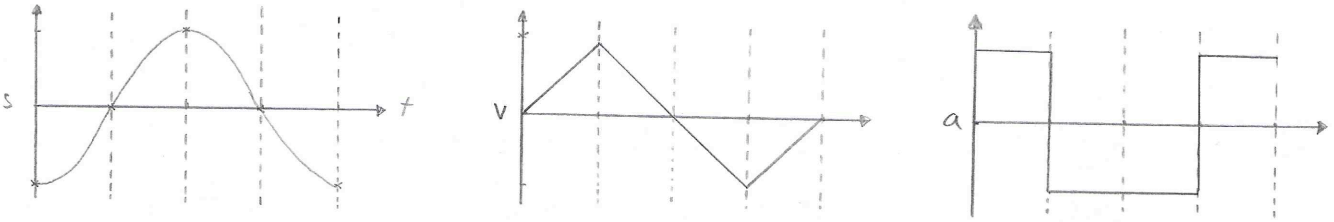
- base quantities: length (m), time (s), mass (kg), temp (K), current (A)
  7 amount of substance (mol), luminous intensity (cd)

- true value - value obtained in an ideal experiment

- uncertainty - limits of measuring equipement + technique
  - random - different if repeated - average out
  - systematic - repeating gives same influenced result
    - check for zero error

- absolute uncertainty $x \pm \delta x$
  - percision of measuring equipement or $\frac{1}{2}$ of range of repeated readings. use the greater



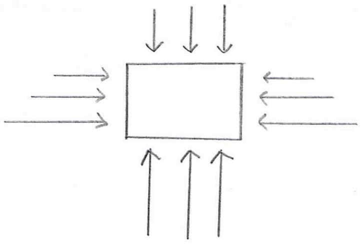
- projectile motion - only force acting is weight
  - V_x = constant $a_x = 0$ $a_y = -g$

- Newtons laws of motion
  - 1 - an object will remain at rest or in a state of uniform motion unless acted on by a resultant force
  - 2 - force is the rate of change of momentum $F = \frac{dp}{dt}$
    - rate of change of momentum of a body is equal to the resultant force acting on it
  - 3 - if object A excerts a force on B. B will excert an equal but opposite force on A.

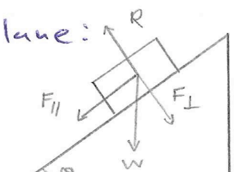
- mass - amount of matter in a given substance
  - the property of a body to resist change in state of motion (measure of inertia)

- resistive forces - viscous drag - force an object experiences when moving though a fluid

- upthrust - originates from the pressure difference of fluid on upper and lower surface of object



- inclined plane:



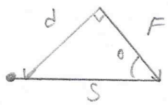
$F_{\parallel} = W \sin \theta$

$F_{\perp} = R = W \cos \theta$

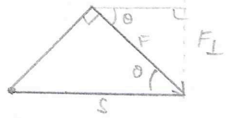
- centre of gravity - point where entire weight appears to act
- centre of mass - point where entire mass seems to be concentrated

- moment - product of force applied and perpendicular distance of the pivot from the line of action of the force

$M = Fd$ $[M] = Nm$

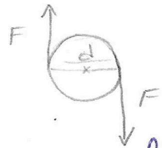


$d = s \sin\theta$
$M = Fs \sin\theta$



$F_\perp = F \sin\theta$
$M = Fs \sin\theta$

- couple of forces - pair of forces of equal magnitude acting in opposite direction parallel but not along same line

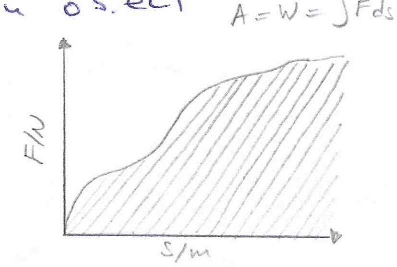


↳ torque of couple = $M_c = Fd$ d - perpendicular distance between lines of action of forces

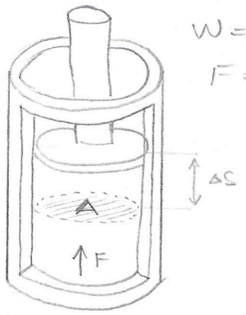
- equilibrium conditions
↳ no net force is acting on it, no net momentum is acting on it

- E - measure of ability of a system to preform work
- Work - energy transfer when a force displaces an object $A = W = \int F ds$

$W = Fs$ +ve when done by a force
-ve when done against a force



- law of conservation of E
↳ E can not be created or destroyed only changed in form. total E of system is constant



$W = Fs$ $P = constant$
$F = PA$ $\Delta V = As$
$W = PAs$
$= P\Delta V$
$W = P\Delta V$

- GPE - gravitational potential energy
$\Delta GPE = mg\Delta h$
- kE - kinetic energy
$\Delta kE = \frac{1}{2} m (v^2 - u^2)$

- power - rate at which E is transferred
- rate at which work is done

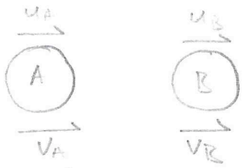
$P = Fv$

- motive power - power outputted by a powered object
- efficiency - ratio of useful work to total work $\eta = \frac{W_{useful}}{W_{total}}$
- momentum - product of objects mass and velocity

$p = mv$ $[p] = Ns = kgms^{-1}$ $F\Delta t = \Delta p$

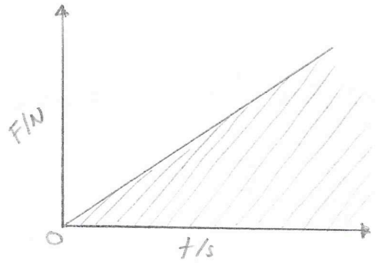
- law of conservation of linear momentum
  ↳ in an isolated system Σp before and after an event are equal provided no external force acts

- ellastic collision - collision in which kE is conserved $e = 1$
- inellastic collision - kE not conserved so some dissipated
- perfectly elastic collision - kE conserved
  - p conserved
  - relative speed of approach = relative speed of separation



$$\vec{v}_B - \vec{v}_A = \vec{u}_A - \vec{u}_B$$

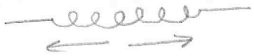
- in explosions initial $p_i = 0$ so also $p_f = 0$
- impulse of a force - J $J = F_{avg} \Delta t = \Delta p$

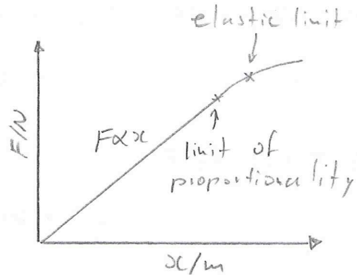


$A = F_{avg} \Delta t = \frac{1}{2} b h$
$= \int F dt$

- density - $\rho = \frac{m}{V}$
- pressure - normal force acting per unit crossectional area $P = \frac{F}{A}$

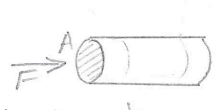
$P = \rho g h$

- force applied to spring: - compressive 
  - tensile 
- restoring force - force applied by the spring against force causing the deformation

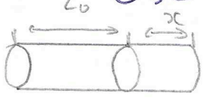


- hookes law $F = kx$ $[k] = Nm^{-1}$ $k \approx$ stifness
- limit of proportionality - point beyond which Hookes law is no longer obeyed
- elastic limit - point beyond which spring no longer returns to original shape
  - elastic deformation

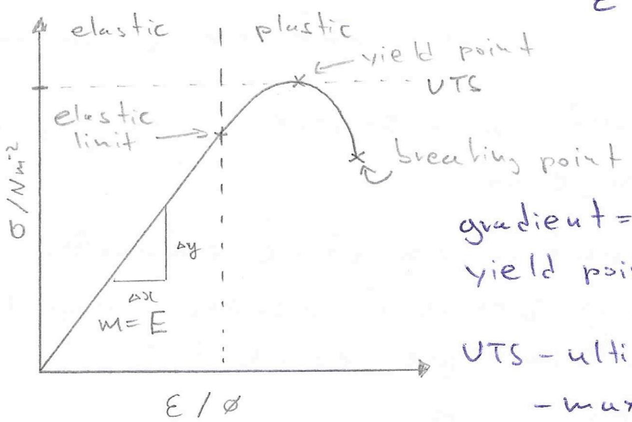
- young modulus - ratio of tensile stress to strain for material obeying hookes law $E = \frac{\sigma}{\varepsilon} = \frac{F L_0}{A x}$



tensile stress
$\sigma = \frac{F}{A}$



tensile strain
$\varepsilon = \frac{x}{L_0}$



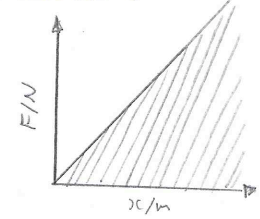
gradient = young modulus
yield point - large increase in extension

UTS - ultimate tensile strength
- max tensile stress

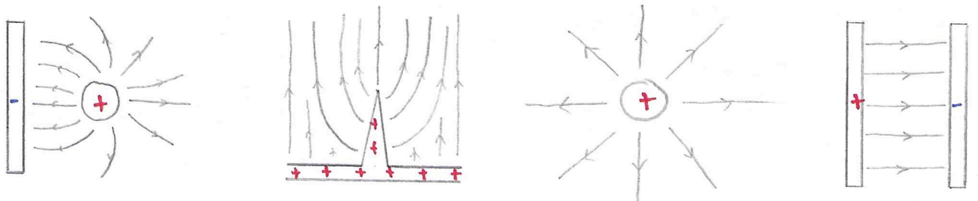
- EPE – elastic potential energy – E stored in a body due to a load (force) causing deformation
  - ↳ for hookean material

$EPE = \frac{1}{2} k x^2$

$EPE = Fx = A$
$= \int F dx$



- electric field – region of space where a charged particle experiences a force



radial   uniform

- electric field strength – force experienced at a point per unit charge exerted on a stationary positive charge at a point in the field

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

- in a uniform electric field E is constant $E = \frac{V}{d}$ $F = qE$ $= q\frac{V}{d}$
- current – rate of flow of charge $I = \frac{\Delta Q}{\Delta t}$
- e^- drift in random directions overall − → +
- mean drift velocity – steady velocity of e^- colliding with ions as they pass the wire
  - v_d
- number density – conduction electrons (charge carriers) per unit volume
  - n for Cu $n_{Cu} \approx 10^{29} m^{-3}$

$I = nAv_dq$ I – current n – number density A – CS area V_d – mean drift velocity q – charge

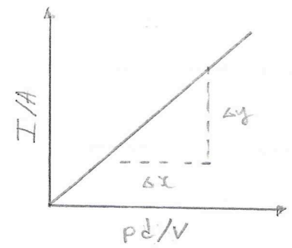
- Coulomb – charge which flows past a point in a time of 1s when a current of 1A is flowing
- charge allways multiple of e $+e = 1.6 \times 10^{-19}$ C
- potential difference – between A, B is the E per unit charge as the unit charge moves from A → B

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

- EMF – E transferred by a source in driving a unit charge around a complete circuit
- Ohm's law – current in an ohmic conductor is proportional to the voltage across it provided temp + other physical conditions are constant

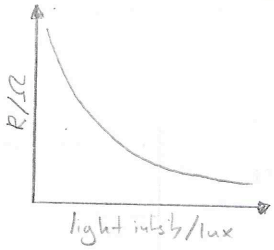
$V \propto I$ $V = RI$ $\therefore R = \frac{V}{I}$

- resistance - measure of the extent to which a material opposes the flow of charge (e^-s)
- Ohm - resistance of a component when a pd of 1V drives a current of 1A through it



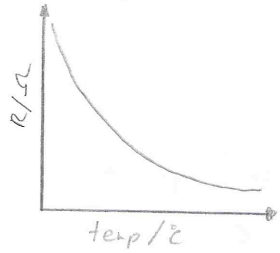
$m = \frac{1}{R}$

Ohmic



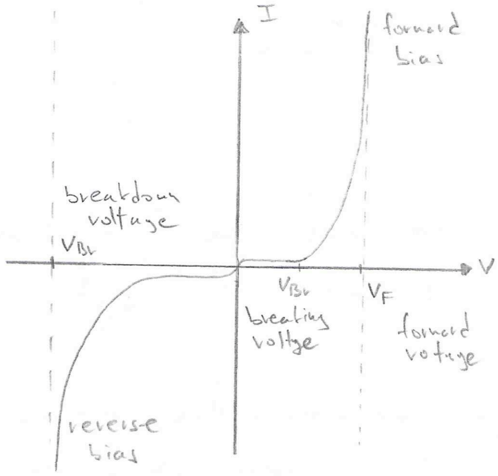
dark ≈ 5MΩ
light ≈ 500Ω

LDR



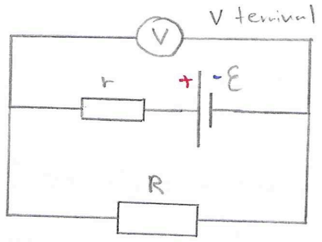
NTC
PTC

Thermistor



Diode $V_{Br} \approx 0.6V$
LED $V_{Br} \approx 2V$

- as temp ↑ R ↑ since v_d ↓ due to collisions with ions - moving faster so more collisions
- resistors in series $R_T = \sum_{i=1}^{n} R_i$ resistors in parallel $R_T = \frac{1}{\sum_{i=1}^{n} \frac{1}{R_i}}$
- kirchoff's law
  - ↳ 1st law - sum of currents leaving a junction = sum of currents entering the junction
  - ↳ 2nd law - sum of emf around any loop in circuit = sum of pds around each loop
- efficiency - measure of how well a device transforms energy to useful forms
- resistivity - measure of property of material of how much it opposes the flow of charge

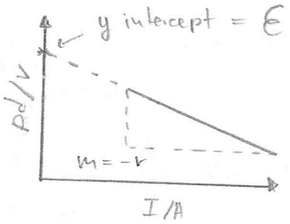


$\rho = \frac{RA}{l}$ $R = \frac{\rho L}{A}$ $P = IV = \frac{V^2}{R} = I^2R$

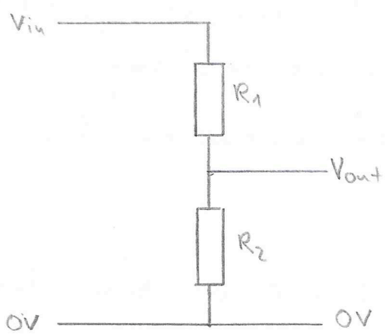
- cell with internal resistance

terminal pd = emf - lost volts $\varepsilon = I(R+r)$
emf = terminal pd + lost volts $= V + Ir$

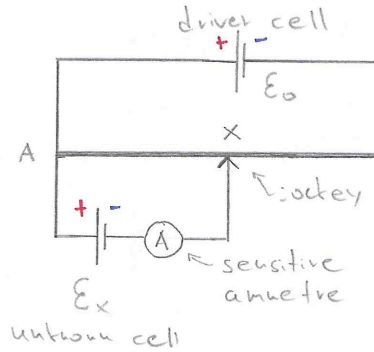
assuming R of Ⓥ is ∞ as $R \to \infty$ $I \to 0$
$V_{terminal} \to \varepsilon$



- potential dividers



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

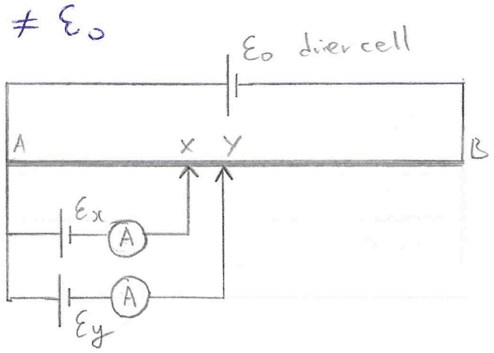


at equilibrium point $I = 0$ $V_{AX} = \mathcal{E}_x$

r negligable since $I = 0$

$$\mathcal{E}_x = \frac{AX}{AB}\mathcal{E}_0$$

current still flows in $\mathcal{E}_0$
so $V_{AB} \neq \mathcal{E}_0$



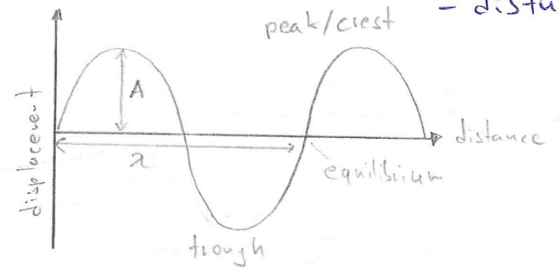
- to overcome this use setup to compare 2 emf's ($\mathcal{E}_x$, $\mathcal{E}_y$) $\frac{\mathcal{E}_x}{\mathcal{E}_y} = \frac{AX}{AY}$

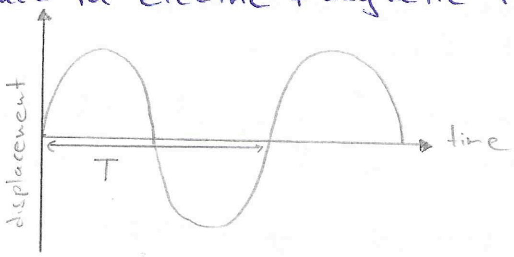
- wave - periodic disturbance in a medium or space
  - transfer E or info without transferring matter between 2 points

- progressive waves - move outward from the source
  ↳ 2 types: 1) transverse - oscilates perpendicular to direction of propagation of wave
  2) longitudional - oscilates parallel to direction of propagation of wave

- mechanical waves - oscillations of particles in physical medium
  - do not propagate in vacuum

- electromagnetic waves - produced by acceleration of charge
  - disturbance in electric + magnetic field in space





compression

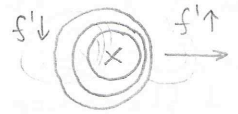
rarefaction

- displacement - distance of a particle from equilibrium position
- amplitude - A - maximum displacement
- period - T - time it takes for a particle to make 1 complete oscilation
  - time for object producing wave to complete 1 oscilation
- frequency - f - number of oscillations passing a certain point per unit of time
- wavelength - λ - distance along medium between 2 succesive particles with same displacement and phase of motion
- phase difference - ϕ - fraction of a complete cycle between two points on a wave
- wave front - all points which started from the source at same time

- polarised waves - oscilate in a single plane normal to propagation
  - only transverse waves
- when a wave hits a boundary it is reflected with a phase difference
- intensity of a wave - I - power supplied per unit crossectional area

$I = \frac{P}{A}$ $[I] = Wm^{-2}$ - directly proportional to amplitude squared

$I \propto A^2$ $v = f\lambda$ $f = \frac{1}{T}$



- doppler effect - apparent change in frequency of a wave caused by relative motion between source and observer (redshift in light)

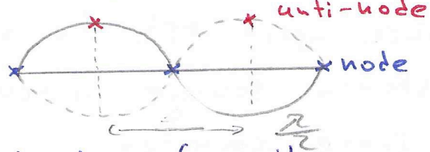
$f' = f\frac{(v+v_o)}{(v-v_s)}$

- all em waves travel at $c = 3.0 \times 10^8\ ms^{-1}$ in vacuum

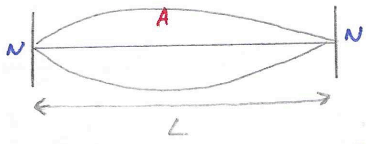
as they enter a medium $v\downarrow$ f is constant so $\lambda\downarrow$

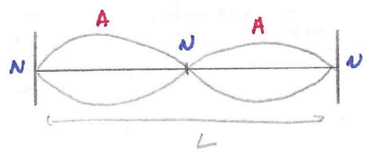
Radio	Microwave	Infra Red	Visible	Ultra Violet	X rays	γ rays
10^6	10^{-1}	10^{-3}	7×10^{-7}	4×10^{-7}	10^{-8}	10^{-10}
10^{-1}	10^{-3}	7×10^{-7}	4×10^{-7}	10^{-8}	10^{-13}	10^{-16}

- superposition - when 2 or more waves overlap the resultant displacement at a point is equal to the sum of individual displacements at that point
- if both waves in phase (+ve or -ve) = constructive interference
  both waves out of phase (+ve and -ve) = destructive interference
- antinode - maximum displacement
- node - no displacement

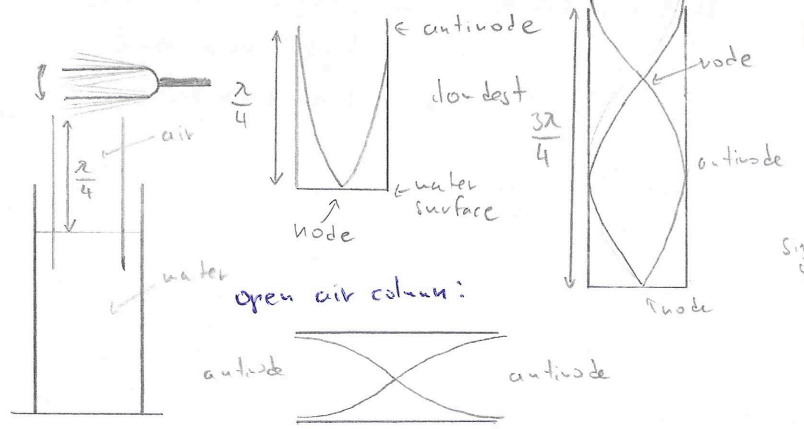


- stationary wave - stores E but doesnt transfer it
  ↳ created: - 2 progressive waves of = speed, wavelength, frequency, amplitude travelling in opposite directions superimpose
- λ and f of progressive and stationary are equal
- first fundemental frequency $f_0 = \frac{V}{2L}$ $\lambda = 2L$
- Second harmonic $f_1 = \frac{V}{L}$ $\lambda = L$

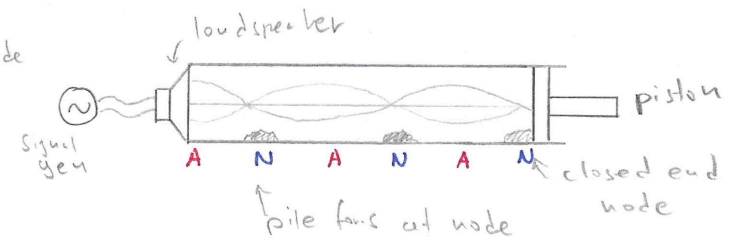




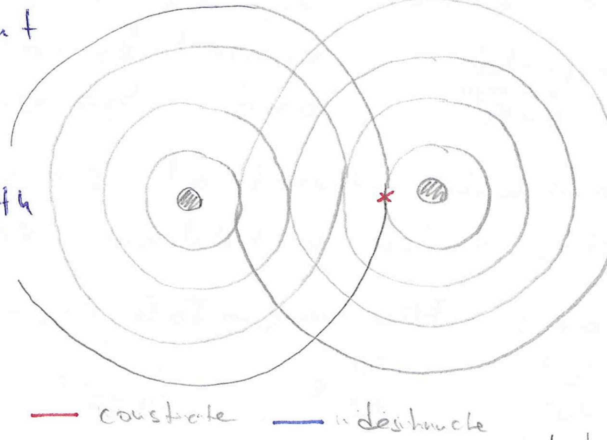
- resonance tube:



kundt's experiment
↳ used to determine speed of sound

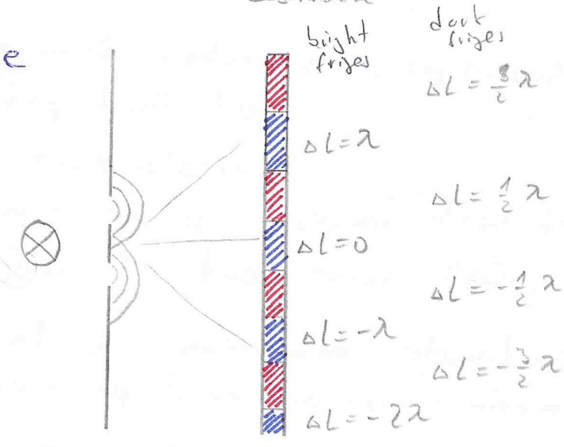


- diffraction - spreading out / bending of waves as they pass obsticle or through a gap
  - ↳ explenation - Hyugen - Fresnel principle : each point at wave front acts as infinitesimal wave source to produce secondary waves which superinpose
- monochromatic - emitted with only one f or λ
- coherent - all waves either exactly in phase or at a constant phase difference
- laser = monochromatic and coherent



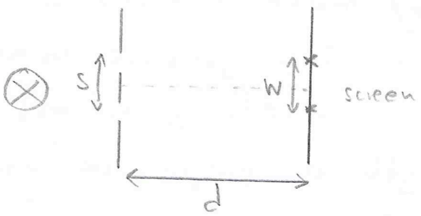
- constructive interference
  - ↳ path difference between 2 coherent sources = integer multiple of wavelength
  - path difference $= n\lambda \quad n \in +\mathbb{Z}$
- destructive interference
  - ↳ path difference $= (n+\frac{1}{2})\lambda \quad n \in +\mathbb{Z}$

- fringes - places of constructive interference

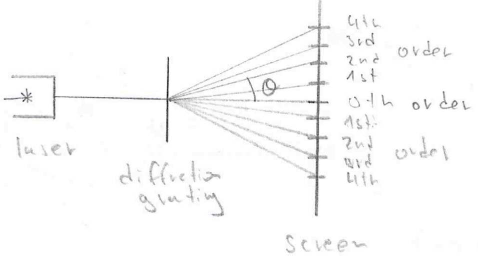


- conditions for double slit interference
  - ↳ coherent waves
  - ↳ slit width appropriate for beams to overlap sufficiently
  - ↳ suitable distance apart slits for wavelength
  - ↳ sufficient distance source → screen

$W = \lambda \frac{d}{s}$ — W - fringe separation, s - slit separation, d - distance to screen



- diffraction grating - plate with many close spaced parallel slits



for grating with m lines per metre

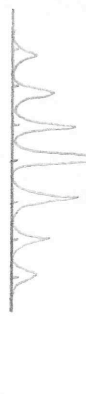
$d = \frac{1}{m}$

$n\lambda = \frac{1}{m}\sin\theta$

$n\lambda = d\sin\theta$

n - order of fringe

θ - angle between light ray and horizontal



- α particle scattering experiment
  - ↳ α particles deviated pass through - repulsive force between α particle and the charged nucleus
  - ↳ most α particles have little or no deviation - atom is mostly empty space
  - ↳ very few deviated at angles > 90° - most mass of atom is concentrated in small space

$m_e = 9.11 \times 10^{-31}$ kg $m_p = 1.67 \times 10^{-27}$ kg

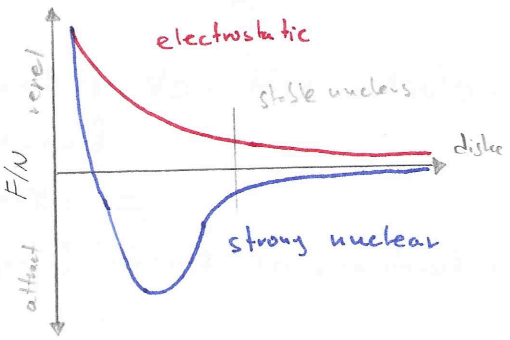
$r_{proton} \approx 10^{-15}$ m $r_{nucleus} \approx 10^{-15} - 10^{-14}$ m $r_{atom} \approx 10^{-10}$ m

$A = Z + N$

- A - nucleon number Z - proton number N - neutron number
- nucleide - specific combination of protons and neutrons
- isotopes - nuclei of same element ∴ same Z but different number of neutrons N therefore nucleon number A
- ion - electrically non neutral atom (charged)

^1_1H protium ^2_1H deuterium ^3_1H tritium

- strong nuclear force - acts at small distance $\approx 10^{-14}$ m
  - cancels out repulsion of p^+ in nucleus
- weak nuclear force - responsible for β decay



subatomic particles

- leptons (unaffected by strong nuclear force)
  - eg.) $e^-, e^+, \nu, \bar{\nu}, \mu$
- hadrons (affected by strong nuclear force)
  - baryons (consist of 3 quarks)
    - eg.) p^+, n^0
  - mesons (consist of 2 quarks)
    - eg.) π

barions are more stable in a nucleus

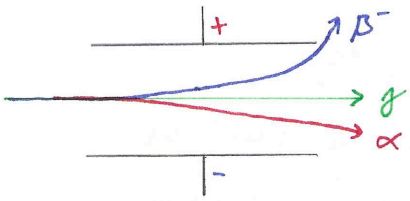
- p^+ is most stable baryon eventually all barions decay to p^+

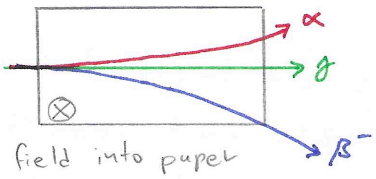
	quarks			anti quarks		
	up u	down d	strange s	up $\bar{u}$	down $\bar{d}$	strange $\bar{s}$
charge	$+\frac{2}{3}$	$-\frac{1}{3}$	$-\frac{1}{3}$	$-\frac{2}{3}$	$+\frac{1}{3}$	$+\frac{1}{3}$
strangeness	0	0	-1	0	0	+1

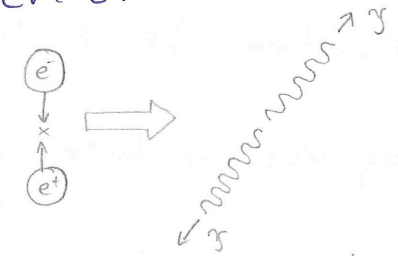
Force - Acts on - Range - Exchange particle

Strong Nuclear - quarks - 10^{-15} - gluon
Weak Nuclear - quarks + leptons - 10^{-17} - Z^0, W^+, W^- bosons
Electromagnetic - charged particles - ∞ - photon γ
Gravity - particles with mass - graviton

- ionisation - fast moving α / β particle collides or passes near an atom and knock/drag out an e^- forming an ion
- α particle - most ionising - high mass + moves slowly $\therefore$ long interaction
  - low penetrating - 5-6 cm in air stopped by paper
  - cloud chamber, solid state detector, GM tube
- β particle - less ionising - light + moves quickly
  - moderately penetrating - few m of air or mm of Al
  - GM tube for β^- radiation
- γ rays - least ionising - only increases E of e^-
  - most penetrating - m of concrete or cm of Pb







electron + position $\rightarrow$ 2 photons

- electron volt - eV - E transfered when an e^- travels through pd of 1V
  - $1 eV = 1.60 \times 10^{-19}$ J
- fundamental force - force which can not be explained in terms of action of other forces
- annihilation - when particle + anti-particle collide their E is given out as 2 photons mass is lost $M \rightarrow E$
- pair production - photons dissapear giving particle + antiparticle $E \rightarrow M$

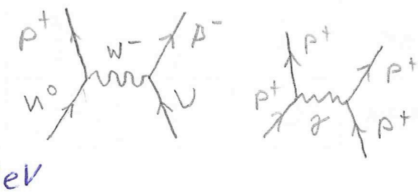
β^- decay: ${}^1_0n \rightarrow {}^1_1p + {}^0_{-1}e + \bar{\nu}$ $\quad$ β^+ decay: ${}^1_1p \rightarrow {}^1_0n + {}^0_{+1}e + \nu$

$d \rightarrow u + {}^0_{-1}e + \bar{\nu}$ $\quad$ $u \rightarrow d + {}^0_{+1}e + \nu$

α decay: ${}^A_ZX \rightarrow {}^{A-4}_{Z-2}Y + {}^4_2\alpha$ $\quad$ γ decay: ${}^A_ZX \rightarrow {}^A_ZX + {}^0_0\gamma$ (E)

- Neutrino - little mass, no charge, hard to detect
  - β^- / β^+ emitted at range of velocities so something must carry extra KE
- charge + mass-energy conserved in decay
- Specific charge - charge per unit mass - $C kg^{-1}$

feynman diagram:



α - $\frac{1}{10}$ c $\quad$ β^- / β^+ - range $\approx \frac{99}{100}$ c $\quad$ γ - c

4 MeV $\quad$ $\frac{1}{2}$ MeV $\quad$ 10 keV - 10 MeV