PARTICLES AND RADIATION

$$E = hf = \frac{hc}{\lambda}$$

The energy of a photon of EM radiation is directly proportional to its frequency

Planck's constant

$$h = 6.63 \times 10^{-34}\,Js$$

$$1eV = 1.6 \times 10^{-19} J$$

Work done on an electron in accelerating it through a potential difference of 1 Volt. It is a convenient unit for energy where

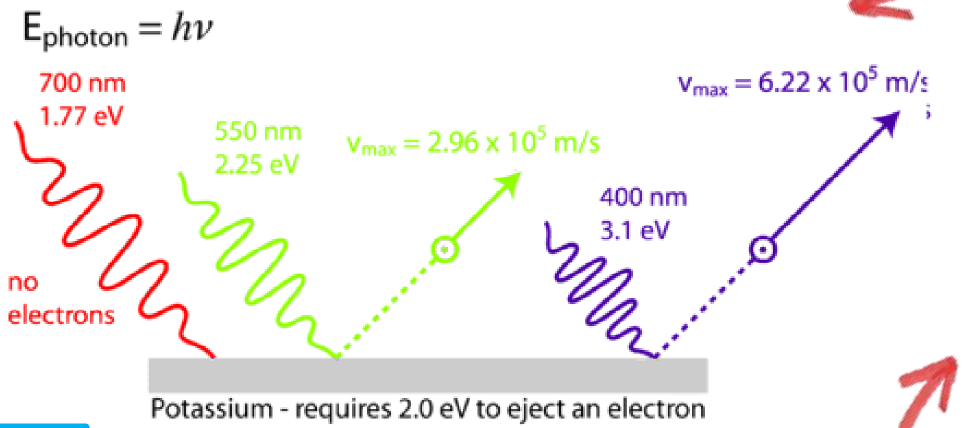
$$f_0 = \frac{\phi}{h}$$

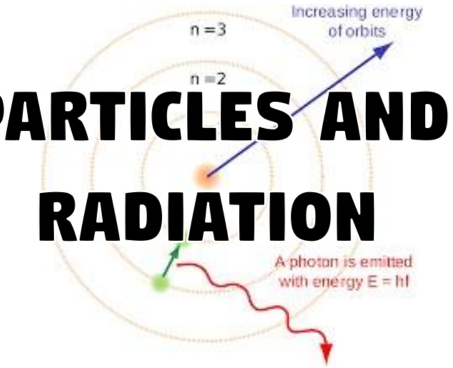
The threshold frequency, f_0 is the minimum frequency of EM radiation needed to release an electron from the surface of a metal

$$\phi = hf_0$$

Work function, ϕ (phi) is the minimum amount of energy needed to release an electron from the surface of a metal

Photoelectric effect



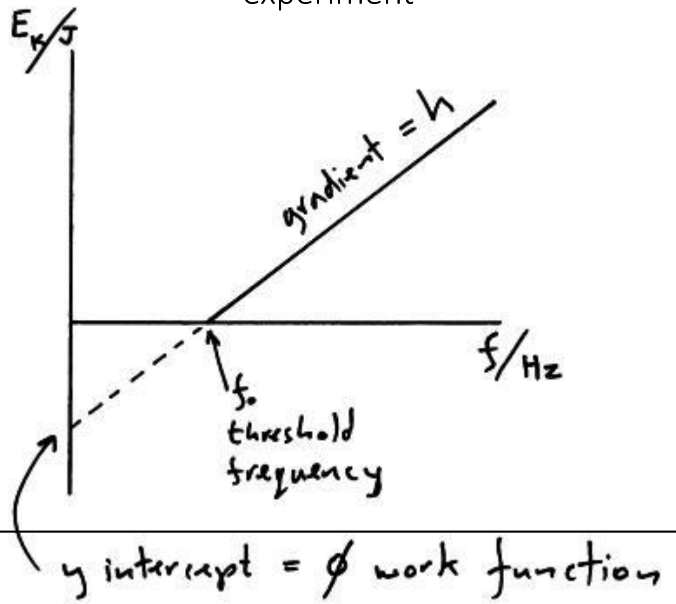


$$hf = \phi + E_{k(max)}$$

- Photons are absorbed by electrons on a one to one basis
- Some electrons are deeper in the metal than others
- This means that they require more energy than the work function to be released, so their kinetic energy will be lower than those from the surface

$$eV_s = E_{k(max)}$$

Stopping potential, V_s is the potential difference needed to stop the fastest moving electron in a photocell experiment



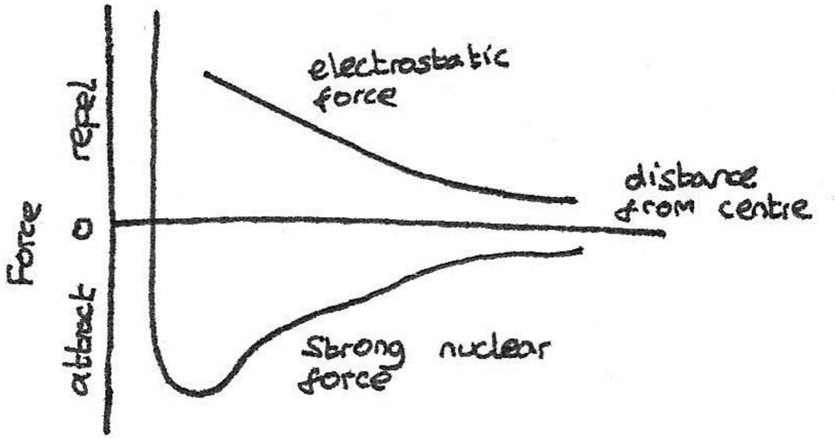
Key
Blue equation – *Given formulae*
Red equation – *Not given formulae*

$^{A}_{Z}X$

A = the 'nucleon' number = p + n
Z = the Proton number = p
X = symbol for a particular element

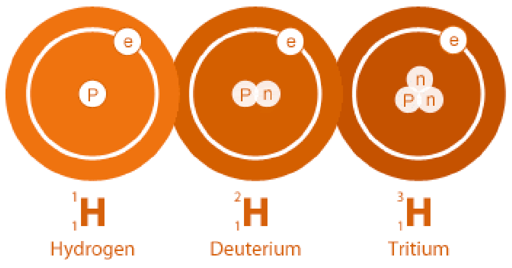
$$Specific\ Charge = \frac{Q}{m}$$

Specific charge is the charge to mass ratio for a particle/nucleus/ion. (Ckg^{-1})



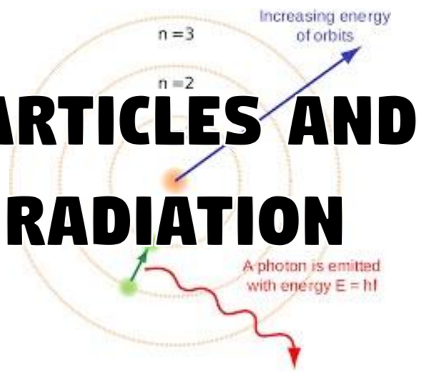
Hydrogen (H)

AND TWO OF ITS ISOTOPES.



ISOTOPES: Atoms with the same number of protons but different number of neutrons.

PARTICLES AND RADIATION

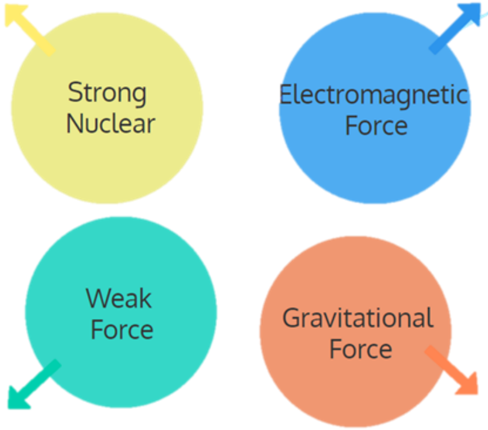


Strong Nuclear Force: It's range is approx. 3 femtometres (1fm = 10^{-15}m).
It has the same effect between protons and neutrons.
From 0.5-3fm it is an attractive force.
Below 0.5fm it becomes repulsive

Fundamental Forces and their Bosons

Gluon: interacts with hadrons

Virtual Photon: interacts with charged particles

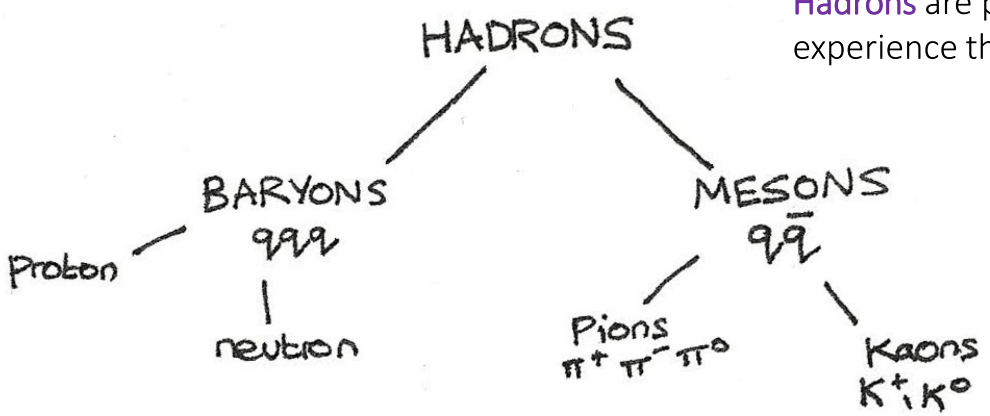


W^+ or W^-: Interacts with all particles

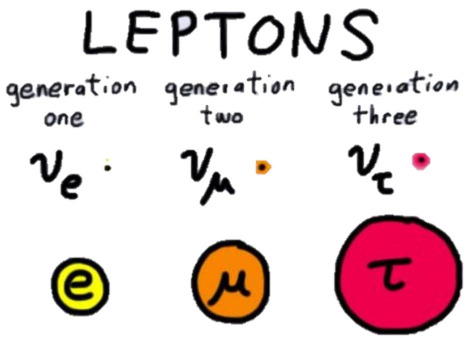
Graviton: interacts with all particles

Alpha Decay, α	Beta minus decay, β^-	Beta plus decay, β^+
Nucleon number decreases by 4 Proton number decreases by 2	Nucleon number stays the same Proton number increases by 1	Nucleon number stays the same Proton number decreases by 1
$X^A_Z \rightarrow X'^{A-4}_{Z-2} + \alpha^4_2$	$X^A_Z \rightarrow X'^{A}_{Z+1} + \beta^{-\,0}_{-1} + \bar{V}_e$	$X^A_Z \rightarrow X'^{A}_{Z-1} + \beta^{+\,0}_{-1} + ve$

Key
Blue equation – *Given formulae*
Red equation – *Not given formulae*



Hadrons are particles that experience the strong nuclear force



Leptons are fundamental particles that don't feel the strong nuclear force.

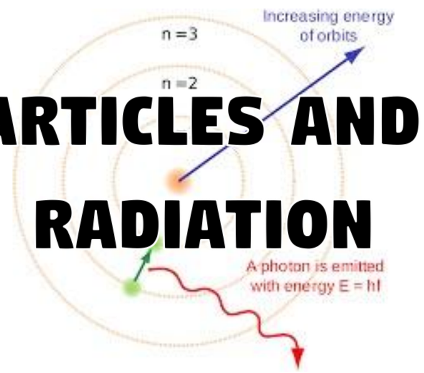
Examples of leptons include the stable electron (e−) and unstable muon (μ−) and tau (τ−) which both decay into electrons.

Neutrinos are also leptons, with a different neutrino for electrons (ν_e), muons (ν_μ) and tau leptons (ν_τ). Neutrinos have negligible mass, no charge and only interact through the weak interaction.

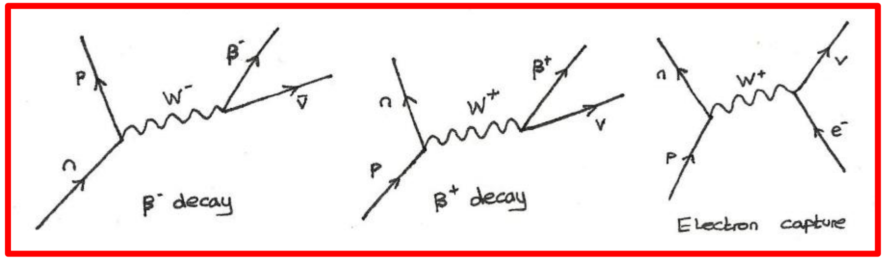
Baryons are hadrons that have a qqq or $\overline{qqq}$ quark composition

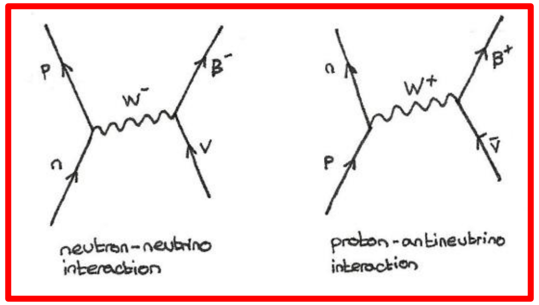
Mesons are hadrons that have a $q\bar{q}$ quark composition. All mesons are unstable and are able to interact with the baryons through the strong interaction

PARTICLES AND RADIATION

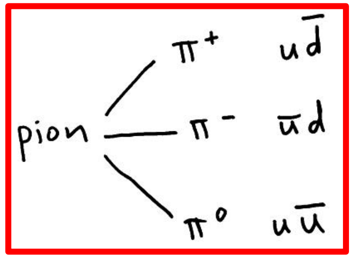


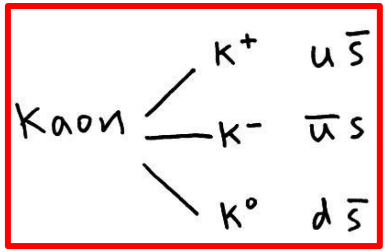
FEYNMAN DIAGRAMS





QUARK STRUCTURE OF ALL MESONS



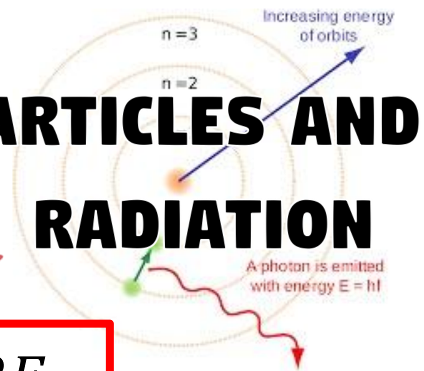


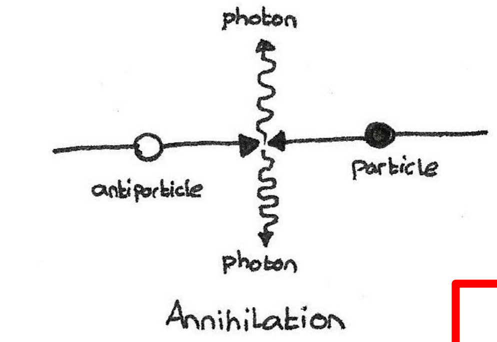
CONSERVATION LAWS

1. Charge must always be conserved.
2. Baryon number must always be conserved.
3. For strong interactions, strangeness is **always conserved**. However with the weak interaction, strangeness is not conserved.
4. must also be conserved. This means that the individual e.g. lepton numbers: L_e, L_μ must individually be conserved.

Key
Blue equation– *Given formulae*
Red equation – *Not given formulae*

PARTICLES AND RADIATION

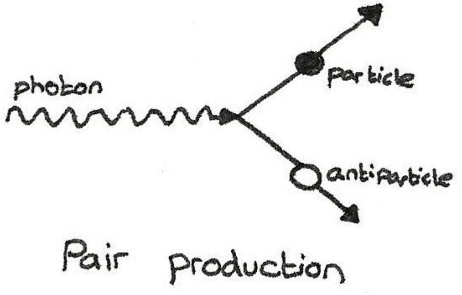




Annihilation

The minimum energy of one photon produced is equal to the rest energy of one of the particles which have been annihilated

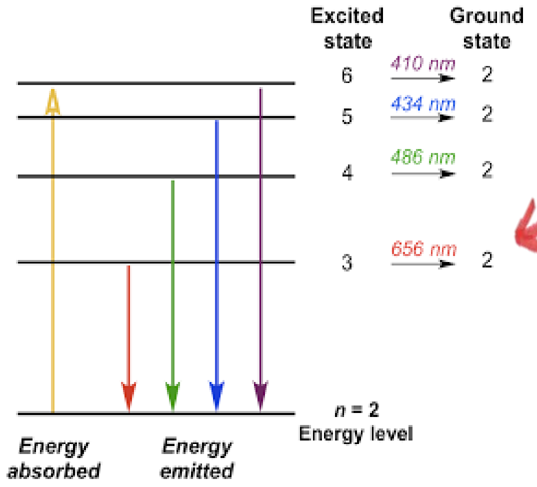
$$E_{min} = hfmin = E_0$$



Pair Production:

The minimum energy needed for pair production is equal to double the rest energy of one particle produced

$$E_{min} = 2E_0$$



An electron must gain a specific amount of energy in order to be excited to a higher energy level. These are known as discrete energy levels.

The de-excitation of an electron between two discrete energy levels will emit a photon of EM radiation.

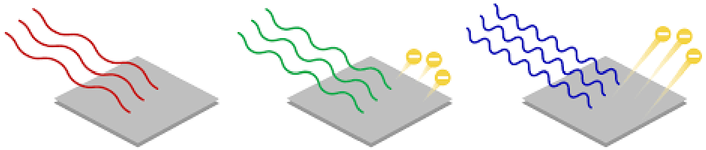
large $\Delta E = small\ \lambda$

small $\Delta E = large\ \lambda$

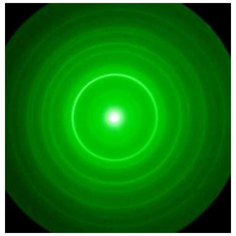
$$hf = E_1 - E_2$$

WAVE PARTICLE DUALITY

The photoelectric effect gives evidence for light as a particle as the kinetic energy depends on the frequency of the light not the intensity.



The wave nature of electrons was shown through the production of diffraction patterns, when accelerated electrons in a vacuum interact with the spaces in a graphite crystal.



DE BROGLIE WAVELENGTH

Particles with a larger momentum will have a smaller de Broglie wavelength.

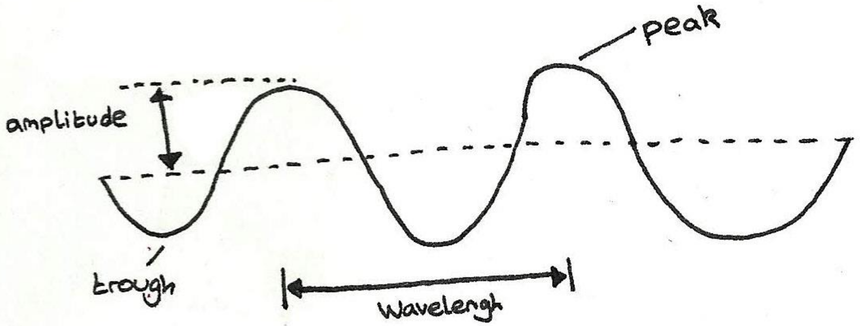
$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

Blue equation– *Given formulae*

Red equation – *Not given formulae*

WAVES

TRANSVERSE WAVES



Transverse waves are waves in which the direction of oscillations are perpendicular to the direction of wave travel.

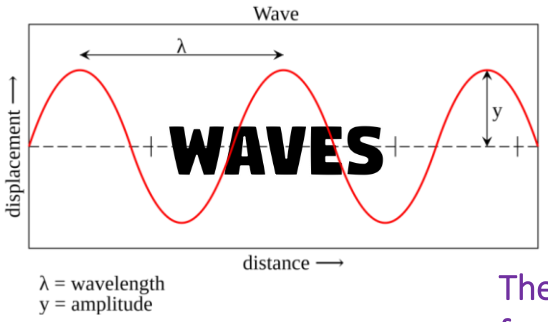
Longitudinal waves are waves in which the direction of oscillations of are parallel to the direction of wave travel.

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

Frequency is the number of complete cycles of wave passing a fixed point per second. The unit for frequency is hertz (Hz)

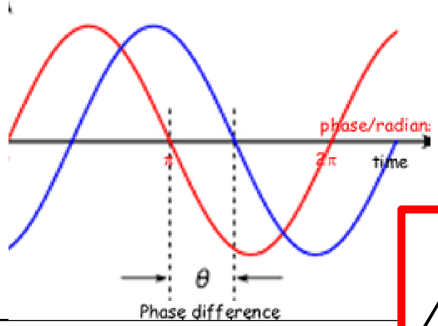
The period of a wave is the time taken for one complete cycle to pass a fixed point. Measured in seconds, s

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



$$c = f\lambda$$

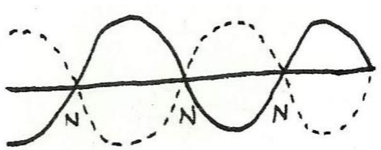
The speed, frequency or wavelength of a wave can be calculated by using the following equation:



The phase difference between two vibrating particles is the fraction of a cycle between the vibrations of two particles.

$$\Delta\phi = \frac{2\pi\Delta d}{\lambda} \ or \ \frac{2\pi\Delta t}{T}$$

STATIONARY WAVES

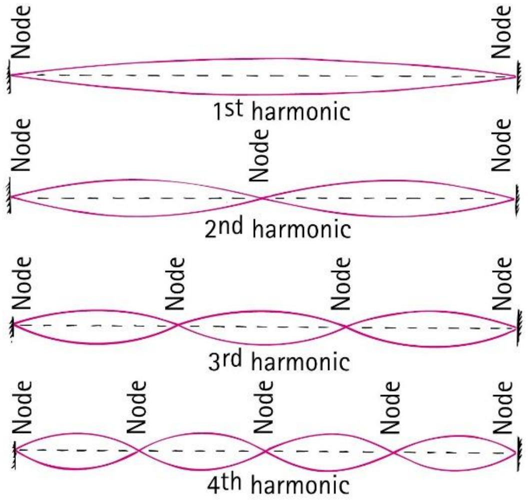


Stationary waves are formed when two progressive waves, travelling in opposite directions are in phase which results in destructive interference at nodes

FUNDAMENTAL FREQUENCY

$$f_n = \frac{nc}{2L}$$

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



The fundamental frequency/harmonic of vibration consists of a single loop with a node at each end. Where n is the n-th harmonic

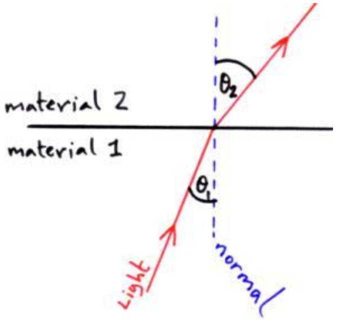
$$f = \frac{n}{2L}\sqrt{\frac{T}{\mu}}$$

Where μ is the total mass of the string divided by its total length (mass per unit length, kgm^{-1}).

$$\mu = \frac{m}{l}$$

Key
Blue equation– *Given formulae*
Red equation – *Not given formulae*

REFRACTIVE INDEX



$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

Snell's law

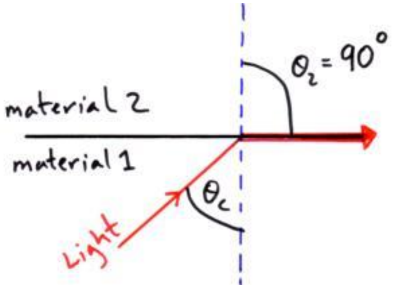
θ_1 is the angle of incidence

θ_2 is the angle of refraction

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

The refractive index, n, must always be higher than 1! The higher the number, the more optically dense the medium is.

CRITICAL ANGLE



The critical angle can only occurs when light goes from a more dense to a less dense medium.

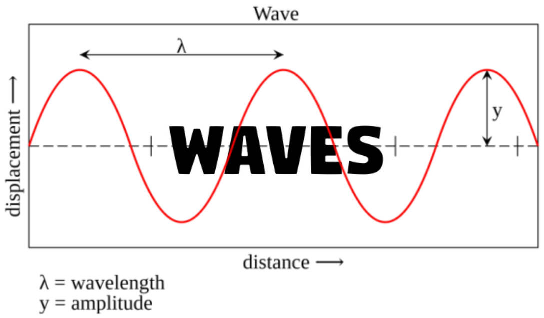
$$sin\theta_c = \frac{n_2}{n_1}$$

n_2 is the more dense medium in this case

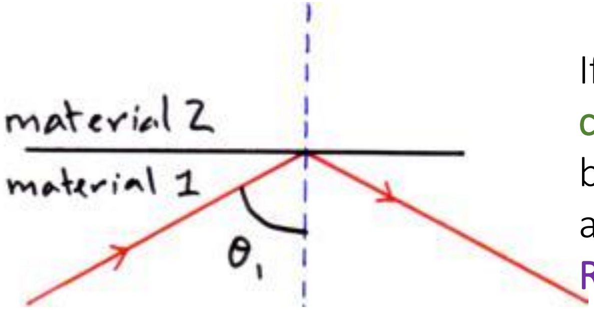
If the second material is air then $n_2 = 1$

$$sin\theta_c = \frac{1}{n_1}$$

WAVES

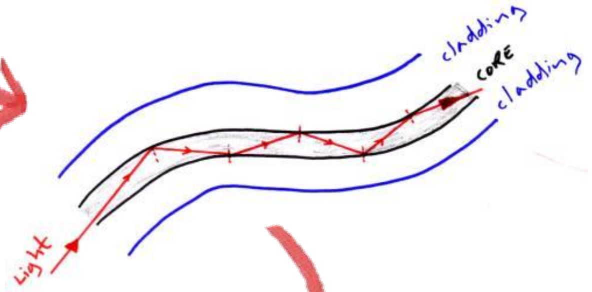


TOTAL INTERNAL REFLECTION



If the incident angle is greater than the critical angle then light reflects at the boundary between the two material and this is called Total Internal Reflection.

STEP-INDEX OPTICAL FIBRE



How they work:

1. Core is transmission medium for EM waves to progress by total internal reflection.
2. Cladding provides lower refractive index so that total internal reflection takes place
3. Offers protection to the core, also prevents crossover of signal.
4. Small diameter core so less light is lost, less multipath dispersion

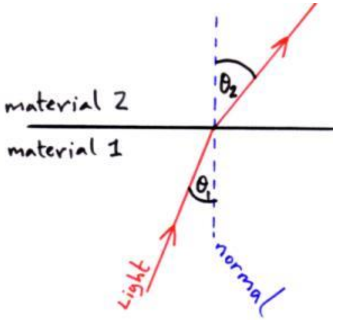
Key

Blue equation– *Given formulae*

Red equation – *Not given formulae*

WAVES

REFRACTIVE INDEX



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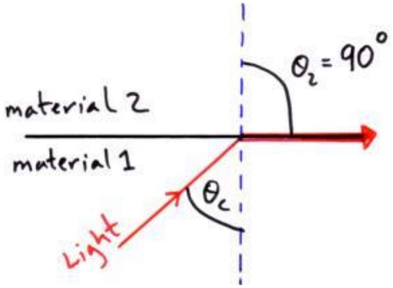
CRITICAL ANGLE



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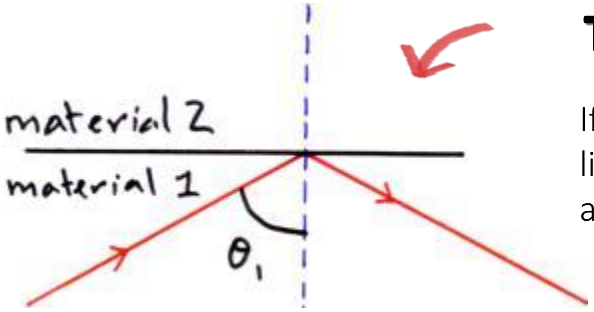
TOTAL INTERNAL REFLECTION



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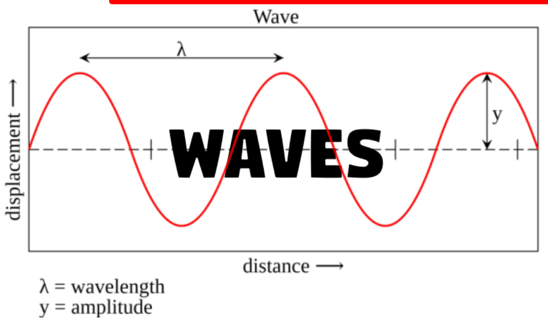
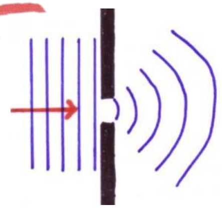


SINGLE SLIT DIFFRACTION

To increase the amount of 'spread':

- Decrease size of gap
- Increase wavelength



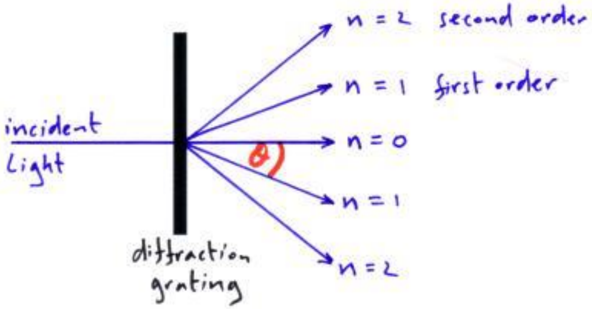
Single Slit Diffraction produces wide central bright fringe. The other bright fringes get dimmer as you move away from the centre.

$$w = \frac{n\lambda D}{s}$$

DIFFRACTION GRATING

A diffraction grating is a large number of regularly spaced, narrow slits.

$$d\sin\theta = n\lambda$$



$$\lambda = \frac{d\sin\theta}{n}$$

$$d = \frac{1}{N}$$

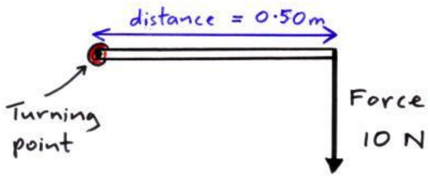
N lines per metre on a diffraction grating

Key
Blue equation– *Given formulae*
Red equation – *Not given formulae*

MECHANICS

MOMENTS

A moment is the force multiplied by the distance perpendicular from the line of action of the force to the pivot. Measured in Nm.

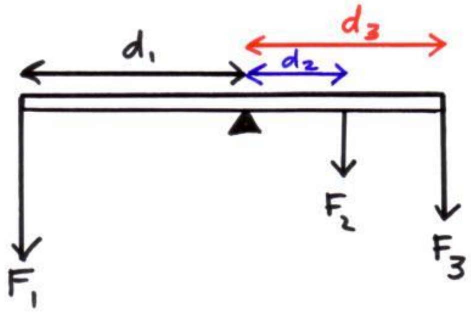


$$Moment = Fd$$

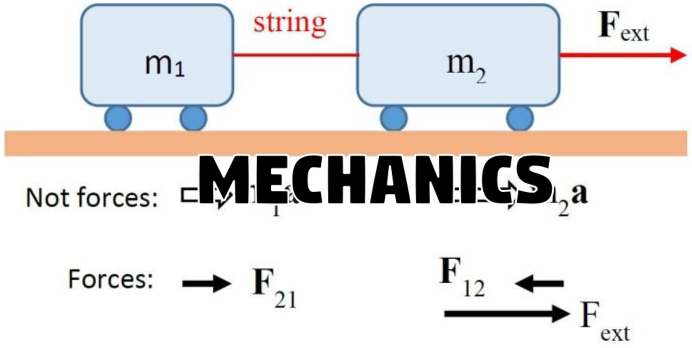
PRINCIPLE OF MOMENTS

When an object is in equilibrium the sum of the anticlockwise moments about a turning point must be equal to the sum of the clockwise moments.

$$\sum clockwise\ moment = \sum anticlockwise\ moment$$



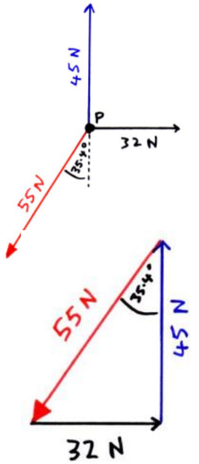
$$F_1d_1 = (F_2d_2) + (F_3d_3)$$



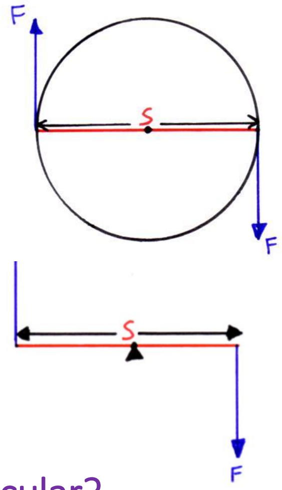
FORCES IN EQULIBRIUM

An object is in equilibrium if ;
The resultant force acting on the object is zero.
The sum of the moments acting on an object must be zero.

If the forces are in equilibrium the head of the last forces will meet the tail of the first forming a closed triangle, see the example to the bottom right



COUPLE



A couple is two equal forces which act in opposite directions on an object

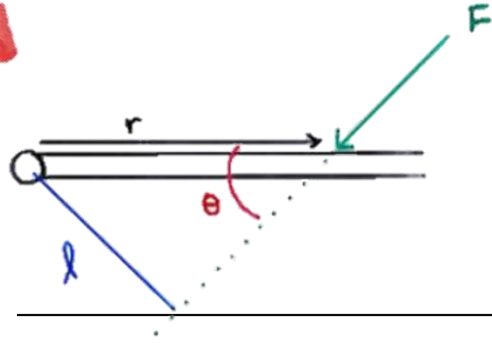
$$Moment\ of\ a\ couple = Fs$$

Force not perpendicular?

Turns out that L is the shortest distance along line of force to the axis. So it turns out that:

$$l = r\sin\theta$$

l= perpendicular distance
r = distance from pivot to force
θ = angle between r and F



Key
Blue equation– *Given formulae*
Red equation – *Not given formulae*

SUVAT EQUATIONS

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

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

$$v = u + at$$

$$s = \left(\frac{u+v}{2}\right)t$$

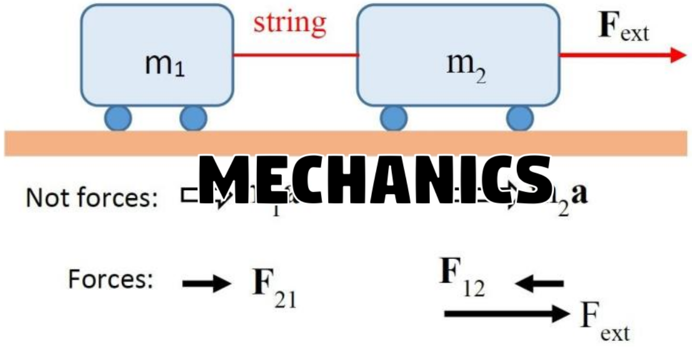
$$v^2 = u^2 + 2as$$

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

Assumptions made when using SUVAT:

- No air resistance acting
- Object is moving uniformly so the **acceleration is constant**

MECHANICS

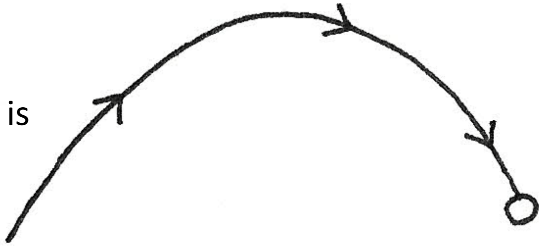


PROJECTILE MOTION

The vertical and horizontal components of the object are **independent and do not impact each other.**

The vertical acceleration = **g**

The **horizontal velocity** of the object is **constant**

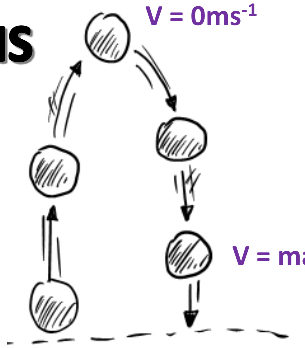


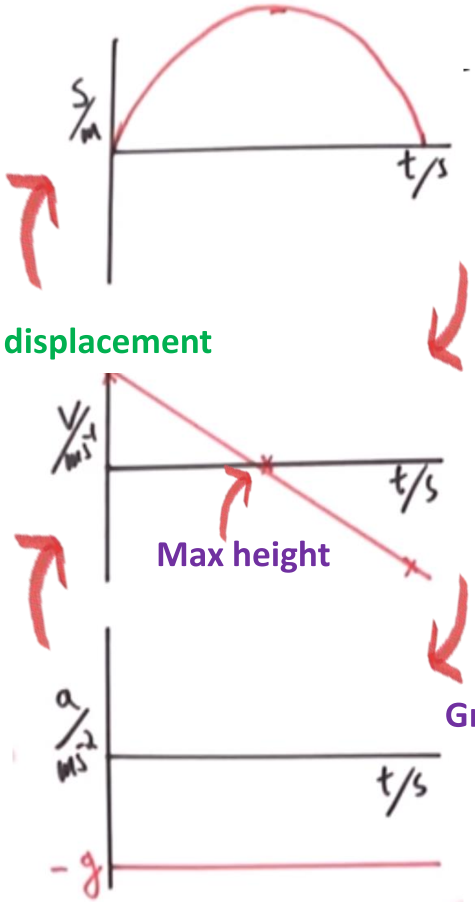
Vertical = $s = ut + \frac{1}{2}at^2$

Horizontal = $s = vt$

MOTION GRAPHS

For an object thrown up into the air. **Motion graphs** have been drawn below.





Gradient = velocity

area = displacement

area = velocity

Gradient = acceleration

Key
Blue equation– *Given formulae*
Red equation – *Not given formulae*

MECHANICS

NEWTON'S SECOND LAW

$$\sum F = \frac{\Delta(mv)}{\Delta t}$$

The RESULTANT FORCE, F, is directly proportional to the rate of change of an object's momentum

$$F = ma$$

Most commonly known as:

$$F\Delta t = \Delta(mv)$$

Impulse is the resultant force on an object multiplied by the length of time it acts for. It can be measured in Ns or $kgms^{-1}$. *Vector quantity.*

$$P = \frac{\Delta W}{\Delta t} = \frac{Fd}{\Delta t} = Fv$$

In $P = Fv$, F is the force causing the motion. v is the velocity in that direction

Power is the energy transferred per second or the rate at which work is done. It is measured in Watts, W or Js^{-1}

$$efficiency = \frac{useful\ power}{total\ power}$$

$$W = mg$$

Weight is the force of an object under gravity. It is equal to

ENERGY

Energy cannot be created or destroyed. Instead it is converted between different forms. **It is ONLY conserved during ELASTIC collisions**

Work done is the transfer of energy from one form to another when a force is moved through a distance. Measured in joules, J

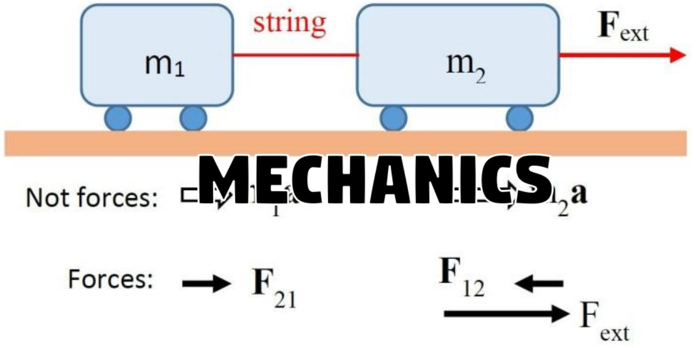
$\cos\theta$ indicates the force must be Resolved in the direction of motion

$$W = Fs\cos\theta$$

$$\Delta E_p = mg\Delta h$$

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

Remember to consider which forms energy is transferred into before making equations equal!



MOMENTUM

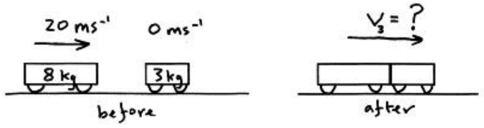
$$\Delta p = m\Delta v$$

Momentum is an object's mass multiplied by velocity. It is measured in $kgms^{-1}$ Vector quantity

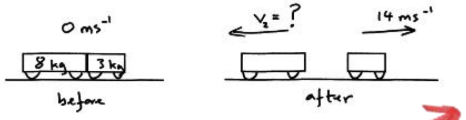
CONSERVATION OF MOMENTUM

$$momentum\ before = momentum\ after$$

$$(m_1v_1) + (m_2v_2) = (m_1 + m_2)v_3$$

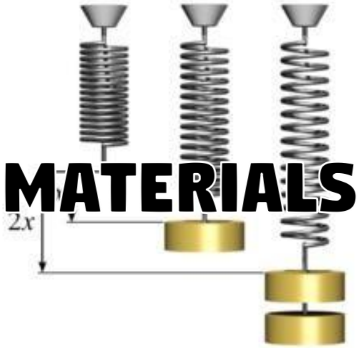


If objects 'stick' together it is an inelastic collision.
P conserved
E is not conserved

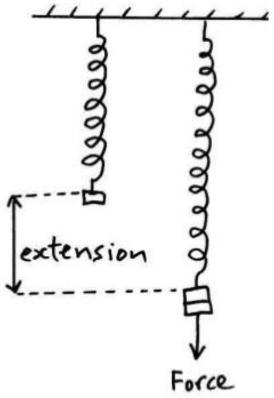


If objects 'rebound' it is an elastic collision – both
E and P conserved

MATERIALS

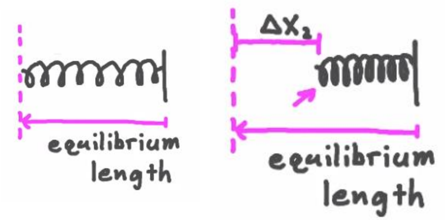


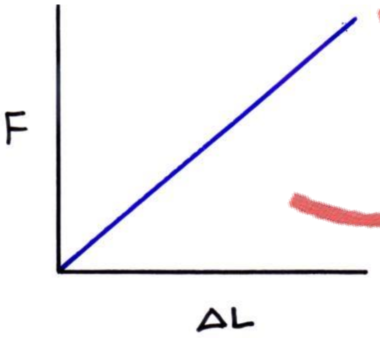
HOOKE'S LAW



The force applied in stretching/compressing a material is directly proportional to its extension until the limit of proportionality.

$$F = k\Delta L$$





The gradient of this graph is equal to the spring constant k.

Energy stored by a stretched/compressed material (obeying Hooke's Law) is the area under the graph.

$$Ep = \frac{1}{2}F\Delta L$$

$$Ep = \frac{1}{2}k\Delta L^2$$

DENSITY

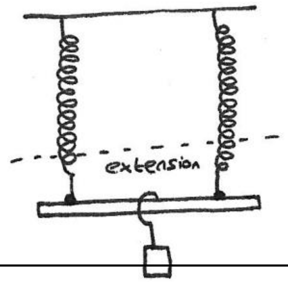
$$\rho = \frac{m}{V}$$

Density is the mass per unit volume of a material, a measure of how much mass each cubic metre of volume contains. It is measured in kgm^{-3}

An alloy is a solid mixture of two or more metals. The density of the alloy can be found by dividing the mass of both metals by the volume.

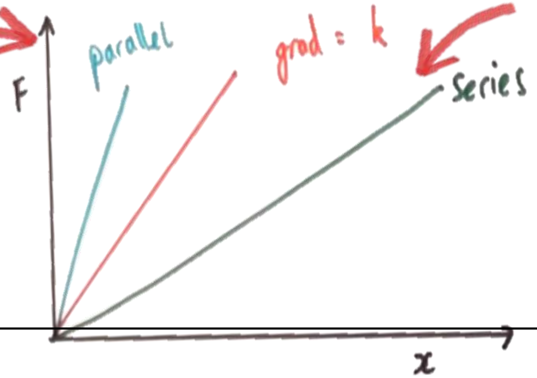
$$\rho = \frac{\rho_1 V_1 + \rho_2 V_2}{V_1 + V_2}$$

SPRINGS IN PARALLEL



In Parallel the weight is supported by both of the springs,

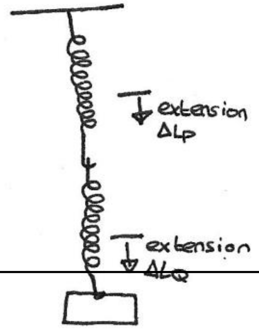
$$k_{eq} = k_1 + k_2$$



SPRINGS IN SERIES

For springs in series, the extension of the springs is doubled (if they are identical). This then means the equivalent spring constant is:

$$\frac{1}{k_{eq}} = \frac{1}{k_1} + \frac{1}{k_2}$$



Key
Blue equation – *Given formulae*
Red equation – *Not given formulae*

MATERIALS

YOUNG MODULUS

$$\text{Young Modulus} = \frac{Stress}{Strain}$$

The Young Modulus of a material is a measure of how difficult it is to change the shape of a material. The higher the value, the stiffer the material. It is measured in Pa.

$$\text{Tensile Stress} = \frac{F}{A}$$

This is the force applied in deforming a material divided by its cross-sectional area. Measured in Nm^{-2} or Pa

$$\text{Tensile } Strain = \frac{\Delta L}{L}$$

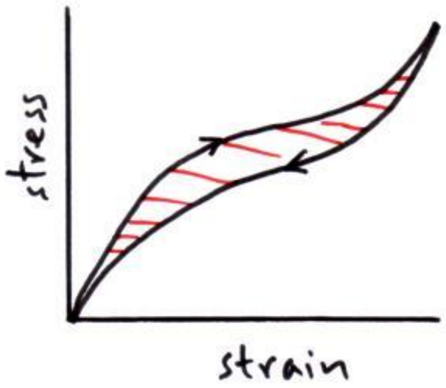
Strain is the extension of a material divided by its original length. It has no units as it is a ratio

Young Modulus then, can be expressed by:

$$\text{Young Modulus} = \frac{\text{FL}}{\text{A}\Delta L}$$

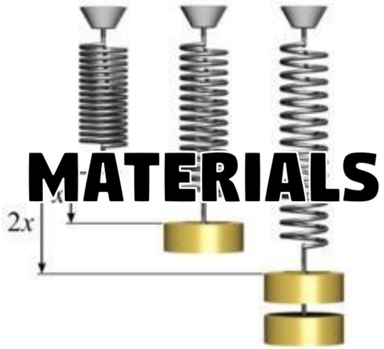
Key
Blue equation – *Given formulae*
Red equation – *Not given formulae*

STRETCHING RUBBER

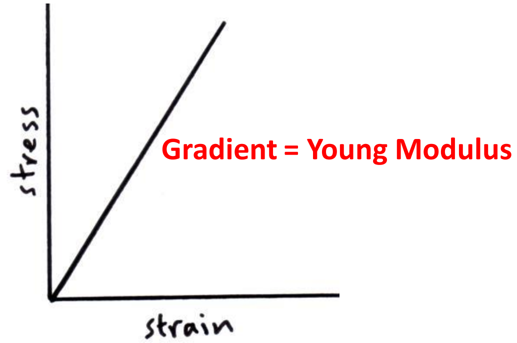


When rubber is stretched and released energy is lost as heat and this is called hysteresis. The area between the two lines is the energy lost per unit volume.

$$\text{Energy } lost\ per\ unit\ volume = \frac{1}{2} x\ Stress\ x\ Strain$$

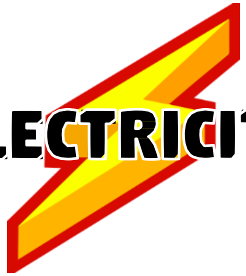


STRESS VS STRAIN: BRITTLE



STRESS VS STRAIN: DUCTILE

L = the limit of proportionality, Hooke's law applies up to this point.
E = elastic limit, beyond this point the material is permanently stretch and it will not go back to its original length.
Y = yield point, beyond this point small increases in force give much big increases in length.
B = breaking point / breaking stress, the material breaks at this point.



ELECTRICITY

$$I = \frac{Q}{\Delta t}$$

Current is the rate of flow of charge passing a point per second. Measured in amps, A or Cs^{-1}

$$V = \frac{W}{Q}$$

Potential difference is the work done per coulomb of charge passing between two points in a circuit. It is measured in volts, V or JC^{-1}

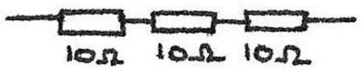
$$R = \frac{V}{I}$$

Resistance is the ratio of the potential difference across a component to the current passing through it. It is measured in Ω

$$\rho = \frac{RA}{L}$$

Resistivity is a property specific to a material which measures the resistance to the flow of current when taking into account the cross sectional area and its length. It is measured in Ωm.

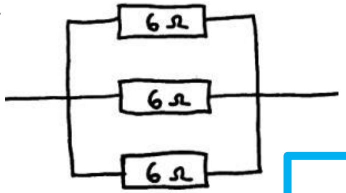
RESISTORS IN SERIES



Resistors are in series with each other there total resistance is just there individual resistance added together.

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

RESISTORS IN PARALLEL



Resistors are in parallel with each other there total resistance is lower than in series

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots$$

POWER AND ENERGY IN CIRCUITS

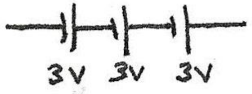
$$P = IV = I^2R = \frac{V^2}{R}$$

Electrical Power is the rate of energy transfer from an electrical component. Doubling the current through a component will quadruple the power losses of a component.

$$E = VQ = ItV$$

Total energy transferred by a component in a given time

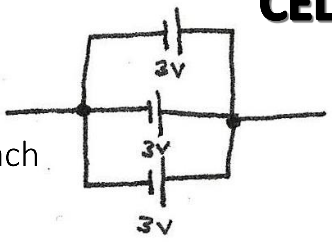
CELLS IN SERIES



When cells are positioned in series, the total emf is equal to the sum of all the potential differences.

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

CELLS IN PARALLEL

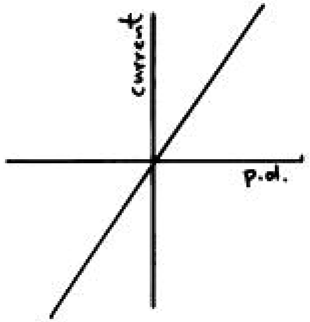


When cells are in parallel, the total potential difference supplied is equal to the pd of one of the cell

$$V_T = V_1 = V_2 = V_3$$

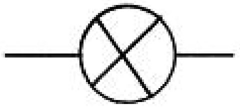
Key
Blue equation– *Given formulae*
Red equation – *Not given formulae*

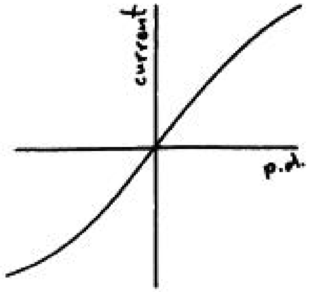
OHMIC CONDUCTOR



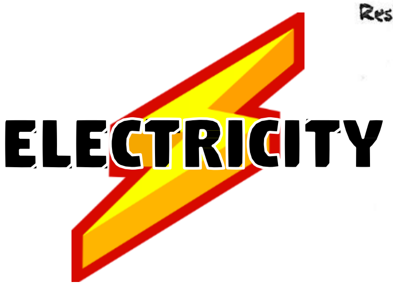
Ohms Law: The electrical current in a conductor is directly proportional to the potential difference applied to it provided the temperature remains constant.

FILAMENT LAMP



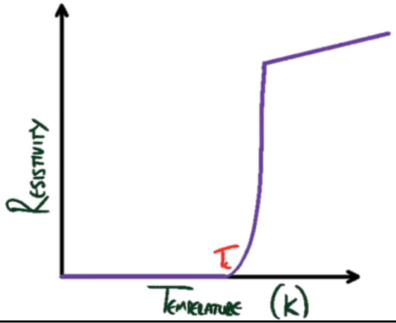


I and V start off directly proportional but the graph curves because as the filament heats it's resistance goes up.

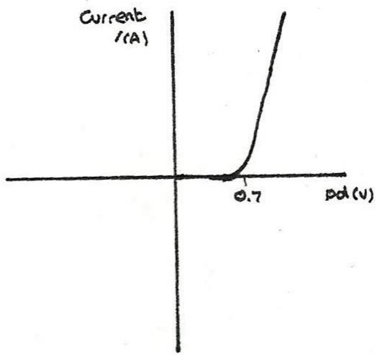


SUPERCONDUCTORS

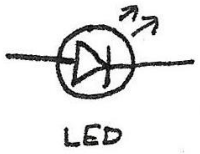
When some materials are cooled to a critical temperature (TC) the resistance of the material falls to ZERO. This state of zero resistance is when the materials become superconducting.



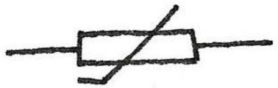
DIODE (FORWARD BIASED)

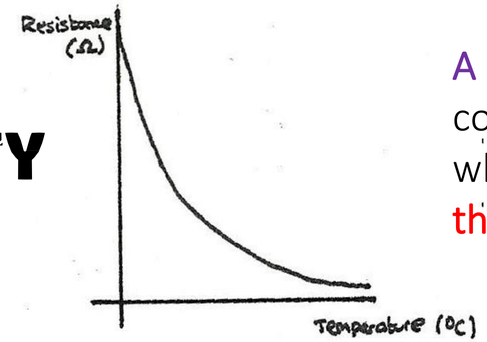


Diodes are designed to only allow current to flow in one direction. The forward bias of a diode is the direction in which the current is allowed to flow. Most diodes have a threshold of around 0.6V-0.7V before they will conduct.



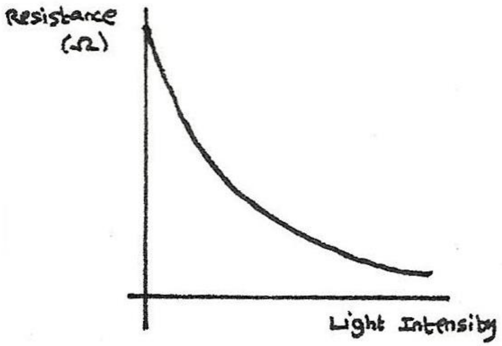
THERMISTOR





A NTC (negative temperature coefficient) thermistor is a resistor where the resistance decreases as the temperature increases.

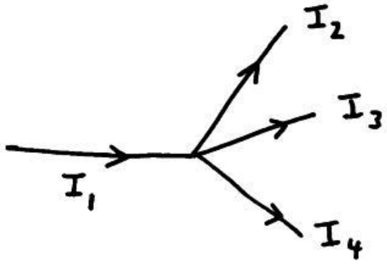
LDR



Light dependent resistors are resistors where the resistance decreases as the light intensity increases.

Key
Blue equation– *Given formulae*
Red equation – *Not given formulae*

KIRCHOFF'S FIRST LAW



Kirchoff's First law states that the current entering a junction is equal to the current leaving it.

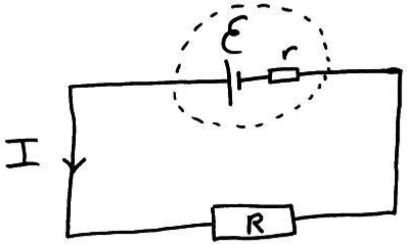
Conservation of charge : the total charge flowing into a junction of wires must equal the total charge flowing out of the junction".

$$I_1 = I_2 + I_3 + I_4$$

EMF and Internal Resistance

$$\varepsilon = \frac{E}{Q}$$

Electromotive force (e.m.f), ε is the amount of electrical energy supplied per coulomb of charge from a source. It is measured in volts, V

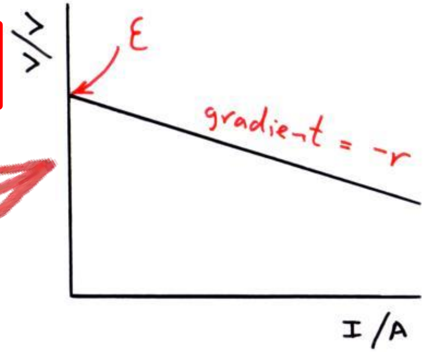


If a power supply has internal resistance, some energy is wasted per coulomb of charge. This is referred to as lost volts (v) . The useful energy transferred per coulomb of charge to the rest of the circuit is called the terminal p.d. (V)

$$\varepsilon = V + \text{v}$$

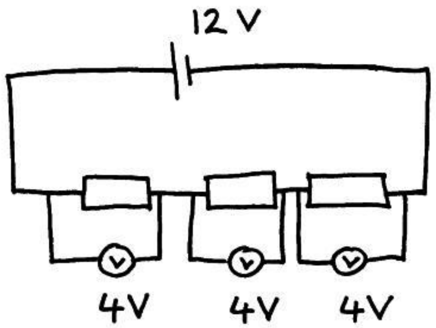
$$\varepsilon = \text{IR} + \text{Ir}$$

$$\varepsilon = I(R + r)$$



ELECTRICITY

KIRCHOFF'S SECOND LAW



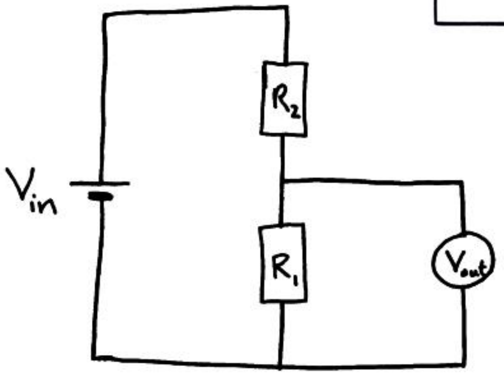
Kirchoff's Second law states the sum of the Emf's in any closed loop in a circuit must be equal to the sum of the potential differences in the closed loop in the circuit.

$$V_0 = V_1 + V_2 + V_3$$

POTENTIAL DIVIDERS

Potential dividers are 2 or more resistors connected in series. They are used to divide the potential difference supplied by a source to different components

$$V_{out} = \frac{V_{in}R_1}{R_1 + R_2}$$



Key
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