Kinematics
Notes

- ## Scalar & Vector Quantities
  - Scalar quantities describe magnitude.
  - Vector quantities describe magnitude and direction.

Scalar Quantities	**Vector Quantities**
Length	Displacement
Area	Velocity
Mass	Acceleration
Distance	Force
Speed	Thrust

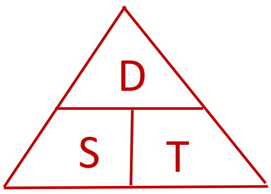
- ## Distance & Displacement
  - Distance is the overall length that an object travels.
  - Displacement is the distance from the origin to final destination.

- ## Speed & Velocity
  - Speed is the rate of change of distance.
  - Velocity is the rate of change of displacement.

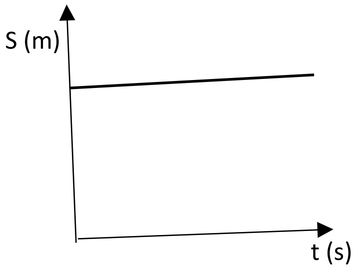
- ## Average vs Instantaneous Speed/Velocity
  - Average Speed is the overall rate of change of distance.
  - Instantaneous Speed the speed an object it is travelling at one moment in time.
  - Average Velocity is the overall rate of change of distance and direction.
  - Instantaneous Velocity is the velocity an object in a moment in time.
  - Converting ms^{-1} **-->** $kmhr^{-1}$
    - Multiply by 3.6
  - Converting $kmhr^{-1}$ **-->** ms^{-1}
    - Divide by 3.6

- ## Free Falling Objects (Gravity)
  - Force due to due gravity is $9.8ms^{-2}$.

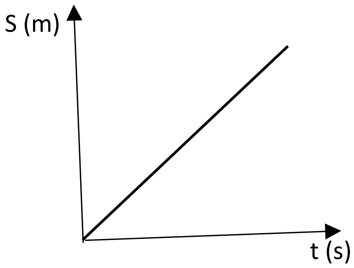
- ## Equations of Motion
  - $v = u + at$
  - $\frac{v+u}{2} = \frac{s}{t}$
  - $s = ut + \frac{1}{2}at^2$
  - $v^2 = u^2 + 2as$
    - Where,
      - v = final velocity (ms^{-1})
      - u = initial velocity (ms^{-1})
      - a = acceleration (ms^{-2})
      - s = displacement (m)



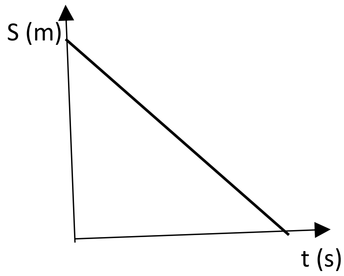
- ## Graphs of Motion
  - **Displacement vs Time**
    - Any point gives instantaneous displacement.
    - Gradient describes instantaneous velocity.
    - Case 1: Uniform Velocity



The object is stationary at a constant distance.

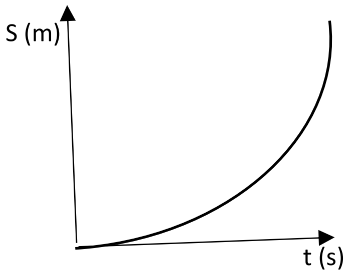


The object's displacement is increasing at a constant rate.



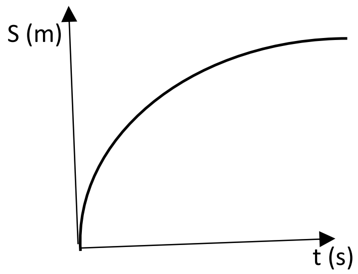
The object's displacement is decreasing at a constant rate.

    - Case 2: Non – Uniform Velocity



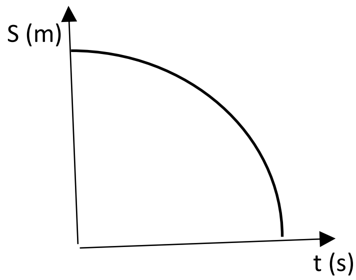
The object's displacement is increasing at an increasing rate. Uniform acceleration.

a > 0



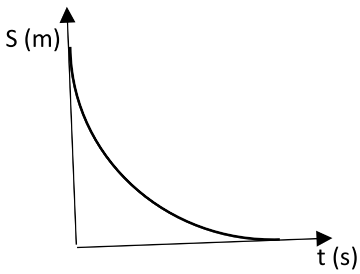
The object's displacement is increasing at a decreasing rate. Uniform acceleration.

a < 0



The object's displacement is decreasing at an increasing rate. Uniform acceleration.

a > 0

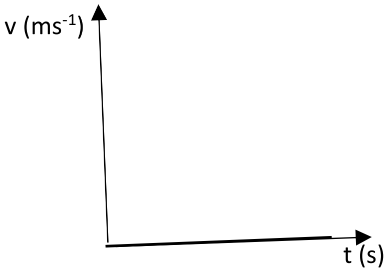


The object's displacement is decreasing at a decreasing rate. Uniform acceleration.

a < 0

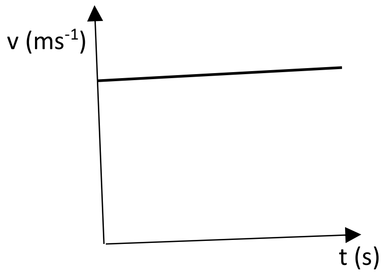
  - **Velocity vs Time**
    - Any point gives instantaneous velocity.
    - Gradient gives acceleration.

- Area gives displacement.
- **NEVER ASSUME WE START AT THE ORIGIN!**
- **Case 1: Uniform Velocity**



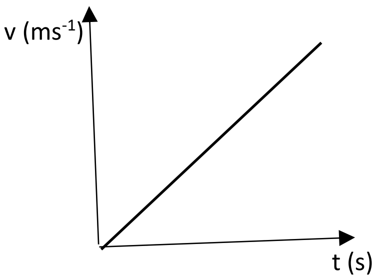
Velocity is zero.

Therefore, stationary.



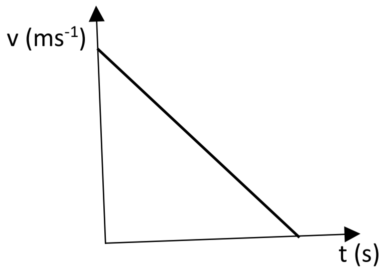
The object is travelling at a constant velocity.

- **Case 2: Non – Uniform Velocity**



Velocity is zero.

Therefore, stationary.

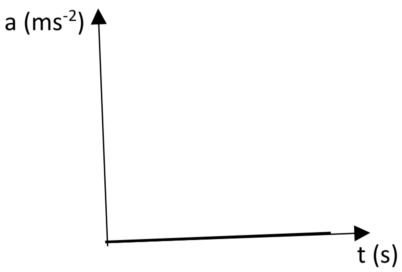


Velocity is decreasing at a constant rate.

Uniform Deceleration.

Acceleration vs Time

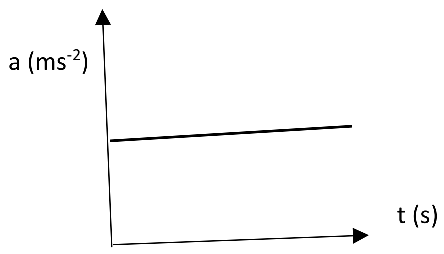
- Any point gives instantaneous acceleration.
- Area gives change in velocity.
- Case 1: Uniform Velocity



Acceleration is zero.

Therefore, constant velocity.

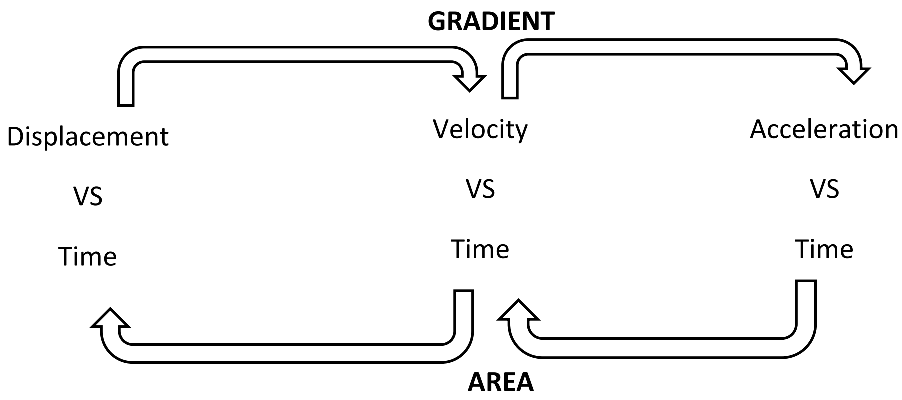
- Case 2: Non – Uniform Velocity



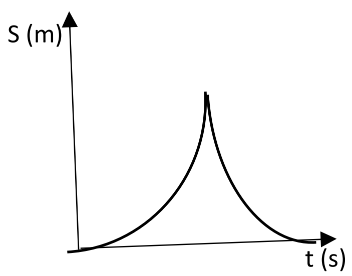
Acceleration is positive.

Therefore, increasing velocity.

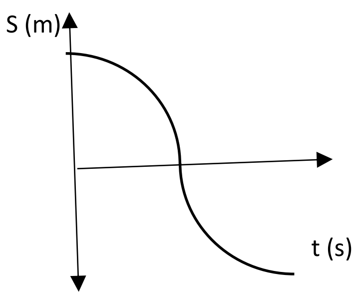
➢ Information in Graphs



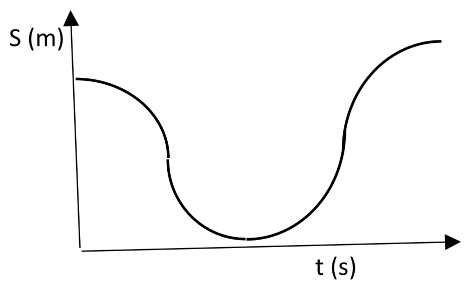
➢ Displacement vs Time Graph: EXAMPLES



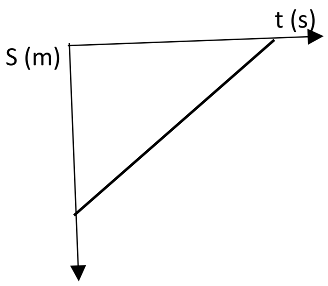
The object's velocity increases then suddenly changes direction & slows down as it moves back to its origin.



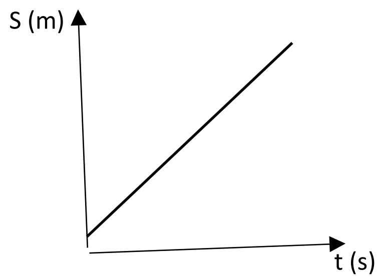
The object's velocity increases as it moves towards its origin & then slows down as it moves away from the origin in the opposite direction.



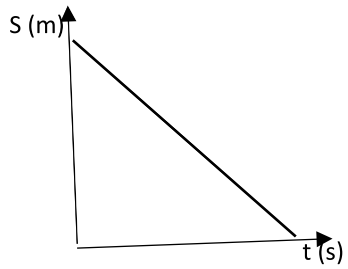
The object speeds up in the opposite direction & is momentarily stationary then the velocity increases before slowing down again.



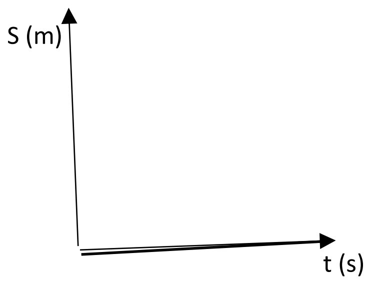
The object is moving toward its origin at a constant positive velocity.



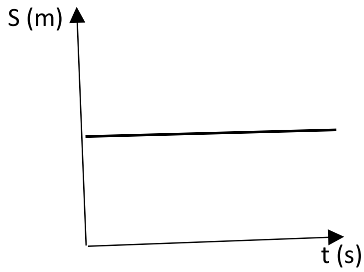
The object is moving away from its origin at a constant positive velocity.



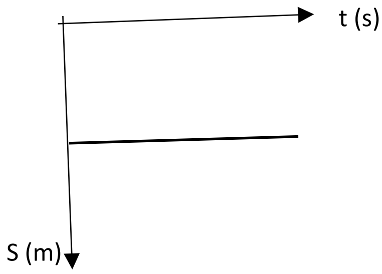
The object is moving towards to its origin at a constant negative velocity.



The object is stationary at its origin.

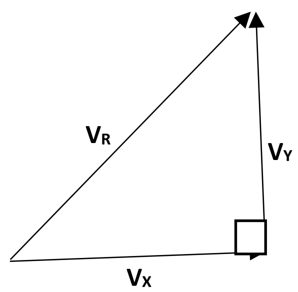


The object is stationary at a positive displacement.

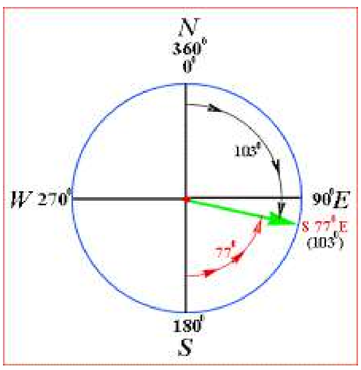


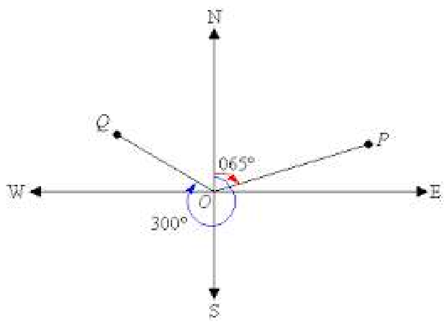
The object is stationary at a negative displacement.

- **Component Vectors & Resolving Vectors**
  - A vector is made up of two perpendicular components.

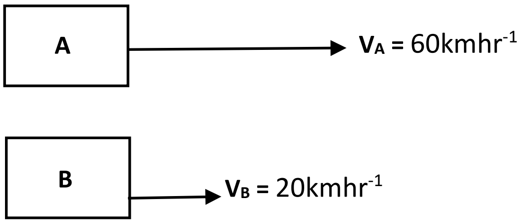


- **Compass & True Bearing**





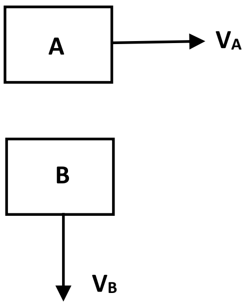
- ## Relative Velocity
  - Relative Velocity is the velocity of an object from one frame of reference.
    - A car travelling at 60kmhr^{-1}, is travelling at 60kmhr^{-1} relative to the ground.
- ## 1D Relative Velocity



- V_A : velocity of object A (relative to the ground)
- V_B : velocity of object B (relative to the ground)
- $V_{A/B}$: velocity of object A relative to object B.

- ## 2D Relative Velocity
  - If two objects are travelling along the X and Y axis.

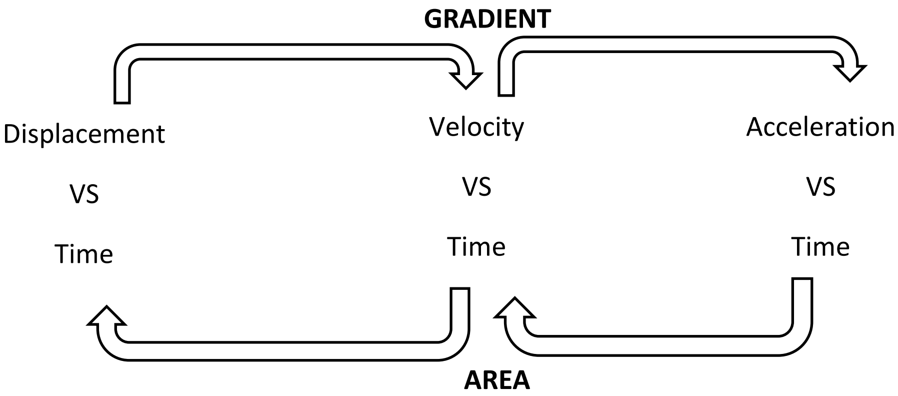
$$v_{A/B} = v_{A/G} - v_{B/G}$$

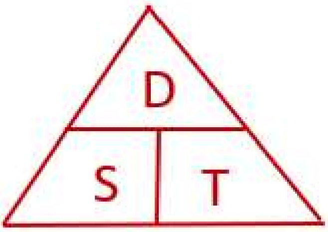


Definitions

WORDS	DEFINITIONS
Scalar Quantities	describe magnitude
Vector Quantities	describe magnitude and direction
Distance	overall length that an object travels
Displacement	distance from the origin to final destination
Speed	rate of change of distance
Velocity	rate of change of displacement
Average Speed	overall rate of change of distance
Instantaneous Speed	speed an object it is travelling at one moment in time
Average Velocity	overall rate of change of distance and direction
Instantaneous Velocity	velocity an object in a moment in time
Relative Velocity	velocity of an object from one frame of reference.

Formulas





$$v = u + at$$

$$v_{A/B} = v_A - v_B$$

$$v^2 = u^2 + 2as$$

$$v_{A/B} = v_{A/G} - v_{B/G}$$

$$\frac{v + u}{2} = \frac{s}{t}$$

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

Dynamics
Notes

- **Force**
  - A force is a push, pull, or twist that changes the motion of an object.
  - It is a vector quantity.
  - Measured using Newtons (N).
  - There are two types of forces:
    - Direct Motion:
      - Force due to physical application.
    - Indirect Motion:
      - Force due to non-physical application.

- **Newton's 1st Law of Motion**
  - "An object will remain at rest or continue at constant velocity, unless acted upon by an external unbalanced force."
  - Known as The Law of Inertia.
  - Inertia is the tendency of an object to resist motion.

- **Friction & Air Resistance**
  - Friction is an external unbalanced force that opposes the motion of an object.
  - Air Resistance is a type of friction which is in air (also known as drag).

- **Newton's 2nd Law of Motion**
  - "The net unbalanced force is equal to the product of the mass of the object and its acceleration."
  - **$F_{net} = ma$**
    - Where.
      - F_{net} – net force (N or $kgms^{-2}$)
      - m – mass (kg)
      - a – acceleration (ms^{-2})

- **Weight Force (W or Fg)**
  - Mass is the amount of matter in an object.
  - Weight is the force that on mass due to gravity.
  - Mass never changes but weight may vary due to location.
  - **$W = mg$**
    - Where,
      - W – weight (N)
      - m – mass (kg)
      - g – acceleration due to gravity (ms^{-2})

Newton's 3rd Law of Motion

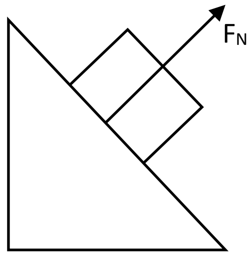
- "For every force, there is an equal and opposite reaction force."
- If you exert a force on a wall, the wall will exert the same force on you.
- Reaction pairs are equal and opposite but act on different objects.

$F_{action} = -F_{reaction}$

$F_{A/B} = -F_{B/A}$

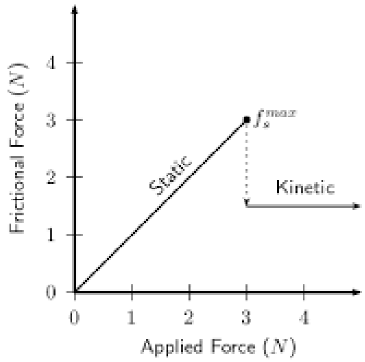
Normal Force (N or FN)

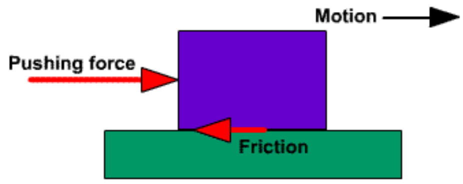
- Normal Force is a force exerted on an object due to the contact between the object & another surface.
- It is always perpendicular to the surface.
- Mostly responsible for opposing the weight force, keeping it at rest.
- **IT IS THE NOT THE REACTION FORCE OF THE WEIGHT FORCE!!!**



Frictional Force (Ff)

- The coefficient of friction (μ) is how difficult it is for the object to slide against two surfaces (μ = 0 – easy to slide, μ = 1 – hard to slide).
- Every pair of surfaces have two coefficient values (μ_s – static coefficient, μ_k – kinetic coefficient).
- When stationary, the frictional force needs to be overcome for the object to move. The static coefficient of friction shows this.
- Once an object has begun motion, less force is required to keep its motion. The kinetic coefficient of friction shows this.
- $\boldsymbol{F_f = \mu F_N}$
  - Where,
    - F_f – Frictional Force (N)
    - μ – static/kinetic coefficient of friction
    - F_N – Normal Force (N)





Connected Masses & Tensional Force

- Connected Masses is when a transfer of force via direct contact.
- Tensional Force is a force applied by an object being stretched.
- Assume the stretched object is weightless.
- Stretchable objects include:
  - String
  - Chain
  - Elastic band
- Tension has the same value throughout the entire material.
- Tension acts away from the point of attachment.

- **Work**
  - Work is the amount of energy used when moving an object.
  - If a force speeds the object, positive work is done.
  - If a force slows the object down, negative work is done.
  - **W = Fs**
    - Where,
      - W = Work done (J)
      - F = Force applied (N)
      - s = Displacement (m)

$$W = \Delta E$$

- **Energy**
  - Energy is the ability to do work.
  - It is a scalar quantity.
  - Measured in Joules (J).
  - Energy can exist in:
    - Sound Energy
    - Heat Energy
    - Kinetic Energy
    - Gravitational Energy

- **Kinetic Energy**
  - It is the energy associated with an objects state of motion.
  - The faster the object, the greater KE. A stationary object has 0 KE.

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

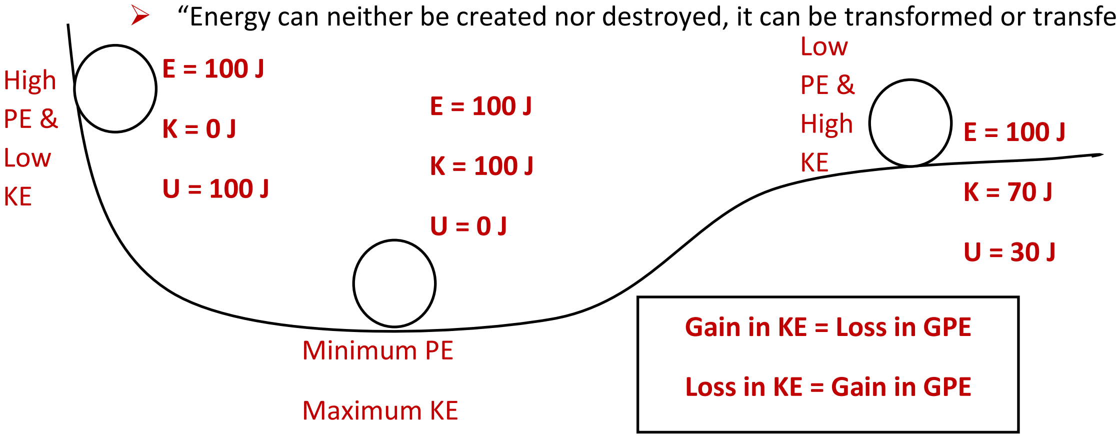
- **Gravitational Potential Energy**
  - It is a form of PE due to mass in the gravitational field.
  - PE is the stored energy that can be released or transformed.
  - An object further away from the gravitational field has a greater GPE.
  - **U = mgh**
    - Where,
      - U – Gravitational Potential Energy (J)
      - m – mass (kg)
      - g – gravitational acceleration (ms^{-2})
      - h – height above surface (m)

- **Mechanical Energy**
  - It is the entire energy the system possesses based on its position and motion.
  - **E = KE + U**
    - Where,
      - E – Mechanical Energy (J)

- KE – Kinetic Energy (J)
- U – Gravitational Potential Energy (J)

The Law of Conservation of Mechanical Energy

- “Energy can neither be created nor destroyed, it can be transformed or transferred”.



Gain in KE = Loss in GPE

Loss in KE = Gain in GPE

Work Done = Change in Energy

Power

- It is the measure of the rate of work done or rate of energy transfer.
- It is a scalar quantity.
- $\boldsymbol{P = \frac{\Delta E}{\Delta t} = \frac{W}{\Delta t} = \frac{Fs}{\Delta t} = Fv}$
    - Where,
        - P – Power (W)
        - E – Energy (J)
        - Δt – time taken (s)
        - F – Force (N)
        - v – velocity (ms^{-1})

Elasticity

- The property of a material to return to its original shape.
- Examples:
    - Spring
    - Rubber brand
    - Bungee jumping rope

Spring Constant

- A number which represents how much force is required to stretch a material.
- Indicated how stiff the spring is.
- Materials with larger spring constants are stiffer.
- Measured in Nm^{-1}.

Hooke's Law

- "The force required to stretch or compress a spring is directly proportional to the deformation of the spring".
- Compressing – pushing force.
- Stretching – pulling force.
- The restorative force restores the spring to its natural length.
- It acts in the opposite direction.
- $\mathbf{F_s = -kx}$
  - Where,
    - F_s – restorative force (N)
    - k – spring constant (Nm^{-1})
    - x – displacement from equilibrium (m)

Elastic Potential Energy

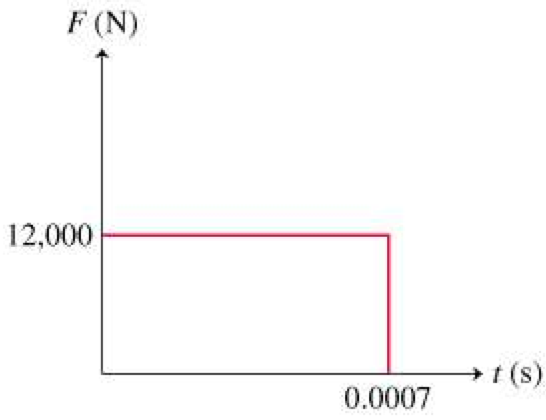
- Also known as 'elastic stored energy'.
- Involves the deformation of an elastic object.
- Energy transfer increases EPE.
- $\boldsymbol{U_E = \frac{1}{2}k(\Delta x)^2}$
  - Where,
    - U_E – Elastic Potential Energy (J)
    - k – spring constant (Nm^{-1})
    - Δx – displacement from equilibrium (m)

Momentum

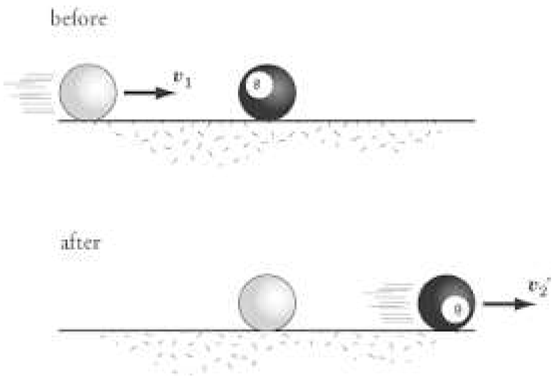
- The quantity of motion of a moving object.
- It is a vector quantity.
- $\boldsymbol{\vec{p} = m\vec{v}}$
  - Where,
    - p – momentum ($kgms^{-1}$)
    - m – mass (kg)
    - v – velocity (ms^{-1})

- ## Change in Momentum
  - Momentum is not constant.
  - Objects change their motion, which change their momentum.
  - $\overrightarrow{\Delta p} = m(v - u)$
    - Where,
      - Δp – change in momentum ($kgms^{-1}$)
      - m – mass (kg)
      - v – final velocity (ms^{-1})
      - u – initial velocity (ms^{-1})

- ## Impulse
  - The change in momentum.
  - If the impact stops the motion, then the Δp is a fixed quantity.
  - Increase time = Decrease impact
  - The area under a Force vs time graph represents impulse.
  - $I = \Delta p = Ft$
    - Where,
      - I – Impulse ($kgms^{-1}$ or Ns)
      - Δp – change in momentum ($kgms^{-1}$)
      - F – Force (N)
      - t – time (s)



- ## Collisions
  - It is any two or more objects which exert a force on each other.
  - An isolated system means no external forces are applied.

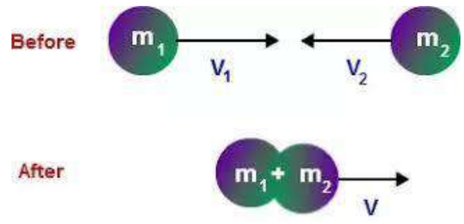


- ## Law of Conservation of Momentum
  - "For a collision occurring between object A an object B, the total momentum of the two objects before the collision are equal to the total momentum of the two objects after the collision.
  - $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$
    - Where,
      - m – mass (kg)
      - u – initial velocity (ms^{-1})
      - v – final velocity (ms^{-1})

- ## Elastic Collisions
  - It is any collision where both momentum and kinetic energy are conserved.
  - Perfect elastic collisions are rarely applicable (mostly done on a microscopic scale).
  - **ASSUME PERFECT ELASTIC COLLISIONS IN EXAMPLES!!!**

- ## Inelastic Collisions
  - During a collision, energy change will occur.
  - In inelastic collision, KE is not conserved.
  - **MOMENTUM IS ALWAYS CONSERVED IN ALL COLLISIONS!!!**
  - During the collision, KE will be transformed (sound, light, or energy deformation).
  - $KE_I = \frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2$
    - Where,
      - KE_{Before}
  - $KE_F = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$
    - Where,
      - KE_{After}
  - A perfect inelastic collision is when two objects collide and stick together and move in the same direction.
  - $m_1u_1 + m_2u_2 = v(m_1 + m_2)$

Law of Conservation of Kinetic Energy



Definitions

WORDS	DEFINITIONS
Force	a push, pull, or twist that changes the motion of an object.
Inertia	the tendency of an object to resist motion.
Friction	an external unbalanced force that opposes the motion of an object.
Air Resistance	a type of friction which is in air.
Mass	the amount of matter in an object.
Weight	the force that on mass due to gravity.
Normal Force	a force exerted on an object due to the contact between the object & another surface.
Coefficient of Friction	how difficult it is for the object to slide against two surfaces.
Connected Mass	when a transfer of force via direct contact.
Tensional Force	a force applied by an object being stretched.
Work	the amount of energy used when moving an object.
Energy	the ability to do work.
Kinetic Energy	the energy associated with an objects state of motion.
Gravitational Potential Energy	a form of PE due to mass in the gravitational field.
Potential Energy	the stored energy that can be released or transformed.
Mechanical Energy	the entire energy the system possesses based on its position and motion.
Power	the measure of the rate of work done or rate of energy transfer.
Elasticity	the property of a material to return to its original shape.
Spring Constant	a number which represents how much force is required to stretch a material.
Momentum	the quantity of motion of a moving object.
Impulse	the change in momentum.
Collision	any two or more objects which exert a force on each other.
Elastic Collision	any collision where both momentum and kinetic energy are conserved.

Formulas

$W = mg$

$F_{net} = ma$

$F_f = \mu F_N$

$W = \Delta E$

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

$W = Fs$

$U = mgh$

$E = KE + U$

Gain in KE = Loss in GPE
Loss in KE = Gain in GPE

Work Done = Change in Energy

$$P = \frac{\Delta E}{\Delta t} = \frac{W}{\Delta t} = \frac{Fs}{\Delta t} = Fv$$

$F_s = -kx$

$$U_E = \frac{1}{2}k(\Delta x)^2$$

$\vec{p} = m\vec{v}$

$\overrightarrow{\Delta p} = m(v - u)$

$I = \Delta p = Ft$

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$$KE_I = \frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2$$

$$KE_F = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$$

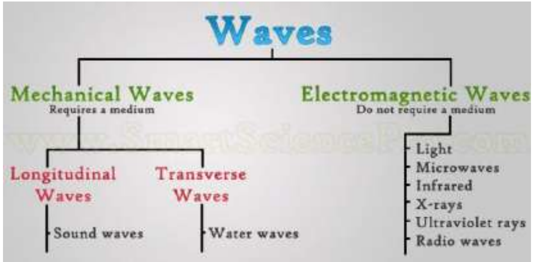
$m_1u_1 + m_2u_2 = v(m_1 + m_2)$

$F_{action} = -F_{reaction}$

$F_{A/B} = -F_{B/A}$

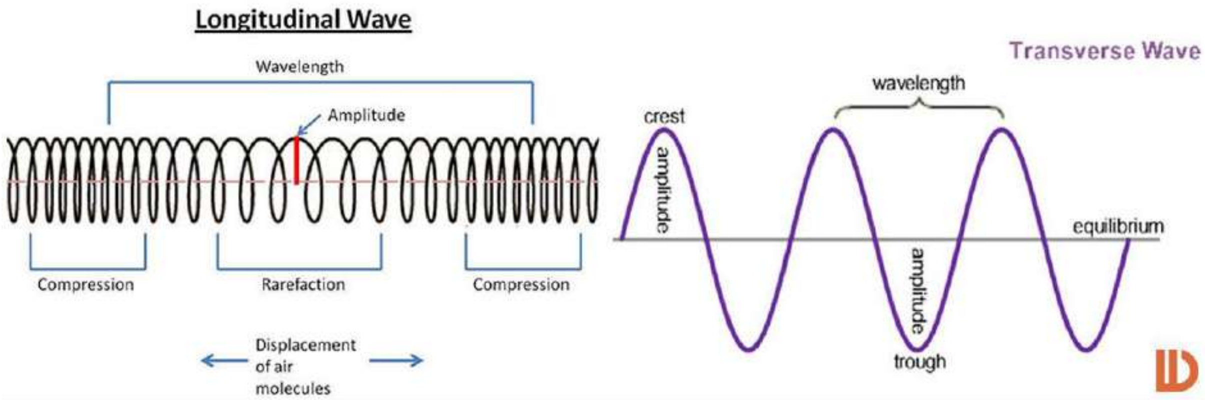
Waves
Notes

- ## Waves
  - A wave is a disturbance/oscillation which transfers energy without transferring matter.
  - A complete wave is a wave that starts at one point and finishes at one point (node to node).

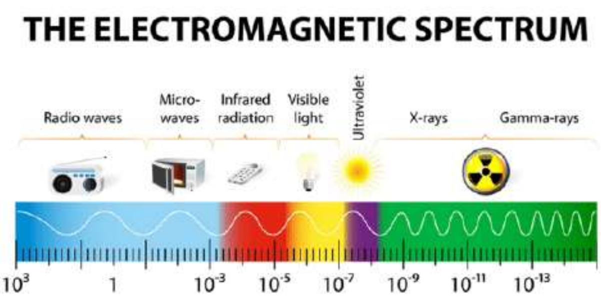


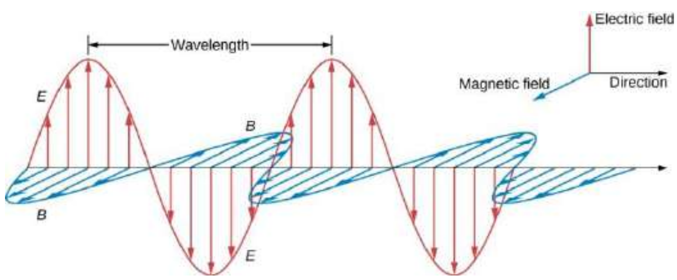
- ## Mechanical Waves
  - Mechanical waves are waves which require a medium to propagate.
  - Motion of particles allow energy transfer.
  - Particles oscillate around a fixed point.
  - Mediums are any form of matter for a wave to travel in.
    - Water
    - Concrete
    - Air

- ## Longitudinal & Transverse Waves
  - A longitudinal wave is where the particles motion oscillates parallel to the direction of motion of energy propagation.
  - Also referred to as compressional waves.
  - Transverse wave is when the particles of the medium oscillate perpendicular to the direction of energy propagation.



- ## Electromagnetic Waves
  - EM waves don't need a medium to propagate.

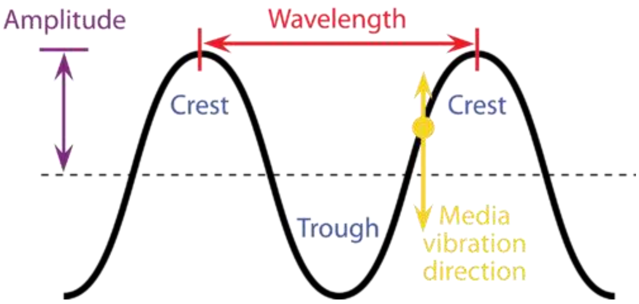




- All EM waves travel at 3×10^8 ms^{-1} in a vacuum or air.
- All EM waves are transverse waves.

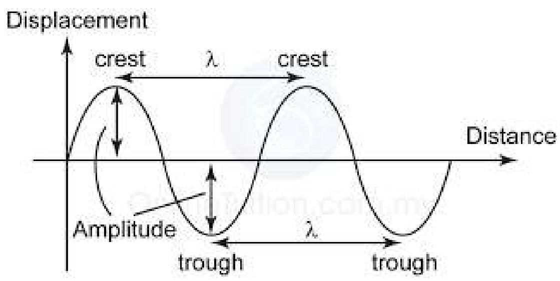
Features of a Wave

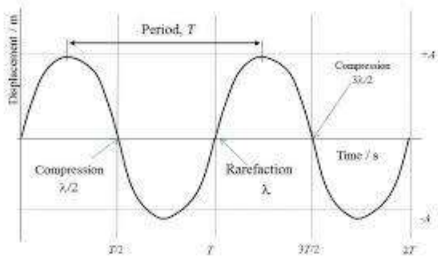
- Crest – the highest point of a wave.
- Trough – the lowest point of a wave.
- Equilibrium – the rest position of the wave.
- Displacement – the vertical distance of particles away from the equilibrium position (m).
- Amplitude – the maximum displacement of particles from the equilibrium position (m).
- Wavelength (λ) – the horizontal distance between two successive identical points on a wave (m).
- Velocity - the velocity at which a wave propagates through a medium.
- Frequency (f) – the number of complete oscillations in one second through a fixed point.
- Period (T) – the time taken for a particle to make one oscillation.



Graphs of Waves

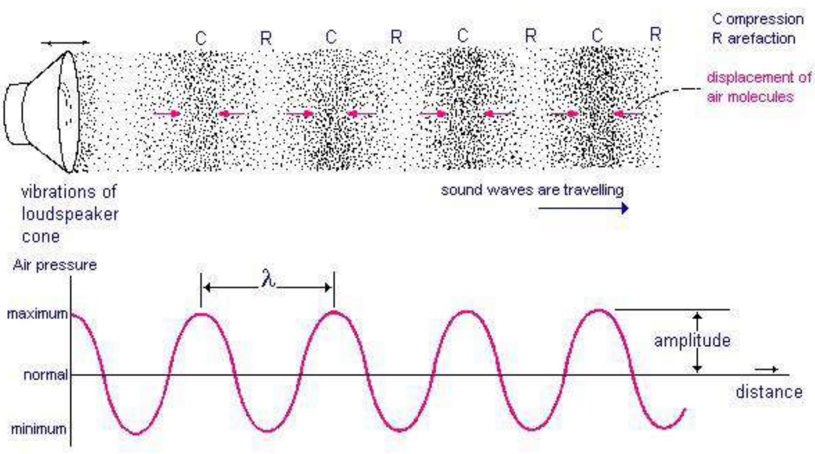
- A displacement vs displacement graph provides information about a wave of one moment. It is a snapshot of a wave. Shows the distance from its equilibrium position.





- A displacement vs time graph provides information about the particles motion as it oscillates.
- Longitudinal waves can be represented on a graph.
- **HOW CAN A LONGITUDINAL WAVE BE SHOWN AS A TRANSVERSE WAVE!!!**

- In a pressure vs distance graph, compressions and rarefactions are shown by peaks and troughs.



Frequency & Period

- T and f have an inverse relationship.
- $T = \frac{1}{f}$
  - Where,
    - T – time taken for one oscillation
    - f – frequency

Velocity, Frequency, & Wavelength

- $v = f\lambda$
  - Where,
    - v – velocity
    - f – frequency
    - λ – wavelength

Wave Behaviour

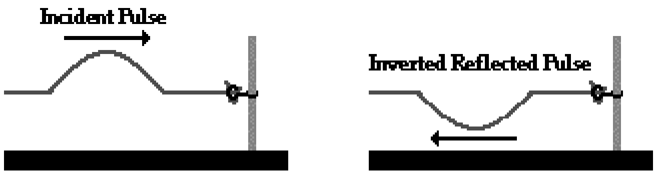
- A wave changes it behaviour when encountering an obstacle.
  - Wave Reflection –when a wave meets a boundary.
  - Wave Refraction –when a wave travels from a denser to less dense medium (or vice-versa).
  - Wave Diffraction –when a wave meets a barrier and travels through an opening.
  - Wave Superposition – when a wave meets another wave travelling in the same medium.

Wave Reflection

- When a wave meets a surface, causing it to bounce back and travel in a different direction.
- Can happen for 1D, 2D, & 3D waves.

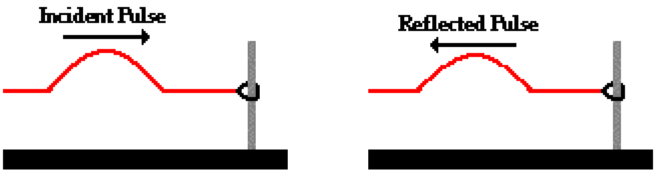
- A pulse is a single vibration.
- A pulse sent down with a fixed point, causes that pulse to reflect in the opposite orientation.

Fixed End Reflection

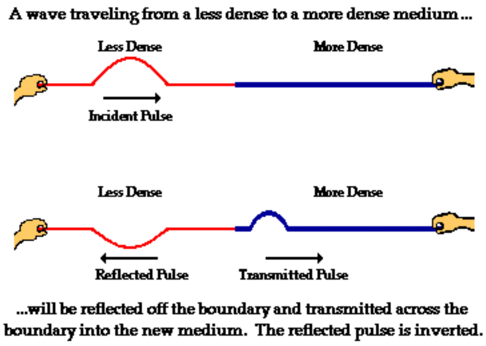


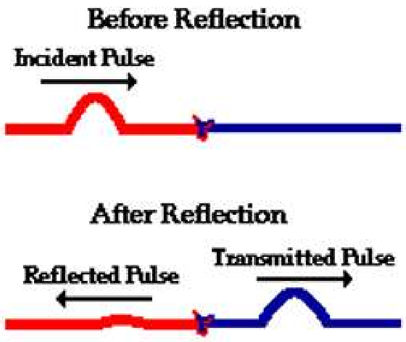
- A pulse sent down with a loose end, causes the pulse to reflect in the same orientation.
- Loose end implies space for rope to move with no friction.

Free End Reflection



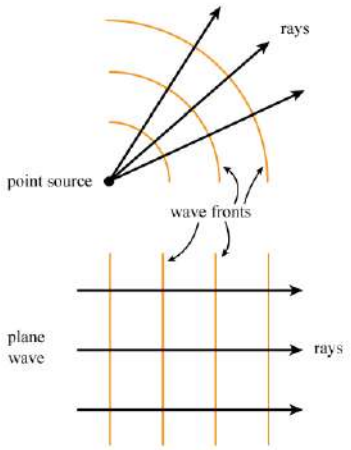
- A pulse sent down in different densities can be reflected or transmitted.

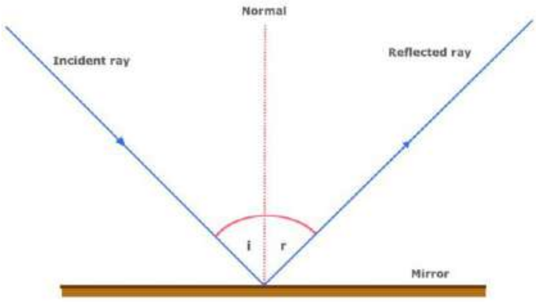




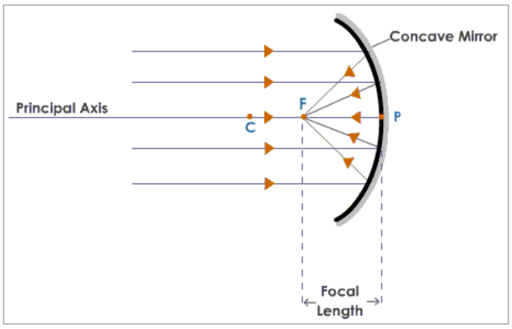
Wavefronts & Rays

- A form to keep track of the propagation of a wave.
- A wavefront is a line that joins all identical points in a phase, in a wave.
  - A line joins all crests.
- A ray shows the direction of propagation and is always perpendicular to the wavefront.
- Distance between two wavefronts is the wavelength.
- Wavefronts come in different shapes:
  - Straight/Plane wavefronts
  - Circular wavelengths
- The Law of Reflection states:
  - “The angle of incidence is equal to the angle of reflection”.
  - “The incident ray, reflected ray and the normal all lie on the same plane”.



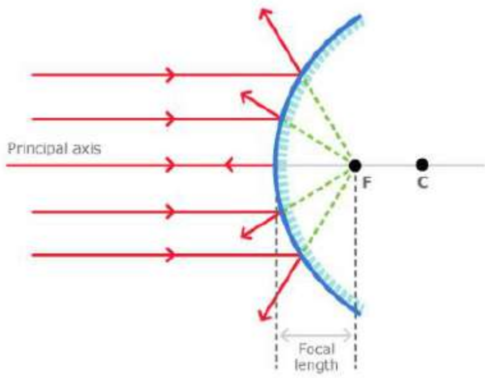


- **Wave Reflection**
  - It is when the wave changes direction of propagation due to the interaction with a reflective surface.

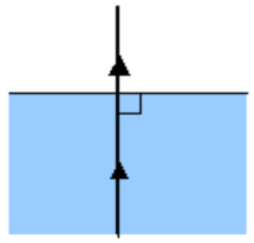


- **Wave Reflection from a Concave Surface**
  - A concave surface is a surface that curves in.
  - The focus is responsible for collecting signals and concentrating them to be retransmitted.

- **Wave Reflection from a Convex Surface**
  - A convex surface is a surface that curves out.
  - Convex mirrors are used in:
    - car mirrors
    - traffic mirrors
    - security mirrors

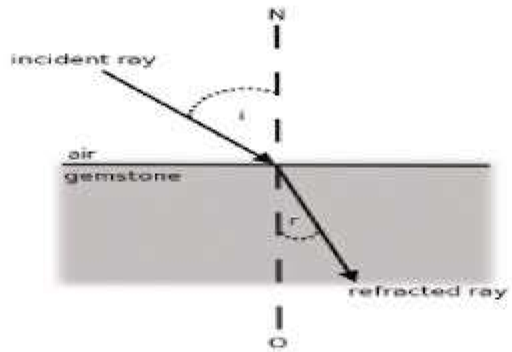


- **Wave Refraction**
  - It is when the wave changes direction of propagation due to a change in velocity, when travelling through a medium.
  - **FREQUENCY REMAINS UNCHANGED!!!**
  - Conditions for refractions:
    - velocity change
    - wave must enter the second medium at an angle other than 90°

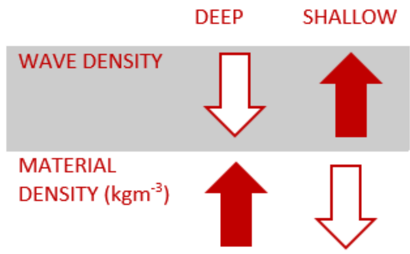


Angle of incidence = 90°

Wave cannot refract if angle of incidence is 90°.



- ## Snell's Law
  - $\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{n_2}{n_1}$
  - A dense medium is a medium where waves travel slow.
  - A less medium is a medium where waves travel fast.



Wave slows down

=

Bends towards normal

Shallow water is denser than deep water.

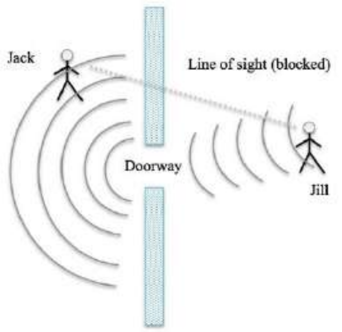
(waves travel faster in deep water)

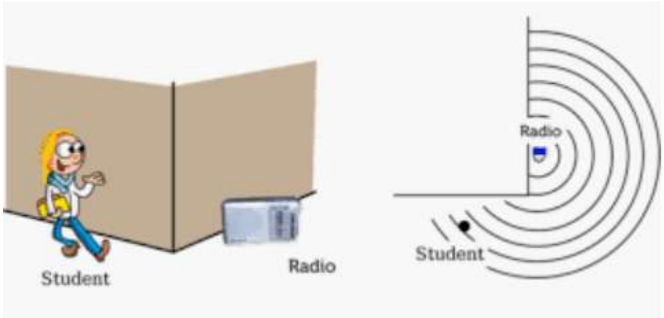
- ## Refractive Index
  - Is the ratio of the speed of light in a vacuum to the speed of light in a material.
  - $n = \frac{c}{v}$
    - Where,
      - n – refractive index of a material
      - c – speed of light in a vacuum (3 x 10^8 ms^{-1})
      - v – speed of light in a material (ms^{-1})
  - Objects with high refractive indexes are **SOMETIMES** referred to as high optical density.

Space and air have a refractive index of 1.

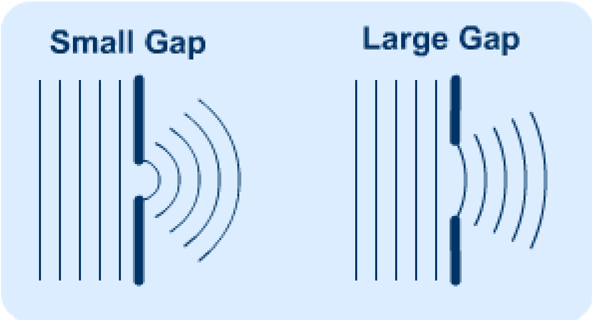
- ## Wave Diffraction
  - It is the spreading of waves into space beyond a gap or obstacle.

- Spreading of sound waves:



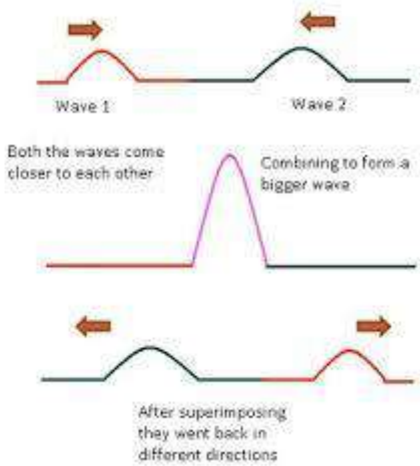


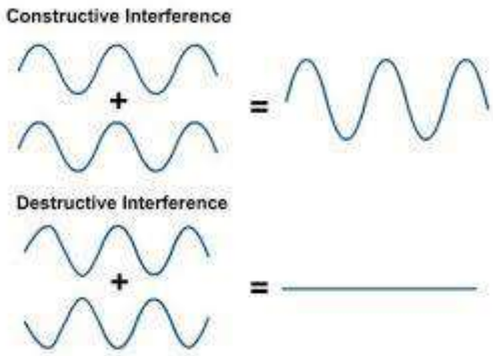
- The greater the wavelength, the greater the spreading.
  - Sound waves can diffract through a door opening but not light waves.
  - This is because a sound wave is larger than the width of the gap.
  - Light waves simply pass but do not diffract.
- **THERE IS NO CHANGE IN VELOCITY, WAVELENGTH, OR FREQUENCY!!!**



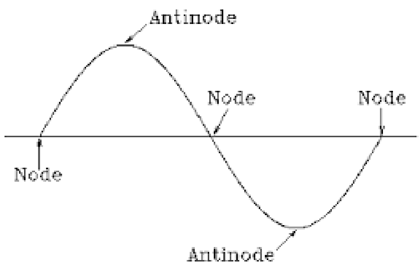
Wave Superposition

- When two waves/pulses travelling in the same medium, interfere each other.
- Superposition is adding waves.
- The resultant wave exists for a moment when two waves meet.
- There are two types of interference:
  - Constructive Interference
  - Destructive Interference



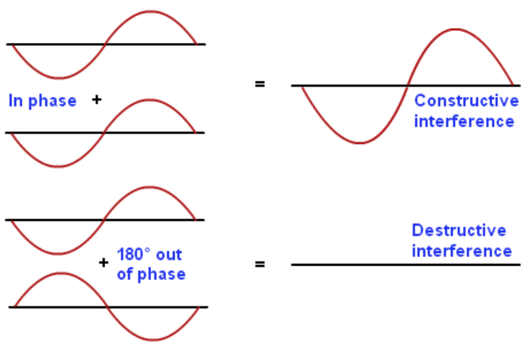


- ## Standing Waves
  - It is a pattern which results from the interference of two identical waves travelling along the same medium in the opposite direction.
  - A node is a point that stays stationary as the wave propagates.
  - An antinode is a point that experiences maximum displacement as the wave propagates.
  - Distance between two nodes is $\frac{1}{2}\lambda$.



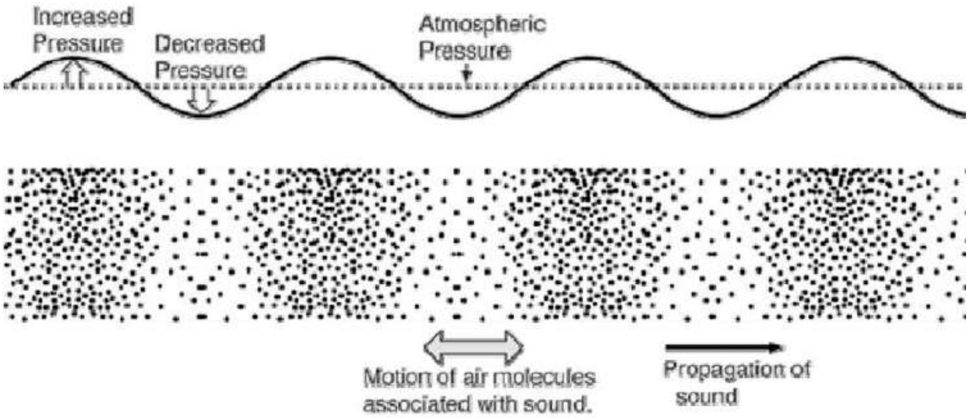
- ## Resonance
  - It is when an object exposed to a driving force is equal to their resonant frequency.
  - Maximum possible energy is transferred to the resonating object.
  - High amplitude can damage object.
  - Hitting the right frequency can cause a glass to shatter
  - All objects that are able to vibrate, do so at their natural frequencies.
    - Vibrations in a guitar, drum, and other instruments.
  - A forced vibration is when an object makes another object vibrate.
    - Vibration of a tuning fork produces a vibration on a nearby tuning fork.
    - Vibration on a speaker causes nearby air molecules to vibrate, producing sound.

- ## Path Difference
  - Is the extra distance travelled compared to another.
  - Constructive Interference:
    - **PD =** $\boldsymbol{n\lambda}$
      - n = integer
  - Destructive Interference:
    - **PD =** $\boldsymbol{\lambda\left(n+\frac{1}{2}\right)}$



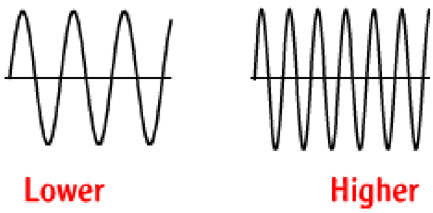
- ## Sound Waves
  - Is a mechanical longitudinal wave.
  - When sound waves vibrate, vibrations create pressure variations within that medium.

- Frequency of wave is determined by frequency of original vibration.

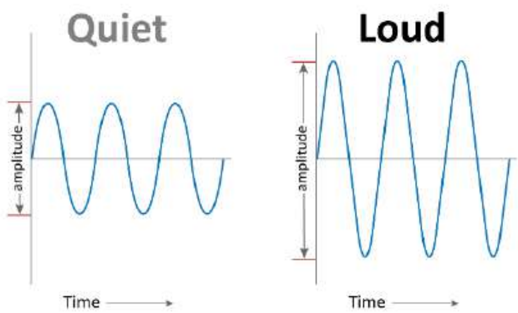


Characteristics of Sound Waves

- **Velocity**
  - Require a medium to travel through.
  - Fastest in solids, then gases, then liquid.
  - Speed of sound in air is 343ms^{-1} (25°C, 1 atom)
- **Frequency/Pitch**
  - Higher frequency - more vibrations - higher pitch
  - High frequency – high pitch
    - E.g. alarm and whistle
  - Low frequency – low pitch
    - E.g. hitting a gong and a horn



- **Amplitude/Volume**
  - Amplitude determines volume.
  - High amplitude – loud sound
  - Low amplitude – soft sound



Intensity of Sound Waves

- Is the amount of sound energy passing through a unit area in one second.
- Is the power per unit area.
- Is a 3D wave, meaning it spreads energy evenly.
- Spreads energy evenly spherical surface area.

$$I = \frac{P}{A} = \frac{P}{4\pi r^2}$$

The Inverse Square Law

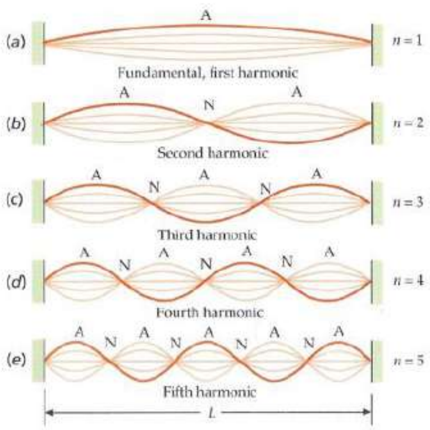
- Intensity decreases in proportion to the square of distance from the source.
  - Distance is doubled – intensity is decreased by a factor of 4.

$$I = \frac{k}{r^2}$$

- ## Behaviour of Sound Waves
  - **Reflection of Sound**
    - Sound is either reflected or absorbed when it meets a surface.
    - Smooth and hard surfaces reflect better than soft and rough surfaces.
    - Can result in reverberation or an echo.
  - **Reverberation**
    - Prolongation of a of a sound wave.
      - When sound is reflected at 17m or less.
  - **Echo**
    - Reflection from a hard surface and rebounds to its original source.
      - When reflected at 17m or more.
  - Reflection of high frequency sound (ultrasound) can be used to produce images of foetus in the womb.
  - High frequency waves diffract less than low frequency waves.

- ## Standing Waves & Music
  - Instruments create standing waves, which create resonance.
  - Music created is dependant on which standing waves are created and which instruments are used.
  - A guitar with fixed end strings cause destructive interference, until one wave remains.
  - Length, tension, density, and thickness are controllable factors.

- ## Standing Waves in a String
  - Resonant frequencies are frequencies at which standing waves are produced.
  - Harmonics are different forms of standing waves.
  - First harmonic is the simplest standing wave with a fundamental frequency.
  - Overtones are higher level harmonics.



$$l = \frac{1}{2}\lambda_1$$

$$l = \frac{2}{2}\lambda_2$$

$$l = \frac{3}{2}\lambda_3$$

$$l = \frac{4}{2}\lambda_4$$

$$l = \frac{5}{2}\lambda_5$$

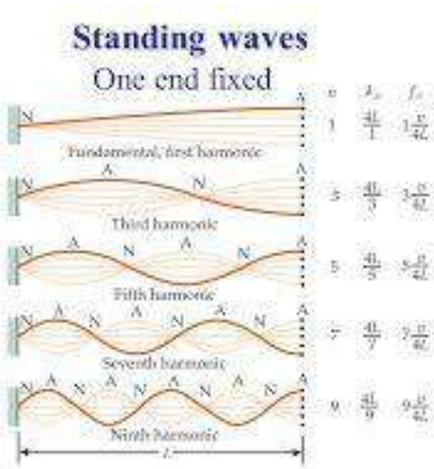
n – harmonic number

$$l = \frac{n}{2}\lambda_n$$

- $\lambda_n = \frac{2l}{n}$
- $f_n = \frac{nv}{2l}$
  - Where,
    - λ – wavelength (m)
    - l – length of string (m)
    - n – number of harmonic (1, 2, 3, …)
    - f – frequency (Hz)
    - v – velocity (ms^{-1})

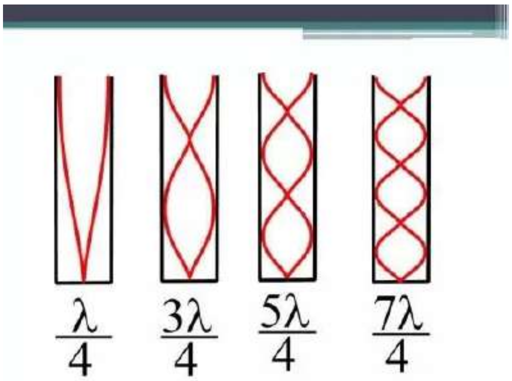
String Fixed at One End

- $\lambda_n = \frac{4l}{n}$
- $f_n = \frac{nv}{4l}$



Standing Waves in Air Columns

- Seen in instruments, such as flute or clarinet.
- When a flutist blows in, a column opens up at both ends, which set up antinodes at both ends.
- When a clarinet has one end open, setting an antinode at one side and a node on the other.

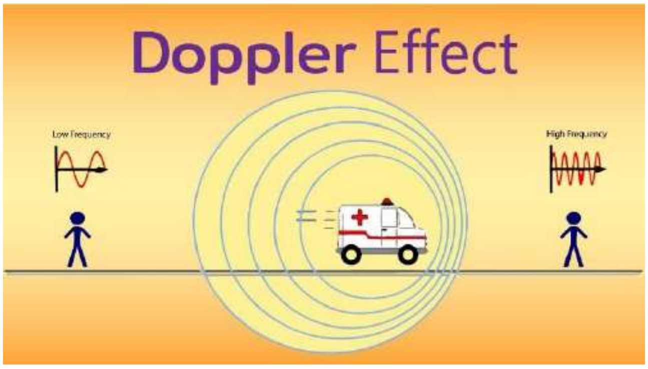


A pipe open at one end can only set up odd number of harmonics, must have a node and an antinode on either side.

Same wavelength and frequency formula as a string with one fixed end.

The Doppler Effect

- Is the observed change in frequency of a wav due to relative motion between a source and an observer.
- Happens when a source and observer experience relative motion.
- It explains the change in pitch when a car passes by.



- No change in pitch – if observer and source are stationary.
- If we stand in front of a moving source, the waves are compressed – decrease in wavelength, increases frequency, higher pitch.
- If we stand behind the moving source, the waves are stretched – increase in wavelength, decrease in frequency, lower pitch.
- **Case 1: Moving Observer**
    - If observer is moving towards source, no change in wavelength.
    - Relative motion between observer and source is:
        - **$v' = v + v_o$**
        - $f' = \frac{f(v+v_0)}{v}$ (When an observer approaches the source)
        - $f' = \frac{f(v-v_0)}{v}$ (When an observer moves away from the source)
- **Case 2: Moving Source**
    - There is no change in wavelength if the source is moving towards the observer.
    - When the source is moving away from the observer.
        - $f' = f\left(\frac{v}{v+v_s}\right)$
    - When the source is moving towards the observer.
        - $f' = f\left(\frac{v}{v-v_s}\right)$
- **Case 3: Motion of Both Objects**
    - When both observer and source are moving.
    - $f' = f\left(\frac{v+v_0}{v-v_s}\right)$
        - v_o - + if observer is moving towards the source (negative if moving away)
        - v_s - + if source is moving away from the observer (negative is moving

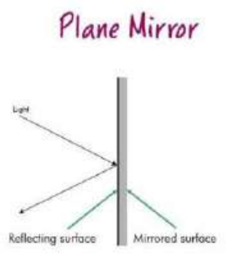
f' – frequency measured by the observer
f – original frequency
λ – original wavelength
λ' – wavelength measured by the observer
v – velocity of wave
v_s – velocity of source

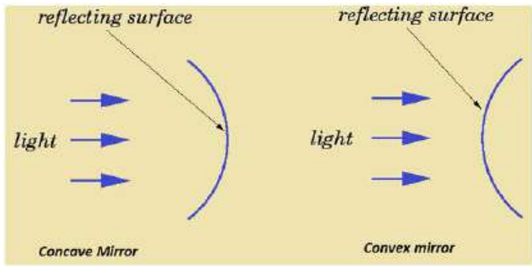
- ## Beats
    - Beats are rhythmic fluctuations of sound intensity.
    - Beats occur when there is a wave interference/superposition of two sound waves of a similar frequency.
    - A slight difference in frequency will cause alternating constructive/destructive interference, causing a regular pattern.
    - Used to tune instruments.
        - Musicians aim to match the instrument frequency with a tuning fork.
        - Matching frequencies won't cause beats.
    - $f_{beat} = |f_2 - f_1|$
        - Where,
            - f_{beat} – beat frequency (Hz)
            - f_1 – frequency of the first sound wave (Hz)

- f_2 – frequency of the second sound wave (Hz)

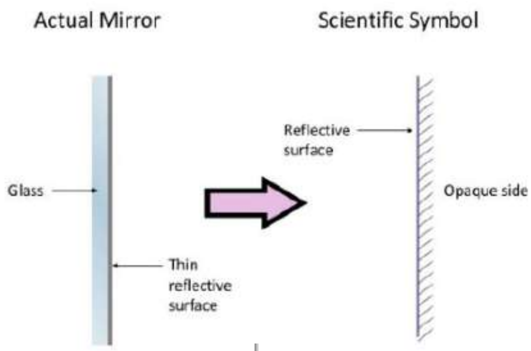
- **Ray Model of Light**
  - Ray is represented by an arrow.
  - Beams are a stream of light that consists of many rays.

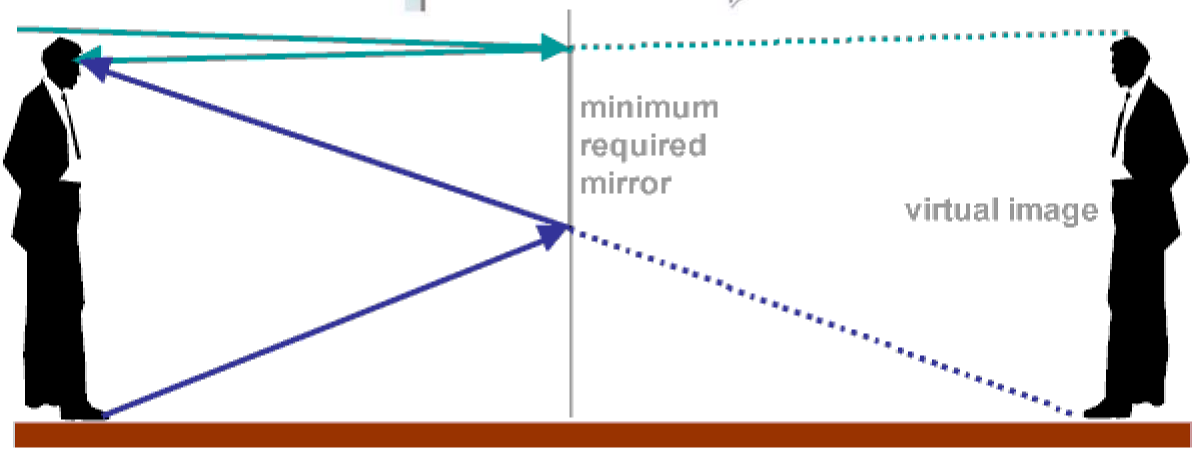
- **Mirrors**
  - There are 3 types of mirrors:
    - Plane mirrors
    - Concave mirrors
    - Convex mirrors



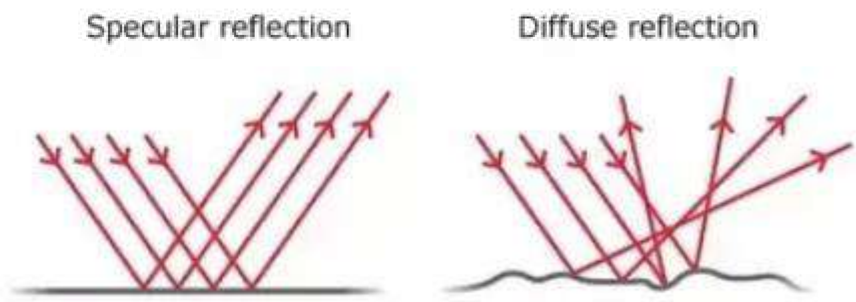


- **Reflection on a Plane Mirror**
  - A plane mirror is smooth and flat allowing specular reflection.
  - A plane mirror always produces virtual images.





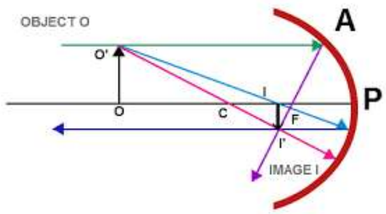
- ## Specular vs Diffuse Reflection

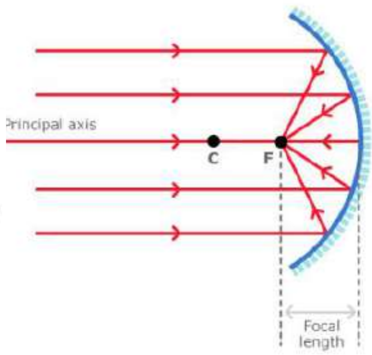


- Reflect parallel.
- Forms clear image.

- Reflected in a scattered manner.
- Forms a distorted or no image.

- ## Reflection on a Concave Mirror
  - Thought as several plane mirrors along a curved plane.
  - All parallel rays reflect towards the focus.
  - Does not determine image formation.

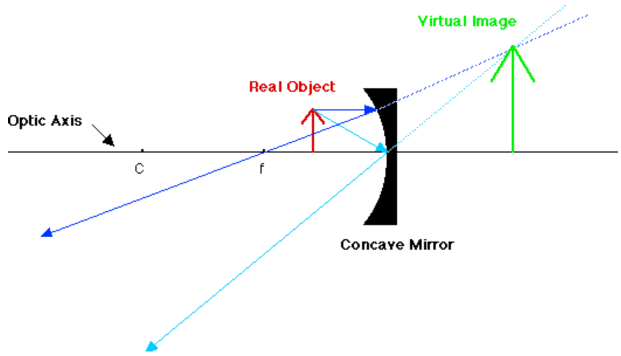


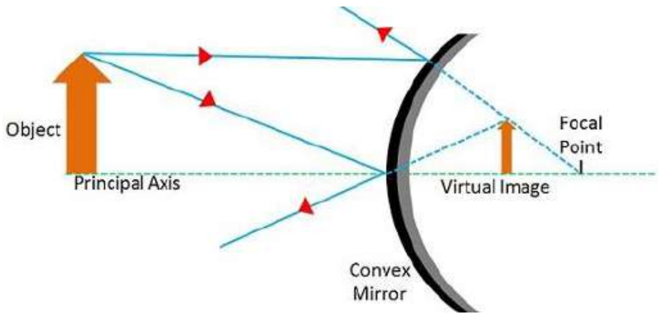


- ## The Mirror Formula
  - Applies for both concave and convex mirrors.
  - $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$
    - Where,
      - f – focal length (+ for concave & - for convex mirrors)
      - u – distance between object & mirror
      - v – distance between image & mirror (- for virtual)

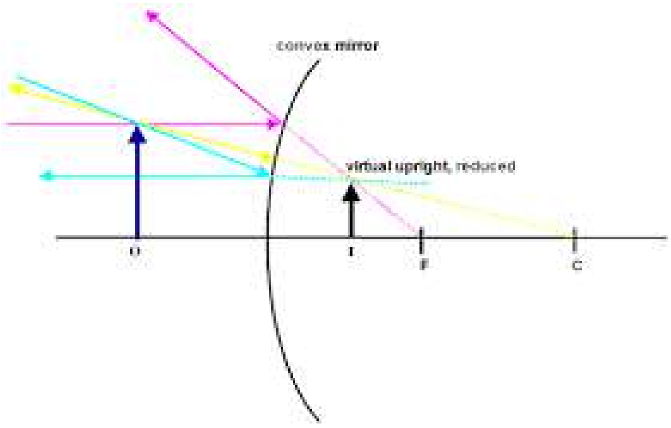
- ## Reflection Terminology
  - **Location**
    - distance between the image & the mirror.
    - Located with reference the centre or focal point.
  - **Orientation**
    - upright or inverted.
  - **Size**
    - Reduced, enlarged, or maintains size.
    - $M = \frac{h_i}{h_0} = \frac{-v}{u}$
      - M – ratio of magnification
      - h_i – height of image (+ if upright & - if inverted)
      - h_o – height of object (+ if upright & - if inverted)

- **Type**
  - Real image:
    - Produced by reflection or refraction when rays converge.
    - E.g. image projected on a cinema screen.
  - Virtual image:
    - Produced when light rays only strike a certain point.
    - E.g. Reflection from a plane mirror.



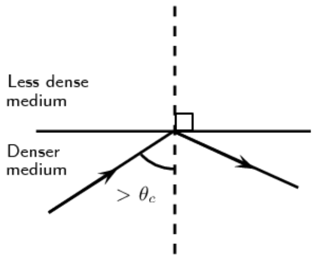


Reflection on a Convex mirror

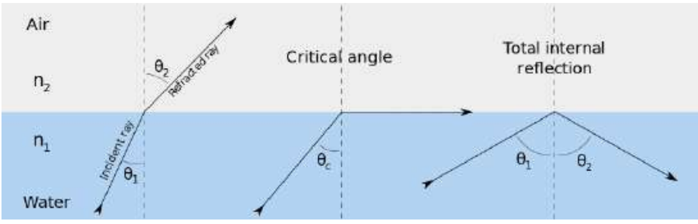


Critical Angle

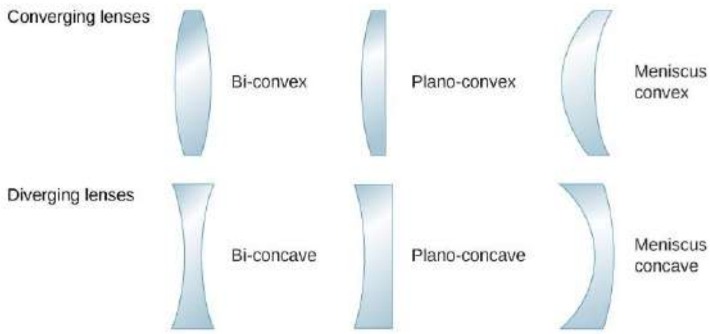
- When travelling, from a dense medium to a less dense medium, the angle of incidence angle forms an angle of refraction of 90°.



- ## Total Internal Reflection
  - Occurs when incidence angles greater than the critical angle.

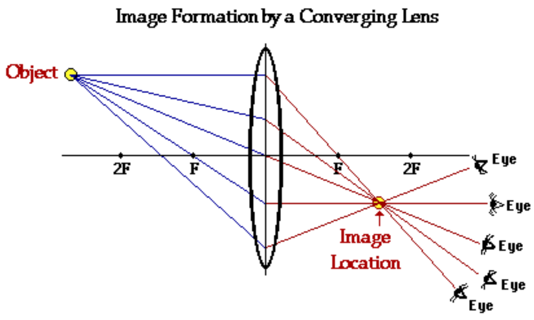


  - Occurs when:
    - Travelling from a denser to a less dense medium.
    - The angle of incidence is greater than the critical angle.
  - Examples:
    - Internet – transmission of data at high speeds
    - Telecommunication – faster and clearer connection
    - Non-invasive diagnosis
    - Treatment

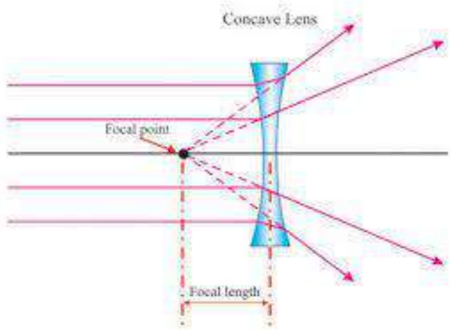


- ## Refraction in Lenses
  - A converging lens refract light, so the rays converge at the focus.
  - A diverging lens refracts light, so the rays diverge. The rays can be traced back to the focus.
  - **THE RAY IS BENT TWICE WHILE TRAVELLING THROUGH THE LENS!!!**
  - **MORE DETAILED RAY DIAGRAM!!!**

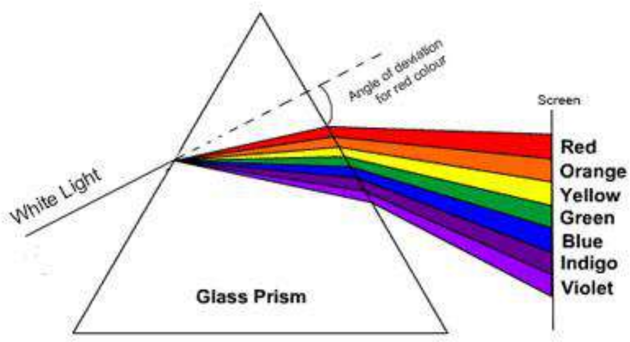
- ## Refraction on Convex Lenses



- ## Refraction on Concave Lenses



- ## Dispersion of Light
  - A white light is a combination of all colours of light with different wavelengths.
  - If white light passes through an object, the component colours are refracted by different amounts, this is called chromatic dispersion.
  - Violet light refracts the most while red light refracts the least.
  - Rainbows are a result of colour dispersion as light is refracted through many raindrops.



Dispersion of light

- ## Light Intensity
  - Light spreads uniformly into 3D space, the energy is distributed in a surface area of a sphere.
  - $I = \frac{P}{4\pi r}$

Definitions

WORDS	DEFINITIONS
Wave	a disturbance/oscillation which transfers energy without transferring matter.
Mechanical waves	waves which require a medium to propagate.
Longitudinal wave	when the particles motion oscillates parallel to the direction of motion of energy propagation.
Transverse wave	when the particles of the medium oscillate perpendicular to the direction of energy propagation.
Crest	the highest point of a wave.
Trough	the lowest point of a wave.
Equilibrium	the rest position of the wave.
Amplitude	the maximum displacement of particles from the equilibrium position (m).
Wavelength	the horizontal distance between two successive identical points on a wave (m).
Frequency	the number of complete oscillations in one second through a fixed point.
Period	the time taken for a particle to make one oscillation.
Wave Reflection	when a wave meets a boundary.
Wave Refraction	when a wave travels from a denser to less dense medium (or vice-versa).
Wave Diffraction	when a wave meets a barrier and travels through an opening.
Wave Superposition	when a wave meets another wave travelling in the same medium.
Pulse	a single vibration.
Wavefront	a line that joins all identical points in a phase, in a wave.
Ray	shows the direction of propagation and is always perpendicular to the wavefront.
Refractive Index	the ratio of the speed of light in a vacuum to the speed of light in a material.
Standing wave	a pattern which results from the interference of two identical waves travelling along the same medium in the opposite direction.
Resonance	when an object exposed to a driving force is equal to their resonant frequency.
Intensity	the amount of sound energy passing through a unit area in one second.
Reverberation	the prolongation of a of a sound wave.
Echo	the reflection from a hard surface and rebounds to its original source.
Doppler Effect	the observed change in frequency of a wav due to relative motion between a source and an observer.
Beats	rhythmic fluctuations of sound intensity.

Critical angle	when the angle of incidence angle forms an angle of refraction of 90^o.
Total Internal Reflection	when incidence angles greater than the critical angle.

Formulas

$$I = \frac{P}{4\pi r}$$

$$PD = n\lambda$$

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

Name	Symbol	
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

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

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$PD = \lambda\left(n + \frac{1}{2}\right)$$

$$f_n = \frac{nv}{4l}$$

$$I = \frac{P}{A} = \frac{P}{4\pi r^2}$$

$$T = \frac{1}{f}$$

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{n_2}{n_1}$$

$$v = f\lambda$$

$$\lambda_n = \frac{2l}{n}$$

$$M = \frac{h_i}{h_0} = \frac{-v}{u}$$

$$I = \frac{k}{r^2}$$

$$\lambda_n = \frac{4l}{n}$$

$$l = \frac{n}{2}\lambda_n$$

$$v' = v + v_0$$

$$f' = \frac{f(v+v_0)}{v}$$

$$f_n = \frac{nv}{2l}$$

$$f' = f\left(\frac{v}{v + v_s}\right)$$

$$f' = \frac{f(v-v_0)}{v}$$

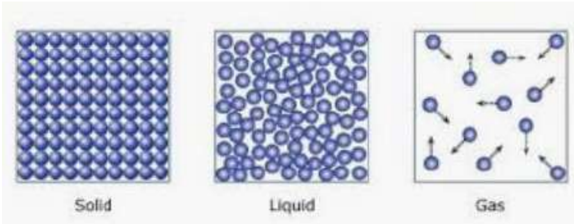
$$f' = f\left(\frac{v}{v - v_s}\right)$$

$$f' = f\left(\frac{v + v_0}{v - v_s}\right)$$

Thermodynamics Notes

- ## Temperature
  - It is a measure of the average kinetic energy of all particles in an object.
  - Not all particles in an object will have the same KE.
  - Temperature is measured in Kelvins but commonly represented by °C.
  - **Temperature in Kelvins = Temperature in °C + 273.15°**.

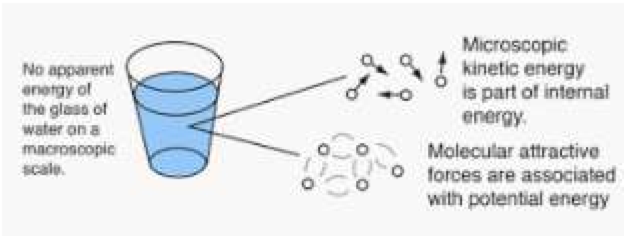
- ## Kinetic Theory
  - The kinetic particle model states that "all matter (solid, liquid, & gas) consists of small particles in constant motion.
  - The particles exert a force and collide elastically as they interact.



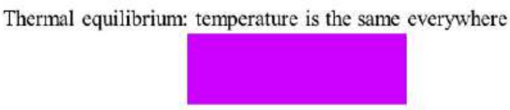
- ## Heat
  - It is the flow of energy from different objects due to differences in temperature.
  - An object can gain or lose heat but cannot have heat.
  - Heat always flows from higher to lower temperature objects.
  - Certain substances heat up faster than others (depends on the heat capacity).
  - $\Delta Q = mc\Delta T$
    - Where,
      - Q – heat (J) [+ is object is warmed & - if object is cooled]
      - m – mass (kg)
      - c – specific heat capacity ($Jkg^{-1}{}^{o}C^{-1}$)
      - ΔT – change in temperature (°C or °K)
  - Heat capacity is how much heat is required to change the temperature of an object.
  - Specific heat capacity is the amount of heat required to change in temperature of 1kg of a substance by 1°C and is an intrinsic property of the material.

Material	Specific Heat Capacity ($Jkg^{-1}{}^{o}K^{-1}$)
Water (at 25°C)	4181

- ## Internal Energy
  - It is the energy associated with the random distorted motion of particles.
  - Hot objects have more internal energy than cold objects.
  - **U = KE + PE**
    - Where,
      - U – Internal Energy
  - **ONLY THE RANDOM KE IS CONSIDERED & NOT ORDERED KE!!!**



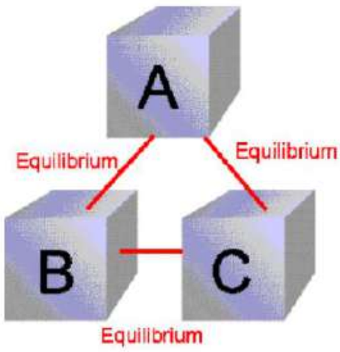
- ## Thermal Contact & Equilibrium
  - Thermal Contact is a state where two objects **CAN** exchange heat (or electromagnetic radiation) between them.
  - Objects in thermal contact are not necessarily in physical contact.
  - Thermal Equilibrium is a state where two objects in thermal contact yet have no exchange in heat.



  - Two objects will have thermal equilibrium if they have the same temperature.
  - A closed system is where heat energy transfers from one section of a system to another and no energy is lost elsewhere.
  - Room Temperature is 25°C.

Energy transferred from hot objects = Energy received by cold object
$-Q_{hot} = Q_{cold}$

- ## Zeroth Law of Thermodynamics
  - "If objects A & B are each in thermal equilibrium with a third object C, then objects A & B are in thermal equilibrium with each other".
  - The chair and the wooden table are in thermal equilibrium at 25°C.
  - However, the metal chair will feel colder than the wooden table.
  - Met conducts more heat away from your hand than the wooden table.
  - Our bodies sense of temperature is based on energy flow.

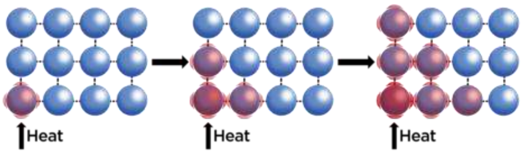


- ## First Law of Thermodynamics
  - It is a version of the law of conservation of energy.
  - "The total energy of an isolated system is constant, energy can be transformed from one form to another, but can not be created nor destroyed".
  - $\Delta U = Q - W$
    - ΔU – Internal Energy (J)
    - Q – Heat added to the system (J)
    - W – Work done by the system, when work is done on the system (J)

- ## Energy Transfer
  - There are three main mechanisms that allow thermal energy to be transferred:
    - Conduction
    - Convection

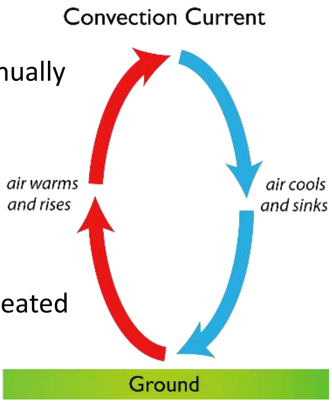
- Radiation
- These mechanisms only occur in thermal contact.
- All three forms allow for the increase in KE of particles in a body.

- **Conduction**
  - It is the transfer of heat through physical collisions between particles.
  - The vibrational amplitude of an area of an object increases due to the higher temperatures from their environment. Which increases the KE of particles in the area.
  - During particle collisions, energy is passed from higher to lower KE particles. Causing an increase in vibrational amplitude. Resulting is a heat transfer throughout the entire body.



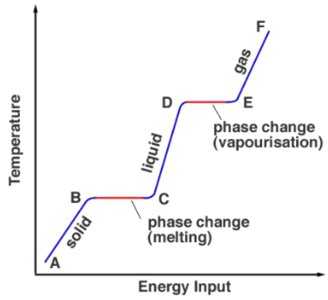
  - $P_{cond} = \frac{Q}{t} = kA\frac{\Delta T}{\Delta L}$
    - Where,
      - P_{cond} – Power of conduction (Watts)
      - Q – Heat (J)
      - ΔL – Thickness of material (m)
      - k – Thermal conductivity of a material ($Wm^{-1}K^{-1}$)
      - A – cross-sectional area (m^2)
      - ΔT – Difference in Temperature/Temperature Gradient (K) [T_{hot} - T_{cold})

- **Convection**
  - It is the transfer of heat due to fluid movement.
  - A fluid is any substance that has no fixed shape and is able to continually deform or flow (liquids & gases).
  - Molecules gain KE and expand when fluids are heated. Expansion causes a fluid to become less dense.
  - Less dense, warmer substances will rise above denser, cooler substances.
  - As hot fluids rise, it pushes denser, cooler fluid down. This is repeated until a substance is heated, forming convection currents.

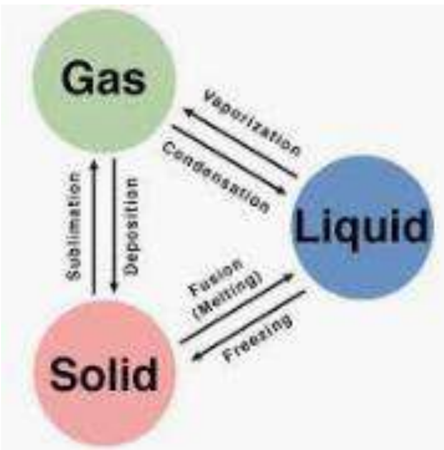


- **Radiation**
  - It is the transfer of heat due to photons of EM waves.
  - Radiation can occur through any object or matter including vacuums.
  - Thermal radiation occurs due to a charged particle in a vibrating object. The oscillation of charged particles releases EM radiation that transfer their KE energy.
  - An object's rate of radiation is proportional to its temperature (in kelvins) to the fourth power.
  - All objects are able to radiate EM waves (the type of EM wave depends on the temperature of the object).
  - The human body radiates EM waves in the infrared part of the spectrum.

- **Latent Heat**
  - It is the energy required to cause a mass to charge it's phase without changing its temperature.
  - There are two types of latent heat:
    - Latent Heat of Fusion
      - Is the energy required to convert a solid to liquid.
    - Latent Heat of Vaporisation
      - Is the energy required to convert a liquid to a gas.



  - **Q = mL**
    - Where,
      - Q – Heat (J)
      - m – mass (kg)
      - L – specific latent heat for particular substances (Jkg^{-1})
  - Latent Heat exists due to the energy required to overcome intermolecular forces.
  - Input energy is required to break intermolecular forces, separating molecules to facilitate for a phase charge (from solid – liquid – gas).
  - While molecules are separated from the energy input, their vibration does not change.
  - Latent Heat only describes the energy required to cause a phase change, not a temperature change.
  - Phase changes are reversable and there are six common ones.



Definitions

WORDS	DEFINITIONS
Temperature	is a measure of the average kinetic energy of all particles in an object.
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Thermal Equilibrium	is a state where two objects in thermal contact yet have no exchange in heat.
Conduction	is the transfer of heat through physical collisions between particles.
Convection	is the transfer of heat due to fluid movement.
Radiation	is the transfer of heat due to photons of EM waves.
Latent Heat	is the energy required to cause a mass to charge it's phase without changing its temperature.

Formulas

Temperature in Kelvins = Temperature in °C + 273.15°

$$\Delta Q = mc\Delta T$$

U = KE + PE

$$\Delta U = Q - W$$

$$P_{cond} = \frac{Q}{t} = kA\frac{\Delta T}{\Delta L}$$

Q = mL

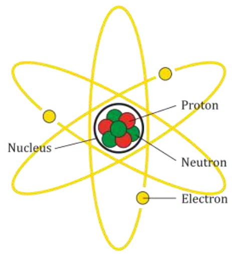
Energy transferred from hot objects = Energy received by cold object

$$-Q_{hot} = Q_{cold}$$

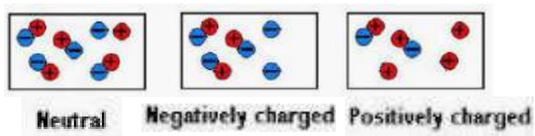
Electricity & Magnetism Notes

- **Electrostatics**
  - It refers to the properties of stationary or slow-moving electric charges with no acceleration

- **Charges**
  - It is a property of matter.
  - All matter consists of atoms.
  - The main components of atoms are:
    - Nucleus
      - Protons and neutrons
    - Electrons surrounding the nucleus

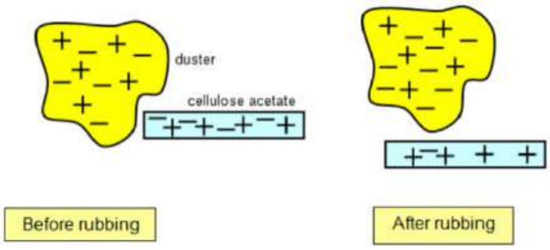


  - Electrons and protons are the elementary charges as they hold the smallest unit of charges.
  - Objects can have different types of charges, depending on their electron and proton content:
    - Neutral objects (no charge)
      - **Number of Protons = Number of Electrons**
    - Charged objects (objects become charged when they lose/gain electrons)
      - Positively charged (number of protons > number of electrons)
      - Negatively charged (number of protons < number of electrons)
  - Remember:
    - Like charges repel
    - Unlike charges attract

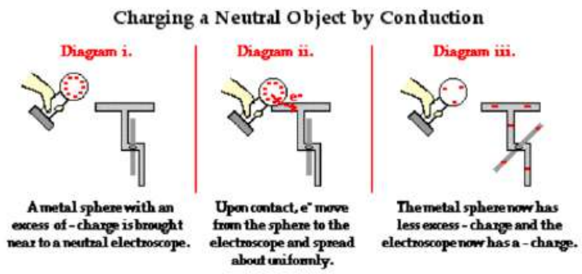


  - Electric charges are called Coulombs (C).
    - **1 Coulomb of charge = 6.25 x 10^{8} electrons/protons**
    - **Charge of 1 electron = -1.6 x 10^{-19} Coulombs**
    - **Charge of 1 proton = 1.6 x 10^{-19} Coulombs**
  - **q = ne**
    - where,
      - q – total charge of objects (C)
      - n – number of electrons lost or gained
      - e – charge of an electron (1.6 x 10^{-19} C)
    - q > 0 - loss in electrons
    - q < 0 – gain in electrons

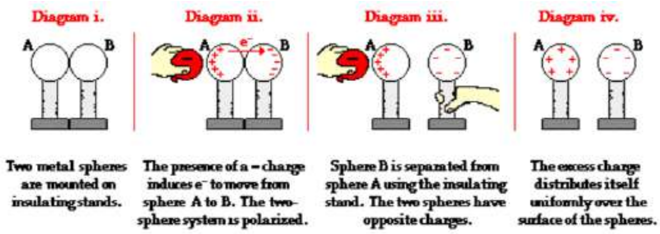
- ## Methods of Charging
  - A neutral object must gain or lose electrons to become charged.
  - The three different ways to charge are:
    - **Friction**
      - Transfer of charges by physical contact
      - Different objects have different tendency to attract electrons
      - When two neutral objects are rubbed against each other, electrons from the lower affinity are removed and given to the object with the higher affinity
      - One object has lost electrons and the other has gained electrons – therefore charged.



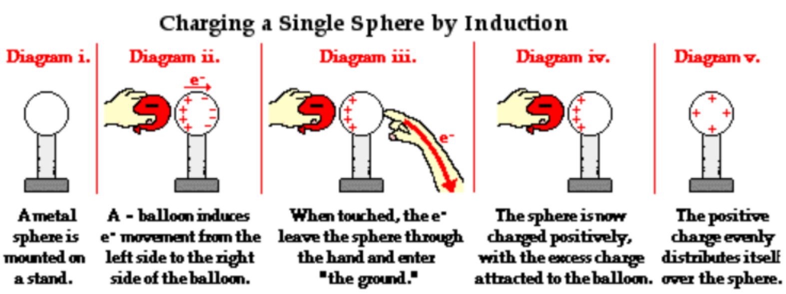
    - **Contact**
      - Coming into physical contact with an existing charged object

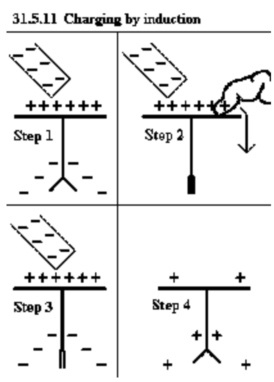


    - **Induction**
      - Without physical contact
      - Scenario 1
        - Polarisation

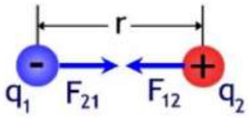


      - Scenario 2
        - The ground is able to transfer/receive electrons and neutralize excess charges.

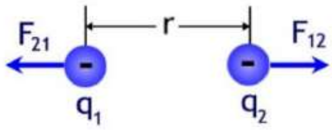




- ## Coulomb's Law
  - Two charges exert a force on each other.
  - Attraction

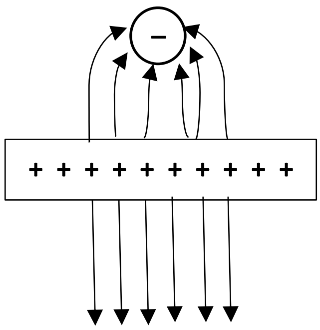


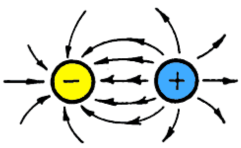
  - Repulsion:
    - $F_{\frac{q2}{q1}} = -F_{\frac{q1}{q2}}$

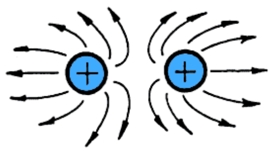


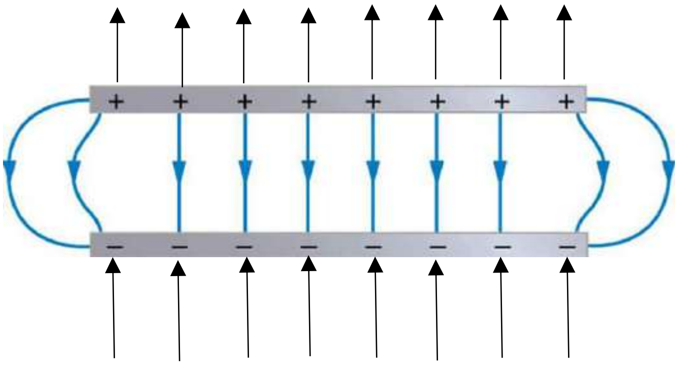
  - Charles found that the force depends on the charges and distance between them:
    - $F_e \propto \frac{q_1 q_2}{r^2}$
    - $F_e = k_e \frac{|q_1||q_2|}{r^2}$
      - Where,
        - k_e – Coulomb constant (8.9876 x 10^9 $Nm^{-2}C^{-2}$ / $\frac{1}{4\pi E_0}$)
        - E_0 – permittivity of free space (8.8542 x 10^{-12} C^2Nm^{-2})
        - r –centre distance between charges (m)
        - q_1 – charge of the first particle (C)
        - F_e – electrostatic force q_2 exerts on q_1 (N)

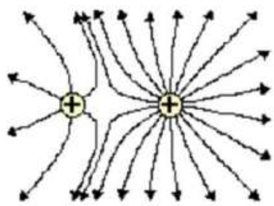
- ## Electric Fields
  - It is a region surrounding a charged particle where another particle will experience a force.
  - Electric Force is a form of field force.
  - Draw lines which represent imaginary forces acting on a positive test charge.
    - Go from + to –
    - Enter and leave perpendicular from charges
    - Stronger electric fields have denser field lines, while weaker electric fields have more spread out field lines.







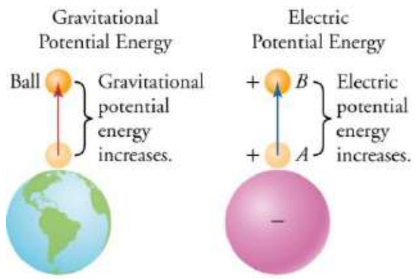




- ## Electric Field Strength
  - $E = \frac{F}{q}$
    - Where,
      - E – electric field strength (NC^{-1})
      - F – size of force on charge (N)
      - q – size of charge (C)
  - It is a vector quantity.
  - q > 0, then F and E have same direction.
  - q < 0, then F and E have opposite direction.

- ## Electric Field and Parallel Plates
  - The electric field between two parallel plates is uniform.
  - The strength of the electric field is the same everywhere between the plates.
  - $E = \frac{V}{d}$
    - Where,
      - E – electric field strength (Vm^{-1})
      - V – potential difference between the two plates (V)
      - d – distance between the electric field plates (m)

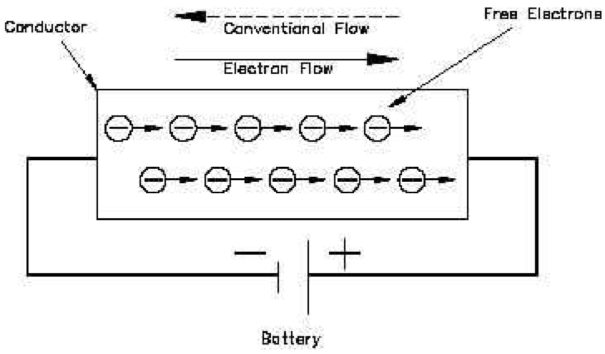
- ## Electric Potential Energy
  - It is the amount of energy stored in a charged object due to its position in an electric field.
  - The change in EPE = amount of energy required to move a charge between two positions against the electric field.



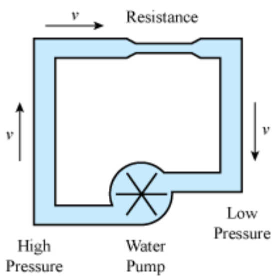
- ## Potential Difference (Voltage)
  - Voltage is the amount of PE lost or gained by 1C of charge between the two points in one electric field.
  - $V = \frac{w}{q}$
    - Where,
      - V – potential difference or voltage (V)
      - W – charge of electric potential energy (J)
      - q – magnitude of charge (C)

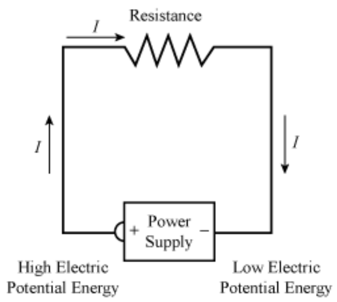
- ## Current
  - It is the rate of flow of energy in a circuit in a fixed point.
  - It is measured in amperes (A).
  - A path of conductive material allows charges to flow.
  - Potential difference is between two terminals.

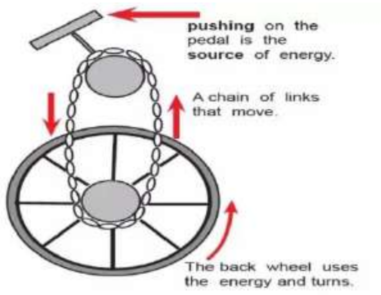
- ## Energy in a Circuit
  - A circuit is a closed connection with components and a power source.
  - Power source supples energy (battery).
  - A battery converts chemical energy into electric potential energy.
  - If a battery supplies 10J of energy, the positive terminal will have 10J and the negative terminal to differ by 10J.
  - Difference in potential energy is known as potential difference.
  - Current is the electron flow and conventional current.
  - Electron flow is the flow of negative charges in a wire.
  - Conventional current travels opposite to the direction of electron flow.



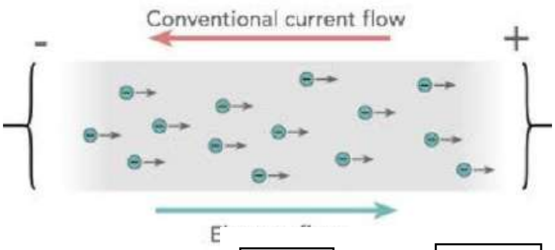
  - $I = \frac{q}{t}$
    - Where,
      - I – current (A)
      - q – charge (C)
      - t – time (s)
  - The voltage source if the battery in the circuit.
  - The voltage source provides a potential difference to push charges.



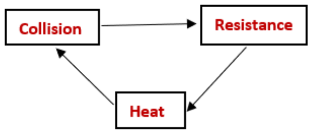




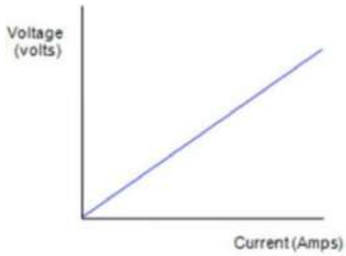
- ## Resistance
  - It is the measure of how hard it is for current to flow through a material.
  - It is measured in ohms.
  - Conductors have low resistance. They allow to flow past easily.
  - Insulators have high resistance. They present current from flowing easily.
  - $R = p\frac{L}{A}$
    - Where,
      - R – resistance (Ω)
      - p – resistivity (Ωm)
      - L – length (m)
      - A – area (m^2)



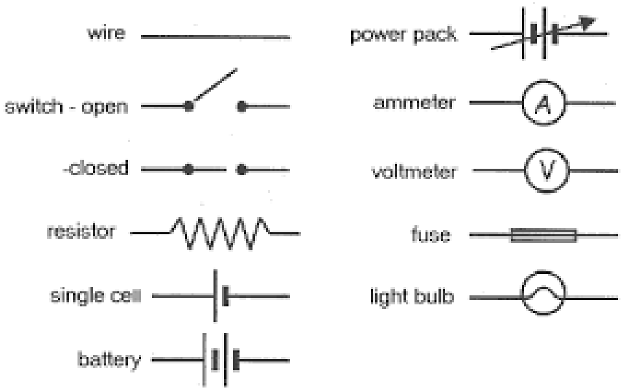
  - Resistance is dependent of temperature.
  - Higher temperatures = more vibration = more resistance.



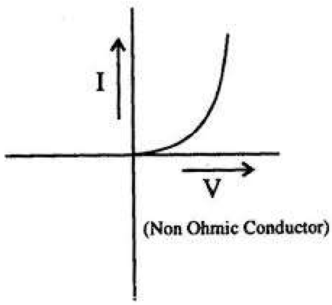
- ## Ohm's Law
  - **V = IR**
    - Where,
      - V – voltage (V)
      - I – current (A)
      - R – resistance (Ω)
  - Materials that obey Ohm's Law are described as Ohmic.
  - Resistors are an Ohmic conductor.



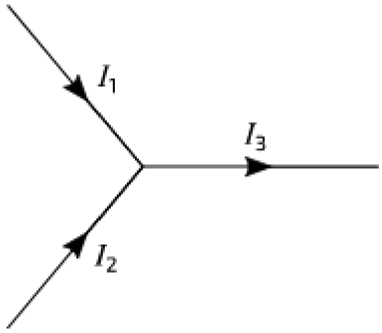
- ## Circuit Symbols



- ## Non-Ohmic Resistors
  - They are components that don't obey Ohm's Law.
    - E.g. light bulbs and diodes.



- **Kirchhoff's Current Law**
  - "At any node, the total sum of all current entering that node must be equal to the total sum of all the currents leaving that node".
  - Based off the principle of conservation of charge.
  - "Charge can not be created nor destroyed, hence the number of charges entering a node must be equal to the number of charges leaving the node".



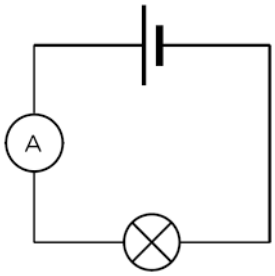
- **Kirchhoff's Voltage Law**
  - "The sum of potential difference across all elements in a closed circuit must be equal to zero.
  - $V_1 + V_2 + V_3 + \ldots = 0$
  - $\sum V = 0$

- **Series Circuits**
  - All components are in one loop.
  - Current in a circuit is constant.
  - If is an open connection or a component breaks, the circuit is then broken.
  - Households use parallel circuits.
  - Components must share the same energy.
  - Every component uses has less EPE to use – dimmer globe.
  - $V_T = V_1 + V_2$
  - $I_T = I_1 = I_2$
  - $V_T = I_T R_T$
  - $R_T = R_1 + R_2 + R_3 + \ldots$

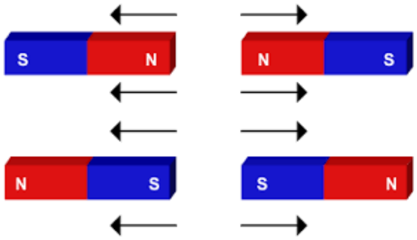
- **Parallel Circuits**
  - Contains more than brank of components.
  - Regardless of which pat a charge takes, when it completes it journey, the voltage must be constant.
  - If a bulb breaks, current will flow into another brank – keeping other bulbs working.
  - $V_T = V_1 = V_2 = V_3 = \ldots$
  - $I_T = I_1 + I_2 + I_3 + \ldots$
  - $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$

- **Measuring Voltage**
  - Voltmeters measure voltage in circuits.
  - Always connected in a parallel circuit.
  - It has high resistance, prevents significant amounts of current flowing out.

- ## Measuring Current
  - An ammeter is used to measure current.
  - It is always connected in a series circuit.
  - It has low resistance, prevents it from using significant amounts of voltage.



- ## Power and Energy
  - Power is the rate of doing work.
  - It measures how fast energy is transformed.
  - $P = \frac{E}{T}$
  - **P = VI**
  - $P = \frac{V^2}{R}$
  - **$P = I^2R$**
  - **E = VIT**
    - Where,
      - P – power (W)
      - V – voltage (V)
      - I – current (A)
      - E – energy (J)
      - T – time (s)
- ## Magnetism
  - It is a property of specific metals that enables them to attract to other metals.
  - They attract to iron, cobalt, or nickel.
  - Magnets contain a north and south pole.
    - Like poles repel
    - Unlike poles attract

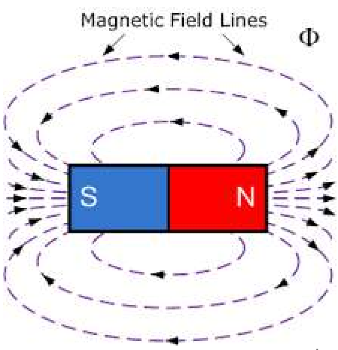


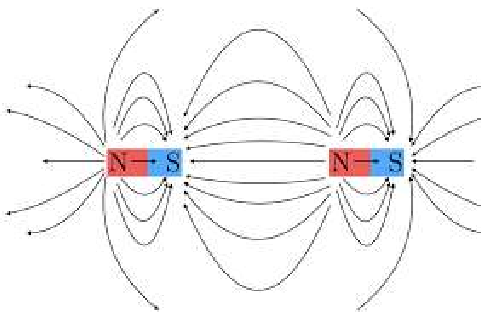
- ## Ferromagnetism
  - Ferromagnetic materials are materials that can be magnetised.
  - Most materials are not ferromagnetic.
  - They have unaligned pairs of electrons.
  - Ferromagnetic materials are:
    - Iron
    - Cobalt
    - Nickel
  - A magnetised object will attract other magnets.
    - String of paperclips attracted to a magnet.
  - Ferromagnetic materials become magnetic by a magnetic field.
  - Magnetised objects produce magnetic field.

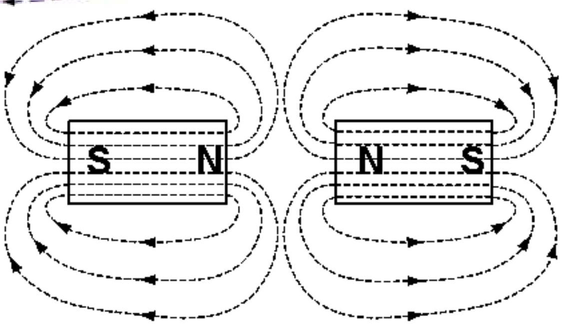
- ## Diamagnetism vs Paramagnetism
  - Diamagnetic materials are weakly repelled by magnetic fields.
    - Gold
    - Silver
    - Copper
  - Paramagnetic materials are weakly attracted by magnetic fields.
    - Molybdenum
    - Lithium
    - Magnesium
  - Most materials cannot be permanently magnetised, they are either diamagnetic or paramagnetic.

- ## Magnetic Fields
  - It is a region surrounding a magnet where it can exert a force on another magnetic material.
  - Created by moving charges, typically electron.
  - Magnetic fields are represented by field line.
    - Field lines are drawn using a north pole.
    - Field lines indicate direction of force acting on north pole.
    - Directed away from the north pole to the south pole.
    - Denser field lines indicate a stronger magnetic field.
  - Always form closed loops.

- ## Drawing Magnetic Fields





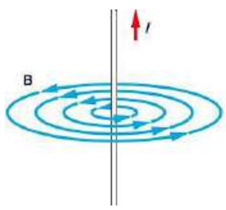


- ## Magnetism & Electricity
  - Hans Christian Oersted found that when a compass was placed near a wire carrying a current, the compass defected.
  - A current carrying conductor will produce a magnetic field.

- ## Right Hand Grip Rule
  - Used to determine magnetic field produced by current through a wire.
    1. Grip the wire with your right hand.
    2. Point your thumb in the direction of conventional current.
    3. Fingers curl around the wire in the direction of the magnetic field.
  - Dots:
    - Field line is coming out of the page.
  - Crosses:
    - Field line is going into the page.

- ## Measuring Magnetic Fields
  - The strength is inversely proportional to the perpendicular distance.
    - Greater distance – weaker magnetic field
  - The strength is directly proportional to the current.
    - Stronger current – stronger magnetic field
  - $B = \frac{\mu_o I}{2\pi r}$
    - Where,
      - B – magnetic field strength (T – Tesla)
      - I – current (A)
      - r – perpendicular distance from the wire (m)
      - μ_o – 4π x 10^{-7} permeability of free space (TmA^{-1})

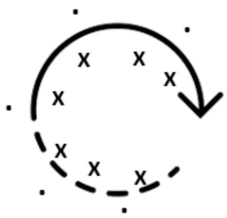
- ## Electromagnets and Solenoids
  - Produced by the presence of an electric current within a current carrying conductor.
  - When the electric field is removed, the magnetic properties cease.
  - Electromagnets are commonly used as temporary sources of magnetic fields.
    - Magnets on scrapyard cranes
  - A solenoid is a wire twisted into a coil to create a stronger magnetic field.
    - Increasing the number of turns – increases the density of field lines – stronger magnet



Straight Wire

=

Circular Magnetic Fields

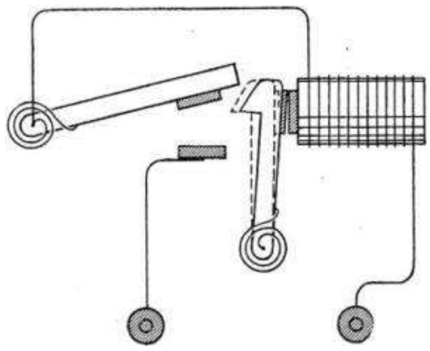


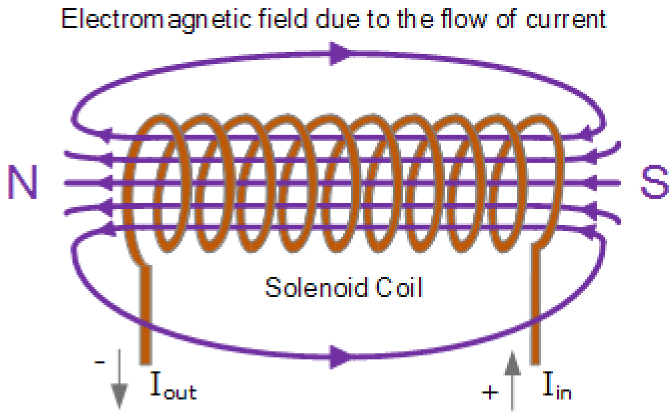
Circular Coil

=

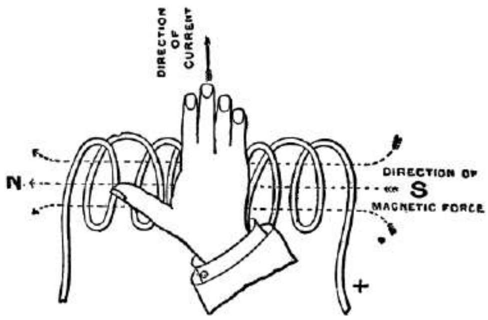
Straight Magnetic Field Lines (bar magnet)

- ## Solenoids
  - Field lines in the coil are denser than outside, magnetic field is stronger than the outside.
  - Direction of magnetic field can be changed by swapping the direction of current.
  - E.g. electromagnets, transformers, and inducers.
  - Used as circuit breakers – safety devices in households.



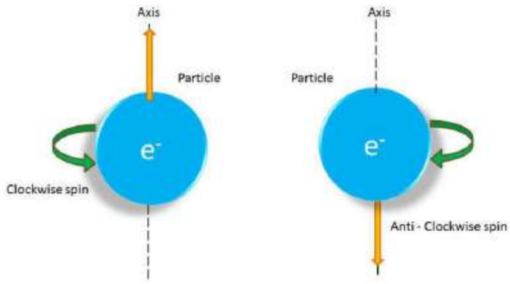


- ## Solenoid Polarity
  - A current carrying solenoid is an electromagnet.
  - An electromagnet behaves like a bar magnet.
  - **Methods:**
    - The Right-Hand Coil Rule:
      1. Grip the solenoid with your right hand.
      2. Curl your fingers in the direction of conventional current.
      3. Your thumb points in the direction of the North Pole.
    - Hint:
      - Think about:
        - Front: Up
        - Back: Down

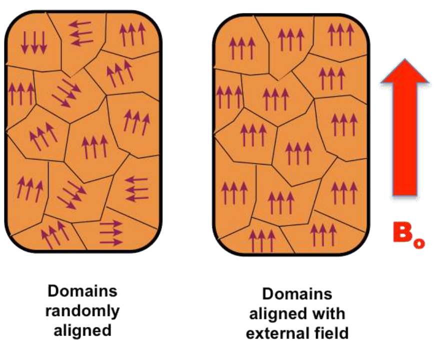


- ## Measuring Magnetic Fields for a Solenoid
  - The strength of the magnetic field within a solenoid is:
    - Directly proportional to the current within the coil.
      - Stronger current – stronger magnetic field
    - Directly proportional to the number of turns of the coil.
      - More wires in the same area – stronger magnetic field
    - Inversely proportional to the length of the solenoid.
      - Stretching a solenoid, less wires in the same area – weaker magnetic field.
  - $B = \frac{\mu_0 NI}{L}$
    - Where,
      - B – magnetic field strength (T – Tesla)
      - N – number of turns of the coil
      - I – current (A)
      - L – length of the solenoid (m)
      - μ_o – 4π x 10^{-7} permeability of free space (TmA^{-1})

- ## Magnetisation (Producing Magnets)
  - Residual magnetisation is if an object can retain its magnetisation.
  - Residual magnetism is dependent on the composition of the material.
  - Orbiting electrons produce their own magnetic fields.
  - Most electrons are paired, of they have another electron spinning in the opposite direction – creating magnetic fields which cancel each other out.
  - Magnetic properties of material arise when there are unpaired electrons.
  - Unpaired electrons line up and form regions known as domains.



  - The domains are arranged randomly, and the material doesn't produce any magnetic fields.
  - With a larger magnetic field, larger domains, align with external field.
    - Larger external magnetic field – larger internal magnetic field.
  - Saturation magnetism is the point at which the external magnetic field causes all electrons to be aligned.
  - When the external magnetic field is removed, the domains become unaligned.
    - Due to the internal energy or thermal energy of the particles in the material.
    - Random particle vibration due to thermal energy destroys the alignment of the domains – decreases magnetism.
  - Lowering temperature will allow it to increase the residual magnetism.



Definitions

WORDS	DEFINITIONS
Electrostatics	refers to the properties of stationary or slow-moving electric charges with no acceleration.
Charges	are a property of matter.
Induction	is charging without physical contact.
Electric Fields	are a region surrounding a charged particle where another particle will experience a force.
Electric Potential Energy	is the amount of energy stored in a charged object due to its position in an electric field.
Voltage	the push force that charges experience in a wire.
Current	is the rate of flow of energy in a circuit in a fixed point.
Resistance	is the measure of how hard it is for current to flow through a material.
Power	is the rate of doing work.
Magnetism	is a property of specific metals that enables them to attract to other metals.
Ferromagnetic	materials are materials that can be magnetised.
Diamagnetic	materials are weakly repelled by magnetic fields.
Paramagnetic	materials are weakly attracted by magnetic fields.
Solenoid	is a wire twisted into a coil to create a stronger magnetic field.
Residual Magnetisation	is if an object can retain its magnetisation.
Potential Difference	is the amount of PE lost or gained by 1C of charge between the two points in one electric field.

Formulas

$q = ne$

Number of Protons = Number of Electrons

$$F_{\frac{q2}{q1}} = -F_{\frac{q1}{q2}}$$

$$F_e = k_e \frac{|q_1||q_2|}{r^2}$$

$$E = \frac{F}{q}$$

$$E = \frac{V}{d}$$

$$V = \frac{w}{q}$$

$$I = \frac{q}{t}$$

$$R = p\frac{L}{A}$$

$V = IR$

$V_1 + V_2 + V_3 + \ldots = 0$

$$\sum V = 0$$

$V_T = V_1 + V_2$

$I_T = I_1 = I_2$

$V_T = I_T R_T$

$R_T = R_1 + R_2 + R_3 + \ldots$

$$P = \frac{E}{T}$$

$P = VI$

$$P = \frac{V^2}{R}$$

$P = I^2R$

$E = VIT$

$$B = \frac{\mu_o I}{2\pi r}$$

$$B = \frac{\mu_o N I}{L}$$