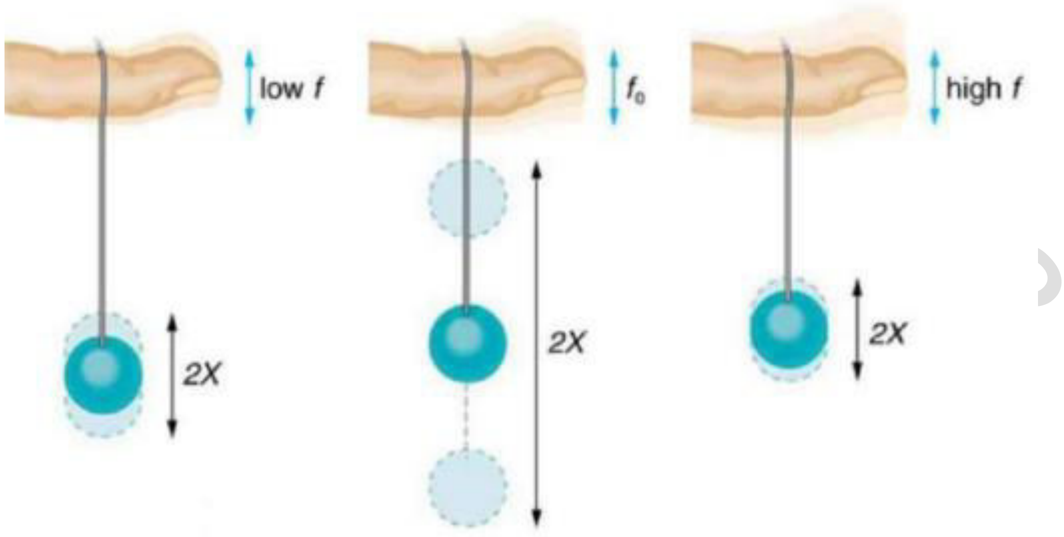
For example, based on the type of metal, length and spacing of the two prongs, a tuning fork will vibrate at the same rate regardless of how hard it is struck

On the other hand, a forced vibration occurs when a body is made to vibrate through the contact with another vibrating body

If an object is continually vibrated with the same frequency as its natural frequency, we are essentially driving it and this frequency is known as driving frequency

- When an object is driven a with its natural frequency, energy is transferred to its oscillation and thus its amplitude increases

For example, consider a paddle ball suspended from a finger



As it is being driven at its natural frequency (i.e. move it up and down), the ball's oscillation increases in amplitude rapidly as long as we keep driving it

- If is being driven at a lower or a higher frequency, then the energy is transmitted less effectively, and thus there won't be a massive increase in amplitude

The phenomenon of driving a system with a frequency equal to its natural frequency is known as resonance

Although resonance is useful in physics it may cause undesirable effects, especially in engineering

For example, in 1940, the blowing of wind against the Tacoma suspension bridge was at such a frequency that it resonated with the bridge's natural frequency

- This drove the energy of the bridge and put it in an unstable swinging state that eventually saw its collapse

Model the behaviour of sound in air as longitudinal wave

Relate the displacement of air molecules to variation in pressure

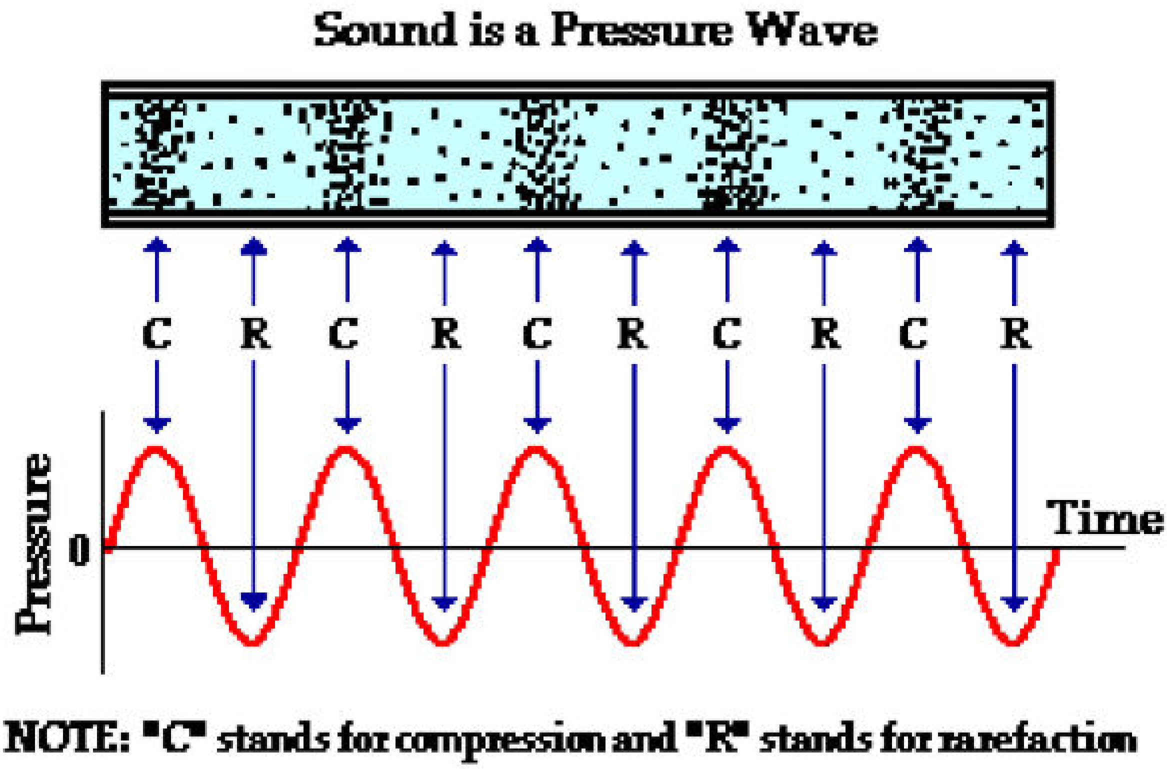
Sound waves are longitudinal waves

- Sound waves are part of mechanical waves, as sound waves must need a medium to propagate through

This means that the particle of the medium oscillate parallel to the direction of energy transfer

Compression is when there is a high density of particles (a high pressure) and rarefaction is when there is a low density of particles (a low pressure)

- Compression allows sound waves to be represented as sinusoidal wave, where the crest represents the areas of compression, and the troughs represent the areas of rarefaction



The more closely packed the particles, the easier for the energy to travel through vibrations and hence the speed of sound

- This is why sound has a speed about 4500m/s in concrete but only a speed of 340m/s in air

Conduct a practical investigation to relate the pitch and loudness of a sound to its wave characteristics

Investigate quantitatively the relationship between distance and intensity of sound

Conduct investigations to analyse the reflection, diffraction, resonance and superposition of sound waves

Pitch and Loudness

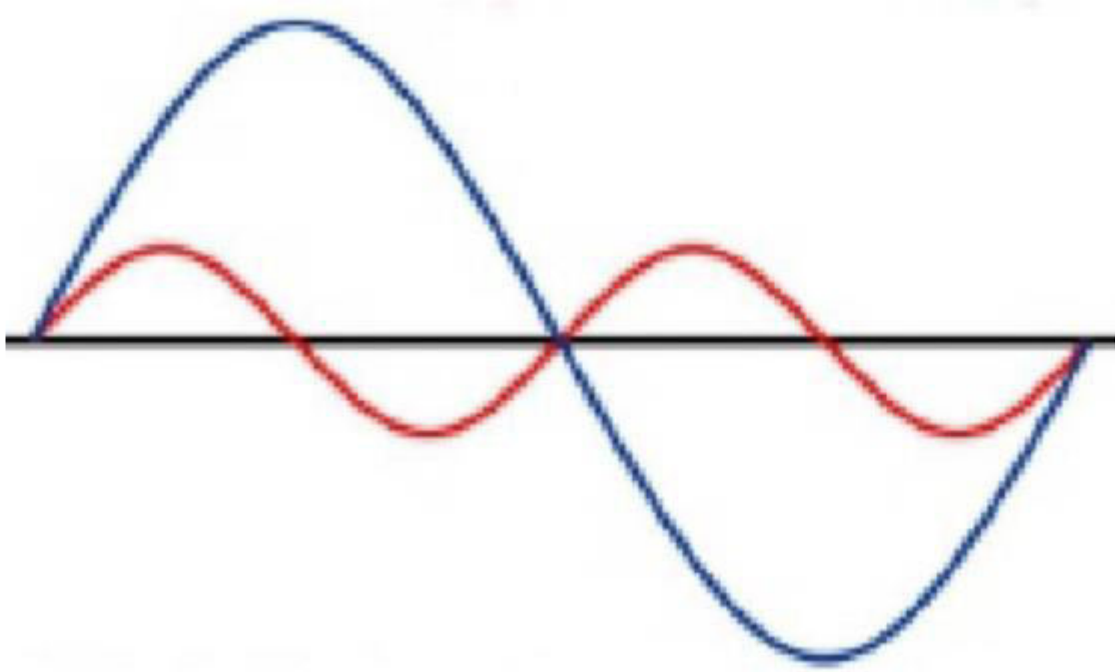
The term loudness refers to the amplitude of the sound wave

- The higher the max displacement of particle, the larger the amplitude and hence the louder the sound

The term pitch refers to the frequency of the sound wave

- The larger the frequency, the higher the sound wave

For example, consider:



- The blue wave has a higher amplitude than the red, and thus its is seen louder wave
- However, the red wave has a higher frequency than the blue, and thus it has a higher pitch

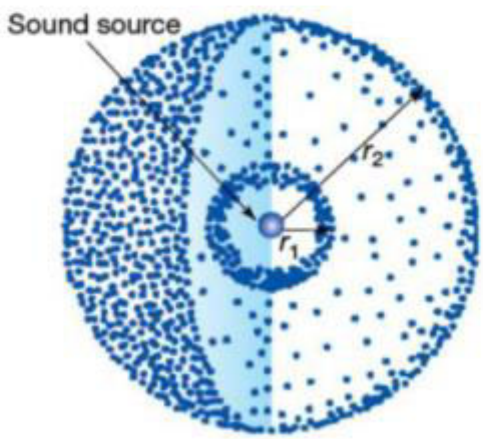
Intensity

The intensity (I) of a sound wave is a measure of the energy it can transfer per unit area in a one second time interval

- As the rate of change in energy is equal to the power (measured in Watts, W) the units of intensity of power is power per unit area,
- $\frac{w}{m^2}$

Intensity can be interpreted to be the variation in loudness with distance

For example, consider:



- The power remains the same, but the area that the energy is distributed over changes
- The area is equal to the surface area of the sphere of radius r:
- $SA=4\pi r^2$
- And hence the formula for the intensity:
- $I=\frac{p}{4\pi r2}$
- The intensity of sound is inversely proportional to the distance from its source
- $I\alpha\frac{1}{d^2}$
- This relation is known as the inverse square law

Humans are able to hear sounds with intensity as low as $10^{-12}Wm^{-2}$, however it is harder to distinguish between sounds of larger intensities

For this reason, a logarithmic scale is used to represent intensity, known as the decibel scale

$$L = 10\log_{10}\left(\frac{1}{I_0}\right)$$

- I_0 is the softest audible sound equal to $10^{-12}Wm^{-2}$

Wave properties

Many of the wave properties also applies to sound waves. These include:

- Reflection
- Diffraction
- Resonance
- Superposition

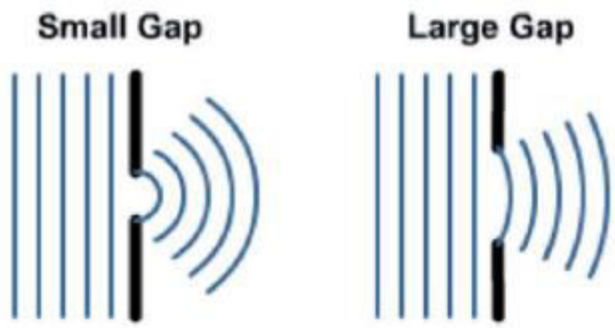
Reflection is when a wave meets a boundary and bounces off

- The incidence angle is always equal to the reflected angle (Law of Reflection)

The reflection of sound waves finds many uses in echolocation and ultrasound as the distance between a body and the source can be determined by using known values for the speed of sound in the medium and the measured of time

Diffraction occurs when waves pass through an opening or meet an obstruction and bend or change direction

- The larger the wavelength relative to the obstruction, the larger the diffraction



- Diffraction is thus the property that makes it possible to hear sounds from around corners, in other rooms and over hills

Superposition

When two sources emit sound of same frequency at the same time, they are said to be in phase

Maxima are the points of constructive interference where the two waves are still in phase

- These occur at coinciding compressions and rarefactions

Minima are the points of destructive interference where one wave has a different phase due to the extra distance covered and hence cancels out some of the other wave

To determine if superimposing waves produce a constructive interference or destructive interference, path length is used

- The path length is the difference between the distance travelled by the sound from each source to point P

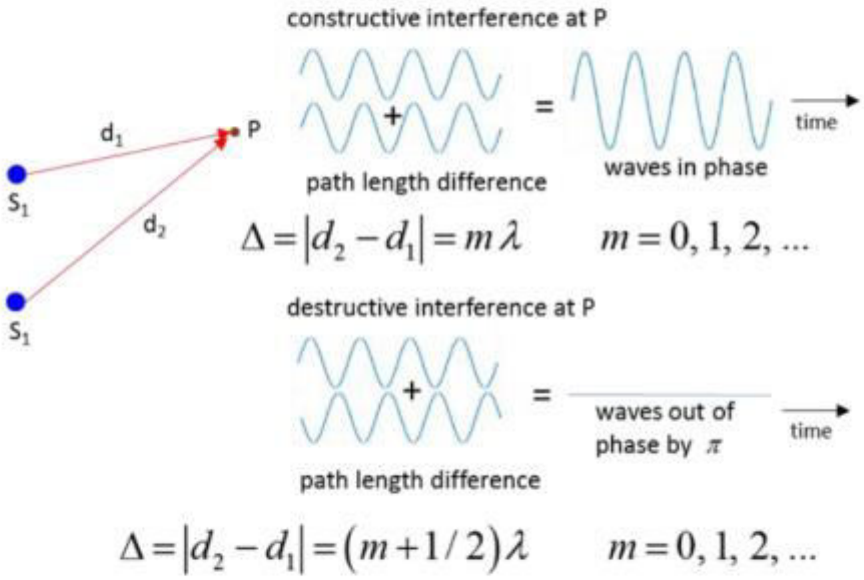
Constructive interference happens at point P if the waves are in the same point in their cycle

- The path difference of the two waves must be equal to an integer multiple of their wavelength
- $d(PS_1) - d(PS_2) = n\lambda$
- $d(PS_1) - d(PS_2)$ is the difference in path length between the two waves

Destructive interference happens at a point P if the waves are exactly 180 out of phase in their cycle

- The difference of the waves must be equal to half of an odd integer multiple of their wavelength

$$d(PS_1) - d(PS_2) = \left(n + \frac{1}{2}\right)\lambda$$



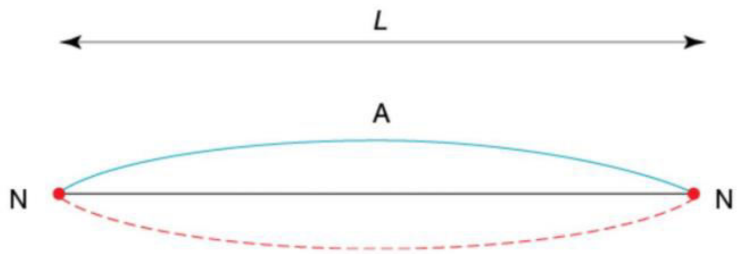
Investigate and model the behaviour of standing waves on strings and/or in pipes to relate quantitively the fundamental and harmonic frequencies of the waves that are produced to the physical characteristics (e.g. length, mass, tension, wave velocity) of the medium

In a standing wave

- Nodes are points along the line of zero displacement
- Anti-nodes are points along the line of max displacement (that is, either the crests or the line of max displacement (either the crests or troughs of standing waves)
- The distance between successive anti-nodes/ nodes is $\frac{\lambda}{2}$

A simple type of standing wave is formed by a string

- When both ends of the are fixed then plucked, the tension in it will cause it to continually vibrate until it loses sufficient energy to do so
- This produces a standing wave with an anti-node in the middle and two nodes at each end (as the ends are fixed):



The above case (where there is a single anti-node in the centre) represents the fundamental frequency (of first harmonic), f_0

Since the distance between the ends (nodes) must be half the wavelength

$L=\frac{1}{2}\lambda_0$

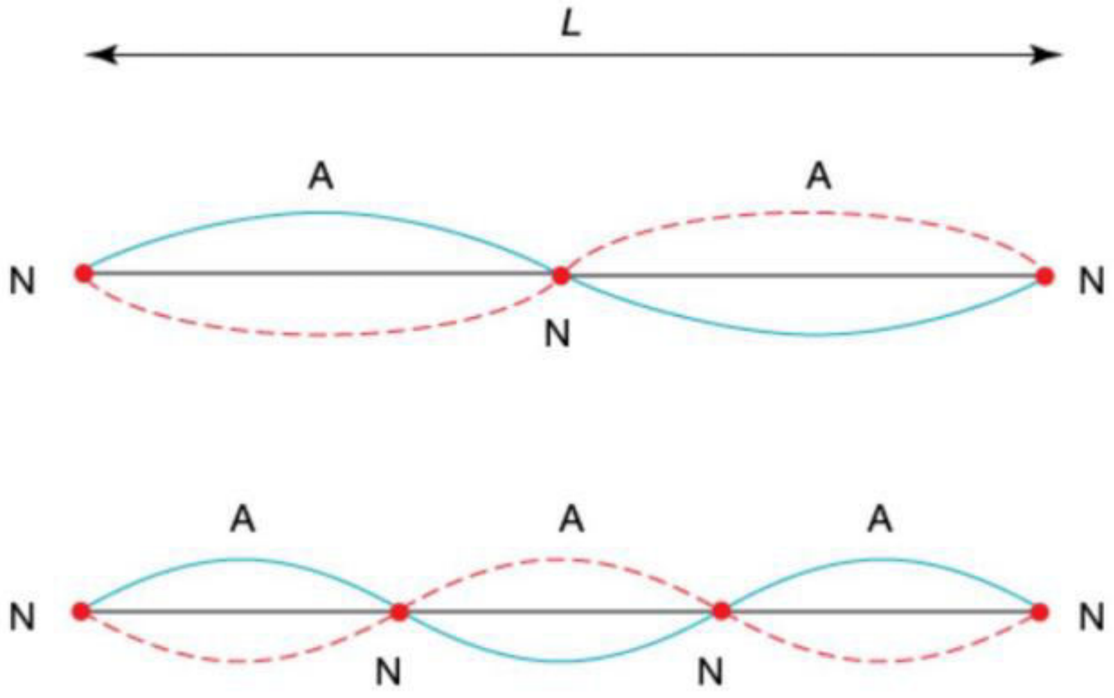
$\lambda_0 = 2L$

Substituting this into the wave equation

$$f_0 = \frac{v}{2L}$$

Harmonic frequencies are integer multiples of the fundamental frequencies

- The second harmonic frequency, f_1 happens when there are 2 anti-nodes, and thus the length of the string is equal to the wavelength
- The third harmonic frequency, f_2 happens when there are 3 anti-nodes, and thus the length of the string is equal to $\frac{3}{2}$ of the wavelength



This means that:

$$f_1 = \frac{v}{L}$$

$$f_2 = \frac{3v}{2L}$$

Following this pattern:

$$\lambda_n = \frac{n+1}{2}L$$
$$fn = \frac{(n+1)v}{2L}$$

- n+1 is the number of anti-nodes formed in the standing wave

The wave speed can be determined along a string given its mass and tension by using the formula:

$$V = \sqrt{\frac{T}{m\ /\ L}}$$

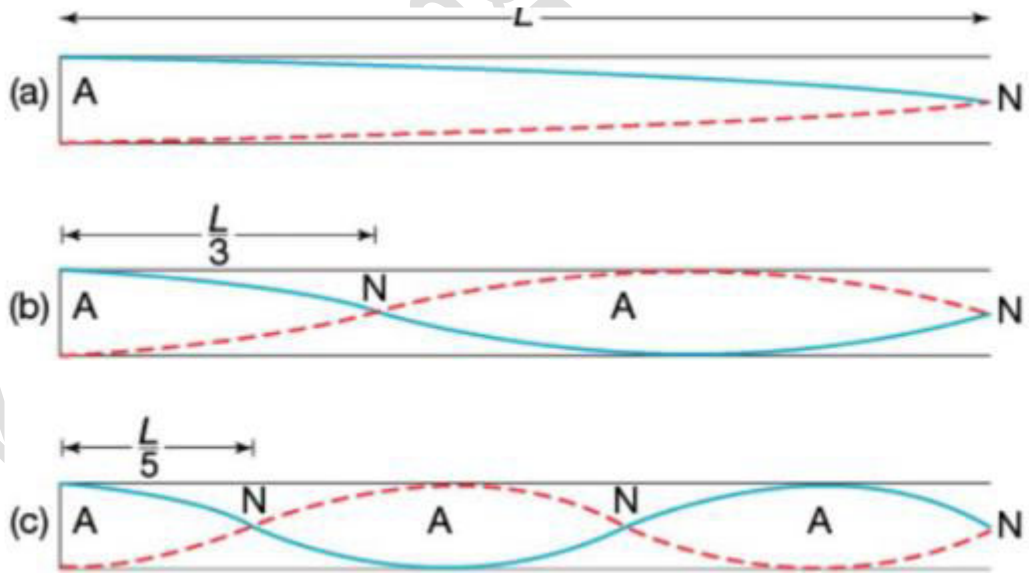
Resonance in Close Pipes

Standing are not limited to strings or transverse waves, but can also appear in scenarios involving pipes

Consider a pipe in which one end is close and another is open

- By analysing the particles outside and inside the pipe, the closed end will have a pressure anti-node and the open end will have a pressure nod

Thus, at the fundamental frequency for a closed pipe, one end will have an anti-node and the other will have a node, all separated by a distance of L



For the fundamental frequency (the first case)

$$\lambda_0 = 4L$$
$$\therefore f_0 = \frac{v}{4L}$$

For the 2nd harmonic frequency

$$\lambda_1 = \frac{4}{3}L$$

$$\therefore f_1 = \frac{3v}{4L}$$

For the 3rd harmonic frequency

$$\lambda_2 = \frac{4}{5}L$$

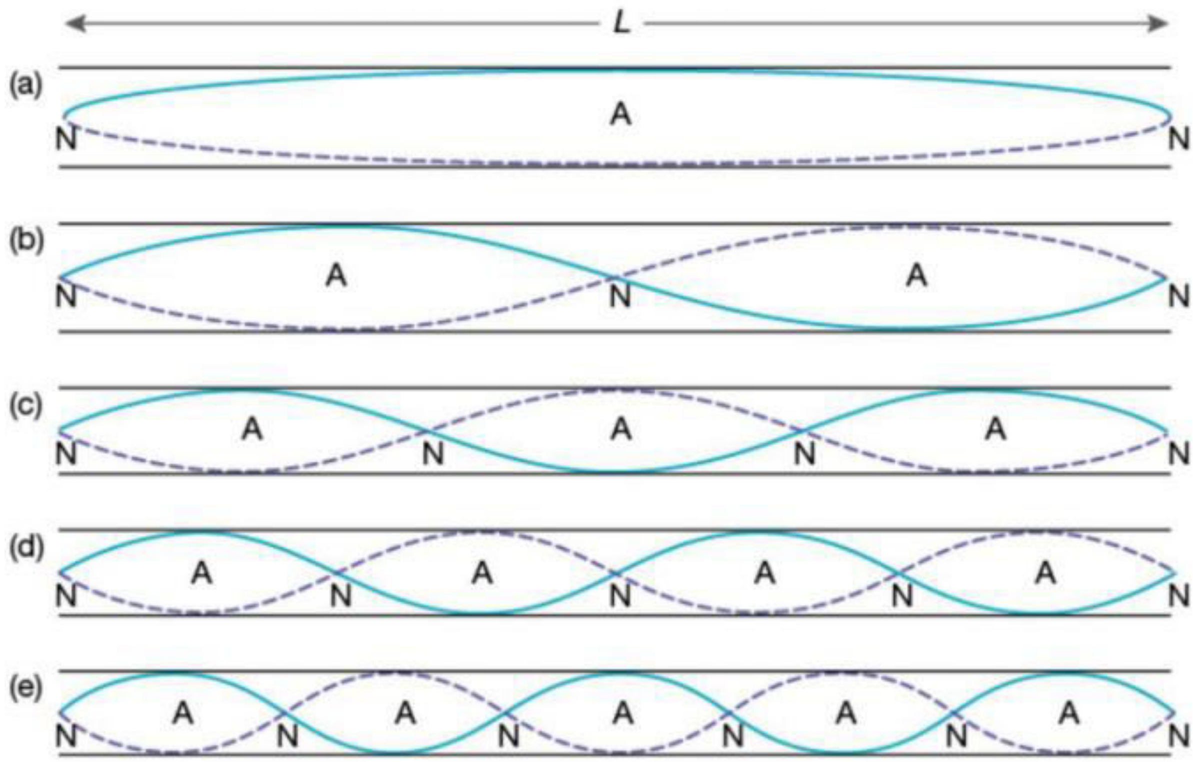
$$\therefore f_2 = \frac{5v}{4L}$$

Following this pattern:

$$\lambda_n = \frac{4}{2n+1}L$$

$$f_n = \frac{2n+1}{4L} = 2(n+1)f_0$$

- The standing waves of up to the 6th harmonic in an open pipe is shown below



And thus, similar to strings

$$\lambda n = \frac{n+1}{2}L$$

$$f_n = \frac{(n+1)v}{2L}$$

Formula Table

Structure	Formula
String	$f_n = \frac{(n+1)}{2L} * v = (n+1) * f_0$
One closed-end pipe	$f_n = \frac{(2n+1)}{4L} * v = (2n+1) * f_0$
Open pipe	$f_n = \frac{(n+1)}{2L} * v = (n+1) * f_0$

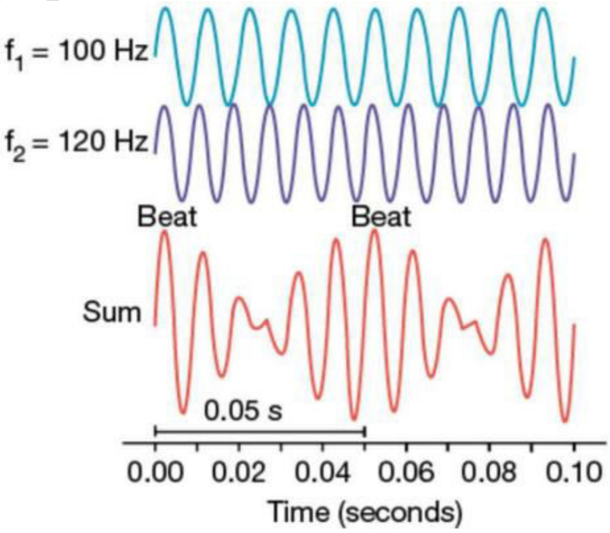
Analyse qualitatively and quantitively the relationships of the wave nature of sound to explain:

Beats $f_{beat}=|f_2-f_1|$

The Doppler effect $f'=f\frac{(v_{wave}+v_{observer})}{(v_{wave}-v_{source})}$

Beats

When two sound waves with similar amplitude but different frequency superimpose, the waves will result in a rhythmic wave with alternating areas of constructive interference and destructive interference



The variation in amplitude (and thus loudness) is termed 'beats'

The beat frequency is given by the difference between the two superimposing waves

$f_{beat}=|f_2-f_1|$

- In the above example, the beat frequency is 120-100=20Hz

Doppler effect

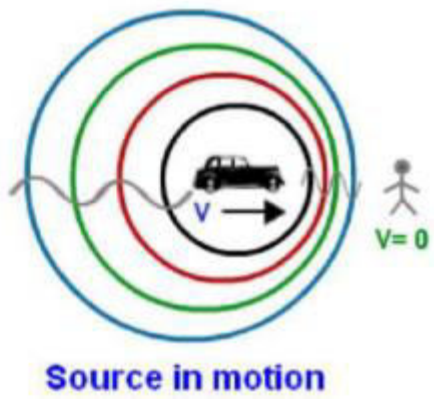
The Doppler effect is the change in the wavelength/frequency of a wave as a result of relative motion between the source and the observer

Consider an ambulance approaching an observer

- As the ambulance is approaching them, the sound will be higher in pitch
- This is due to the wave front gets compressed and thus resulting in a higher frequency and a higher pitch
- However, when the ambulance is travelling away from the observer, the wave can be thought of as being stretched
- This results in a larger wavelength and thus a smaller frequency and having a lower pitch

This apparent change in the frequency/wavelength due to relative motion is known as the doppler effect

- The amplitude does not change, only the frequency/wavelength does



Formulas can be derived for the doppler effect by analysing various scenarios involving relative motion and frequency change

For an observer and source moving towards one another, the new frequency perceived as a result of doppler effect is given by the formula

$f' = f\frac{v+v_0}{v-v_S}$

- f' is the perceived frequency due to the doppler effect
- f is the original frequency of the wave
- v is the velocity of the wave
- v_0 is the velocity of the observer

- v_s is the velocity of the source

For an observer and source moving away from one another, the perceived frequency is given by the formula

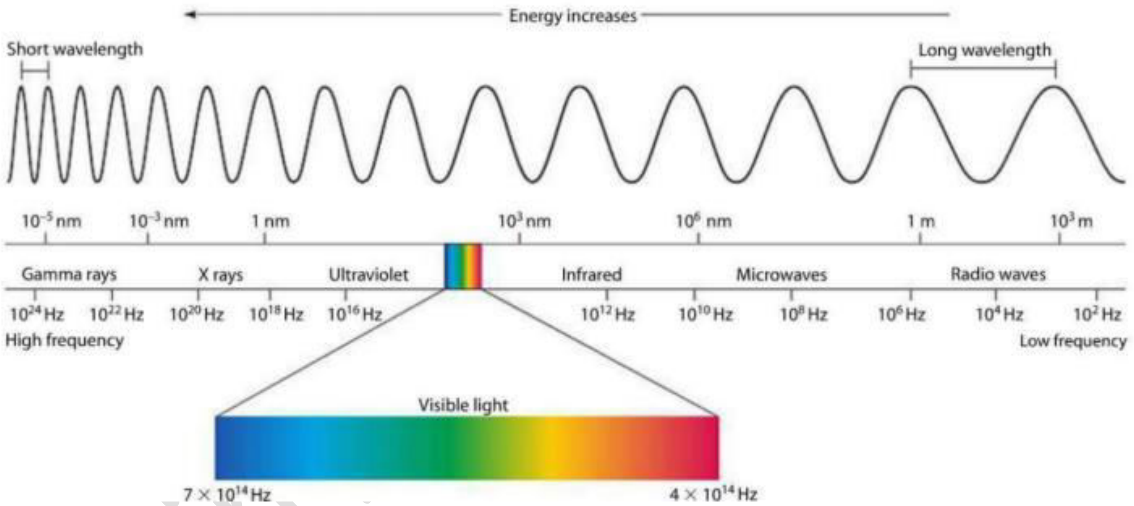
$f' = f\frac{v - v_0}{v + v_s}$

Conduct an investigation to analyse the formation of images in mirrors and lenses via reflection and refraction using the ray model of light

Conduct a practical investigation to demonstrate and the relationship between inverse square law, the intensity of light and the transfer of energy

Electromagnetic waves are non-mechanical waves, in that they do not require a medium to transfer energy

- The visible spectrum of the electromagnetic waves is referred to as light



- All non-mechanical waves travel at the speed of light ($c=3*10^8 ms^{-1}$) and are self-propagating

As light is a wave, they always travel in straight lines and can be reflected, refracted, absorb and exhibit any wave properties

- This is known as the ray model of light

Reflection

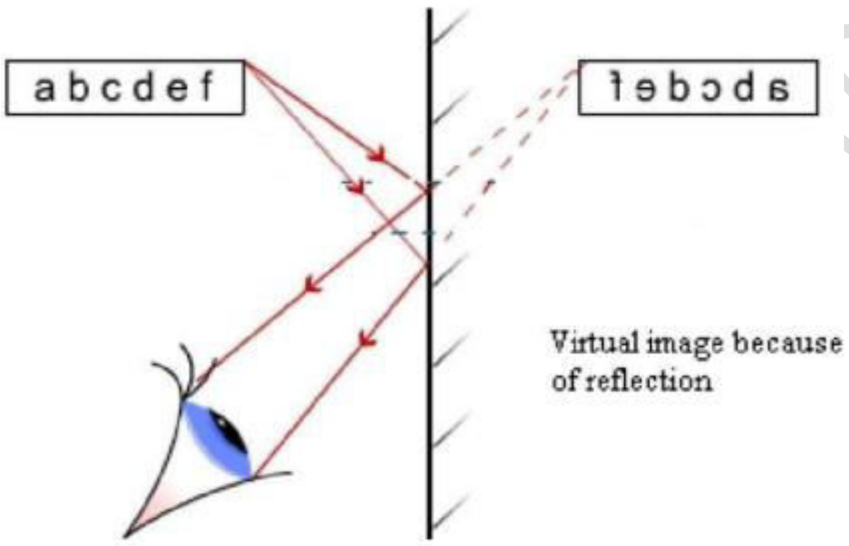
Light behaves in the same way as other waves, when light meets a boundary, or enters a new medium. It may undergo reflection, where the incident rays bounces off the boundary and changes direction

The Law of Reflection will still hold, the incident angle (angle between the incident ray and normal) will always be equal to the reflection angle (angle between the reflected ray and the normal)

- This means that light will also reflect off irregular surfaces and even curved surfaces

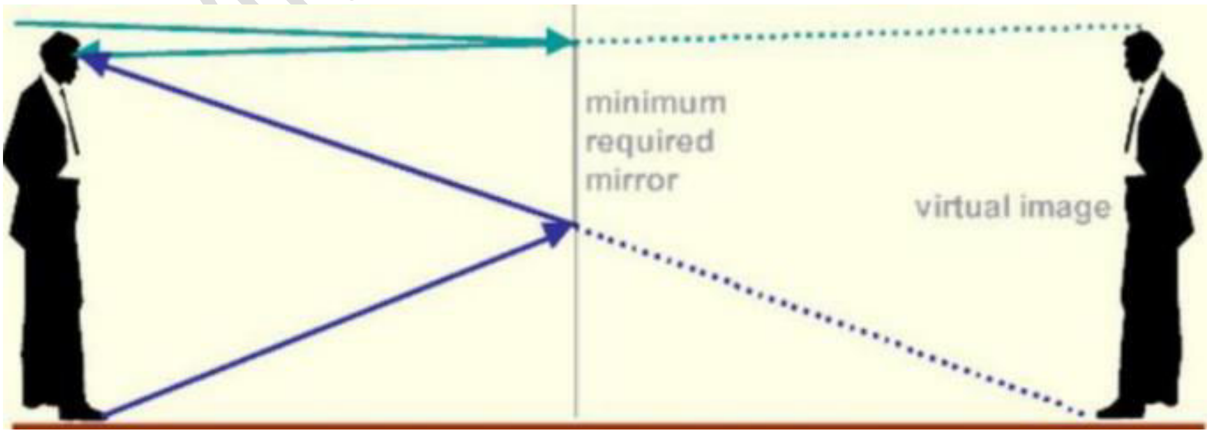
Plane mirrors

When light from an object an object reflects off a straight-line boundary/surface, the object appears to be inverted and a virtual image of the object is seen



- An image that is projected onto a screen is the real image
- An image that appears behind the mirror is the virtual image

Along with the inversion of images, the ray model of light also ensures that during reflection, the size of the original object is exactly equal to the one displayed in the mirror

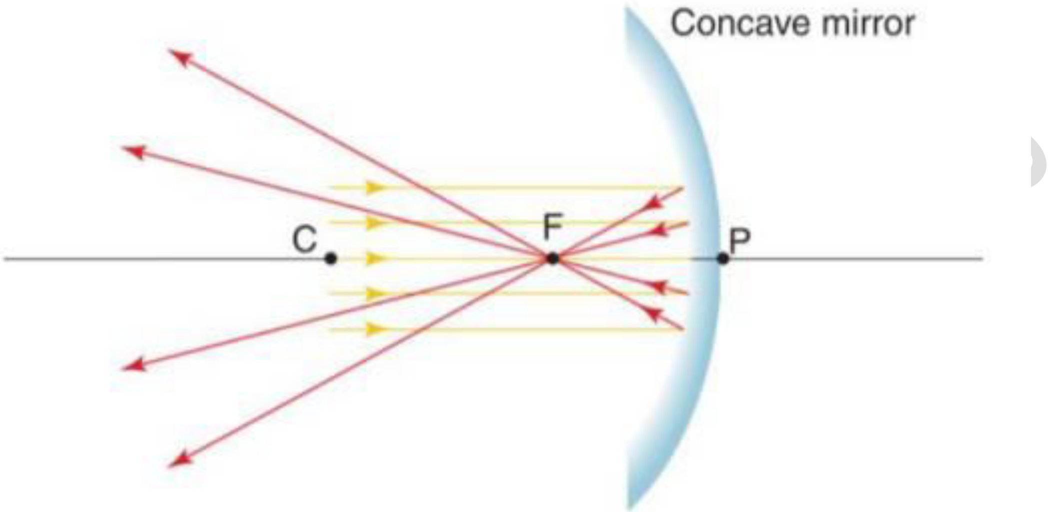


Curved mirrors

Light may also reflect off curved mirror

- These are split into two groups, convex and concave mirrors
- For both convex and concave, light will always follow the law of reflection

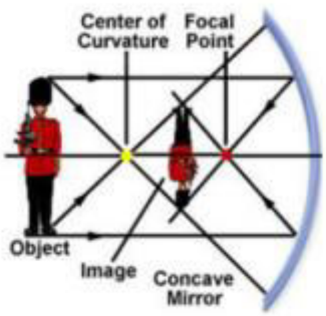
In a concave mirror, the rays reflect back and converge at a point known as the focus



- The point C is known as the centre of curvature and the length PF is known as the focal length. CF is always twice the focal length

Due to the ray properties and the nature, objects appear differently depending on their position relative to the centre of curvature and the focus

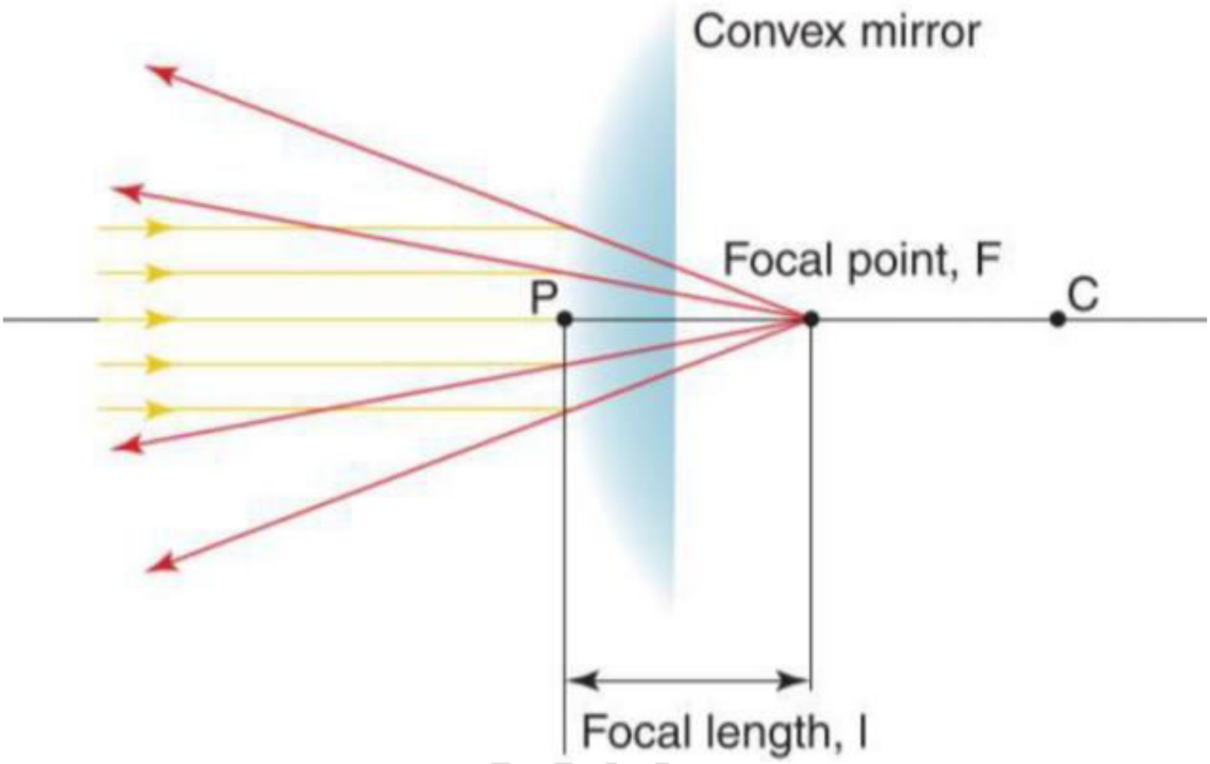
- Objects outside the centre of curvature will appear inverted and smaller than the actual object when seen in between point C and F



- Objects between point C and point F will appear inverted and larger than the actual object when see outside the point of curvature
- Objects within the focal length will appear larger
- If the object is directly on the focal point, no image is formed
- If the object is directly on the centre of curvature, the image will be inverted

Contrastingly, convex mirrors are ones in which the focus and centre of curvature is behind the mirror

- The reflect and diverge the light and hence mainly used to see around corners



Intensity

Intensity (I) is a measure of the energy it can transfer per unit area in a one second interval of time

- The power output of a source *amount of light energy produced per second) is called the luminosity and is given by the units Watts (W)
- Thus, the luminous intensity is given by the formula
- $I = \frac{2}{4\pi r^2}$
- This the exact same equation used to define the intensity of sound waves

As the luminosity of a source (power) remains constant, a relation to compare the intensity at two points r_1 and r_2 can be obtained

$I_1 r_1^2 = I_2 r_2^2$

Conduct investigations to examine qualitatively and quantitatively the refraction and total internal reflection of light

Predict quantitatively, using Snell's Law, the refraction and total internal reflection of light in a variety of situations

Refraction

When light rays enters a new medium, they change both speed and direction at the boundary

- This causes the rays to bend and this phenomenon is known as refraction

A change in velocity of the waves changes its wavelength, but its frequency remains the same

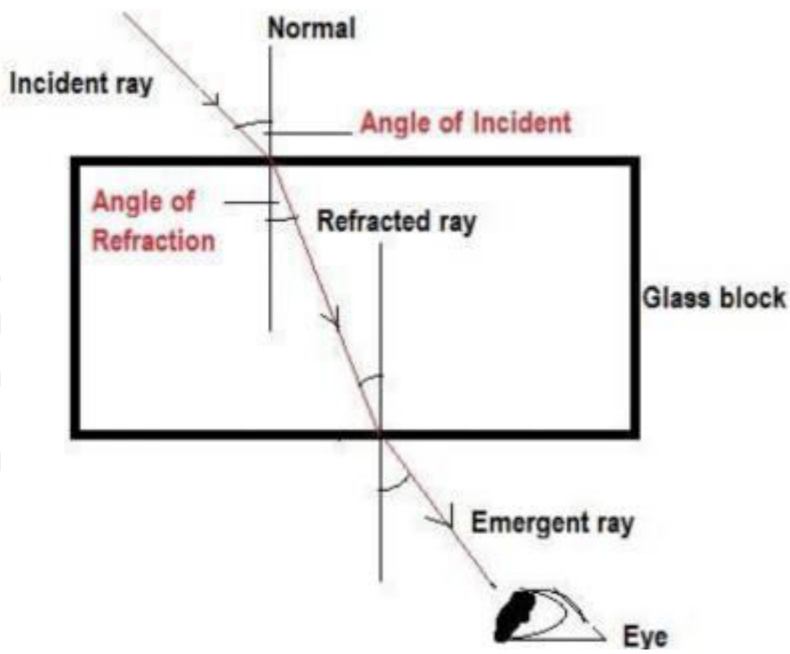
The degree to which the wave changes velocity is dependent on the density of the medium and its approach angle (angle of incidence)

If a wave enters a medium with a higher density, it will bend towards the normal and its velocity decreases (thus wavelength also decreases)

If a wave enters a medium with lower density, it will bend away from the normal and its velocity increases (thus wavelength also decreases)

If a wave enters a medium with lower density, it will bend away from the normal and tits velocity increases (thus wavelength also increases)

- If the wave enters the medium perpendicular to it, it will not bend regardless of its density



Suppose light from a vacuum enters a new medium. The degree to which its velocity changes will depend on the density of the medium

- Thus each material can be described by a value equal to the ratio between the speed of light in a vacuum to the speed in the material itself
- This is known as the refractive index of a material

- $n_x = \frac{c}{v_x}$
- As the density material increase, so does its refractive index

As c remains constant, the velocity of light and refractive index of two mediums can be compared using the formula:

$$\frac{v_1}{v_2} = \frac{n_2}{n_1}$$

The above formula relates the velocity of light in two different medium with their respective refractive index

A relation involving the angle of incidence and angle of refraction (how much the wave bends) can be obtained

A simple way of determining this relation is by conducting an experiment a beam is shone onto a slap Perspex (clear acrylic)

- A light is shone at varying angles of incidence (such as 10°, 20°, 30°,... , 80°) and the respective angles of refraction are recorded
- If the sine of each angle is plotted on a graph of sin(θ_r) against sin(θ_i) a straight would be obtained
- This means that the ration $\frac{\sin\theta_i}{\sin\theta r}$ is constant, and this constant is equal to the ratio of the two velocity of the medium
- This is known as Snell's Law
- $\frac{v_1}{v_2} = \frac{\sin\theta_i}{\sin\theta r}$
- Substituting the ration of refractive index obtained earlier, and the ration between wavelength the following formula is derived
- $\frac{\sin\theta_i}{\sin\theta_r} = \frac{v_1}{v_2} = \frac{n_2}{n_1} = \frac{\lambda_1}{\lambda_2}$
- This formula is used when solving problems involving the refraction of light from medium 1 to medium 2

Total internal reflection

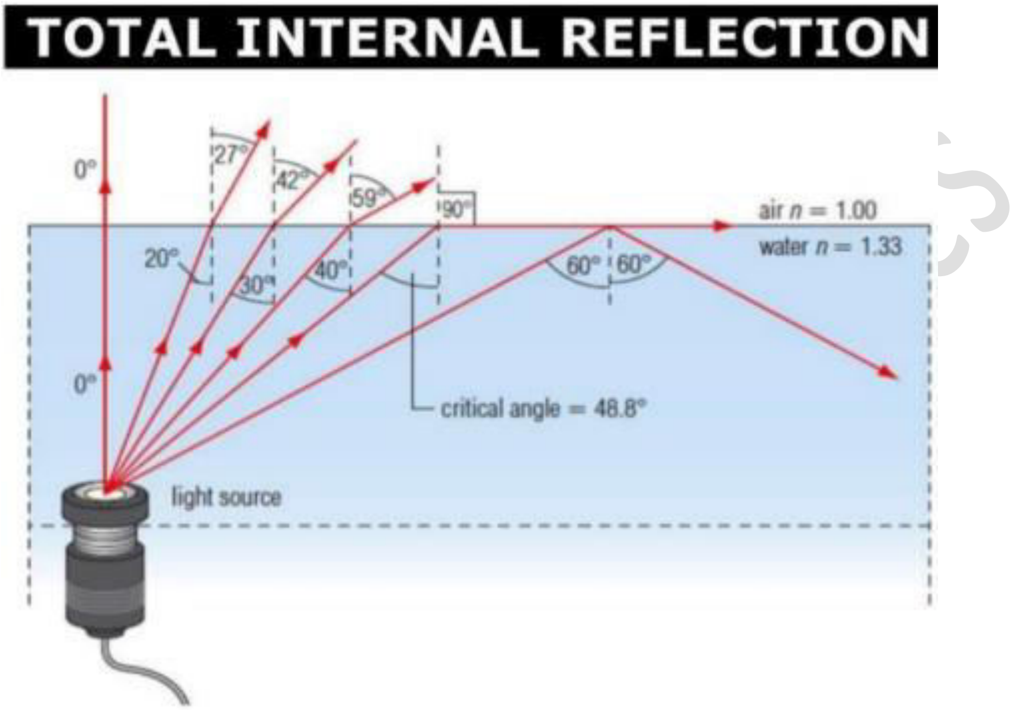
Consider the refraction of a light beam as it enters a medium of lower density (low refractive index)

- If the angle of incidence is increased, the angle of refraction would also increase due to Snell's Law, the wave bends more
- This continues up until a certain angle of incidence in which the refracted beam completely bends 90° and thus travels parallel to the boundary
- The incidence angle at which this occurs is known as the critical angle
- It is found by substituting θ_r=90° into the Snell's Law formula
- $\sin\theta_c = \frac{n_2}{n_1}$

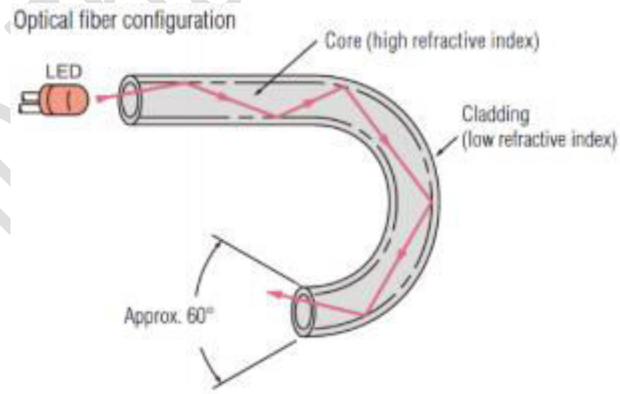
If the incidence is greater than the critical angle, the beam will actually reflect off the boundary

Kevin Zhang

- This phenomenon is known as total internal reflection



Total internal reflection is use widely in Engineering and Physics, especially in optical fibres



Explain the temperature of an object and the kinetic energy of the particles within it

Explain the concept of thermal equilibrium

The kinetic particle theory explains that all matter consists of small particles that are in continual motion

- The particle of a solid vibrates around a fixed position
- The particles of a liquid move around each other and,
- The particles of a gas are in rapid random motion

Heat is a type of energy that can be transferred from one object to another

When heat is transferred to an object, its temperature increases

- Temperature is thus a measure of heat
- Temperature is measured in degrees Celsius or in Kelvins:
- $T_k = T_{^\circ C} + 273$

When heat is transferred to an object, the kinetic energy of the particle increase and they start to vibrate faster

- If enough heat is added to a solid, the particle will vibrate faster and faster such that they break free from its structure and are able to slide around freely
- This is known as the melting of a solid into a liquid
- Similarly adding enough heat to a liquid will evaporate it into a gas

Thermal equilibrium

When a hot object is in contact with a cold object, heat will transfer from the hot object into the cold one

- The temperature of the hot object will thus decrease and the temperature of the cold one will increase
- Eventually both object will have the same temperature, and when this happens, the system has reached thermal equilibrium

Zeroth law of Thermodynamics

Thermodynamics is the study concerned with the relationship between heat (or energy) and work

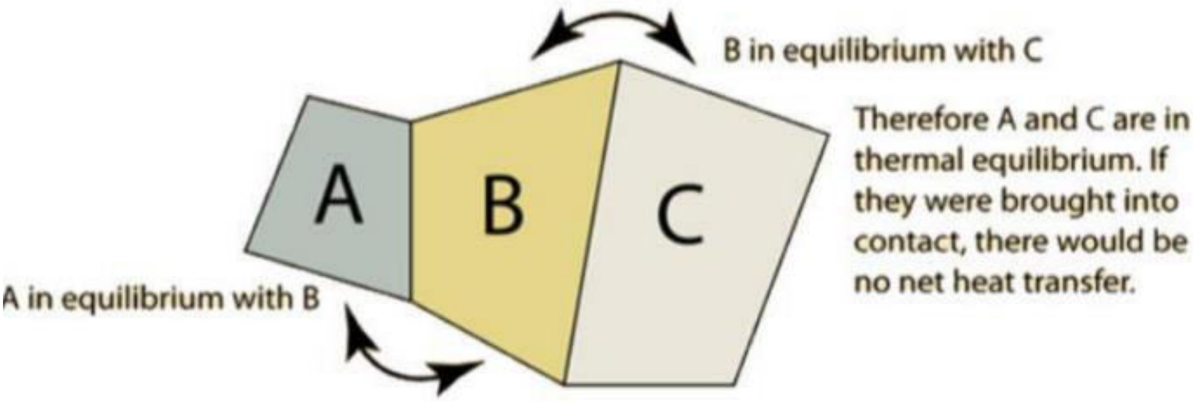
- Like Newtons Law of Motion, there are several important laws associated with thermodynamics

The zeroth law of thermodynamics, which applies to isolated systems

- An isolated system is a system in which no energy or matter can be transferred to the surroundings

This law states that if two objects A and B, are both in thermal equilibrium and are in contact and there is no heat transfer, then they are said to have the same temperature

Furthermore, if A is in thermal equilibrium with B and another object C is in thermal equilibrium with B, the A is also in thermal equilibrium with C



Analyse the relationship between the change in temperature of an object and its specific heat capacity through the equation Q = mcΔT

Conduct an investigation to analyse qualitatively and quantitatively the latent heat involved in a change of state

Specific Heat Capacity

The specific heat capacity of a substance is the amount of energy (J) required to increase the temperature of a specific quantity (usually 1 gram) of that substance by 1°C

- For example, in a swimming pool, the concrete/drains around the pool would feel much hotter than the water itself, which would be relatively cool
- This is because water has a higher specific heat capacity than concrete/metal
- This means more heat energy is required to be inputted into the water to its temperature as opposed to the concrete/metal

The specific heat capacity is denoted as C and is measure in $JK^{-1}g^{-1}$

- The specific heat capacity of water is $4.18JK^{-1}g^{-1}$
- This means that 4.18 joules of energy is required to increase the temperature of 1g of water by 1°C (or 1K)
- The specific heat capacity of other substances is given below:

Substance	Specific Heat Capacity $(J.K^{-1}.g^{-1})$
Water	4.18
Ethanol	2.46
Copper	0.39
Sand	0.48
Lead	0.16

Using the specific heat capacity the amount of heat transferred to an object

Q = mCΔT

- Q is the heat energy in Joules
- M is the mass in g
- C is the specific heat capacity of $JK^{-1}g^{-1}$
- ΔT is the change in temperature of the substance in °C (note that since this a change in temperature, either degrees Celsius or kelvin may be used)

Latent heat

We heat is added to an object, the particle vibrate faster (higher internal energy) and thus its temperature increases

- However, during phase change such as solid melting into a liquid, the temperature actually stays constant although we are continually supplying heat
- This is because the extra heat does not increases the internal energy, instead, it is used to change the state rather than the temperature
- The heat added during this shifting period is known as the latent heat

There are two main types of latent heat:

- The latent heat of fusion is the amount of energy required to change a 1kg of substance form solid to liquid without a change in temperature
- The latent heat of vaporisation is the amount of energy required to change a 1kg of substance from liquid to gas without a change in temperature
  - The latent heat of vaporisation of water is $2.3*10^3$kJ/kg

The latent of any substance can be calculated using the equation

$Q=mL$

- Q is the latent heat
- m is the mass of the substance
- L is the specific latent heat of fusion/vaporisation

Investigate energy transfer by the process of:

- Conduction

- Convection

- Radiation

Model and predict quantitatively energy transfer from hot objects by the process of

thermal conductivity

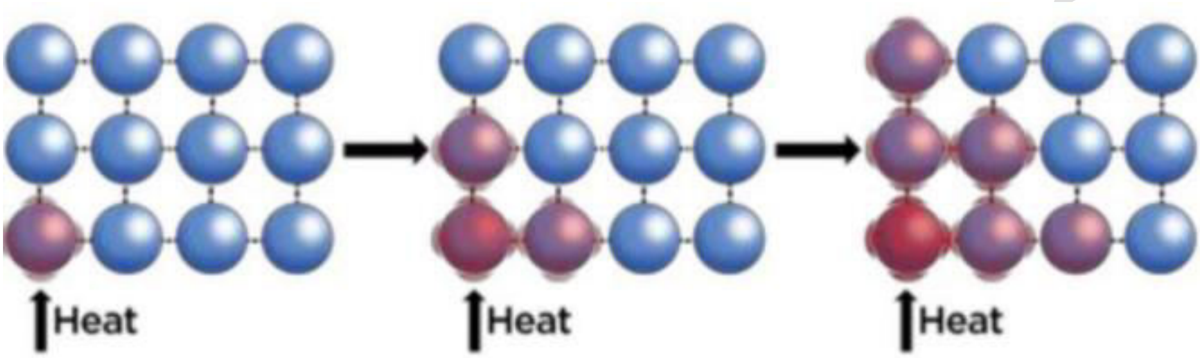
Conduction

When hot objects are brought in contact with a cooler object, heat is transferred from the hot object into a cold one

- This type of heat transfer is known as conduction

Conduction mainly works through the transfer of kinetic energy

- The particles in hot regions vibrate faster and faster, thus transferring its kinetic energy to nearby particles when they bump into them
- These new particles then start to vibrate and thus transferring its energy to its neighbouring particles
- This transfer of kinetic energy from particle to particle until thermal equilibrium is reached



Metals are generally good conductors of heat compared to non-metal as they have delocalised electrons

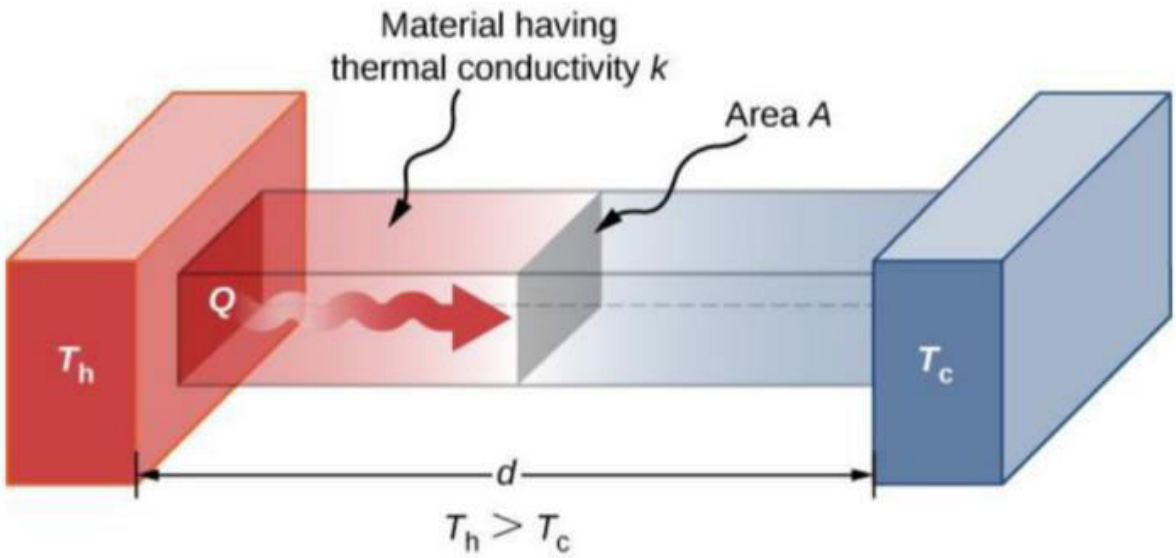
- These delocalised electrons are free moving so that when they gain heat energy, they are able to vibrate more and move around to a large degree
- This means they can pass on the energy much more quickly

The rate at which the thermal is conducted through the material is proportional to the cross section area of the material and the difference in temperature of the mater (T_{hot}-T_{cold}) and inversely proportional to the length of the material:

$$\frac{Q}{t} = \frac{kA\Delta T}{d}$$

- $\frac{Q}{t}$ is the rate of heat transfer
- K is the thermal conductively constant (dependent on the material)
- ΔT
- A is the area of the cross section of material
- d is the length or thickness of the material

- Note all variables are in SI units



Convection

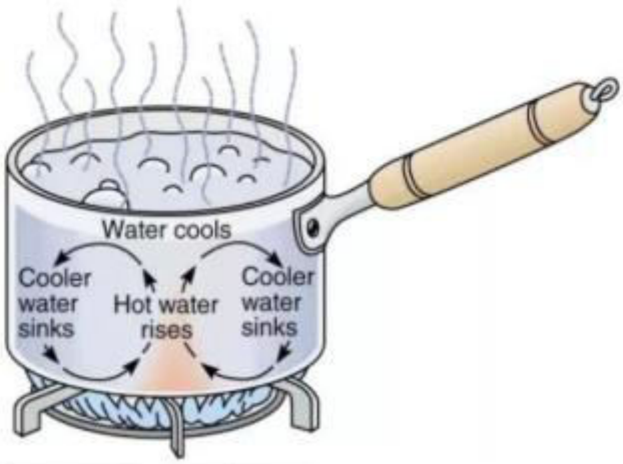
Heat can also be transferred through convection

- This is the transfer of heat by actual movement of fluid (liquid or gas) particles between area of different of different temperature

The movement of these fluid is largely due to buoyant; hot air rises, cold air sinks

For example, consider heating a pot of water

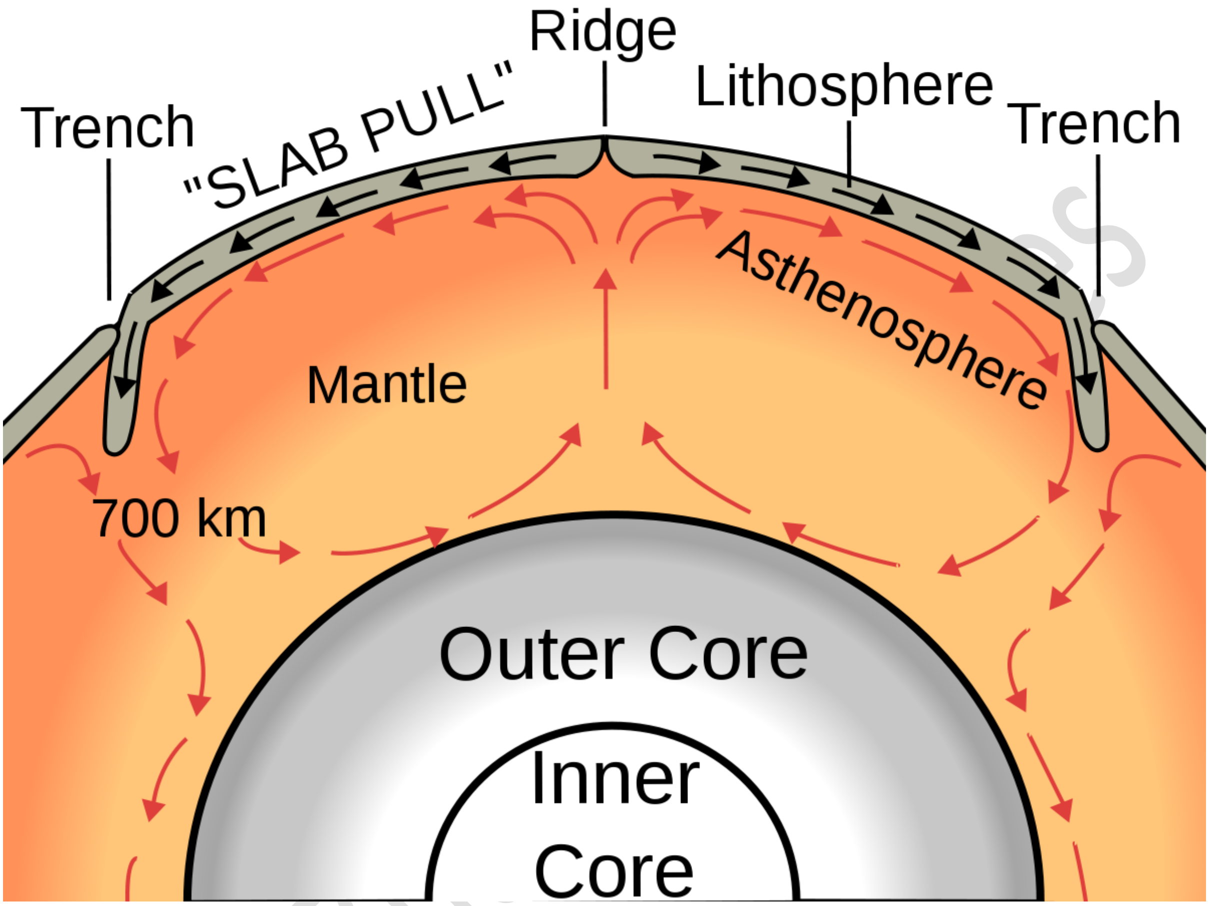
- The hot air rises and hence carries its internal energy with it
- It then cools down and thus sinks
- Heat is therefore transferred in a continual manner through the movement of fluid particles



Convection plays a major role in mantle of the earth

- The heat energy comes from the radioactive decay of elements like uranium
- The convection current in magma drives the tectonic plates

Convection also plays an important role in our atmosphere, which is the cause of some weather phenomena



Radiation

Unlike convection and conduction, heat transfer through radiation does not rely upon any conduct between the heat and the heated object

- Instead heat transfer through radiation is a form of energy transport consisting of electromagnetic waves travelling at the speed of light

Electromagnetic waves are produced through the acceleration of charged particles

- Thus, all substances produce electromagnetic radiation
- The higher the temperature of a substance, the more the charged particles move and thus the more energetic the radiation produced

For example, consider heating up a metal

- At low temperature, it will glow red and thus emit the red portion of the visible light spectrum
- At higher temperatures, more energetic waves are released (high frequency/low wavelength) such as blue then violet light

- Increasing the temperature further would result in even more energetic waves such as infrared, U, etc
- Although the infrared spectrum is invisible to our eyes, it is felt as heat