ZNOTES.ORG

UPDATED TO 2020 SYLLABUS

IB MIDDLE YEARS PROGRAM
PHYSICS

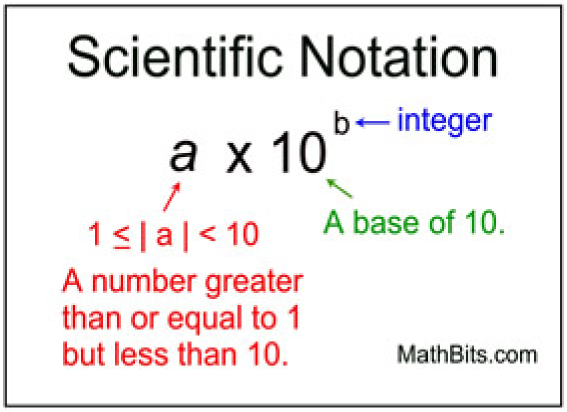
SUMMARIZED NOTES ON THE THEORY SYLLABUS

1. Units and Measurements

1.1. Numbers and Units

- Fundamental vs. Derived Units
- Scientific Notation
- REMEMBER TO INCLUDE UNITS
- SI Units

Quantity	Name of Unit	Symbol	Quantity
Length	meter	m	l
Mass	kilogram	kg	m
Time	second	s	t
Electrical current	ampere	A	I, i
Thermodynamic temperature	Kelvin	K	T
Luminous intensity	candela	cd	Iv
Amount of substance	mole	mol	n



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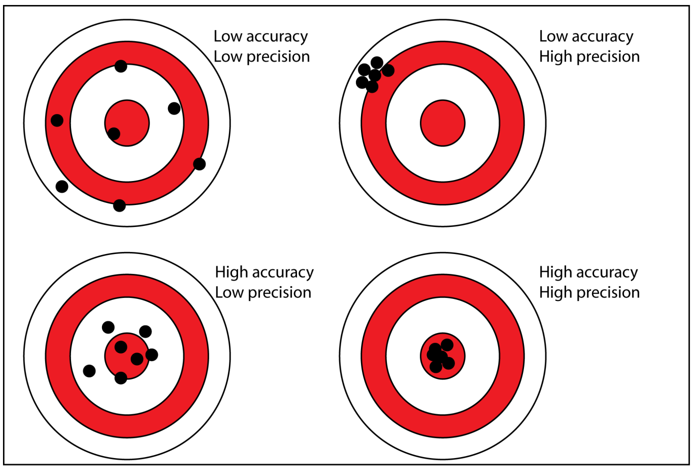
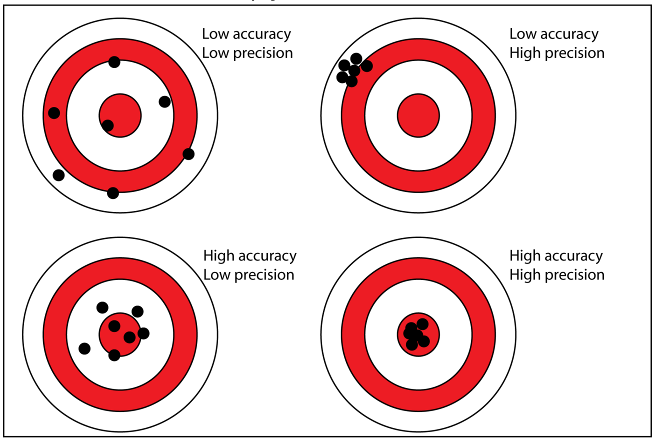
1.2. Accuracy and Precision

- Accuracy - how close the value is to the true value
- Precision - How close the values are to each other



1.3. Conversions

- For km h to m/s, multiply with 5/18
- For m/s to km h, multiply with 18/5



Prefixes

1.3 Units of Measurement

Prefixes: are used to change the size of the unit

Table 1.2 Prefixes Used with SI Units

Prefix	Symbol	Meaning
Tera-	T	10^{12}
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}

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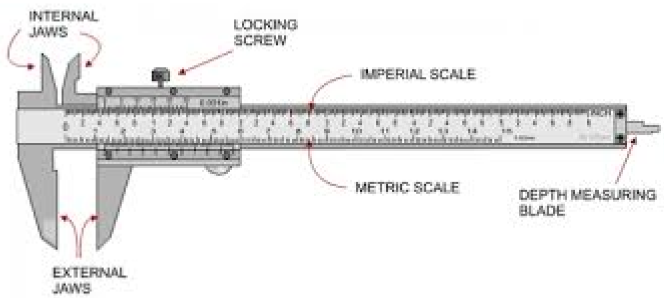
1.4. Vernier Caliper Scale



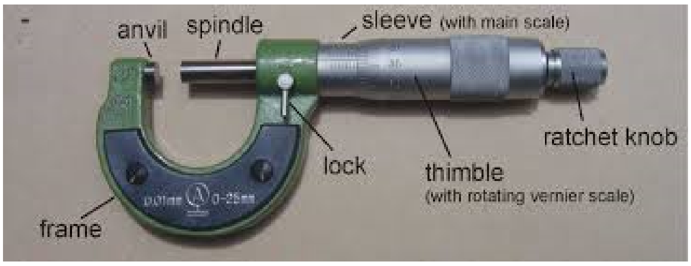
1. Main Scale - The main scale consists of a steel metallic strip graduated in centimeters at one edge and in inches at the other edge. It carries the inner and outer measuring jaws. When the two jaws are in contact, the zero of the main scale and the zero of the vernier scale should coincide. If both the zeros do not coincide, there will be a positive or negative zero error.
2. Vernier Scale - A vernier scale slides on the strip. It can be fixed in any position by retainer. On the vernier scale, 0.9 cm is divided into ten equal parts.

3. Outer Measuring Jaws - helps to take the outer dimension of an object.
4. Inner Measuring Jaws - helps to take the inner dimension of the object
5. Retainer - helps to retain the object within the jaws of the Vernier Caliper
6. Depth Measuring Prong - used to measure the depth of an object

** \n \n **

- To read a Vernier scale
  - Total Reading = MSR + VSR
  - MSR = main scale reading
  - VSR = nth reading on vernier scale × LC
  - Least Count : LC = $\frac{Least count of main scale}{Number of divisions on Vernier Scale}
- Zero error - to calculate the actual value considering the zero error:
  - Total Reading - Zero Error = Actual Reading

1.5. Screw Gauge



- Take the main scale reading from the sleeve
- The vernier scale is on the thimble

1.6. Errors

1. Systematic Errors - due to identified causes and can be eliminated in principle
   1. Instrumental - poorly calibrated instruments
   2. Observational - ex: parallax error in reading a meter scale
   3. Environmental
   4. Theoretical - due to simplification of the model system or approximations in the equations describing it
      1. ex: if theory says surrounding temp doesn't matter in readings but it actually does
2. Random Errors - fluctuations that can causes measurements to be too high or too low; cannot always be identified
   1. Observational - ex: errors in judgement of an observer when reading the scale of a measuring device to the smallest division

2. Motion and Car Safety

2.1. Motion

- motion - the process of something moving or changing place or even just changing position relative to the frame of reference
- scalars - have magnitude only
  - ex: mass, time, distance…
- vectors - have both magnitude and direction
  - ex: velocity, acceleration, force…

vector * vector = scalar; scalar * scalar = scalar; vector * scalar = vector

2.2. Speed & Velocity

- speed - the rate at which an object covers distance
  - speed = $\frac{distance}{time}
  - scalar quantity
  - instantaneous speed - the speed of an object at a certain instant in time
  - average speed - the ratio of the total distance covered to the time period it took to cover that distance
- velocity - displacement / time interval
  - velocity = $\frac{displacement}{time}$
  - vector quantity

2.3. Acceleration

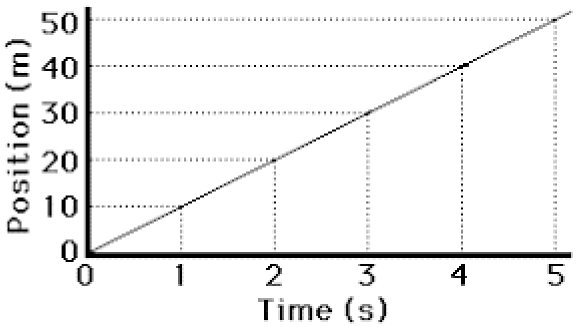
- acceleration - the change in velocity with respect to time OR rate of change of velocity
  - can be changed by changing either speed or direction
  - acceleration due to gravity = g = 9.8 m/s^2

2.4. Reaction Time

- reaction time - the time taken to react to a situation; does not include time take to came to a stop
  - there is no acceleration in this time period
- braking time - the time taken to come to a stop; does not include reaction time
  - acceleration in there during this period
- stopping time = reaction time + braking time

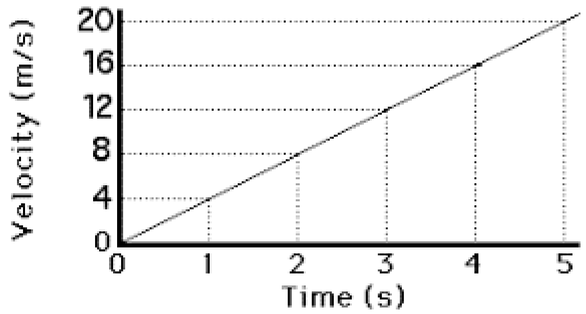
2.5. Graphs

Position Time



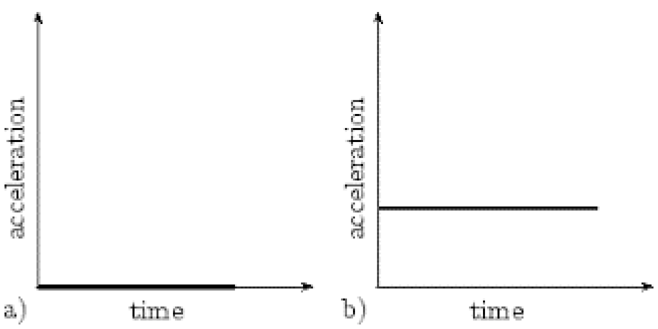
- slope is velocity
  - line is horizontal = object is at rest
  - line is a straight slope means that object is moving with a constant velocity
  - line is a curve means that the object is accelerating

Velocity Time Graph



- slope is acceleration
  - line is horizontal = object is moving with a constant velocity
  - line is a straight slope means that the object is accelerating
- area under graph is displacement

Acceleration Time Graph



- area under the graph is velocity

2.6. Kinematic Equations

1. v = u + at
2. x = ut + $\frac{1}{2}at^2$
3. x = vt - $\frac{1}{2}at^2$
4. v^2 - u^2 = 2as

- These equations only work if acceleration is constant or 0

2.7. Force

- F = ma
  - = $\frac{changeinP}{changeinT}$

Newton's Laws of Motion

1. An object at rest will remain at rest and an object in motion will stay in motion with a constant velocity unless acted upon by an external net force
2. The acceleration of an object is directly proportional to the force acting upon it and inversely proportional to the mass
3. Every action has an equal and opposite reaction

2.8. Momentum

- momentum = mass velocity
  - p = mv
  - units - kg m/s
- Law of Conservation of Momentum
  - Total initial momentum = Total Final Momentum
  - $p_i = p_f$
  - $m_1v_1 = m_2v_2$
- Impulse (J) - quantifies the effect of a force acting over a unit time
  - J = F change in t
  - J = F change in t = change in p
    - this is also known as the impulse-momentum theorem

2.9. Car Safety Features

Seat belts, Airbags, ECU, Load Limiters and Pretensioners

1. Sensors detect the impact - collision sensors attached to the vehicle detects the collision, a signal is sent to the ECU Electronic Control Unit
2. Evaluation of the Impact - The ECU processes the signal from the satellite sensors and diagnoses the severity of the impact. If the impact detected by the ECU is a collision, the ECU sends a signal to activate the pretensioners (gas emitting devices) to the seatbelts
3. The pretensioners go into action - The pretensioners activate and retract some of the seatbelt webbing. By pulling the seat belt webbing back, the pretensioners remove some of the slack between the passengers and the belts, thereby, restraining the passengers in their seats more effectively.
4. The load limiter goes into action as the occupant moves forward
5. Energy of the movement is absorbed - at this moment, the seat belt has positioned the occupant to take advantage of the supplemental restraint system

6. Absorption of the energy of the passengers' movement is completed

Crumple Zone

- Crumple zones are designed to absorb and redistribute the force of a collision
  - They increase the time taken to change the momentum in a crash, which reduces the force involved
  - Most crumple zones are constructed with steel or titanium, high density and low density polymeric foam

Anti Braking System

- Anti brakes benefit you in two ways, you'll stop faster, and you'll be able to steer while you stop
  - Four main components
    - Speed Sensors
    - Pump
    - Valves
    - Controller

Side Impact Bar

- An anti-intrusion bar is a passive safety device, installed in most cars and other ground vehicles, which must protect passengers from side impacts
- Material is most commonly aluminum alloy

Wind Screen

- Made of shatterproof glass so that it will not break into pieces easily
- This will reduce injuries caused by the pieces of glass which scatter during collision

Padded Dashboard

- Padded dashboards are designed to reduce face and chest injuries to the driver and front passenger, in front-on collisions
- They are made from polyurethane foam, while the surface is commonly either polyvinyl chloride (PVC) or leather

Head Rest

- Head restraints are automotive safety feature, attached or integrated into the top of each seat to limit the rearward movement of the adult occupant's head, relative to the torso, in a collision

3. Flight

3.1. Parts of a Plane

1. Fuselage - the central body portion of an aircraft designed to accommodate the crew and passengers or cargo
2. Wing - helps in balancing and improving stability; allows the plane to go up
   1. slats (leading edge) - movable pieces on the front of the airplane wings
      1. increase curvature → increase lift
      2. used during take off and landing to help the plain gain lift at slower speeds
      3. turns back in flight to reduce drag
   2. flaps (trailing edge) - generate more lift at slower airspeed
      1. enables plane to fly at a greatly reduced speed with a lower risk of stalling
      2. useful during take off and landing
      3. when extended further, also generate more drag which slows the airplane down much faster than just reducing throttle
   3. spoilers - plates on the top surface of a wing that can be extended upward into the airflow to spoil it
   4. ailerons - used to generate rolling motion for an aircraft
3. Tail (empennage) - provide stability
4. Horizontal stabilizer - prevents up and down motion of the nose which is called pitch
5. Vertical Stabilizer - keeps the nose of the plane from swinging from side to side which is called the yaw
6. Rudder - controls the yaw
7. Elevators - create lift
8. Engine - propulsion system for an aircraft that generates mechanical power
9. Pylon - used to hold the engine in place on the wing without reducing too much surface area

Forces Involved in Flight

1. Weight
2. Lift - created by differences in air pressure
3. Thrust
4. Drag

Lighter Than Air Flight

- Hot Air Balloons
  - the bag called an envelope contains heated air
  - wicker basket carries people and a source of heat
  - the average density of the hot air is lower than that of the air in the atmosphere
- Airships - any powered, steerable aircraft that is inflated with a gas that is lighter than air
  - rigid airships - framework surrounding one or more gas cells and maintains shape by framework not gas
    - the gas cells are filled with hydrogen and helium and are hence very dangerous and combustible
    - Hindenburg incident

- semi-rigid airships - maintains shape from gas pressure but has a partial rigid frame
- non-rigid airships (blimps) - lighter than air vehicles whose shape is maintained by the pressure of the gas within the envelope

Heavier Than Air Flight

- Powered - Airplane
- Unpowered - Glider
  - glide ratio: glide ratio = vertical height/horizontal distance
  - thermals

No Air Space Flight

- no air
- chemical reaction take place and the gas moves backwards → rocket moves forwards
- gas is at a very high temperature when ignited → high temp exerts pressure → force in combustion chamber

Rotor Blade Aircraft

- when the rotor starts spinning at the from, the velocity increases and the pressure decreases → thrust force is generated
- vertical take off → no runway needed
- tail blade ensures that the back is lifted as well and the helicopter doesn't start spinning in circles
  - can also be done by using double rotors

Types of Engines

1. turbojet
   1. takes in air through the air inlet
   2. compression to increase the pressure
   3. fuel is added into combustion chamber and igniter
   4. turbine
   5. exhaust
2. turbofans
   1. smaller combustion chamber → less noise
   2. air bypass channel
      1. the area creates additional thrust
      2. decreases fuel consumption
      3. more efficient
3. turboprop
   1. prop takes in air
   2. gear ensures that prop doesn't rotate as fast as the turbine
   3. direct downwards because it is at the nose of the plane
   4. contra rotating propellers
4. prop fan
   1. bypass is propelled
   2. combustion chambers
   3. most modern

3.2. How is Lift Generated in Fixed Wing Aircraft?

- Bernoulli's Principle
  - shape of wing
  - speed and pressure of air stream
  - pressure imbalances
- Newtonian Explanation
  - tilt of wing
  - acceleration of passing air stream
  - deflection of air stream

Bernoulli's Principle

- when the speed of a moving fluid increases, the pressure decreases and vice versa
- Bernoulli's equation - P + gh + 1/2pv^2 = constant
- Bernoulli's time argument - there is a greater distance on the top of the wing than below the wong so the air has to travel faster to reach the other side, hence decreasing pressure
  - this argument is wrong
- The coanda effect - a moving stream of fluid in contact with a curved surface will follow the curvature

Archimedes Principle

- density = mass/volume
- pressure in a fluid = gh
- the buoyancy force (FB) is equal to the weight of the fluid displaced by the object
- F_B = gV
- in salt water, the buoyancy is greater because the salt makes the water denser
- density of water = 1000 kg/m^3 OR 1 kg/liter

4. Transformation by Steam

4.1. Introduction

- steam drove the European Industrial Revolution in 18th and 19th centuries
  - mining, manufacturing, travel, transport
  - demand for fuel and steam engines rose
  - wealth boomed
  - societal tensions
- condenser - an instrument for cooling gases
- cylinder - the chamber of an engine in which the pistons move
- piston - a sliding piece of an engine that is moved by or moves against fluid pressure within a cylindrical vessel or chamber
- turbine - an engine that moves in a circular motion when a force is applied to its series of baffles radiating from a central shaft

4.2. Stem Engines

- a machine that converts heat energy of stem into mechanical energy
  - passes steam into a cylinder where it pushes a piston back and forth
  - it is with this piston movement that the engine can do mechanical work
  - applications: mining, manufacturing, transport, electricity, agriculture, heating, atomisation, humidification
  - steam has a very high heat capacity and hence it can do a lot of work before the energy is finally all transformed
- Thomas Savery
  - first steam powered machine; 1698
  - Miner's Friend - an invention designed to pump water out of coal mines
    - no moving parts
    - boiler and pipe
    - water is pumped up through a pipe
      - one end is in water and the other is open to the atmosphere
      - pressure difference is created between the inside of the pump and the atmospheric pressure on the outside → forces water up the pipe
        - vacuum is present inside the pump
    - the force of pressure applied by the air above an area of 1 meter square is 101,000 N
      - this is a pressure of 101,000 N/meter^2
      - this can lift the water vertically upward up to 10.3 m
- Thomas Newcomen
  - partner of Savery; tried to improve the steam pump
  - set a moving piston inside a cylinder
- James Watt
  - double-action steam engine
    - turns back and forth motion into rotational motion

4.3. Particles

- solids - molecules are tightly packed
- liquid - definite volume; no fixed shape
  - loosely packed
- gases - no definite volume or shape
- plasma - a gas in which the atoms are ionized
  - free electrons and positively charged ions
- Brownian motion - random movement of microscopic particles suspended in a liquid or gas

4.4. Energy

- heat - transferred energy
- internal energy - total kinetic and potential energy of all atoms or molecules in a material
- energy transfer - transferring energy from one place to another
- heating - an energy transfer process in which energy input causes the temperature of an object to rise
- cooling - the reverse process to heating and temperature drops when energy is transferred away from an object
- methods of energy transfer
  - conduction - contact
  - convection - heat transfer due to bulk movement of molecules within fluids such as gases and liquids
    - hot modules and cool modules have different densities
    - room heaters
    - refrigerators
  - radiation - infrared to red wavelengths
  - heat from the sun reaches the atmosphere due to radiation and it reaches the surface through conduction
- energy transformation - change of energy from one form to another
  - chemical energy in coal and air is transformed into heat energy that boils water and makes steam
  - energy in steam is transformed into mechanical energy
  - mechanical energy to electrical energy
- law of conservation of energy - total energy of an isolated system remains constant
  - energy can neither be created nor destroyed, but transformed from one form to another
  - E_i=E_f
- work-energy theorem - the net work done on a body by an external force, is equal to the change in kinetic energy of the body
  - also called the work-energy principle
  - W_net=KE_f-KE_0=change in KE
- power - the rate at which work is done OR the rate at which energy is consumed
  - P=W/t=E/t=Fv
  - Units: Watts (W) = J/s = N*m/s

4.5. Measuring Temperature

- temperature - the measure of the average kinetic energy of the particles of a body
  - a measure of how hot or cold something is
- Celsius + 273 = Kelvin
- 1.8(Celsius) + 32 = Fahrenheit
- 0 degrees C = melting point of water; 100 degrees C = boiling point of water
- triple point - the temperature and pressure at which the solid, liquid and vapor phases of a pure substance can coexist in equilibrium
  - triple point of water = 0.01 degrees Celsius = 273.16 K = 32.01 F
- absolute zero - zero degrees Kelvin; no thermal energy
  - 0 K = -273.12 degrees C

4.6. Thermal Equilibrium

- there are no net flow of thermal energy between them when they are connected by a path permeable to heat
- average temperature for two substances
  - $T_average = \frac{m_1T_1+m_2T_2}{m_1+m_2}$

4.7. Thermometers

- Alcohol/Mercury Thermometer
  - Principle of expansion
    - linear
    - areal
    - volume
  - mercury thermometers can cover a wide range of temperatures from -37 to 356 degrees C
  - alcohol thermometers can cover a range of -200 to 78 degrees C
    - dependent on the type of alcohol used
  - to calibrate a thermometer
    - place the thermometer in ice and mark this as the freezing point (0 C)
    - then place it in the steam above boiling water and mark this as the boiling point (100 C)
  - sensitivity of a thermometer can be increased by
    - use a thermometer with a smaller bulb - there will be less surface area and less mercury, so heat can be absorbed more quickly
    - use a glass bulb with a thinner wall as this allows heat to enter the bulb more quickly
    - use a capillary with a narrower bore as this makes the change in length of the mercury column more visible
  - to increase the accuracy of the thermometer, the diameter of the capillary tube must be equal throughout the thermometer
  - mercury thermometer

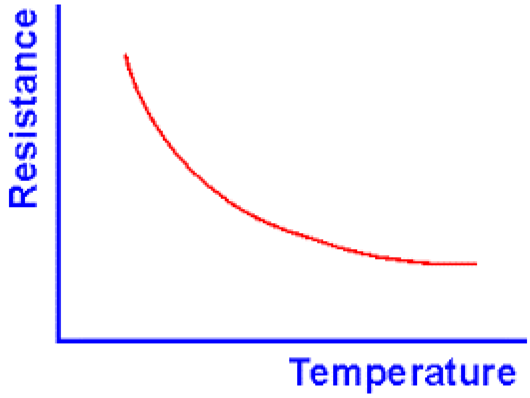
Advantages	Disadvantages
the thread can be seen easilydoesn't wet the side of the tubeexpands uniformly when heatedconducts heat well - responds quickly to temperature changes	freezes at -39 Cpoisonousexpensive

- alcohol thermometer

Advantages	Disadvantages
expands greater than mercuryfreezes at -115 C	transparent - needs to be colored to be easily visiblecling to the sides of the tubethread has a tendency to break

** \n **

- thermistor thermometer
  - resistance thermometer
  - resistance depends on temperature
  - resistance - provides resistance to electrons
    - normal resistors don't change properties → 100 ohms stays 100 ohms
  - thermistor changes resistance based on heat
    - resistance is set in amperes
    - calibration is in Farenheit



  - they are highly sensitive and the small bead also amplifies this
  - errors may occur in the calibration algorithms
    - some heat may be lost due to the resistance of the wires and hence effect readings
    - purity of the wire may have an effect
  - light dependent resistors change resistance based on light
    - ex: museums and street lights
- Thermocouple Thermometer
  - Peltier effect - when two dissimilar metals are joined together to form two junctions, emf is generated within the circuit due to the different temperatures of the two junctions of the circuit
    - one portion of the junction is places on a source whose temperature is to be measure while the other end is maintained at a constant reference temperature
  - -200 to 1100 degrees C
  - two materials have two different internal energies
    - voltage
  - Bimetal thermostats
    - expansion of solids
      - ex: toasters
  - factors that may affect accuracy of the readings
    - poor electrical/thermal connection at the hot junction
      - both metals must be at the same temperature at the hot junction
    - impurities in the materials
    - poor insulation

4.8. The Gas Laws

- Boyle's Law: Pressure-Volume
  - the volume of a given amount of gas held at constant temperature varies inversely with the applied

    - pressure when the temperature and mass are constant
    - $V \alpha 1/P$
- Charles' Law: Temperature-Volume
    - the volume of a given amount of gas held at a constant pressure is directly proportional to the Kelvin Temperature
    - $V \alpha T$
- Gay-Lussac's Law: Pressure-Temperature
    - the pressure of a given amount of gas held at a constant volume is directly proportional to the Kelvin temperature
    - $P \alpha T$
- Avogadro's Law: Volume-Amount
    - if the amount of gas in a container is increased, the volume increases and vice versa when pressure and temperature are held constant
    - $V \alpha n$
- The Ideal Gas Law- PV = nTR
    - n is the number of moles, R is the universal gas constant = 0.0821 L-atm/mole-K

4.9. Emitters and Absorbers

- black is the best emitter and absorber but the worst reflector
- silver/ shiny metals are the best reflectors but the worst emitters and absorbers
- white is a good reflector and a bad emitter and absorber

4.10. Evaporation

- the process of a substance in a liquid state changing to a gaseous state due to an increase in temperature and/or pressure
- to increase evaporation
    - increase the temperature
    - increase surface area
    - reduce humidity
    - blow air across the surface
- cooling effect of evaporation
    - sweat
    - refrigerators
        - refrigerant flows through the compressor which raises the pressure of the refrigerant
        - the refrigerant flows through the condenser, where it condenses from vapor form to liquid form, giving off heat in the process
        - the refrigerant goes through the expansion valve, where it experiences a pressure drop
        - refrigerant goes to the evaporator
        - refrigerant draws heat from the evaporator which causes the refrigerant to vaporize
        - evaporator draws heat from the region that is to be cooled
        - vaporized refrigerant goes back to the compressor to restart the cycle

4.11. Specific Heat Capacity

- the amount of heat per unit mass required to raise the temperature by one degree Celsius
- it is a measure of the resistance of a material to temperature change
- $E = mc\triangle T$
- the specific heat capacity of water is 4.186 joule/gram ≈ 4.2 joule/gram
    - water is a good coolant because of its high heat capacity
        - this means that it can easily absorb large amounts of heat from its surroundings
    - the ideal coolant is: high heat capacity, low viscosity, low cost, non-toxic, chemically inert and does not corrode the cooling system

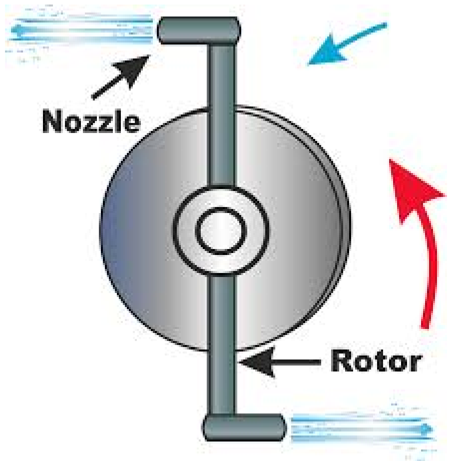
4.12. Latent Heat

- The heat required to convert a solid into a liquid or vapor or a liquid into a vapor without change of temperature
    - instead of being used to raise the temperature, the energy is used to break the bonds between the molecules
- specific latent heat of fusion (L) - the heat needed to change a mass of 1 kg of the substance from a solid at its melting point into liquid at the same temperature
    - ice has a specific latent heat of fusion of 330,000 J/kg
        - the real latent heat of fusion is 300,000
        - this is because some energy is provided from the surroundings
- Energy Transferred (Q) = mass * specific latent heat
- Latent Heat of Vaporization-
    - when a material in a liquid state is given energy, it changes from liquid to vapor
    - the energy absorbed in this process is called the heat of vaporization

To calculate energy when latent heat and specific heat capacity are given $E = mc\triangle T + mL$

4.13. Types of Turbines

- Reaction turbine



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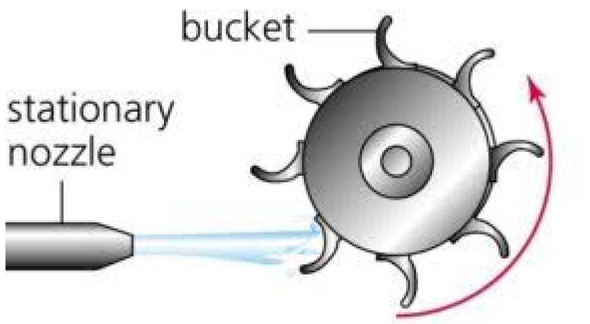
  - develops torque by reacting to the pressure or weight of a fluid
  - Newton's third law of motion
  - as steam is forced out of the nozzle, the steam exerts a force in the other direction on the nozzle
  - the nozzle is free to move so it moves backwards with respect to the steam
  - noisy, prone to breaking, and hard to regulate speed
- Impulse Turbine
  - 

  - steam is directed from stationary nozzles onto suitably shaped blades on a wheel
  - force is applied directly to blades, causing the rotation
  - ideal for producing he rate of relative motion needed to produce high levels of alternating current

4.14. Steam Locomotion

- Steam Engine -
  - increased the pressure in the engine and hence the temperature increased as well → steam has a greater kinetic energy when it is released to do work
  - stem vented through chimney so partial vacuum was created → boiler could be heated quicker
- Piston Engine (Newcomen) -
  - Furnace - uses coal as fuel to heat up water in boiler which generates steam
  - the steam enters the condensing cylinder when the inlet valve is opened and piston is pushed up
  - valve is then closed and a jet of cold water is sprayed into the condensing cylinder through water injection pipes → steam rapidly cools and creates a vacuum → piston is pushed down
  - used for drawing water from well and for mining
- Watt -
  - cylinder was kept hot at all times to avoid energy wastage caused by cooling
  - combined furnace and boiler sent steam into stem inlet pipe
  - series of inlet and exhaust valves - double inlet for steam in order to force the piston up and down
    - active and exhaust steam
    - hot water tank
    - exhaust steam goes to cold water tank
      - condenser and pump
      - the water is condensed and pumped into the hot water tank which circulates to the boiler
  - piston cylinder
  - bean
  - rotary arm → sun and planet gears
  - for every 1000 kgs of coal used by Newcomen, Watt used 250

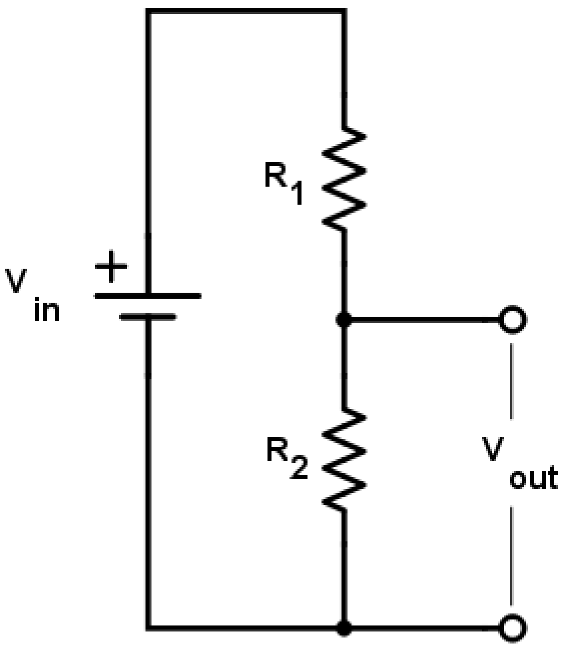
Newton's Law of Cooling

- rate of heat loss of a body is directly proportional to the difference in the temperatures between the body and its surroundings

5. Electrical Circuits

Electricity - electrical energy; a type of energy fuelled by the transfer of electrons from negative to positive points within a conductor

- electrical charge (Q) - the physical property of matter that causes it to experience a force when placed in an electromagnetic field
  - electrons are the charge carriers that flow in an electrical circuit from the negative to positive terminals
  - units: Coulombs (C)
  - charge on one electron = $1.6/10^{-}19C$
  - total magnitude of charge in a given space
    - Q = ne
    - where n = no. of electrons and e = $1.610^{-}19C$
  - drift speed - the average velocity of the free charges
  - speed of electromagnetic field propagation: propagated by photons → speed of light
- current (I) - rate of flow of electric charge
  - units: Amperes (A)
  - I = Q/t
  - flows from positive to negative
- voltage (V) - energy applied per unit charge
  - units: Volts (V) ; Joules/Coulomb
  - V = E/Q
  - voltage divider - a simple circuit which turns a large voltage into a smaller one
    - simplest voltage divider: two resistors are placed in series across the batter
      - used to change the potential difference across one component so that a lower voltage can be used in another part of the circuit



Kirchhoff's Laws:

1. Kirchhoff's Current Law (KCL) - the sum of all the currents into a junction is the same as the sum of all the currents out of that junction OR the algebraic sum of all the currents entering and leaving a node is equal to zero
   1. Nodes should be defined as either dividing of current or joining of current but not both
2. Kirchhoff's Voltage Law (KVL) - the sum of the input of voltage is equal to the sum of voltage drops in a loop OR the algebraic sum of all the voltages in a loop is equal to zero

5.1. Types of Electrical Circuits:

series - exactly one electrical path
parallel - all components are connected across from each other, forming exactly two sets of electrically common points

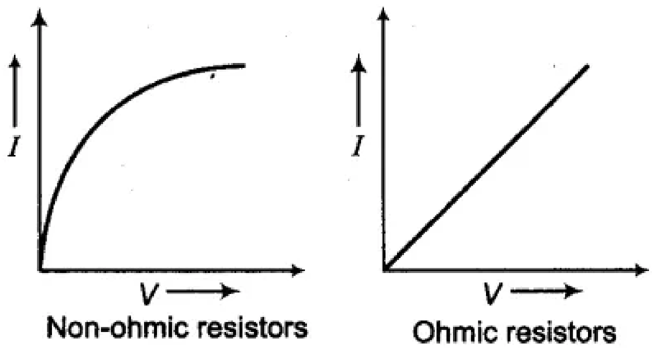
Series Circuits	Parallel Circuits
One electrical pathCurrent remains constantVoltage gets dividedResistance is higher, hence higher voltage is needed and it isn't practically possible	Multiple electrical pathsCurrent gets dividedVoltage remains constantConnect an infinite amount of sourcesmore resistances → more current drawn

Resistance:

- the measure of the degree to which a conductor opposes an electric current through that conductor
  - units: ohms
  - R = pL/A
- equivalent resistance:
  - for series: $R_eq = R1 + R2 + R3...Rn$
  - for parallel: 1/Req=1/R1+1/R2+1/R3...1/Rn

5.2. Ohm's Law

- the potential difference across an ideal conductor is proportional to the current through it
- I = V/R
- ohmic resistors - constant resistance
  - they follow Ohm's law
  - the only ohmic resistor is a straight wire
- non-ohmic resistors give a curve with an increasing gradient
  - resistance increases as current increases
  - ex:
    - filament bulb - resistance goes up when it's heated
    - thermistor - more heat → less resistance
    - LDR - higher light intensity → lower resistance
      - attach LDR in parallel with the bulb for streetlights



- diodes - only allows current to flow in one direction
  - if it flows the other direction, no current is allow through the diode
  - forward bias = positive to positive (on state)
  - reverse bias = positive to negative (off state)
- used in LDRs and thermistors

Superconductors

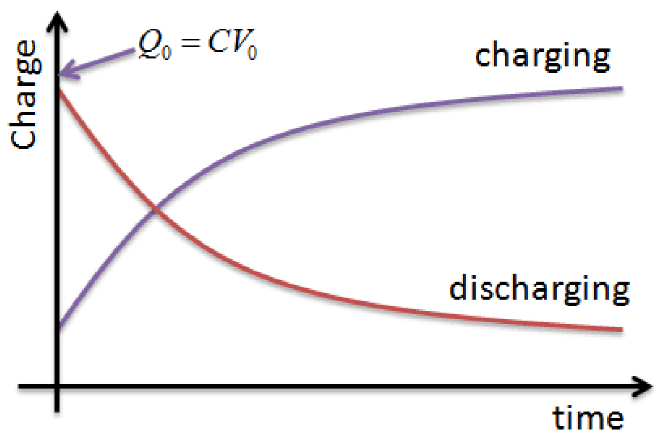
- a material that can conduct electricity with no resistance once they are cooled to a temperature called the transition temperature (T_c)
- at the transition temperature, the resistance suddenly drops to zero
- less power loss
- applications:
  - maglev (magnetic levitation) trains
    - use the principle of magnetic repulsion to make the train "levitate"
      - in repulsion maglevs, the magnets on the underside of the train repel the magnets on the track
      - in guidway maglevs, the magnets on the underside of the guidway are positioned to attract the magnets on the wraparound section of the maglev
      - the guideway has a long chain of electromagnets and current is altered quickly

        - to push the train forward
    - less resistance → less energy loss
    - liquid nitrogen keeps the temperature low
        - cost is less than voltage source
- MRI - reduction of power loss; large magnetic field needs to be created → require lots of energy; resistance of wires needs to be almost 0 → wire coils used in the MRI are bathed in liquid helium at -269 C
    - patient is placed into a strong, constant magnetic field → hydrogen nuclei of the body to line up their combined magnetic effects in the direction of the field
        - randomly distributed and wobble on axis
        - spin up = lower-energy state; spin down = higher-energy state
    - second field is added to the first field in a variety of different angles
        - all protons become spin-down
        - second field is turned off → emit radiation which is picked up by an antenna
            - signals provide information about hydrogen density throughout the body
    - signals and densities give an image of the structure of organs, lesions and other tissues

5.3. Electronic Circuits and Devices

Capacitors

- an electrical component used to store energy electrostatically in an electric field
- contains two electrical conductors (plates) separated by a dielectric (insulator)
- applications -
    - DC blocking capacitor
    - low pass filter and high pass filter
    - protects from peak currents
- capacitance - the ability of a system to store electric charge
    - C = eA/d
    - units: Farads
    - permittivity in a vacuum = 8.85 x 10^-12
- charge - discharge graph



Diodes

- conduct electric current in one direction
- have an anode (positive) and cathode (negative)
- made of semiconductors
- doped with extra positive charged
    - added impurities
    - pn junction breaks down
    - threshold voltage
- applications
    - half wave rectifier
        - converts bidirectional current into unidirectional current
        - coke bottle industry
            - change frequency of cycle
    - full wave rectifier (type 1/ bridge rectifier)

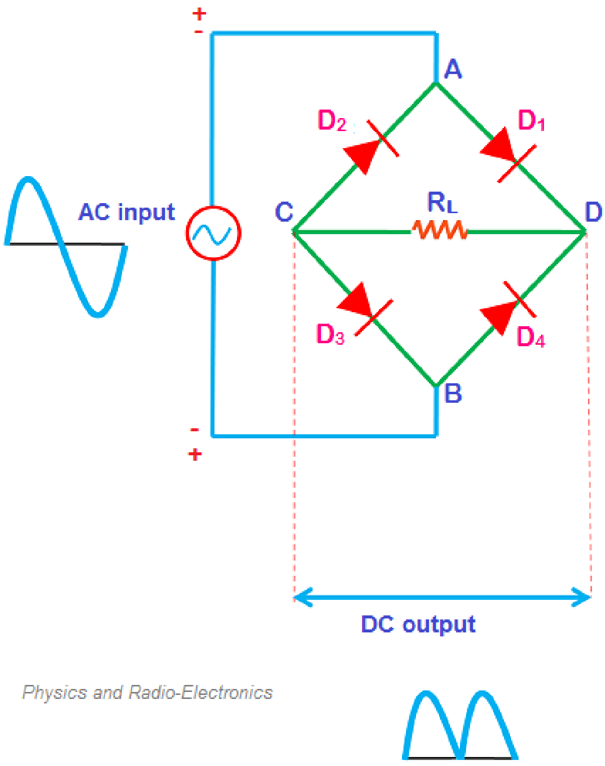
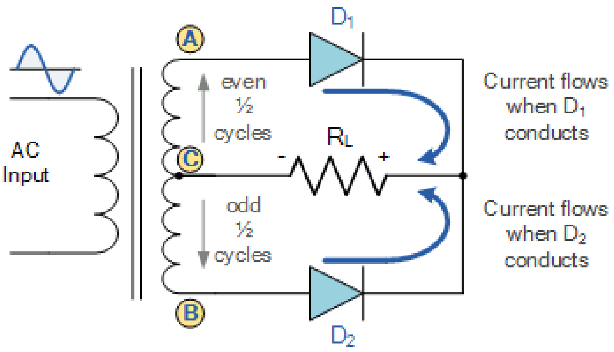
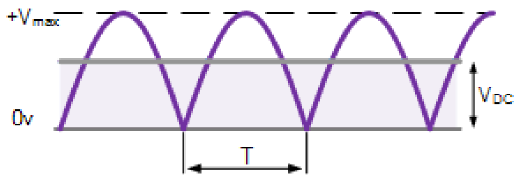


Fig: Bridge Rectifier

    - full wave rectifier (type 2)

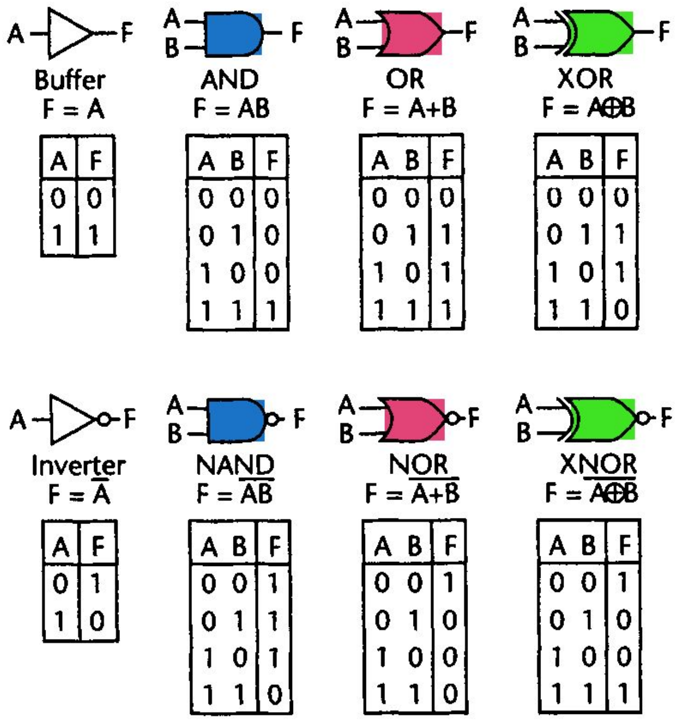




Resultant Output Waveform

- there is a transformer in place to change the voltage
    - transformers are also used in battery chargers

5.4. Logic Gates



A	F
0	0
1	1

A	B	F
0	0	0
0	1	0
1	0	0
1	1	1

A	B	F
0	0	0
0	1	1
1	0	1
1	1	1

A	B	F
0	0	0
0	1	1
1	0	1
1	1	0

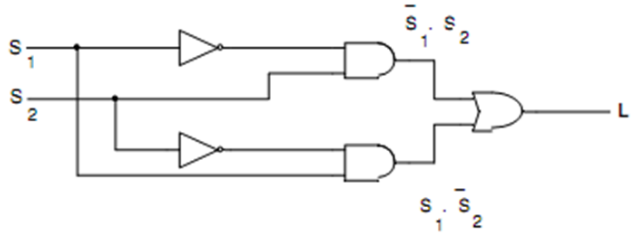
A	F
0	1
1	0

A	B	F
0	0	1
0	1	1
1	0	1
1	1	0

A	B	F
0	0	1
0	1	0
1	0	0
1	1	0

A	B	F
0	0	1
0	1	0
1	0	0
1	1	1

- the NOT gate inverses the number
- AND is multiplicative and OR is additive
- NAND - AND in series with NOT
- NOR - OR in series with NOT
- (E)XOR - same inputs - 0; different inputs = 1
- (E)XNOR - same inputs = 1; different inputs = 0
- two way switch



Static Electricity

- two objects are rubbed together
- one object gives up electrons and becomes more positively charged white the other material collects electrons and becomes more negatively charged
- one material has a weakly bound electrons and the other has many vacancies in its outer shells
- ex: shuffling of feet across carpet

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5.5. Magnetism

- magnetic poles
- making a magnet
    - stroking method - by stoking a bar of steel with a bar magnet, the domains become aligned and a north and south pole are induced
    - electrical method - placing a bar of steel or iron in a coil of wire (solenoid) and passing DC current through the wire
- types of magnetic materials
    - hard magnetic materials - difficult to magnetize bu do not readily lose their magnetism
        - ex: steel, alcomax, magnadur
        - used for permanent magnets
    - soft magnetic materials - easy to magnetize but easily lose magnetic property
        - ex: iron, mumetal
        - applications: electromagnets and transformers
    - diamagnetic
        - all electrons are paired so there is no permanent net magnetic moment per atom
        - slightly repelled by a magnetic field
        - material doesn't retain magnetic properties when the external field is removed
        - ex: copper, silver, gold
    - paramagnetic
        - some unpaired electrons
        - slightly attracted by magnetic field
        - does not retain magnetic properties when field is removed
        - ex: magnesium, molybdenum, lithium, tantalum
    - ferromagnetic
        - many unpaired electrons
        - strong attraction to magnetic fields
        - able to retain magnetic properties after external field has been removed
        - ex: iron, nickel, cobalt

- non-magnetic materials: brass, copper, zinc, tin, aluminum and nonmetals
- a magnet can be demagnetized be either hammering or heating as this jumbles up all of the domains

6. Electromagnetism

- energy (E) - the capacity of a physical system to do work
  - units: Joules
  - E = VQ = V(It)
- power (P) - the rate at which energy is consumed
  - units: J/s or Watts (W)
  - P = IV $= I^2R = V^2/R$

6.1. Energy Sources

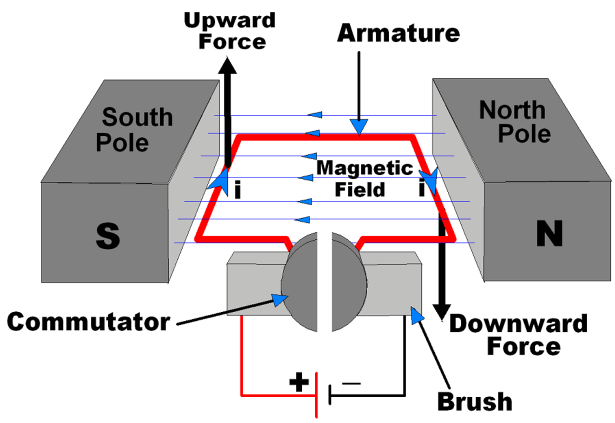
- Non-Renewable - do not form or replenish in a short period of time
  - ex: crude oil, natural gas, coal, uranium (nuclear energy)
  - all fossil fuels are non renewable but not all non-renewable energy sources are fossil fuels
- Renewable - regenerate
  - ex: Biomass (wood, solid waste, landfill and biogas, ethanol, biodiesel), hydropower, geothermal, wind, solar
  - green energy - minimal impact on environment
  - why we don't use them
    - expensive
    - not always available

6.2. Magnetic Effect of Current

- in a wire
  - if an electric current is passed through a wire, a weak magnetic field is produced
  - magnetic field lines are circular
  - field is strongest closest to the wire
  - more current → stronger field
  - right hand rule: thumb = direction; fingers = magnetic field
- in a coil
  - solenoid; stronger magnetic field
  - similar to a bar magnet; has poles
  - more current → more field strength
  - more turns → more field strength
  - thumb = pole; fingers = current
- electromagnets
  - can be switched on and off
  - coil + core
  - current flows through core → magnetic field → core is magnetized
    - 1000x times stronger than coil alone
  - core = soft magnetic material
  - increase strength by more turns or more current
    - reversing current direction changes direction of the magnetic field
- applications of an electromagnet
  - magnetic relay - A relay is an electromagnetic switch operated by a relatively small electric current that can turn on or off a much larger electric current
    - The input circuit is switched off and no current flows through it until something (like a switch closing) turns it on. The output circuit is also switched off.
    - When a small current flows in the input circuit, it activates the electromagnet, which produces a magnetic field all around it.
    - The energized electromagnet pulls the metal bar in the output circuit toward it, closing the switch and allowing a much bigger current to flow through the output circuit.
    - The output circuit operates a high-current appliance such as a lamp or an electric motor.
  - circuit breakers - turn off a circuit when the current goes above safe levels
    - a switch is connected to either a bimetallic strip or an electromagnet
    - when the switch is in the on position, the electricity can flow through the circuit
    - however, when the current jumps to unsafe levels, the electromagnet is strong enough to pull down a metal lever connected to the switch linkage
      - this moves the moving contact away for the stationary contact
    - the circuit breaks and current stops flowing
  - magnetic storage - magnetic tape, floppy disks, hard disk drives
    - audio tape is covered with layer of ferromagnetic material like ferrous oxide
    - binary info is stored with the help of magnetic poles

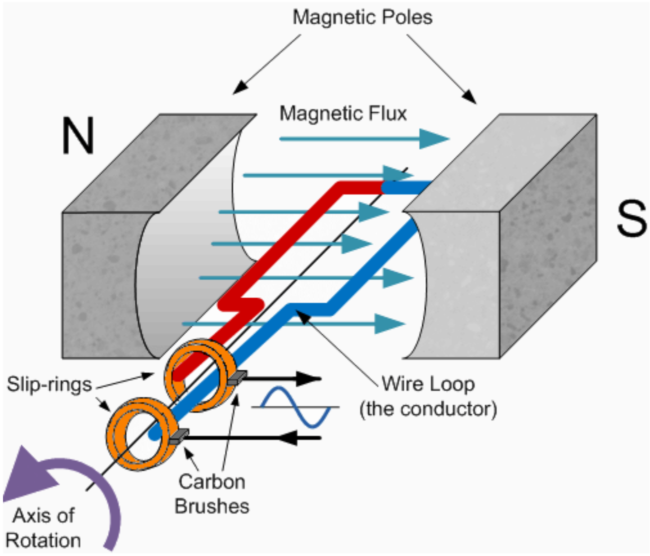
6.3. Magnetic Force

- fleming's left hand rule
- DC motor - magnet, armature, brush, commutator segment, power source



DC Motor Conceptual Diagram

- AC motor - slip rings, AC power source



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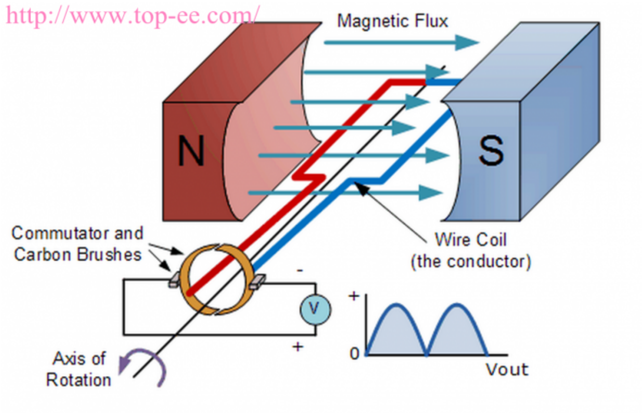
6.4. Electromagnetic Induction

- Tesla (T) = Unit for magnetic field = 10,000 Gauss (G OR Gs)
- Weber (Wb) = unit for magnetic flux
  - magnetic flux - total amount of magnetic field passing through an area
- when a wire with cuts a magnetic field, voltage/emf is produced
  - emf → causes current to flow in a closed circuit
  - galvanometer/sensitive ammeter
  - Fleming's right hand rule
- electromagnetic induction - production of emf across an electrical conductor in a changing magnetic field
- Faraday's Law - the emf induced in a conductor is proportional to the rate at which the conductor cuts the magnetic field
  - increase emf by
    - moving the wire faster
    - using a stronger magnet
    - increase length of the wire
  - reverse emf
    - move wire in opposite direction
    - change magnetic field direction
  - increasing emf induced in a coil
    - moving magnet faster
    - stronger magnet
    - more number of turns
- Lenz's Law - the induced current always flows in a direction that opposes the change which produced it OR an induced emf is always opposite to the rate of change in magnetic field
  - can be observed when we move a magnet towards or away from a coil with current
- DC generators



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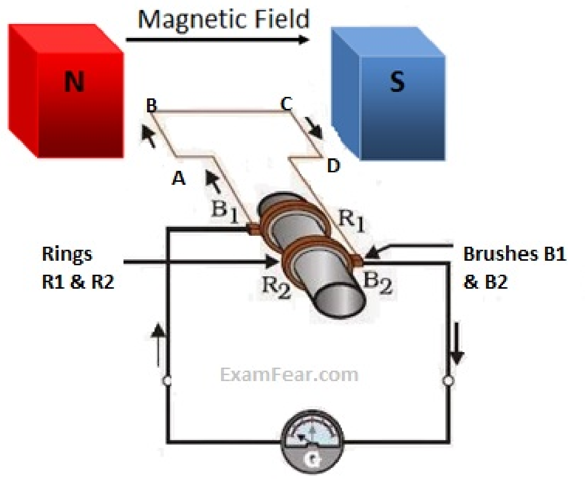

  - converts mechanical energy into electrical energy
  - armature, shaft, field magnet, slip rings, brushes
  - sinusoidal graph

Transformer

- when we use higher voltages and lower currents, there is less energy wastage
  - electricity from power plants is sent down wires at extremely high voltages to save energy
- primary and secondary currents
- through electromagnetic induction, the current passing through the first coil induces current in the second coil
  - coils are wrapped around a core for efficiency
    - made of soft iron bar
- must use AC current in order to "cut the magnetic field"
- power remains the same: P = IV initial = IV final
- step down
  - primary turns > secondary turns
  - voltage decreases - secondary voltage/primary voltage = secondary turns/primary turns
  - current increase - secondary current/primary current = primary turns/secondary turns
- step up
  - primary turns < secondary turns
  - voltage increases
  - current decreases
- shell type - two cores
  - the radius of the outer coil is larger, hence the length of the wire is greater

- even if you take the same number of turns, it acts as a step up transformer
- more efficient
  - 2 cores = greater magnetic field; entire portion of the coil is in very close contact to the coils and hence there is more utilization
  - less magnetic leakage due to overlapping coils
- core type - one core
  - easier to repair
    - in a shell type transformer, if the primary coil is damaged, the secondary coil also needs to be dealt with
    - core types are easier to repair
  - all large transformers are core types
  - smaller appliances like microwaves and chargers are shell types
- used in laptop chargers and induction chargers
- power loss
  - magnetic field leakage
  - heating effects in core and coil
  - can be reduced by
    - placing coils closer together
    - using a laminated core to reduce eddy currents
    - using a thick copper wire to reduce resistance: R = pL/A
- eddy currents - the random movement of electrons in a thick sheet
  - happens while cutting a magnetic field
  - emf is also generated inside the core and due to the change in direction there is heat loss
    - random direction = loss of currents
  - laminated core - a series of thin sheets attached to each other
    - used to prevent heat loss
  - eddy currents are useful in metal detectors
    - metals under the earth are large masses and produce eddy currents

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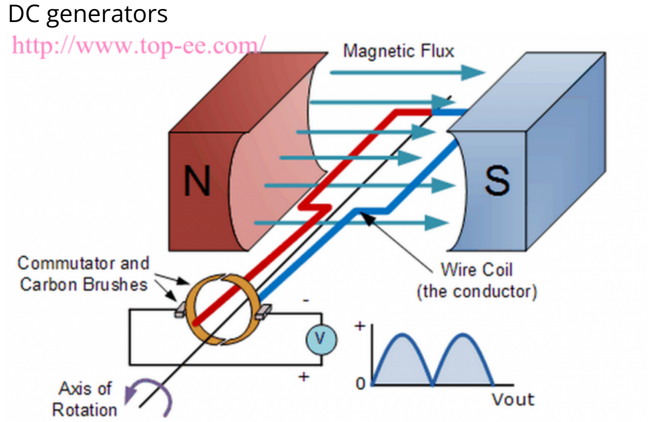

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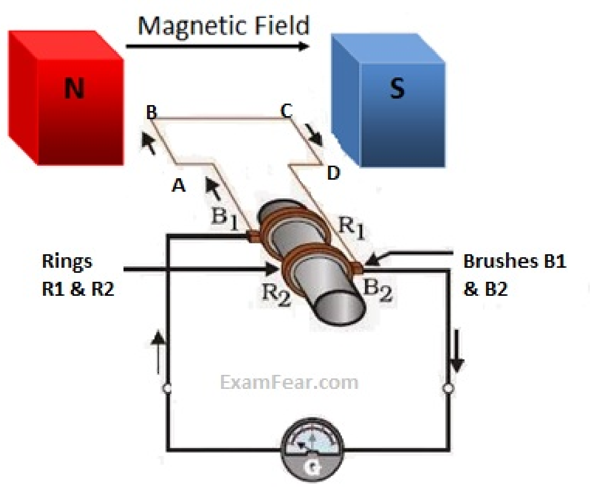

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7. Waves

- wave - a disturbance that carries energy from place to place
- classification
  - mechanical - need a medium; ex: sound
    - transverse - waves in which the medium moves at right angles to the direction of the wave
      - crests and troughs
      - mean position
    - compression/longitudinal - the medium moves back and forth in the same direction as the wave
      - compression and rarefactions
  - electromagnetic - doesn't need a medium; ex: light

7.2. Wave Properties

- wavelength - the distance between one point on a wave and the exact same place on the next wave
  - consecutive crests or troughs
  - consecutive starting points
  - the wavelength in a longitudinal wave is the distance between two consecutive points that are in phase
    - compressions or rarefactions
- frequency - how many waves go past a point in one second
  - unit: Hertz (Hz)
  - waves/second
  - f = 1/period = 1/T
  - higher frequency → more energy in the wave
- amplitude - how far the medium moves from rest position
  - distance from undisturbed level (rest position) from highest or lowest point
  - for longitudinal waves: the closer together the particles, and the further apart the compressions and rarefactions → the larger the amplitude
  - A α E → E = CA^2 where
    - C is a constant
    - E is energy applied
    - A is amplitude
- wave speed - depends on the medium in which the wave is travelling
  - varies in solids, liquids and gases
  - wave speed
    - v = λ f
    - units: mHz OR m/s
  - mechanical waves travel faster in solids and slower in gases
  - electromagnetic waves travel faster in a vacuum and slower in solids

7.3. Change in Wave Direction

- reflection - wave bounces off a surface
  - law of reflection: angle of incidence = angle of reflection
- refraction - waves can bend
  - when a wave enters a new medium, the speed changes

    - the refracted ray bends towards or away from the normal
        - violet moves towards the normal
        - red moves away from the normal
        - when we go from a rarer medium to a denser medium, the ray bends towards the normal
        - when we go from a denser medium to a rare medium, the ray bends away from the normal
- diffraction - bending of waves around an object
    - small obstacle obstacle → large diffraction
    - large wavelength → large diffraction
    - large obstacle → small diffraction
    - small wavelength → small diffraction
    - ex: solar eclipse
- interference - two waves superimpose to form a resultant wave of greater, lower of same amplitude
    - ex: noise cancellation headphones
    - superposition: result = sum of cause
    - constructive and destructive interference
- when a wave enters a new medium
    - mechanical waves
        - frequency (the vibration of each molecule) is constant
        - speed changes → wavelength changes
            - speed increases in water because there is less space between particles
    - electromagnetic waves
        - frequency remains constant
        - speed changes → wavelength changes
            - speed decreases in water as there is more interaction with the medium and hence energy is lost
    - frequency must remain constant in order to conserve the energy (E = hf)
- discontinuity
    - low density to high density = hard boundary
    - high density to low density = soft boundary
- reflection from a boundary
    - when reflected from a hard boundary, the amplitude reverses
        - Newton's Third Law - every action has an equal and opposite reaction
    - when reflected from a soft boundary the amplitude remains the same
        - change between kinetic and potential energy

Ultrasound

- an ultrasound is wave with a frequency higher than 20,000 Hz
    - infrasound - frequency is less than 20 Hz
- when there is a higher density difference, there is more reflection and when there is a lower density difference, there is less reflection
    - to reduce the difference between the air and the skin, a gel is applied
    - at the air-skin boundary, 99% of ultrasound waves are reflected
- how it works:
    - after the ultrasound waves penetrate through the skin, they hit an organ
        - some waves are transmitted through, but some are reflected
        - the reflected waves travel back to the ultrasound probe
            - the time taken and the intensity of the echo to return are measured
    - this information is used to build up an image in varying shades of gray on a computer screen
    - some waves are absorbed and the energy is converted into heat energy
        - the heating effect is small and no harm has been observed in the history of this technique
- ultrasound is the only type that has enough energy to penetrate the body
    - frequency = 2-18 mega Hz
- ultrasound isn't an ionizing radiation so it isn't harmful
- you can't use ultrasound on lungs because they are filled with air

echo - reflection of a sound wave; use soft materials to reduce echo
\n

7.4. Electromagnetic Waves

- travels through the mediums of electric and magnetic fields
    - electric and magnetic fields are mutually perpendicular
- electromagnetic wave - waves that are propagated by simultaneous periodic variations of electric and magnetic field intensity

Properties

- All objects emit EM waves
- the wavelengths become shorter as the temperature of the material increases
    - temperature increase → more energy → higher frequency → decreases wavelength
    - the wavelength is inversely related to the temperature whereas the frequency is directly related to the temperature
- they carry radiant energy
    - radiant energy = heat energy
    - ex: microwaves, infrared

Speed of EM Waves

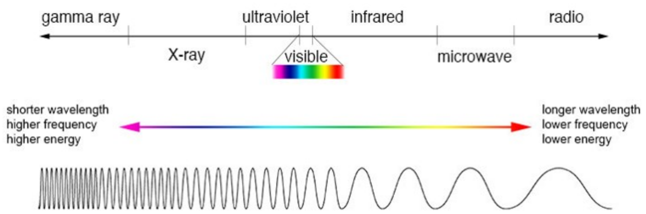
- c = speed of light
- c = $3\backslash*10^8$ m/s in a vacuum
- as density increases, particle interaction increases → loss of energy → lower speed
    - mechanical waves are faster in solids, EM waves are slower

- speed: v = λ f → λ =v/f → λ =c/f
  - and f and inversely proportional

Particle Wave Duality

- since E = CA^2, if energy increases, then more electrons should be emitted
  - Einstein found that frequency effects electron emissions
  - photons = small packets of energy
  - energy depends on frequency
- E = hf where h is Planck's constant

7.5. The Electromagnetic Spectrum



- lead has a high density, so 15 cm lead can be used to block even high frequency waves
- radio waves
  - wavelength - 1 mm to 100 km
  - James Clerk Maxwell - developed the unified theory of electromagnetism in the 1870s and predicted the existence of radio waves
  - Heinrich Hertz then applied Maxwell's theory to produce radio waves
  - convert information into electrical signals
    - transmitter and receiver
    - transmits information as sine waves
    - sine waves need to be modified
      - pulse modulation - on and off; ex: morse code
      - amplitude modulation - overlay sine waves → fluctuation in amplitude → static
      - frequency modulation
  - other: space wave, ground wave, sky wave
  - they can penetrate through walls because the walls are too thin and the radio waves are large
  - used for communication
  - RADAR and SONAR
  - birds are affected by radio waves as the magnetic field disrupts their navigational skills → get confused and fly in all directions → die
  - naturally generated by lightning or astronomical objects
- microwaves
  - frequency = 1-360 Hz
  - wavelength = 30 cm to 1 mm
  - telecommunication
    - wifi transmits microwaves
    - phones → larger demand → frequency
  - microwave ovens
    - magnetron (power is supplied here) → 12 cm waves → waveguide → stirrer
    - waves go in all directions + bouncing
    - turntable → even cooking
    - dangers
      - non-ionizing
      - electric sparks
      - heat damage to eyes; cataract; painful burns
      - leaking
    - destroys + deforms food molecules → new compounds
  - cell towers interfere with body's emf
- gamma wave presentations
  - high energy levels
  - wavelength < 10 picometers
  - nuclear fission
    - 2 hydrogens → helium
    - loss of mass → release of lots of energy
  - fusion: helium splits
  - therapy - cancerous tumor DNA is damaged with gamma radiation → cells die
    - gamma knife therapy/radiosurgery
      - precision: 200 tiny beams
  - astronomy
    - gamma ray bursts - most energetic form of light
      - collisions of compact objects
    - can't penetrate atmosphere
      - telescope or high altitude balloons
      - observe space patterns
  - mild radiation sickness - small doses → radiation poisoning: GI, skin, hair
  - severe radiation poisoning - larger acute doses/ accumulation
    - can result in death
    - bone marrow failure: RBCs and WBCs
  - cancer - daughter cells may contain damaged copies; neoplasm
  - sterilization
    - dry heat sterilization - hot air
    - moist heat sterilization - hot air + water vapor
  - applications of gamma sterilization
    - sterilize human tissue
    - food sterilization
    - heat and moisture sensitive objects
    - very expensive and can be dangerous
    - gamma rays can kill the bacteria by creating an unsuitable environment
- UV rays
  - 10-400 nm wavelength
  - 1015-1017Hz
  - invisible to humans but can be seen by bees
  - UVC = most harmful; atmosphere absorbs all UVC rays
  - UVB = cancerous
  - applications
    - camera
    - UV pass filter
    - fluorescent inspection

    - sterilization
    - vitamin D; cholesterol
    - tanning; increases melanin
    - eczema; limited mutated cell division
  - more vitamin D → more endorphins and navigation
  - side effects: cancer, sunburn, immune system, snow blindness and cataract, weakens plastic, photodegradation

7.6. X Rays

- photographic film is placed under a part of the body and a short pulse of X-rays are sent through the area
  - bones absorb most of the X rays but they can still pass through the soft tissue
  - transmitted rays strike the film and turn the film from white to black
    - white shadow of the bone against a black background
    - film is now replaced by digital radiography which captures the image on a screen
- X ray ,machine consists of an electron gun and a tungsten alloy in a vacuum
  - current flows through the tungsten filament → heating effect → filament is heated and heats a metal plate
    - some electrons of the cathode escape the surface of the metal and form and electron beam (this is called thermionic emission)
  - a very high voltage is connected across the metal plate and the tungsten alloy target → cathode becomes very negatively and anode becomes very positively charged
    - electrons are repelled from the cathode and attracted to the anode
      - accelerate across gap at a very high speed
      - decelerate rapidly on hitting the target
  - some electrons orbiting the tungsten atoms absorb the energy of the decelerated electrons and then emit the energy as X-rays
    - higher accelerating voltage = higher frequency of the X rays
    - for more X-rays, increase the current in the tungsten filament → more electrons released
  - target it rotated to avoid having the same point hit continuously → cooling

7.7. Nuclear Imaging

- shows body functions rather than body anatomy
- radioisotopes + pharmaceutical = radiopharmaceutical
- alpha, beta and gamma radiation
  - alpha and beta don't penetrate skin so it doesn't matter
  - gamma comes out and emits out of the body
    - magnitude is measured for imaging
- take a nuclear material such as thorium and mix it in a drink and swallow it
  - more common method = injection
  - most common material = technetium-99m
- radioisotope is circulated throughout the body
  - as it decays. gamma rays are emitted through the patient's tissues and detected by a gamma camera
  - gamma image is converted into a visible image on a computer screen
  - amount and position of radiation help detect if there are any blockages and see if body function is fine
- it is safe because half-life of technetium-99m is low so radiation doesn't remain in the body for too long
  - decay particles = low-energy beta radiation
    - excreted from the body in 24 hours via the kidneys
- precautions: lead gloves, aprons and lead-glass syringes

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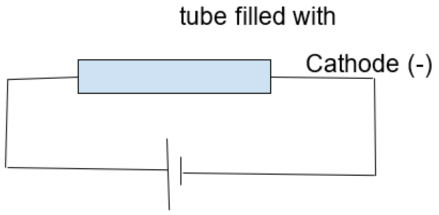
7.8. Radiotherapy

- treatment of cancers and other diseases with ionising radiation (X rays and gamma rays are commonly used)
  - DNA of cancer cells are destroyed → cells dies
  - some healthy cells die but they can replace themselves
- external beam radiotherapy
  - energy depends on position of cancer - deeper cells = higher energy X rays
  - beams of radiation are focused on the target tissue at different angles → reduced the damage done to healthy tissue as only one beam passes through a point
  - small doses over a few days or weeks → allows healthy cells to repair themselves
- internal radiotherapy
  - radioactive implant is placed directly in a tumor or body cavity → radiation does is concentrated in a small area
  - as soon as the implant is removed, the patient is no longer radioactive
    - for "permanent" implants, the patient has to stay in the hospital for a few days
  - used for cancers of cervix, uterus and tongue
- systematic radioisotope therapy
  - radioisotope is either delivered into the patient's bloodstream or swallowed
    - the radioisotope is absorbed by the cancerous tissue due to its chemical properties
    - cancer cells absorb the radiation and die

8. Light and Sight in Focus

8.1. Sources of Light

- luminous
  - incandescent - produces light when heated
    - collision of electrons (winding of coil) → friction → heat → light
    - IR as well
  - Light Emitting Diodes (LED) - produces light when voltage is applied to semiconductors
    - cost saving and better for health
      - less life span
      - pn junction spoils permanently
      - LED screen is power saving but has burn in issues
  - fluorescent bulbs



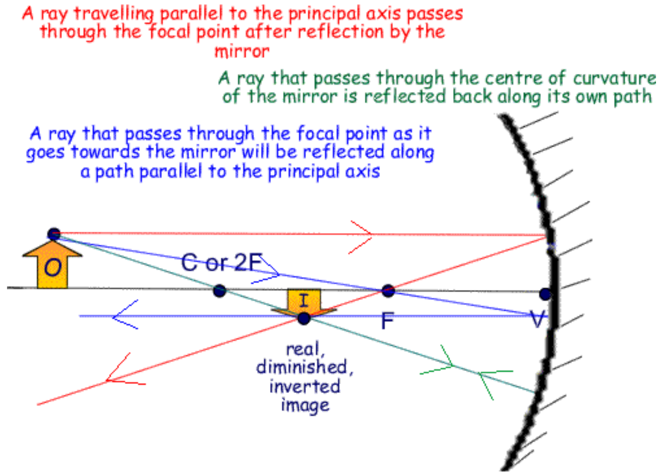
    - (has a transformer to step up voltage)
    - mercury is excited by electrons → releases UV radiation
    - phosphorus powder absorbs UV radiation and glows
    - CFL - compact fluorescent light
  - high-intensity discharge (HID)
    - intensity = power/area
    - arc between anode and cathode in a pressurized tube
    - used for street lights
  - luminescent - produces light due to chemical reaction
- non-luminous - ex: moon, planets, etc...

Classification of Reflection

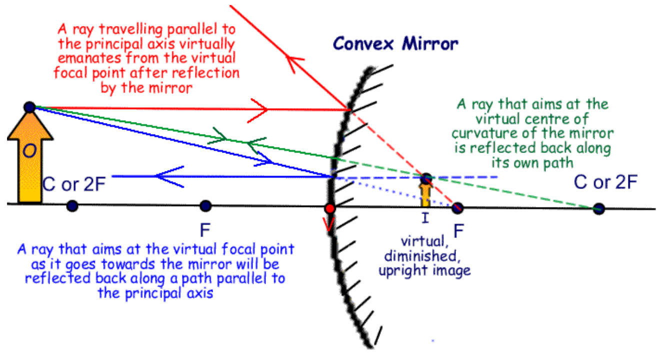
- bending of light - reflection and refraction
- regular reflection - all normals are parallel
- irregular/diffused reflection - normals are not parallel → irregular surface

8.2. Mirrors

- plane mirror
  - virtual image
  - same size as object
  - same distance
  - reversal image
  - magnification (m) = image dimension/object dimension
    - M = 1 for plane mirrors
- concave mirror



  - inner surface is shiny
  - focus, center of curvature, principle axis, radius
  - C = 2F
  - as the object gets closer to the mirror, the image moves away and height increases
  - screen is required
  - conditions
    - if object is at C, image will be below C
    - if object is between C and F, image will be beyond C
    - if object is between F and C, image is on the other side of the mirror
    - if the object is at F, no image is formed
    - If object is beyond C, the image will form between C and F
  - uses: dentists mirrors, shaving mirrors, torch light, front light of car, aircraft landing, etc...
- Convex mirror



  - outside is shiny
  - virtual image, upright, smaller in size, image formed between the mirror and F
  - image gets bigger as object gets closer to the mirror
  - uses - side view mirrors, road corner mirrors

Real vs. Virtual Image

Real	Virtual
Formed by real intersection of reflected light rays Can be received on a screenAlways inverted	Imagery intersectionCan't be on screenAlways erect

Mirror Formula

- f = focal length, v = image distance, u = object distance
- 1/f=1/v+1/u
  - f= uv/u+v
- sign conventions
  - along the direction of the incident ray = positive
  - against the direction of the incident ray = negative
  - height above principal axis = positive
  - height below principal axis = negative

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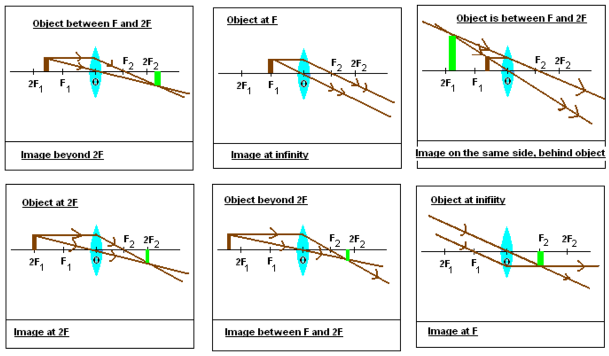
8.3. Refraction

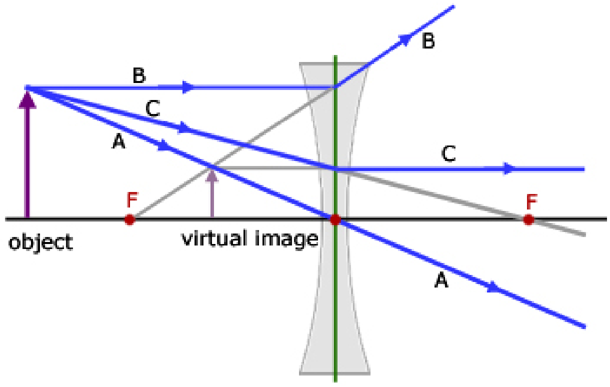
- change in direction of a wave passing from one medium to another caused by its change in speed
- Descartes-Snell Law
  - $n_1 sin_1 = n_2 sin_2$
  - n is the refractive index
    - n = c/v
  - 1is the angle of incidence
  - 2is the angle of refraction
  - as the angle of incidence increases, the reflective intensity increases
  - critical angle- if angle of incidence goes beyond the critical angle, there is total internal reflection
    - the incident angle at which the refracted ray makes 90 degrees with the normal
      - refracted ray is parallel to interphase
    - total internal reflection - all intensity is reflected in same medium
      - optical fibre → sound wave → light wave → optical fibre
      - only happens BEYOND the critical angle
    - only happens from denser to rarer medium
      - still happens beyond the critical angle
    - reflected ray obeys the angle of reflection

8.4. Lenses

- a transparent curved device usually made from glass that is used to refract light
- convex
  - thicket at center than edges
  - converging lens
  - biconvex (two curvatures), equiconvex(same on both sides), plano-convex, concavo-convex (converging meniscus ex: contacts), etc…
  - ray through center of lens ⇒ undeviated
  - conditions are same as mirrors



- concave
  - diverging lens
  - biconcave, equiconcave, plano-concave, diverging meniscus



- we can use convex and concave lenses together for practical applications

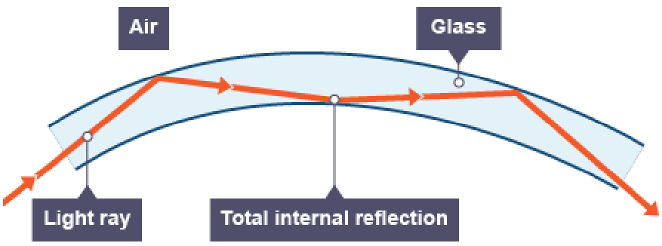
8.5. Visual Impairments

- vision loss, blond or partial vision
  - legal blindness
    - 25 ft vision vs the 250 ft of a normal person
- affects 21.9% of India
- causes: physical injury, mutation, infection, cataracts, lazy eye, diabetes, glaucoma
- types: farsighted, nearsighted, muscular degeneration
- diagnosis: Snellen's test (chart), Visual field test, tonometry test (glaucoma)
- treatment: extent, case, age, health, diabetic, cataract surgery, magnification systems, medication
- color blindness
  - genetic - light sensitive cones; sometimes an issue in signal pathways
  - more common in men
    - 1/12 men vs 1/200 women
    - unilateral dichromacy - one normal and one b/w eye
    - types: green/red, blue/yellow, total
  - symptoms: difficulty distinguishing between color, sensitive to bright light, can't see shades and tones
  - treatment: tinted filters
- hypermetropia/hyperopia (long sightedness) - images form behind the retina
  - can't see close objects
  - short axial length → image beyond the retina
  - common in adult

- causes: eyeball is shorter than normal; refractive error
- glasses - convex lenses bend light rays; contact lenses
- laser eye surgery can reshape the cornea
  - LASIK
- myopia - image forms in front of retina
  - causes: eyeball is too long, cornea is too curved
  - symptoms: can only see nearby objects, blurry vision, squinting, headaches
  - glasses - concave lenses; contact lenses
  - refractive surgery

8.6. Optical Fibres and Endoscopes

- optical fibre - consists of a very thin, flexible glass tube surrounded by a cylinder of less optically dense glass
  - fibre is then covered in black plastic to prevent light entering from outside
- light shone into the optical fibre hits the boundary of glass at an angle greater than the critical angle, and is hence reflected
  - this happens repeatedly → light travels down the optical fibre



- medical endoscopes have two bundles of fibres
  - illumination bundle - carries light from a strong light source to the part of the body which needs to be examined
  - image bundle - light reflected back travels through this bundle, and the image formed by this light can be observed by using an eyepiece or on a computer screen
- keyhole surgery - endoscopes allow doctors to take small tissue samples (biopsies), remove foreign objects, and carry out minimally invasive surgery
  - 3-4 small incisions are made → tube is inserted → endoscope passed through tube → image from endoscope displayed on screen
    - mini surgical instruments can be operated from outside the body by observing the images on the screen
  - benefits: quicker post-operative recovery, less scarring, less pain, fewer possibilities of infection after operation
  - ex: hernia repair, gallbladder removal, removal of appendixes and ovarian cysts, treatment of ulcers

9. Atomic Physics

9.1. Introduction to Atoms

- simple atomic model
  - everything is made of atoms
    - central nucleus: protons + neutrons = nucleons
      - held together by strong nuclear force
    - electrons
      - held in orbit due to attraction between opposite charges
  - proton = 1835x mass of electron
  - elements - chemically simplest substances that cannot be broken down using chemical reactions
    - smallest piece = atom
    - atomic number = no. of protons
  - isotope - different versions of the same element
    - different masses but identical chemical properties
    - same atomic number, different mass number
- Brownian motion - the random movement of microscopic particles (in a fluid), as a result of continuous bombardment from molecules of the surrounding medium
- antimatter - the opposite of normal matter
  - have same properties (such as mass) of their matter counterparts, but with an opposite charge
  - antihydrogen (represented by H with a line over it) consists of an positron orbiting an antiproton nucleus

9.2. Radiation

- ionization - turning atoms into ions
  - if a gas becomes ionized, it will conduct electric current
  - in living things, ionization can damage or destroy cells
  - nuclear radiation can remove electrons from atoms in its path
    - X-ray, UV, gamma
  - gamma has high penetrating power, alpha has low penetrating power
  - alpha is very ionizing; releases 2 protons → more force on electrons
    - beta releases 1 electron
    - gamma doesn't release anything; least ionizing because they are uncharged
  - alpha particles are also slower so they have more interaction time with the electrons the pass; more force + slower → more ionization

Type of Radiation	Alpha particle	Beta particle	Gamma ray
Symbol	α or ${}^4_2\alpha$ or ${}^4_2He$	β or e^-	γ (can look different, depends on the font)
Mass (atomic mass units)	4	1/2000	0
Charge	+2	-1	0
Speed	slow	fast	very fast (speed of light)
Ionising ability	high	medium	0
Penetrating power	low	medium	high
Stopped by:	paper	aluminium	lead

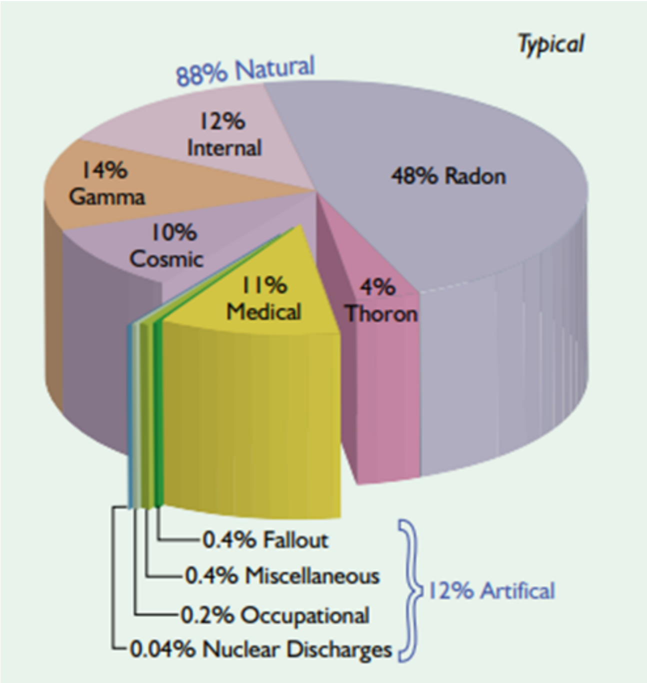
- Alpha particles
- Beta particles
- Gamma rays

Effects by Electric and Magnetic Fields

- Magnetic Field: Fleming's Left Hand Rule
  - Beta - current is opposite the direction of the electron's motion so the direction of the particle is opposite the direction given by the rule
  - Alpha - same direction as conventional current
  - Gamma - no charge = no current = no force
- Electric Field
  - Beta = negative = attracted to positive plate
  - Alpha = positive = attracted to negative plate
  - Gamma = no charge = continues in a straight line

Radiation Dangers

- nuclear radiation can destroy or damage living cells → cancer
- high intensity and/or long exposure time = greater risk
- radioactive gas and dust maybe taken into the body through air, food, or drink
  - ex: coffee is grown in areas with lots of radioactive elements in the soil
    - absorbs radiation → coffee beans are now radiated
    - you ingest the radiation
  - very difficult to remove from body and can cause damage to deep cells
- alpha = most harmful because it is highly ionizing
  - stopped by skin
- beta and gamma can penetrate the skin and get to internal organs
- background radiation - the small amount of radiation around us all the time because of radioactive materials in the environment



  - radon is present in rocks
  - internal = food consumption
  - gamma - cement in ground contains isotopes
  - cosmic = space, asteroids, gamma rays

  - medical = imaging
- absorbed dose - amount of energy absorbed per kg of tissue
  - gray (Gy) = Joule/kg
  - radiation doses are usually expressed in sieverts (Sv)
  - average dose of radiation per person from natural sources = 3 mSv per year

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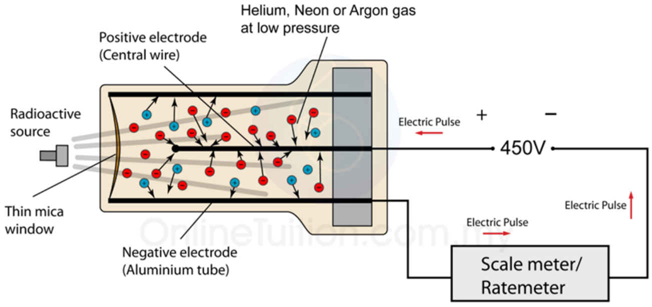
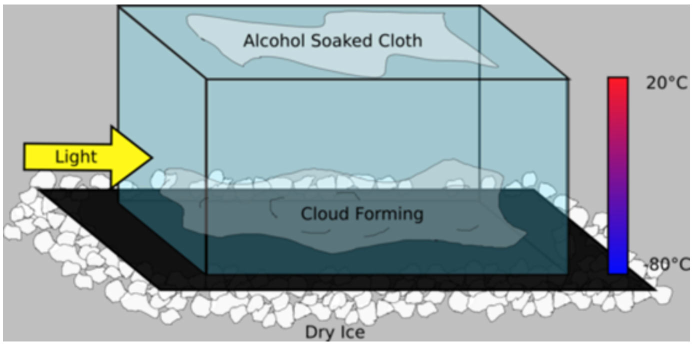
9.3. Geiger-Muller (GM) Tube



- unit = counts/seconds
  - number of particles detected = counts
- detects presence of radioactive elements
- the tube is connected to a battery
  - body is negative
  - electrode is positive
- insulator and thin window of mica
  - thin window is used to allow radiation to pass through
- there is also a scale
- fill the tube with an inert gas at a low pressure
- rate meter - counts/second OR decay/second
- scaler = total decay' total number of particles detected by the tube
- amplifier & loudspeaker - click sound when each particle or burst of gamma radiation is detected
  - rubbing = change in current = change in sound
  - count the number of sounds → amplifier increases the volume of the sound
- ex: alpha radiation
  - ionizes gas
    - ions are attracted to the plates → charge is produced on the plates
    - scale fluctuates
      - change in current = change in potential (voltage) → scale fluctuates
  - increase in change in current = more radiation
    - observe from the scale reading

Cloud Chamber



- detects the passage of charged particles that result from radioactive decay
- air within cloud chamber is saturated with alcohol vapor and chilled with dry ice
  - alcohol gets condensed/vaporized easily
  - dry ice decreased the temperature → alcohol vapor gets supersaturated
- black background
- alpha particles ionize the saturated vapors → attract other tiny droplets
  - ions create chains that are easily visible

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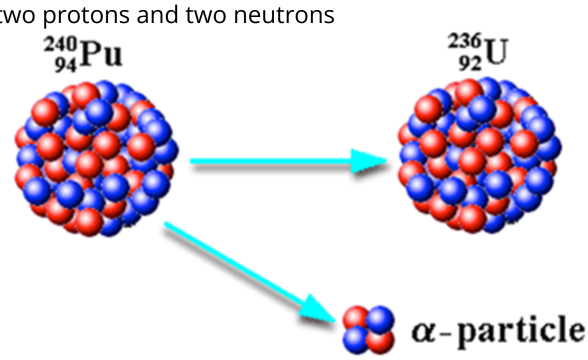
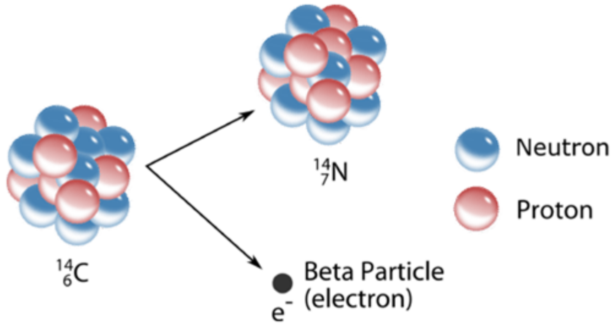
9.4. Radioactive Decay

- an isotope is radioactive if it has an unstable arrangement of neutrons and protons in its nuclei
- radioactive decay - the emission of protons, neutrons, electrons or positrons to stabilize an atom
  - parent nucleus = original
  - daughter nucleus = the nucleus formed
    - daughter nucleus + emitted particles = decay products
- alpha decay - unstable because of protons
  - when an alpha particle is emitted, the nucleus loses two protons and two neutrons

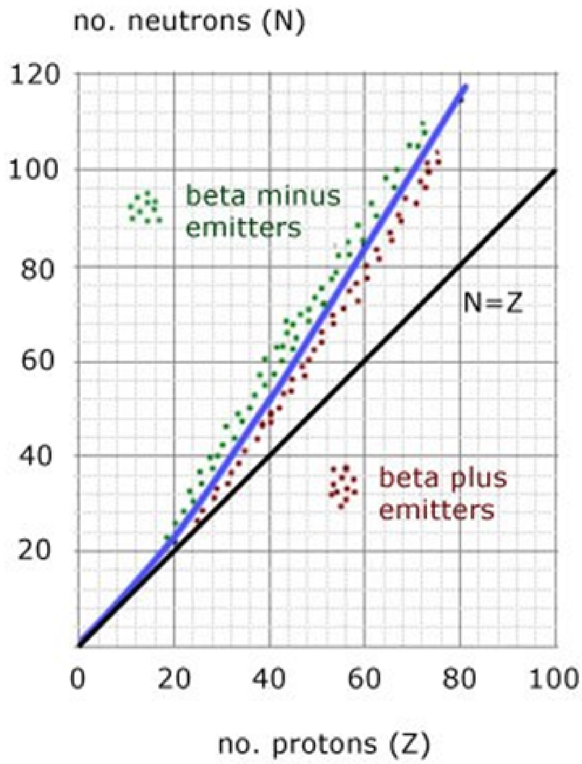


$$^{240}_{94}Pu \longrightarrow {}^{236}_{92}U + {}^{4}_{2}He$$

- beta minus decay - excess neutron
  - neutron changes into a proton plus an electron
    - proton stays in the nucleus
    - electron = beta particle
  - atomic number increases by 1; atomic mass is the same



- beta plus decay - excess proton
  - proton is converted into a neutron and a positron
    - neutron stays in the nucleus
    - positron = beta particle
  - same atomic mass; atomic number reduces by one
- gamma emission - when alpha or beta particle is emitted, the nucleons are in an excited arrangement
  - as they become more stable, the lose energy which is emitted in a burst of gamma radiation
  - doesn't change mass or atomic number; there is a rearrangement of configuration
- stability of the nucleus - depends on balance of protons and neutrons
  - too many of either disrupts the binding energy from the strong nuclear force → unstable nucleus
  - unstable nucleus achieves stability through radioactive decay



  - the heaviest isotopes decay by alpha emission (proton >83)

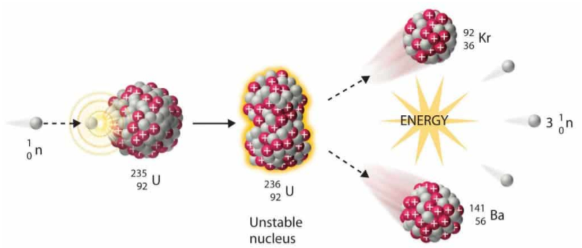
Half-Life

- time taken of half of the nuclei to decay
  - mass becomes half

- activity - the average number of disintegrations per second
  - SI Unit: Becquerel (Bq)
  - exponential decay curve

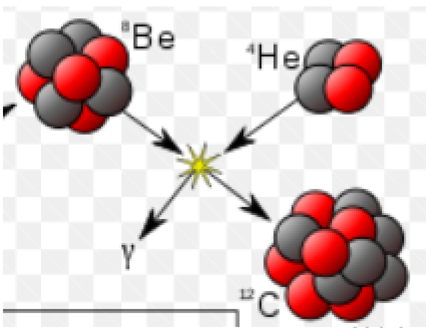
9.5. Nuclear Energy

- when decay particles are emitted, the collide with surrounding atoms → move faster → heat energy is released
  - nuclear energy → thermal energy
  - 1g of uranium = 3 tonnes of coal in terms of energy
- rate of decay is slow
  - collide neutrons with atoms → instability
    - nuclear reaction is triggered by the neutron
    - addition of neutron causes instability
    - after the extra neutron is released, it collides with another nucleus
      - continues until element completely stabilizes
      - particle acceleration
- nuclear fission - nucleus of an atom splits into smaller parts; triggered by excess neutron
  - triggered by the neutron

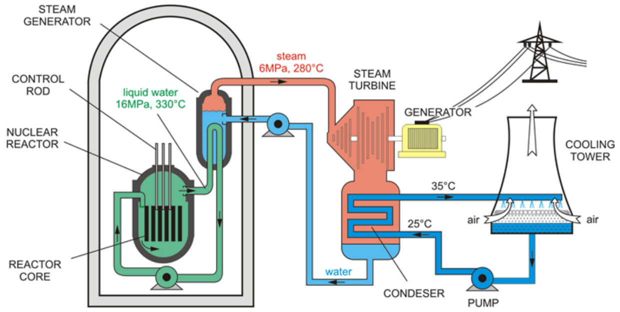


- nuclear reactor

$$^{218}_{84}Po \longrightarrow {}^{214}_{82}Pb + {}^{4}_{2}He$$



  - mix polonium with beryllium and reactions take place simultaneously
    - this is used to initiate the reaction



- moderator - reduce energy of fast neutrons for more efficient fission
  - materials such as graphite
    - heavy water = D2O
  - nuclear reactor is kept safe
- controller - absorbs neutrons
  - rods of boron or cadmium
    - boron and cadmium become isotopes
  - if the moderator isn't working, partially dip the controller rod in to take over that function
- cooling tower = condenser
- concrete walls are used to stop radiation from penetrating
- neutron source - mixture of polonium and beryllium
- nuclear fuel - uranium
- you can't send water directly because
  - contamination of all parts of the system
  - loss of fuel source

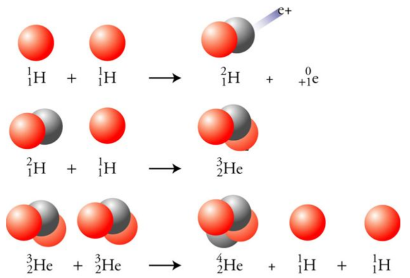
Nuclear Waste

- fuel needs to be replaced every 3-4 years
  - fission products build up - very dangerous and can't be released into the environment
  - isotopes include: strontium 90, iodine 131, plutonium 239
- in the US, they dump lead containers containing waste into the sea beds
  - this works for now, but we need to think about storage 1000s of years down the line as half lives are very long; this problem still hasn't been solved
- storage
  - reprocessing plant - unused fuel and plutonium are removed
  - remaining waste is sealed off and stored with thick shielding

Nuclear Fusion

- 2 atoms combine → product
- found of the Sun's surface
  - 4 hydrogen molecules → helium + 2 positrons + energy
    - very hard to do because same charges
  - possible on Sun because
    - high gravity → being pulled to core
    - high energy
    - high temperature

Nuclear Fusion in the Sun

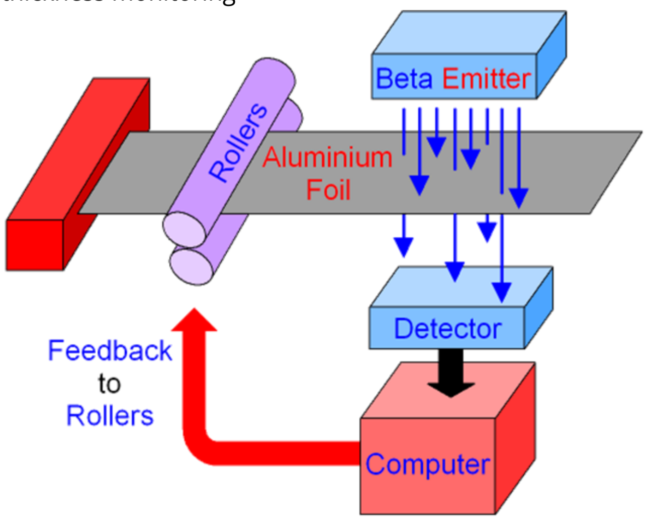


- Energy is released from these fusion reactions that we receive as **LIGHT** and **HEAT**!
- **NOTE: 3** hydrogen-1 atoms required (total), yet only **2** produced
  – **The Sun is running out of fuel (hydrogen-1 atoms)!**

- very huge amount of energy is released
  - requires very high temp and pressure

9.6. Applications of Radioactivity

- tracers
  - function of body organs - drink liquid containing a gamma emitter and check for concentration in a particular body part using a detector
  - fertilizer uptake by adding tracer to soil water
  - detecting pipe leakage
  - nuclear imaging technique
- thickness monitoring

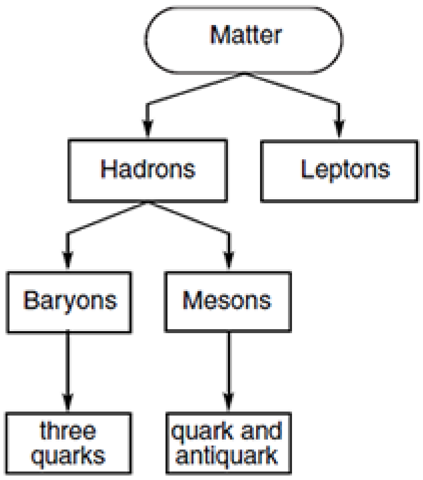


- carbon dating
  - proportion of C-14 in body
    - ratio of C-12 to C-14
  - measure the C-14 left to estimate age of specimens
- dating rocks
  - radioisotopes are trapped in rocks when they are forming
  - potassium-40 decays creates stable argon-40
  - uranium isotopes decays to create stable lead isotope
  - estimate the age of the rocks
- smoke detectors - make use of the ionizing property of alpha radiation
  - ionizing chamber with a positive and negative electrode, and a small amount of a radioisotope
    - Americium-21 has a very long half life of over 400 years and is a good source of alpha particles
      - ensures that the smoke detector is reliable
  - ionizing chamber has channels which allow air from the room to flow inside
    - particles emitted from the Americium-21 collide with oxygen and nitrogen from the air, causing them to ionize
      - these ions and electrons are attracted to the electrodes → current is produced
  - when smoke enters, the smoke particles collide with the radioisotope → no ionization occurs → current drops
    - circuit detects this drop → triggers alarm to beep

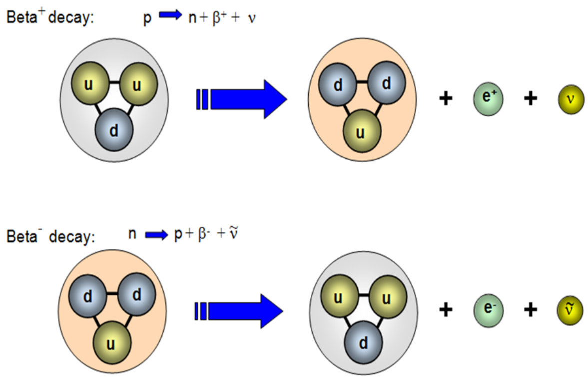
9.7. Atomic Models

** \n **

- Democritus → Dalton → Thomson → Bohr
- Quantum Cloud Model
  - double dumble region
- Canal rays - Eugen Goldstein
- Heisenberg's Uncertainty Principle: △ x △ p = h/4 \pie
  - you can know the momentum or the position of a particle but not both
- quarks



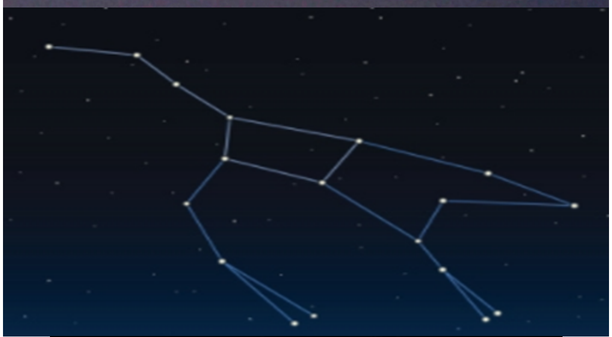
- up quarks: top, us, strange
  - each have +⅔ charge
- down quarks: down, charm, bottom
  - each have a -⅓ charge
- neutrons = 2 down + 1 up
- protons = 2 up + 1 down
- antiproton = 2 antiups + 1 antidown



- particles that interact with the Higgs field have mass
  - this is just a prediction

10. Astrophysics

- History
  - Egyptians - Sun God Ra
  - Greek divided stars into patterns called constellations - meaningful patterns that are well known
- constellations - group of stars that make meaningful patterns through imaginary outlines
  - 88 official ones
  - no new ones for hundreds of years
  - add new stars to existing constellations
  - largest constellations: Hydra, Virgo, Ursa Major

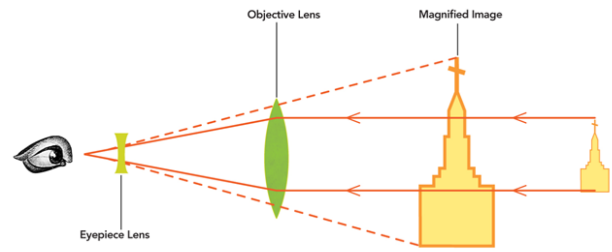


  - the Big Dipper is also known as "the Plough" and is a part of Ursa Major
- Hipparchus - Greek astronomer; identified and catalogued over 850 stars
  - European Space Agency (ESA) → Hipparchus satellite
    - study distance, radiation and other properties of celestial objects
- Ptolemy - Egypt; used the writing of Aristotle → geocentric model
- retrograde motion - when celestial objects appear to move back on their paths
  - Ptolemy - suggested that planets move in little circles of their own while orbiting Earth → epicycles
  - this is on the geocentric model which is false
- heliocentric model - sun is at the center
  - Nicolaus Copernicus
  - 16th century
  - not accepted by the church → feared that their teachings would be questioned
  - retrograde motion is due to the relative speed of the planets
    - apparent motion
    - visible between two planets, outer and inner
- Tycho Brahe - the Sun revolves around the Earth but the other planets revolve around the Sun

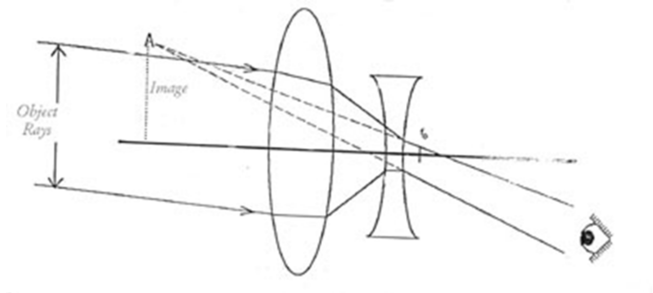
10.2. The Refracting Telescope

- first refracting telescope - Netherlands, 1608

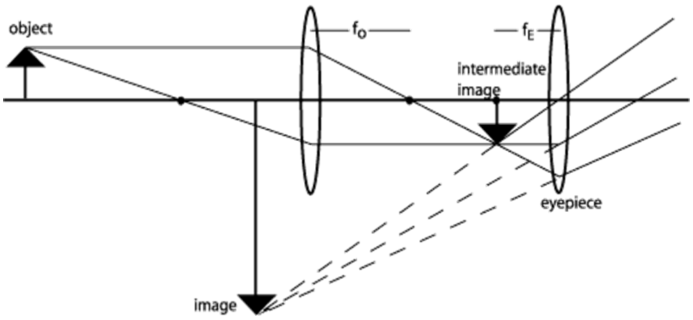
Lippershey's telescope



  - Hans Lippershey, Zacharias Janssen, Jacob Metius
  - M = 4 (4x magnification)
    - M = image height/object height
  - given to the Dutch army to observe enemies
    - Italy found out that the Dutch had this
      - approached Galileo to make a similar model
      - gave a toy model to Galileo
        - toy was 1.5x, wanted 6x
      - Galileo achieved 8x
- Galileo later achieved 20x magnification → used a converging objective lens and diverging eyepiece lens and this increased magnification



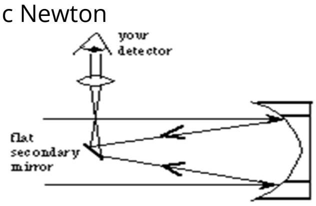
- he gave this to the leader of Italy
- he soon got Cataract as he used it to look at the Sun
- 1611 - Johannes Kepler - used a convex lens for the eyepiece → Keplerian telescope
  - increased the length → more focal length
    - increases divergence from focal point
  - drawback = way too long
  - advantage of Galileo: divergence depends on the lens
  - first constructed in 1630 by Christoph Scheiner



- magnification of refracting telescope
  - M = f_o/f_*e where f_*o = focal length of objective lens and fe = focal length of eyepiece
    - curvature of f_o must be smaller
      - curvature is inversely proportional to focal length
    - when curvature is smaller, fo is greater and hence, greater magnification
- Galileo's unpopular findings
  - Copernicus is correct
  - published results comparing Ptolemy with Copernican model unfavorable
  - punishment: publication banned, condemned to house arrest for the rest of his life
- disadvantages of the refracting telescope
  - chromatic aberration - color distortion
    - longer wavelengths are bent less than the shorter wavelengths

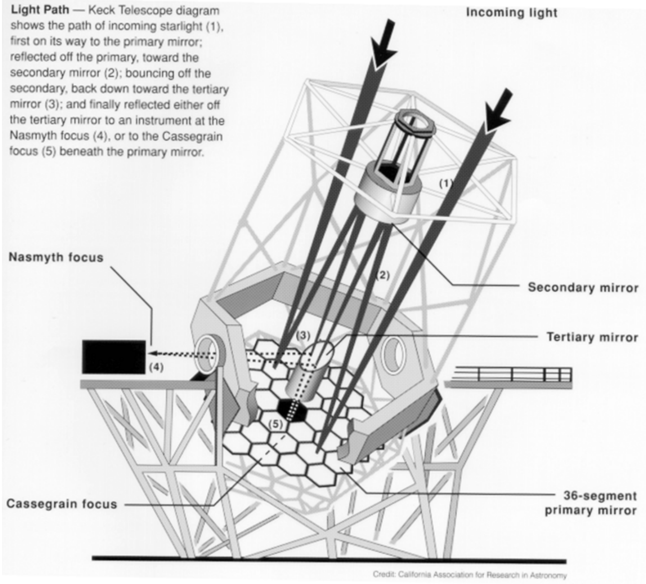
10.3. The Reflecting Telescope

- 17th century, Isaac Newton

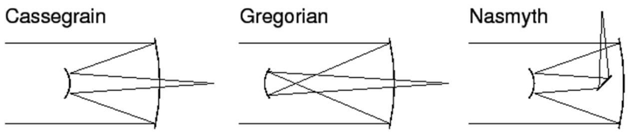


Popular Newtonian design found in many amateur telescopes

- used a concave lens to converge rays
  - distortion was present due to the blocking mirror
    - fixed with a plane mirror at a 45 degree angle
- Keck Telescope

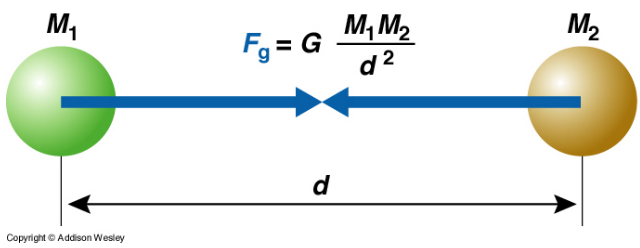


- 36 segments - ensure that all parts have curvature
- second concave mirror - converges again so that rays can be captured on a smaller space
  - plane mirror can be smaller
  - similar to the 10 lens system in phone camera
- nasmyth - final focal point is perpendicular to the rays
- location of secondary focus



10.4. Newton

- 1687 - Principia
  - ideas about gravity and motion
  - proposed that gravity attracts objects to Earth
    - keeps stuff in orbit
    - pendulum can be used to find the strength of gravity
- Newton's Law of Gravitation

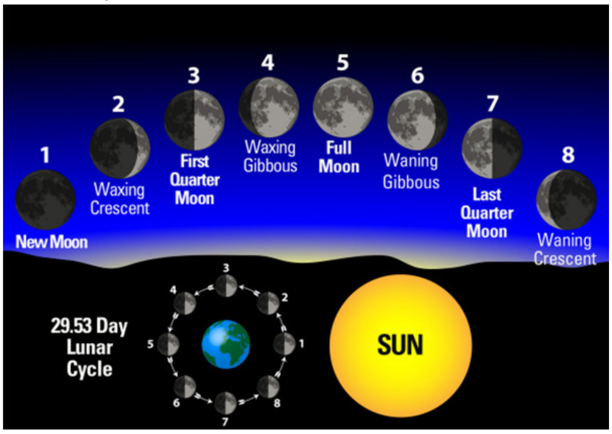


$G = 6.67408 \times 10^{-}11m^3kg^{-}1s^{-}2$

- experiment - design an experiment to find the value for the strength of gravity on Earth
  - T = $2\pi\sqrt{l/g}$
    - graph $T^2 vsl$

10.5. Planets and Satellites

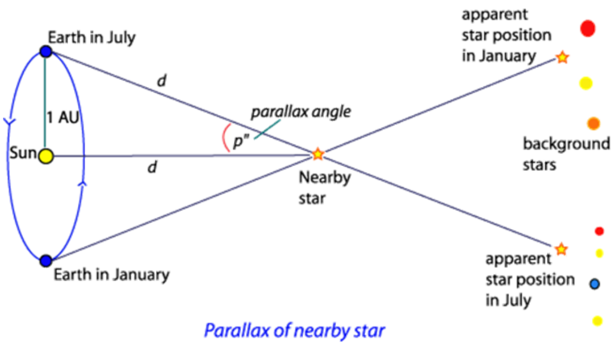
- Earth - rotating on own axis and orbiting the Sun
  - tilted at an angle of 23.5 degrees from vertical
    - perihelion = closest to the Sun
  - aphelion = farthest from the Sun
- eccentricity - how circular an orbit is
  - between 0 and 1
    - if 0, there is a perfectly circular orbit
    - if 1, then it's a straight line
  - eccentricity = c/a where a is a constant
- seasons - seasons exist because its axis doesn't stand up straight
- the moon - believed that there is a tilt due to a collision a long time ago
  - Theia is the thing that hit earth and caused the tilt
  - also the cause for the moon
    - the moon is a revolving particle of dust
  - phases of the moon as caused by the angle between the Earth, the Moon and the Sun



- satellites - a moon, planet, machine, etc... that orbits another body
  - natural vs artificial
  - geosynchronous orbit - same, constant position above earth
    - geostationary orbit - same, constant position above earth near equator
    - 23,000 miles above Earth
    - one revolution per day
    - used as broadcasting satellites
  - low earth orbit (LEO) - high speed, goes around all of earth
    - ex: Hubble Space Telescope
    - International Space Station
    - first 100-200 miles of space
    - easiest orbit to enter and stay in
    - easiest orbit to enter and stay in
    - used for data communication
    - polar orbit - north/south poles
      - used for mapping
    - highly elliptical orbit - communication satellites
    - lower orbits = higher speeds
    - orbital speed =
      - $2\pi r/T$
      - v = $\sqrt{GM/r}$

10.6. Stars

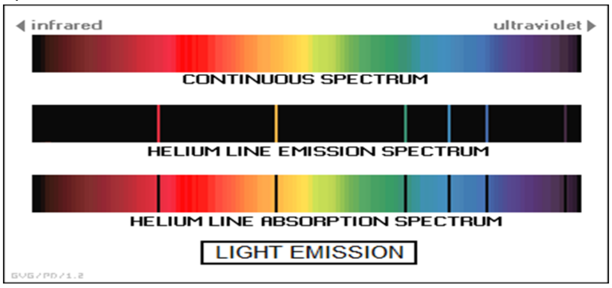
- apparent brightness - how much energy is coming from the star per square meter per second
  - units: Watts/m^2
  - P = E/T and I = P/A
    - P is power, I is intensity, E is energy and A is area
  - I = E/TA
- astronomers used apparent magnitude
  - comes from the ancient Greeks
  - each increment in magnitude is an increase in apparent brightness of 2.5
    - 1 is brighter than 2, is brighter than 3, etc..
      - 1>2>3>4>5...
  - very bright star = 1st magnitude
  - negative magnitudes are used for very bright objects
- measuring distance
  - 1 AU (astronomical unit) = 150 million km
  - 1 light year = distance travelled by light in one year = 9.461 * 10^13 km
  - 1 Parsec (pc) = 3.26 light years = 3.0842 * 10^13 km
    - distance at which one AU subtends an angle of one arcsecond
  - nearest star = Proxima Centauri = 1.3 parsecs
- Stellar Parallax
  - the apparent shift of position of any nearby star against the background of distant objects
  - distance from earth can be computed trigonometrically
    - more distant object = smaller parallax
  - parallax angle
    - as the angle becomes smaller,
      - sin θ = θ (theta is very very small)
    - one second: each degree is split into 60 parts
      - each part is a minute
      - the minute is split into 60 parts
        - this is called a second



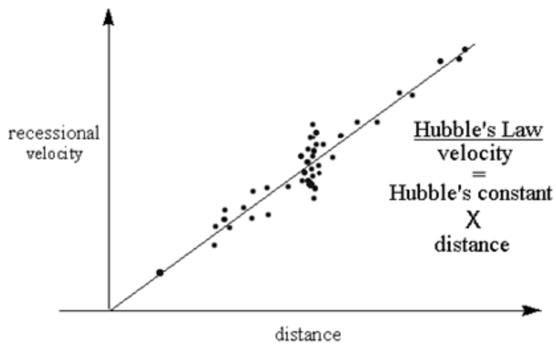
Parallax of nearby star

- d = 1/p
- angle measured in arcsec and distance in parsec
- Measuring temperature
  - Wien's Law - determines at what wavelength the intensity of radiation emitted from a blackbody reached its max point
  - as temp increases, max intensity is observed at lower wavelengths
    - the shorter the peak wavelength, the higher the temperature of a star

  - T = $2.910^{-}3/\lambda_{m}ax$
  - 2.9 * 10^-3 = Wien's constant
  - lambda max is the wavelength at the maximum intensity
  - can be used to find the surface temperature of distant stars
- atomic spectra
  - spectrum - radiation emitted by a star
    - can be observed by passing its light (radiation) through a prism
    - colors of the visible spectrum are seen without break
    - different elements have different spectra. each one being distinctive
  - understand the composition of a star
    - colored lines = spectral lines
  - emission spectrum - colored lines on a dark background
  - absorption spectra - give a continuous spectrum with dark lines where the bright lines of a an emission spectrum would be
    - intensity of lines tells us about the amount of an element
    - also tells about surface temperature as more fusion reaction → more heat
  - each element has a unique spectra
  - diffraction - by using a diffraction gradient (made of thousands of small slits) we we can observe the spectrum of radiation emitted from a source



- Doppler effect
  - change in frequencies from a higher frequency to a lower frequency
  - Red Shift
    - when we observe spectral patterns, they are seem to be shifted slightly away and towards the red end of the spectrum
    - inverse = blue shift
    - galaxies are moving away from us → at one point they were closer together
    - they all started off at the same place
    - evidence for the Big Bang Theory
  - blue frequencies → red frequencies
  - stars can be close and red if the surface temperature is low
  - Experiment: use a sound source such as a phone and recorder such as an mp3 device or audacity
    - record a sound with both you and the source being stationary
    - record the sound as you move away from the source
      - repeat while moving away at different speeds
- The Big Bang Theory
  - all the energy was together in one place → something triggered an explosion → space and energy sent in all directions → high velocity and temperature
  - universe expanded and cooled
    - particles formed → atoms
  - → nebulae, stars, galaxies
  - no sound as there were no particles, only energy
    - energy was converted into particles
    - equal amounts of matter and antimatter
      - antimatter + matter = photons
    - there was just a bit more matter than antimatter
      - we are left over dust from the big bang
- Big Crunch - one of the theoretical scenarios for the ultimate fate of the universe, in which the metric expansion of space eventually reverses and the universe re-collapses, ultimately causing the cosmic scale factor to reach zero or causing a reformation of the universe starting with another Big Bang
- Hubble's Law - as stars move away, the velocity increases
  - recession speed - speed at which a galaxy moves away from us
    - galaxies that are farther away are moving away from us at a faster speed than galaxies that are close to us
  - age of the universe = 14.3 billion years
    - time taken to pull back everything to a single point
  - Hubble's constant = 45-90 km/sec/Mpc



    - Hubble's Law: $v = H_o d$

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