UNIT 1: TRANSFORMATION BY STEAM:

Heat is a form of energy; it transfers from hot to cold. Temperature is the measure of the average kinetic energy. (More kinetic energy = More heat)

There are three main types of heat transfer:
1. Conduction: Heat transfer between two solids, it occurs due to direct contact between the objects.
2. Convection: Heat transfer in liquids and gases, it occurs due to a difference in thermal energy between particles, heat transfers by the movement of these particles: more thermal energy rises, less thermal energy sinks. Convection current is a repetition of rising and sinking.
3. Radiation transfers through electromagnetic waves, e.g.: heat from the sun.

Thermal expansion: Materials expand when heated, and contract when cooled.

There are three main gas laws, which add up to one ideal gas law:
Boyle's Law: P1V1 = P2V2, initial pressure and volume = final pressure and volume at a constant temperature and pressure is inversely proportional to volume at a constant temperature.
If you increase the volume of gas particles have more space to roam, and collisions decrease and the pressure decreases.
Charle's Law: V1/T1 = V2/T2, volume and temperature are directly proportional at a constant pressure. It is like thermal expansion heating a material expands it and increases the volume.
Gay-Lussac's Law: P1/T1 = P2/T2. Pressure and temperature are directly proportional at a constant volume. When the temperature increases, kinetic energy increases, particles collide more, increasing the pressure.
Combined Gas Law: P1V1/T1 = P2V2/T2, this is only important. We can derive all other laws by keeping either pressure, volume, or temperature constant:

1. **To Derive Boyle's Law**:
   - Keep T constant ($T_1 = T_2$):
   $$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \quad \text{becomes} \quad P_1V_1 = P_2V_2.$$
   This is Boyle's Law.
2. **To Derive Charles's Law**:
   - Keep P constant ($P_1 = P_2$):
   $$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \quad \text{becomes} \quad \frac{V_1}{T_1} = \frac{V_2}{T_2}.$$
   This is Charles's Law.
3. **To Derive the Pressure Law**:
   - Keep V constant ($V_1 = V_2$):
   $$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \quad \text{becomes} \quad \frac{P_1}{T_1} = \frac{P_2}{T_2}.$$
   This is the Pressure Law.

Specific heat is the amount of energy required to raise the temperature of an object weighing 1kg by 1 degree Celsius. It is used in this formula: e=mc (change in time). 'c' is the specific heat capacity (all materials have their own specific heat capacity), m=mass, e = energy.

Latent heat is the energy absorbed/released during a phase change (e.g.: liquid to gas). During this time rather than the energy heating or cooling the substance, it is used to make or break bonds to change form. During this time there is no change in temperature (0 degree Celsius ice and water).

Formula:

The energy required for a phase change is calculated as:

$$Q = mL$$

Where:

- Q: Heat energy (in Joules, J)
- m: Mass of the substance (in kg)
- L: Specific latent heat (L_f or L_v, in J/kg)

2. **Types of Latent Heat:**
   - **Latent Heat of Fusion (L_f):**
     Energy needed to change 1 kg of a substance from solid to liquid or vice versa, at constant temperature.
   - **Latent Heat of Vaporization (L_v):**
     Energy needed to change 1 kg of a substance from liquid to gas or vice versa, at constant temperature.
3. **No Temperature Change:**
   During a phase change, the temperature remains constant because the energy is used for breaking or forming bonds, not increasing the particle speed (kinetic energy).

UNIT 2: MOTION AND CAR SAFETY:

Main SI units: (s) = displacement, (u) = initial velocity, (v) = final velocity, (a) = acceleration, (t) = time.

Motion graphs: Distance time, Velocity time, Acceleration time graphs. In all of these graph's acceleration is on the x axis, being the independent variable, while the others being on the y axis, being dependent on the time value.
The area under curve is always the y value divided by the x value.
In a distance/displacement time graph, y/x = d/t = velocity/speed (depending on the question).
In a velocity time graph, y/x = v/t = rate of velocity = acceleration.
In an acceleration time graph, y/x = a/t = rate of acceleration = rate of change of velocity.

Newton's three laws of motion are:
1. Law of inertia: an object in motion or at rest will stay in that state, unless acted on by an unbalanced force.
2. Force is directly proportional to mass and acceleration; mass and acceleration are inversely proportional to each other: f=ma.
3. Each and every action has an equal and opposite reaction.

Using the main SI units for this unit we can derive three main 'SUVAT' equations:
1. v=u+at, 2. v^2 = u^2 + 2as, 3. s = ut+1/2at^2

Car safety features are designed with all of these motion fundamentals in mind.
1. Seat belts: According to newtons first law an object in motion will remain in motion, unless acted upon by an unbalanced force. When the car suddenly stops (unbalanced force), the passenger continues to travel forward, the seat belt aims to counteract that force by stretching and applying force in the opposite direction to avoid a collision.
2. Air bags: In the case of the car suddenly stopping the inflated air bags are deployed which aim to cushion the force of the travelling passenger. The force is spread out across the large area of the air bag, which reduces the pressure as pressure and area are inversely proportional.
3. Crumple zones: Crumple zones which are located in the front and rear of the vehicle, reduce the time over which the car suddenly stops, so that the affect of inertia isn't as major as it would have been.

UNIT 3: FLIGHT:

Momentum is the mass multiplied by the velocity of an object. p = mv. Momentum is a vector quantity as it has direction (velocity) and magnitude, which means it can be negative if an object is travelling in the opposite direction. Momentum is measured in: kgms^-1.

The conservation of momentum principle states: In a closed system with no external forces, the total momentum before the interaction = total momentum after interaction.
For example: Two particles are travelling towards each other. Particle on the right is travelling at +30,000 kgms^-1 momentum, and the particle at the left is travelling in the opposite direction at 50,000kgms^-1, it is going in the other direction so it will be -50,000. The momentum before the interaction is 30,000 + -(50,000) = -20,000. Momentum before interaction = momentum after interaction, which means both particles will now move together with momentum of 20,000 kgms^-1 towards the left. In this case the velocity will decrease due to the collision, however the mass will increase as both particles are travelling together as one particle so mass= mass of particle 1+2.

A more relevant example is a gun that is stationary, it has 0 velocity, and thus 0 momentum. However, after it fires a bullet, the momentum of the bullet goes in the forward direction, and so to compensate the gun recoils backwards with an equal momentum, and when equating their momentum, it adds up to 0, which abides by the law momentum before = momentum after.
To make a question out of this if the gun weighed 2kg, where as the bullet weighed 5g with 120m/s momentum, find the velocity of the backward recoil of the gun.
m initial = m final
2V = 0.005x120
V =0.005 x 120/2 = 0.3m/s. It was in the opposite direction so the recoil velocity of the gun after the bullet was fired = -0.3m/s

Impulse is the change of momentum. However, we can derive the formula:
Newton's second law: f = ma, a = v-u/t
f = (mv – mu)/t
mv = momentum, mu = initial momentum
f = (final momentum – initial momentum) time
f = change in momentum / time (Force is the rate of change of momentum)
Force x Change in time = Rate of change of momentum (impulse)
Force x change in time = impulse.

UNIT 4: MEDICAL PHYSICS:

Waves are disturbances, mostly in the form of vibrations that transfer energy. They can travel through a medium (mechanical waves), or a vacuum (electromagnetic waves).

The two main types of waves are: Transverse and Longitudinal.
The vibrations in transverse waves are perpendicular to the wave's propagation.
The vibrations in longitudinal waves are parallel to the waves propagation.

Parts of a wave: Crest is the highest point the wave, trough is the lowest point of a wave, the distance from one crest to another, or one trough to another is called wavelength.
Frequency is the number of wavelengths completed per unit of time, lower wavelength = higher frequency, thus they are inversely proportional.
Amplitude is the height of the wave measure from a crest to the equilibrium position (middle of the wave).

Compressions and rarefactions are more relevant in longitudinal waves. Compression is an area where the particles are tightly packed together, due to high pressure and density, rare fraction is an area where the particles are spread apart, due to low pressure and density.

Speed = d/t

Wave speed = wavelength/t

1/t = frequency

Wave speed = wavelength x frequency

Electromagnetic waves: EM waves are transverse waves (electric field vibrates vertically, magnetic field vibrates horizontally). EM waves travel at the speed of light in a vacuum but are slower when travelling through a medium. They are produced when charged particles accelerate.

The electromagnetic spectrum is a range of all EM waves classified by their wavelength and frequency. The spectrum is shown from shortest to longest wavelength, EM waves that have longer wavelengths have shorter frequency. Energy is directly proportional to energy, with the waves with lowest frequency being strongly ionizing (has enough energy to remove electrons from atoms).
Radio waves (used in radio signals) have the highest wavelength and lowest frequency, meaning they have the least energy and can do no harm to the body.
Visible light is in the middle of the EM spectrum, and it is the only EM wave that the human eye can see, too much exposure to visible light can cause damage to the eye.
Following visible light in the EM spectrum are three more waves: UV, X Ray, and Gamma, ordered in least frequency to most. UV rays mostly come from the sun on earth, it provides vitamin D to the body, however too much exposure to it can cause damage to the skin. X Rays are used to create black and white images of the bones and organs inside the body, it does not have immediate effects, however two much exposure can result in chronic diseases, they are much more hazardous than UV waves.

Wave Type	Key Applications
Radio Waves	Communication (radio, TV, cell phones), GPS, and broadcasting.
Microwaves	Cooking (microwave ovens), radar systems, and satellite communication.
Infrared	Thermal imaging, remote controls, night vision devices, and heating.
Visible Light	Vision, illumination, photography, and fiber optic communication.
Ultraviolet	Sterilization of medical equipment, vitamin D for the body.
X-rays	Medical imaging (e.g., X-rays for bones), airport security, and industrial inspections for cracks.
Gamma Rays	Cancer treatment (radiotherapy), sterilizing medical tools, and studying cosmic phenomena in astrophysics.

Gamma rays have the highest frequency and most energy, they are produced from the hottest and most energetic objects in the universe (regions around blackholes, supernova explosions). They are used to kill cancer cells in medicine, however too much exposure to these waves can cause cell damage and increase the change of cancer.
White light is made up of all colours, frequencies, and wavelengths of the EM spectrum.

UNIT 5: MAKING SENCE OF ELECTRICITY:

Electricity is the flow of current. In a circuit current is opposite to the flow of electrons. Electrons flow from the negative terminal of the battery to the positive terminal, current flows from positive to negative, this is in the case of current electricity.
There are two main types of electricity: Static electricity, and current electricity.
Static electricity is the accumulation of electric charges on a surface. An example of static electricity is the phenomena of lightning, which occurs due to an accumulation of charges in the clouds and atmosphere, which is quickly discharged in the air in the form of electricity.

Electric charges can accumulate through few different types of charging:
Charging by friction: By rubbing to materials together the electrons from one object to another, leaving them both with two opposite charges. Some materials have more tendency to lose/gain electrons. Fur, glass and metals tend to lose electrons and become positively charged. Rubber, plastics, similar materials tend to gain electrons and become negatively charged.
Charging by conduction: By bringing a neutral metal and a charged rod, and making them come in contact, the electrons transfer from one object to another (depending on the charge of the rod), leaving the neutrally charged metal with a charge.
Charging by induction: Two neutrally charged metals in contact, can be left with two opposite charges, with a metal rod. By bringing a charged metal rod, the electrons of both metals will either repel or get attracted, if they attract, the electrons will get accumulated in the sphere that is closer to the rod, if they repel the electrons will get accumulated in the sphere away from the rod, either way, both metals will be left with opposite charges. After removing the rod and separating the metals, you will be left with two opposite charged metals.
Charges can be accumulated through friction, conduction and induction, however objects discharge when coming in contacSt with an oppositely charged object, the quick discharge of electrons can generate shocks, discharges that are faster and in larger scale produce larger shocks.

An electric field is the region around a charged object. Electric fields are represented by lines of force negative lines are inwards and positive lines are outwards.
Coulomb's is the measure of the force of attraction/repulsion between two charges. The force is directly proportional to the product of magnitude of both charges (q1 and q2), and it is inversely proportional to square of distance between them (r).
Formula: $F = k \times q1q2/r^2$, in this k is coulomb's constant = 8.99×10^9.

Current electricity is the electricity that flows through a circuit. The components of a basic circuit are: wires, cell, bulb or electric device. Current (I) = Charge (Q)/Time (t).
The basic formula to measure the current flowing through a circuit is: V = IR, V = voltage, I = current, R = resistance. Voltage is measured in volts, current is measure in amperes, resistance is measure in ohms. A device called voltmeter is used to measure the voltage, whereas a device called ammeter is used to measure current. Resistance resists the current whereas voltage, also known as potential

different is what pushes the electricity, and allows electrons flow.
There are some other components that can be found in a circuit, such as a switch to start and stop current flow, a resistor to increase the resistance, a rheostat to modify the resistance, etc.
It is crucial for a component to be place properly and receive enough current to work. A bulb measured in x ohms requires y amperes of current to light up or be bright. Similarly, an ammeter must be placed in a series circuit and a voltmeter must be placed in a parallel circuit.

A series circuit is a circuit with all components placed together with only 1 path of electricity, each component receives the same amount of electricity as the other, an ammeter is placed over here as the current is constant.
A parallel circuit is where the components are placed in different paths and there are more paths of electricity, points between these paths are called junctions, the current is divided in these junctions based on the amount of resistance in the junction. However, the overall current in the entire circuit is the same, it is just divided. Voltmeter is placed in parallel due to the fact that 0 current flows through it, if it were to be placed in series the circuit would just stop, as current is equal in all components in a series circuit.
In a series circuit the total resistance is the sum of all resistance (from components, resistors) in the circuit: $R = R1 + R2 + R3...$
In a parallel circuit the total resistance is less than the sum of all resistance in the circuit. $1/R = 1/R1 + 1/R2 + 1/R3...$

There are four factors that affect the resistance in a circuit: Area of cross section of wire, length of wire, external temperature and material of wire. Resistance is directly proportional to length as the electrons will have to encounter more obstacles and the current flow will reduce, it is directly proportional to temperature as the kinetic energy will increase, the collisions will increase and the current will reduce, it is directly proportional to material (rho), and is inversely proportional to area, as the electrons will have more space to roam and the current will increase.
Thus, the formula is: $R = \rho \times L / A$, rho is resistivity of material, each material has a different value it is a measure of how resistive the material is of current.

Energy(J) is the ability to do work(J), and power is the rate of work done: Work done/time, or energy/time, which is measured in joules/second, the SI unit for power is 'watts (W)'
In electricity work done = voltage x current: $W = VI$. Electrical work done is the rate of transfer of electrical energy.
$W = VI$, using ohms law: $V/R = I$, $V = IR$, plugging into voltage formula
$W = I^2R$ and V^2/R. And also Energy = Current x Voltage x time.

- Kilowatt (kW): 1 kW = 1000 W
- Megawatt (MW): 1 MW = 1,000,000 W
- Horsepower (hp): 1 hp ≈ 746 W (This is an older unit, but still used in some contexts)

1 unit of electricity is the standard tool of measuring the amount of energy consumed in households, and the electricity bill is paid accordingly, with x amount of money being paid for y amount of units of electricity consumed.
1 unit of electricity = 1KWH.
1KW = 1000W

1 hour = 3600s
Power = energy/time
Power x time = energy
Energy = 1000W x 3600s (1KWH)
Energy = 3.6×10^6
1KWH = 3.6 million joules
1 unit of electricity consumes 3.6 million joules of energy.

UNIT 6: ASTROPHYSICS:

Nebula is a giant cloud of dust and gas made up of ionized/molecular hydrogens. Nebula forms into stars. When the core temperature reaches a certain point, it forms helium releasing energy as a star. Younger stars are hotter, blue in colour, older are red and cooler.
Stars of lower mass turn into red giants, after shedding their outer layer leave behind a white dwarf. Stars of larger mass turn into super giants, they undergo supernova explosions (huge explosions that small stars don't), they leave behind neutron stars and black holes (black holes are regions with ultra strong gravity where not even light can escape).

Planets are celestial bodies that orbit stars.
Terrestrial Planets: Rocky planets, with liveable conditions.
Gas Giants: Large planets with thick atmospheres (Jupiter, Saturn).
A solar system includes a star which is orbited by other planets and celestial objects that are bound by its gravity (comets, asteroids, satellites).
Asteroid is a small rocky object that orbits the sun, similar to a terrestrial planet, but is too small to be called a planet, and has different orbits that overlap the orbits of other planets. The asteroid belt is a region with a large number of asteroids located. The asteroid belt is located between the orbits of mars and Jupiter.
Comets are a frozen celestial object, made of a mixture of elements that orbit the sun, with different orbital planets.
Satellites are objects that orbit stars, suns or moons (e.g.: the moon that orbits earth, and the international space station).
Two types of satellites:
Geostationary: Orbit earth at the same rate at earth's orbit so it appears stationary on earth. Uses: Communication, TV, Weather observation.
Polar orbiting Satellites: Orbit earths poles, covering the planet multiple times (orbit length is lesser). Uses: Earth and weather observation.

Geocentric model centuries ago basically says that everything in the universe orbits Earth. This was disproven by Gallileo, and his discovery of the movement of, planets, moons, etc.

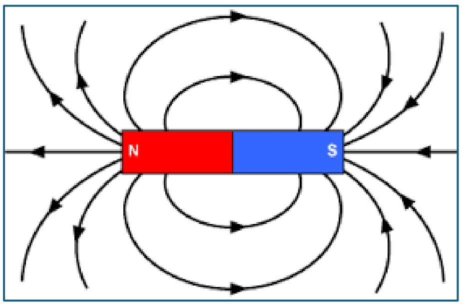
The universe is made up of multiple galaxies, galaxies are made up of stars, celestial bodies and other celestial objects.
The Big Bang theory is about how are universe started which traces back 13.8 billion years ago. The universe originated from an extremely dense and hot state that began with a cosmic explosion.
Dark matter: Invisible matter that exerts gravitation effects, dark energy: invisible energy that is responsible for the expansion of the universe.

Solar eclipse: Moon passes between earth and sun, moon sized shadow on earth.
Lunar eclipse: Earth pass between moon and sun, earth's shadow darkens the moon.

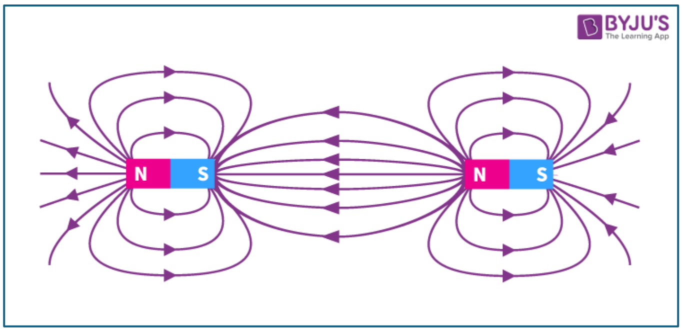
Kepler's Laws of Planetary Motion:
1. Planets orbit stars in an elliptical orbit in one focus.
2. A planet sweeps out equal areas in equal times.
3. The square of a planets orbit period is proportional to cube of its distance from a start.
time^2 is proportional to distance^3.

UNIT 7: ELECTROMAGNETISM:

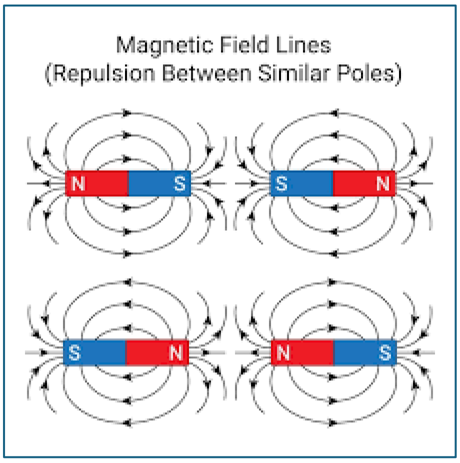
A magnet is a metal that produces a magnetic field. Some metals are magnetic while others aren't due to their distribution of electrons. These are the primary properties of a metal bar magnet. Like poles attract, unlike poles repel.

This is an image displaying a magnetic field: 

The field lines travel from the north pole into the south pole.
Magnetic field of attraction:



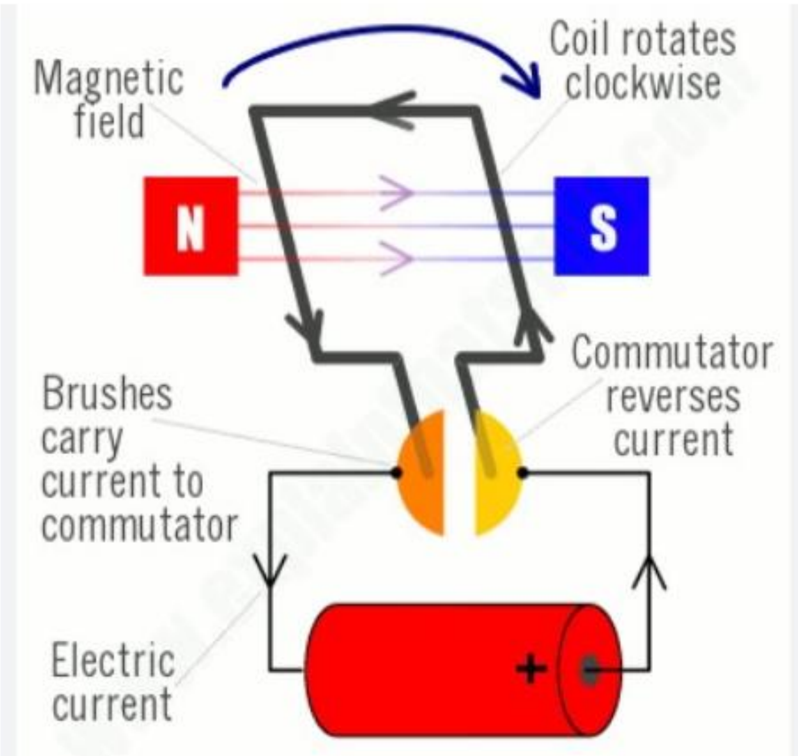
Magnetic field of repulsion:



Electric currents producing magnetic fields is the concept of electromagnetism.
A current carrying wire has its own circular magnetic field around it. The direction of field lines can be depicted with the right hand thumb rule. Thumb is direction of current, fingers are magnetic field lines.

A curled wire is a coil, the current is flowing in different directions, and different magnetic fields are interacting with each other creating one strong magnetic field. Increasing the number of turns in a current carrying coil, makes the magnetic field stronger.
When the current carrying coil is wrapped around a soft iron core it creates an electromagnet with the same field as a bar magnet, but with an adjustable field strength.
Ways to increase the strength of magnetic field of an electromagnet: Increase the current, increase the number of turns, increase the density of the soft iron core.

When a current and magnetic field interact it creates a force, founding the basis of the working of motor. To find the direction of force we use Flemming's left hand rule. Thumb is force, index finger is magnetic field (perpendicular to thumb), middle finger is current (directly opposite to thumb).
An electric motor uses 2 forces in opposite directions to create a force that creates a spinning motion. When there are two current carrying wires (opposite directions) in between of a north and south pole magnet, they will both experience forces in opposite directions (Flemmings left hand rule). When you connect the two wires in which the current is flowing in opposite directions and turn on the current. The opposite forces will cause the circuit to spin. But the wires will also turn and change the terminals and cause the circuit to spin the opposite direction. To fix this connect the wires to a split wring commutator, that changes the terminals every half turn so that the circuit rotates in one direction constantly.



In this image current is flowing from positive to negative as usual, as the current reaches travels it will come to the south pole side of the coil. The magnetic field is towards the right, the current is upwards, which will make the force downwards as the current continues flowing towards the north pole side of the coil, the magnetic field is in the same direction, but the current is downwards, which will create an upwards force. These forces will make the coil rotate clockwise, the commutator reverses the current ensuring that the terminals do not switch and affect the direction of rotation. Electric motors use DC because of the split ring commutator (more info later).

To increase the speed of rotation add more turns to the coil, increase the magnetic field strength or increase the current provided.

An electric motor turns current and magnetic field into force. However a generator turns force and magnetic field into current. A changing magnetic field induces current, and the magnetic field can be changed using a force. When a magnet is put through a coil it would induce potential difference in it due to the change in magnetic field. The size of current produced can be increased if the coil has more turns, the force is applied faster, and the magnet is stronger. The direction of the induced current can be changed by swapping poles of the magnet.

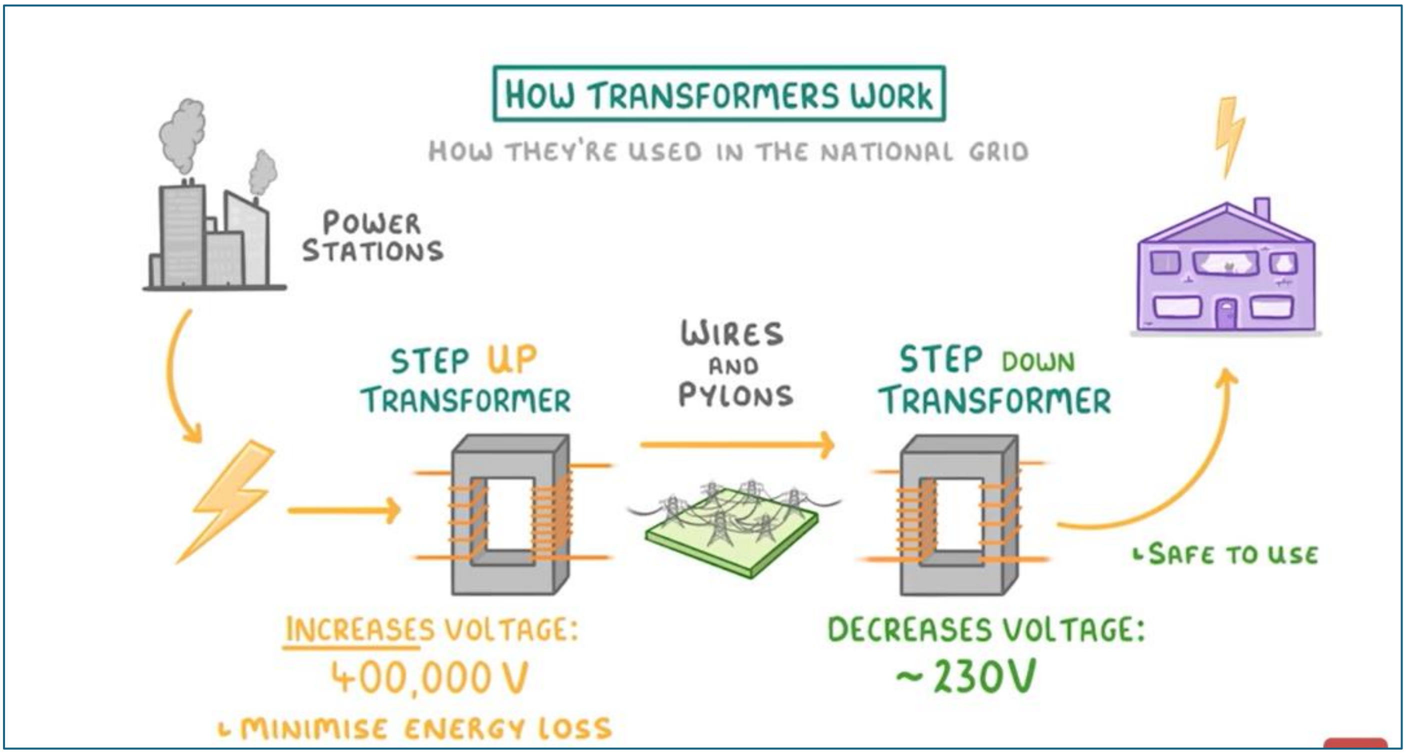
To find the direction of current use Flemmings right hand rule, fingers denote the same thing as left hand rule. To find the direction in real time we use a galvanometer that shows the direction and size of current.

The circuit set up for a generator is similar to a motor, however there is no battery to produce current, rather there is an axle at the end of the coil, which can be rotated across the magnets and produce a current and instead of a split wring commutator there are slip rings that are crucial to ensure that the current produced is alternating. The way in which In power stations different methods are used to apply the force on a turbine (serves the purpose of axle) and subsequently on the generator to produce an alternating current.

The current that can produced can be alternating or direct. The current is the same in both of them, but the direction of the current produced in alternating current keeps changing. In a voltage time graph, an alternating current produces a sin graph, while direct current produces a horizontal line graph, with constant voltage as time passes.

A transformer is used to increase/decrease voltage and current while keeping the power constant. Normally voltage and current are directly proportional but in terms of power they are inversely proportional P=IV, P/I = V.
Transformers consist of a soft iron core, a primary coil wrapped around one side of the core through which current is passing, and a secondary coil that is wrapped on the other side of the core that is connected to an external circuit.
The way the transformer works is: An alternating current is provided to the primary coil causing current to flow and creating a magnetic field across the primary coil. The alternating magnetic field in the primary coil induces a current in the secondary that is connected to a secondary circuit and the current is used for other purposes. In this we turned current into current which could be seen as of no use. However, it depends on the number of coils in the primary and secondary coil.

In a step up transformer in which the goal is to increase voltage, the number of turns in the primary coil are less than the secondary coil. To calculate voltage produced. When dividing the turns in secondary coil against turns in primary coil we get the scale factor value. Multiply the scale factor value to voltage and you will get the new voltage. In this scenario the current is decreased as voltage and current are inversely proportional but the power is constant.
In a step down transformer in which the goal is to reduce voltage, the number of turns in the primary coil are more than the secondary coil. Similarly, divide the no.of turns in secondary by primary to find the scale factor, naturally the number will be less than 1, multiply it by voltage to find the new decreased voltage value, and increased current value. Just like before power is constant.



Power stations generate turn force into voltage and alternating current as discussed in the generator section. It goes through a step up transformer voltage increases current decreases. The voltage is transported over long distances, the current is reduced and is in the form of alternating current which is why the energy loss in the form of heat is reduced. If it did not go through a step up transformer large amounts of energy would be lost in the form of heat. It goes to a smaller power station in an area near houses and decreases the voltage and increases the current before providing it to households for safety purposes.

Transformer calculation formulas:

$$\frac{V_p}{V_s} = \frac{n_p}{n_s}$$

$$V_p I_p = V_s I_s$$

'V' IS POTENTIAL DIFFERENCE
'n' IS NO. OF TURNS OF THE COIL
'I' IS CURRENT
'p' – PRIMARY
's' – SECONDARY

A TRANSFORMER HAS 18 TURNS ON ITS PRIMARY COIL, 54 TURNS ON ITS SECONDARY COIL, AND AN INPUT POTENTIAL DIFFERENCE OF 45V. CALCULATE ITS OUTPUT POTENTIAL DIFFERENCE.

Np = 18, Ns = 54 (step up)
Vp = 45V.
Vs = 54/18 x 45 = 135V.
Formula 1: The primary and secondary voltage ratio = primary and secondary no.of coil turns ratio

USING THE SAME TRANSFORMER, IF THE INPUT CURRENT WAS 12A WHAT WOULD THE OUTPUT CURRENT BE?

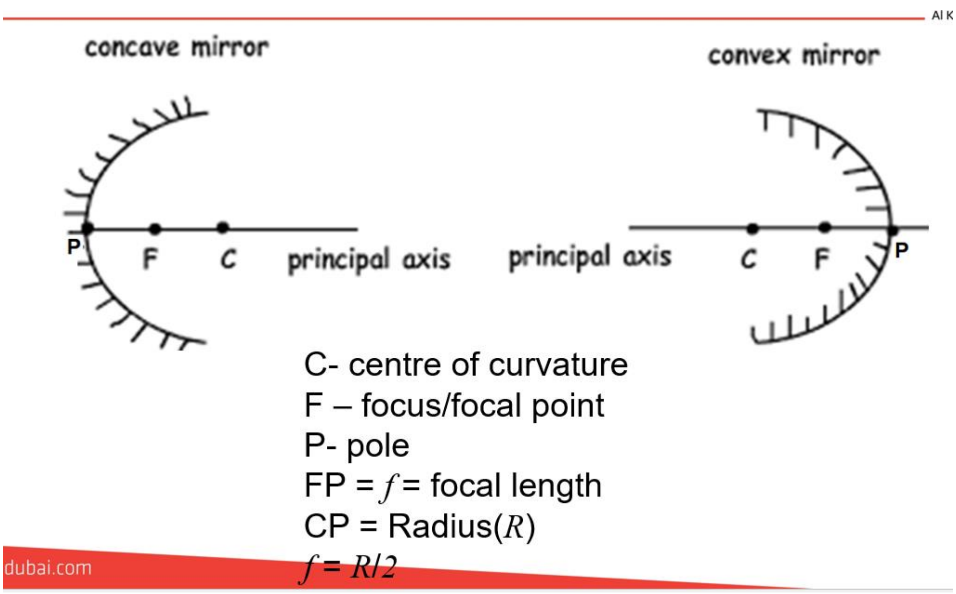
Ip = 12 Vp = 45 Vs = 135
45x12 = 135 x Is
45x12/135 = Is = 4A. (this formula is only applicable for 100% efficient transformers as input power cannot be equal to output power in realistic circumstances as power in the form of energy will be form in one way or another).
Formula 2: Applicable for ideal transformers, input power = output power

UNIT 8: WAVES, LIGHT

Light energy: It is a form of EM radiation, energy from photons. Light travels in rays. A beam of light are multiple rays.
In parallel beams, after the light exits the light source, the rays travel parallel to each other.
In convergent beams, after the light exits the light source, the rays come towards each other and converge at a point.
In divergent beams, after the light exits the light source, the rays move away from each other, diverging.

Reflection: Reflection is when light hits a mirror and bounces back. The ray of incidence is the ray of light before hitting the mirror, and the ray of reflection is the ray of light after bouncing of the mirror. Angle of incidence = angle of reflection. This is calculated using a line called 'normal'. The normal is always drawn perpendicular to the mirror, between the incident and reflected ray. The angle formed by the incident ray and normal is angle of incidence, the angle formed by the reflected ray and normal is angle of reflection, and the two angles are equal to each other.
When the incident ray is parallel to the normal. The reflected ray travels in the same path just in the opposite direction, and the angle of incidence and reflection are 0.

The image formed by a plane (flat) mirror is virtual, same size, upright, but laterally inverted (left is right, right is left), and the distance between the object and the mirror, is = the distance between the virtual image and the mirror.
Concave mirrors (laterally inverted C shape) produce images of different sizes, and real and virtual images, depending on their position.
Convex mirrors always form virtual, upright, smaller images, no matter the position.

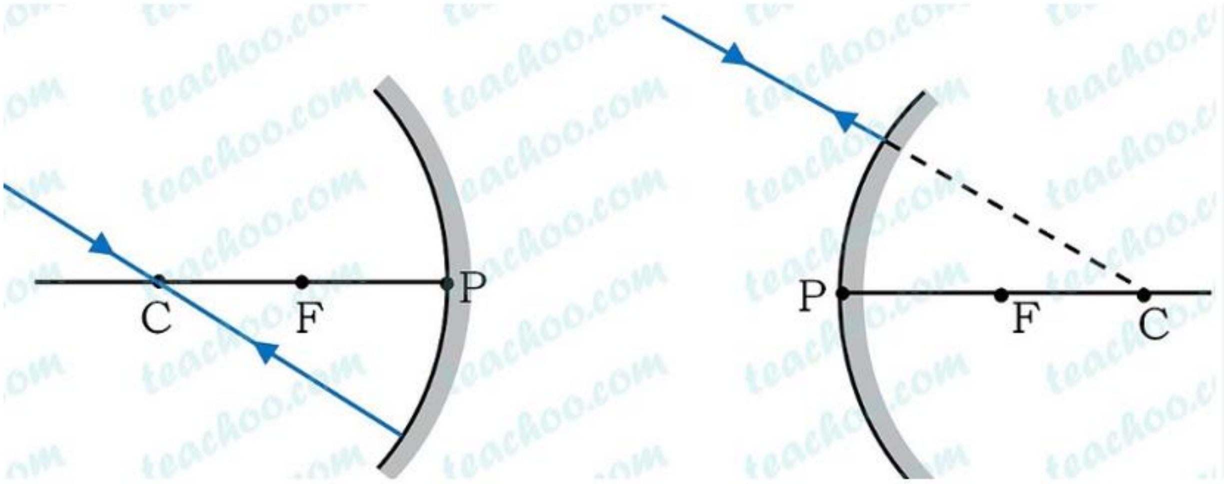


concave convex mixed in this.

Focal point is point at which rays meet. If you join concave and convex mirror it forms a circle. The center of the circle is the centre of curvature. Pole is the equivalent to optical lens, in lenses, center of the mirror. Principle axis is the line from the pole stretched forward.

1) Any incident ray traveling parallel to the principal axis on the way to the mirror will pass through the focal point upon reflection.

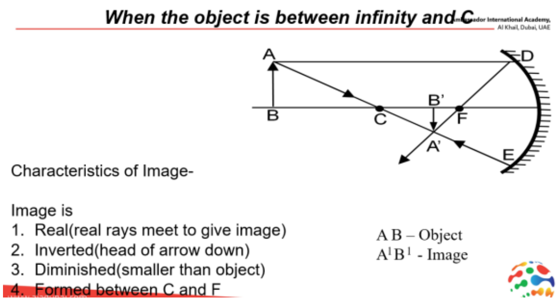
2) Any incident ray passing through the center of curvature on the way to the mirror will travel back in the same direction.



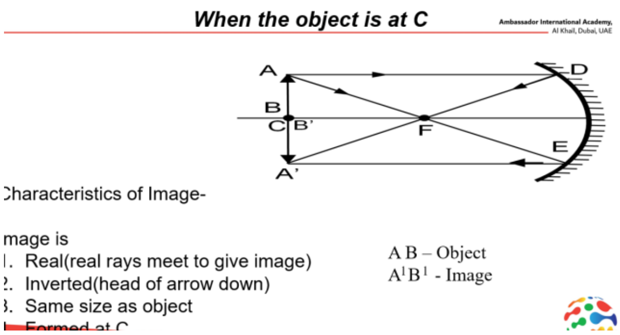
(3 not mentioned here if a ray passes through F it reflects and the ray travels parallel to the principle axis.)

In concave (in all diagrams the object is AB, one rays is travelling from A parallel to principle axis, one ray is travelling downwards/upwards and getting reflected):

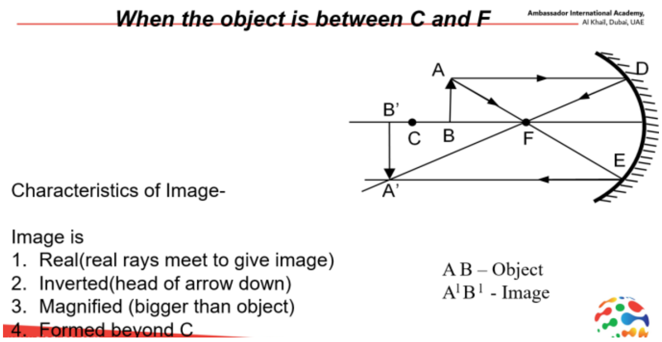
If the object is beyond C:



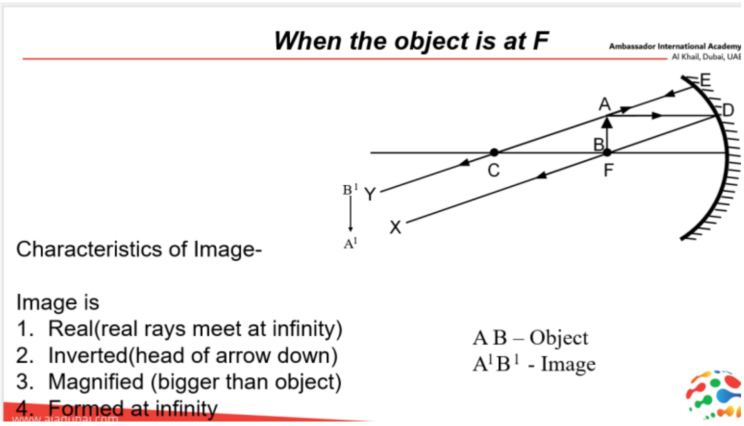
If the object is at C:



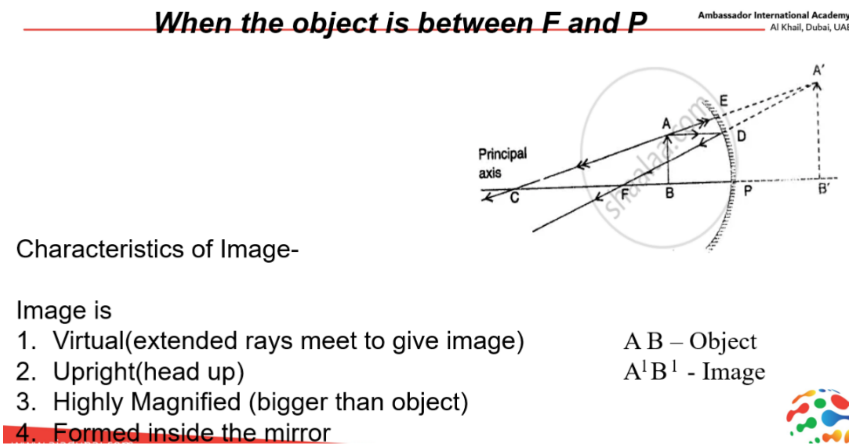
If the object is between C and F:



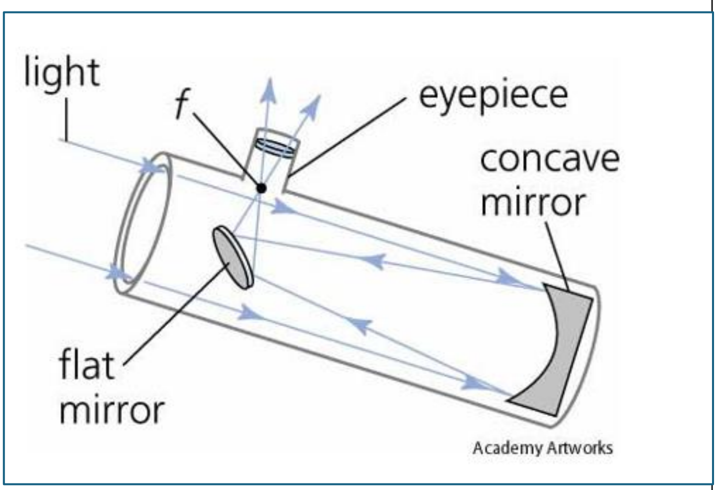
Object at F:



Object between F and P:

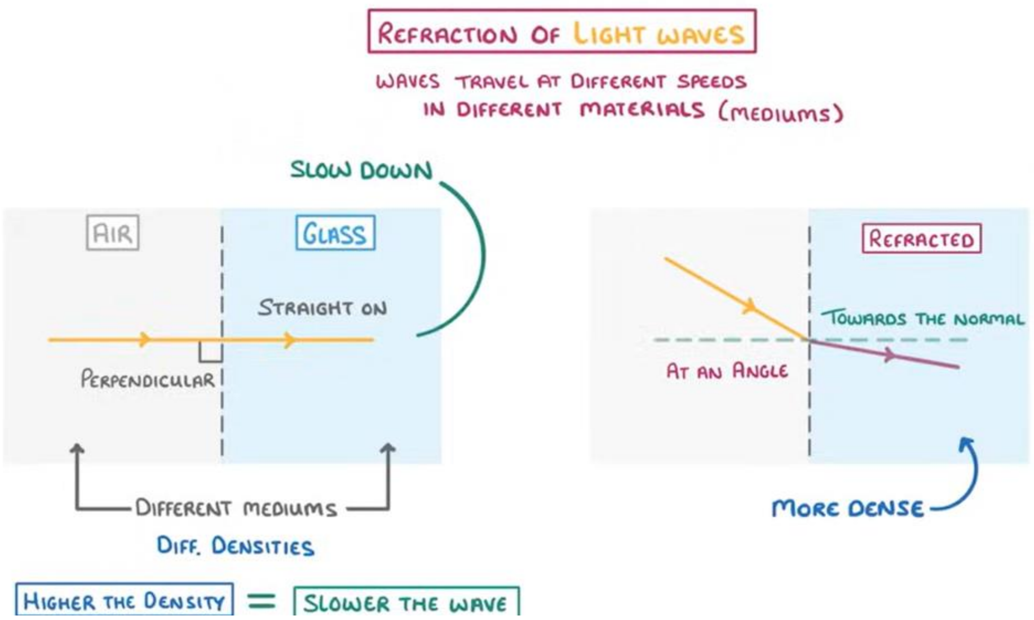


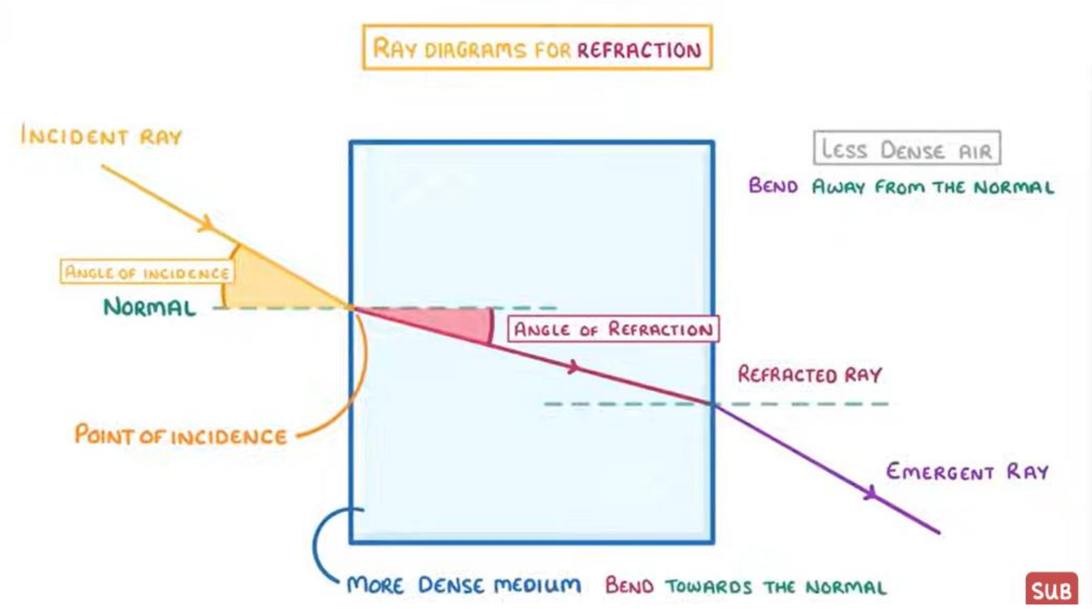
you don't need to memorise all these just remember the three rules of drawing reflected diagrams and you will figure out where the image forms, whether upright or not. Just remember closer to pole, larger image, at curvature real size, beyond curvature diminished, and concave always forms real image unless between F and P.



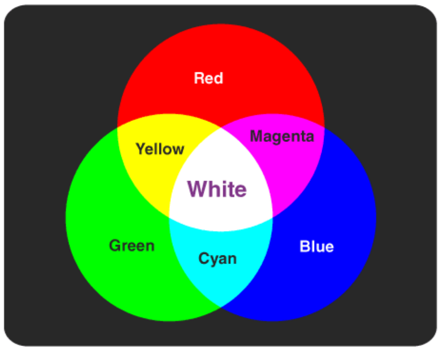
Telescopes use concave mirrors. Two light rays are entering parallel to each other. The rays reflect of the concave mirror and create an enlarged image. The light rays of the enlarged image reflect of the flat mirror and converge at F (object at infinity creates image at F). This enlarged image is seen through the eyepiece. Planets and other celestial objects are all beyond the centre of curvature of the mirror and can be enlarged through telescopes and form images at the focal point.

Refraction is the phenomena of light bending after changing the medium its travelling through. All EM waves travel at the same speed, they just have different wavelengths and frequencies. However, their speed changes based on the medium they are travelling through. Vacuum it is fastest. The speed depends on the density of the medium. Speed increases when density decreases. When the velocity changes the displacement of light changes causing it to bend.
When the light wave is travelling perpendicular to a refracting medium (passing through the normal), the light wouldn't bend it would just slow down, which would not be noticeable at all as light travels really fast). If the incident ray travels at an angle into a denser medium the light would bend. The direction it bends depends on the density. Less dense to more dense = bend towards normal. More dense to less dense = bend away from normal.





Dispersion is the result of white light being refracted. White light contains all colours, frequencies, and wavelengths of the EM spectrum.



When white light changes medium all of the different light waves of different colours refract. They refract at different speeds, as some colours have higher frequencies and wavelengths then others. Colours with greater wavelengths bend the least (red), and vice versa (violet bends most). This is how when white light is shot into a triangular prism. The light bends creating a rainbow. Concept of rainbow is white light from the sun travelling through then travelling through a different medium (rain), and then all the different colours diffracting.

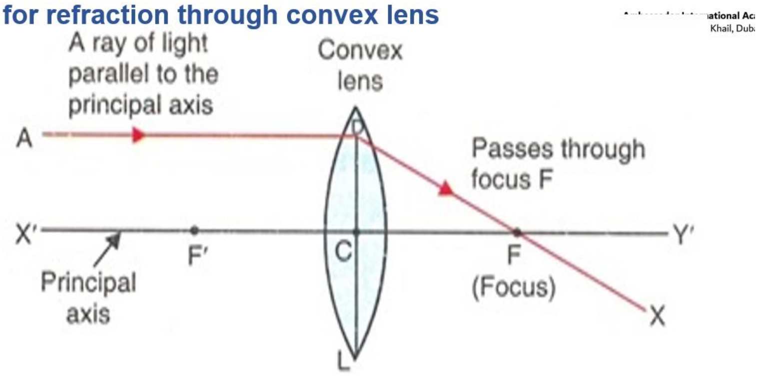
Back to refraction, the formula for knowing how much light bends in a specific medium is: n=c/v. v = speed of light in the material. C = speed of light in vacuum, n = refractive index.

As the angle of incidence increases, the angle of refraction comes closer to 90 degrees. When its at 90 degrees it is on the surface of the material the incident ray came from. If the angle increases, the light will refract to the same surface the incdenct light came from, which is reflection, hence the concept of total internal reflection.

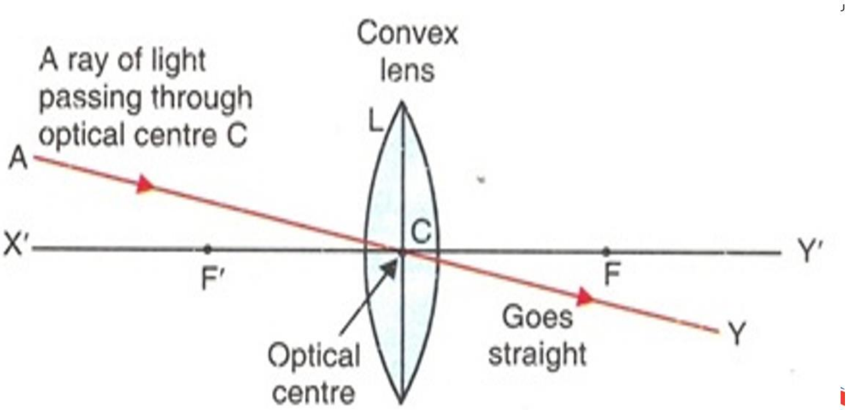
Just like mirrors, there are concave and convex lenses that refract, instead of reflect like they do in mirrors. Convex are bulging outside and create converging rays. Concave bulges inside and creates diverging rays.(its like opposite of concave and convex mirrors).

Just like there are rules for concave mirrors there are rules for convex lenses.

Rules for refraction through convex lens

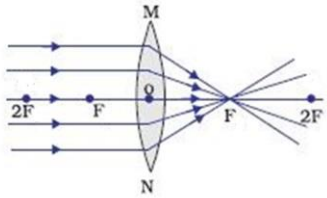


. C is like 0 (optical center)



Cases of image formation:

Case (i) Object at infinity



Characteristics of Image-

Image is
1. Real(real rays meet at F)
2. Diminished to a point
3. Formed at F

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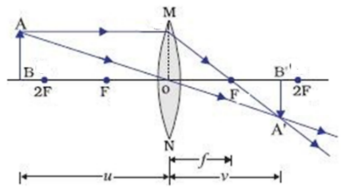
Case (ii) Object at beyond 2f



Characteristics of Image-

Image is
1. Real(real rays meet)
2. Inverted
3. Diminished
4. Formed between 2F and F

Case (iii) Object at 2f

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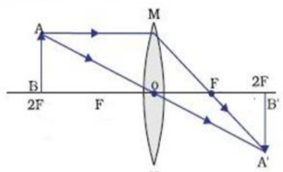
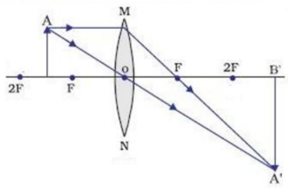


Characteristics of Image-

Image is
1. Real(real rays meet)
2. Inverted
3. Same size
4. Formed at 2F

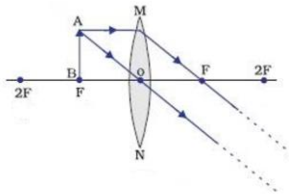
Case (iv) Object in between f and 2f



Characteristics of Image-

Image is
1. Real(real rays meet)
2. Inverted
3. Magnified
4. Formed beyond 2F

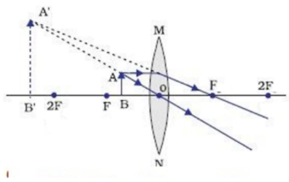
Case (v) Object at f



Characteristics of Image-

Image is
1. Real(real rays meet)
2. Inverted
3. Magnified
4. Formed at infinity

Case (vi) Object distance < f



Characteristics of Image-

Image is
1. Virtual (extended rays meet)
2. Upright
3. Highly Magnified
4. Formed on the same side

In concave lenses the image is always virtual and diminished, just the position changes based on where the object is.

Diffraction is when light bends to avoid a barrier. Rather than discussing rays over here we talk about wave fronts which are lines that are perpendicular to rays. They can curve. When two diffracting rays meet, they interfere. The interference can be constructive or destructive. When the waves match waves and troughs then the interference is constructive, and they turn into one big wave with the amplitudes of both waves added up (and amplitude is proportional to energy). Destructive interference is when waves and troughs don't match, and so the amplitudes cancel each other out. (this is called superposition).

UNIT 9: FUNDAMENTAL PARTICLES:

Formation of modern atomic model: Atomos is a Greek word describe a piece of matter that is indivisible and the smallest existing particle. John Dalton in 1803 took inspiration from the idea and invented the concept of an 'atom', indivisible matter, nothing inside. JJ Thompson found that some parts are positively charged, while others are negatively charged. He came up with the plum pudding model. Rutherford's experiment of shooting alpha particles to a thin gold sheet, found out that only a small dense portion of the atom (nucleus) is positively charged. James Chadwick discovered the neutron, and Niel Bohr discovered electrons orbit the nucleus containing protons and neutrons. (Modern atomic model).

Atomic number of an element = no.of protons, mass number/nucleon number = no.of protons+neutrons.

The nucleus of an atom becomes unstable when there is a great difference in the number of neutrons and protons. To regain stability it emits radiations to become stable. The particles that could be radiated are either alpha, beta or gamma particles:

Alpha particles are the same as a helium atoms nucleus (2 protons 2 neutrons 0 electrons), due to its relatively high mass it is strongly ionizing, but has weak penetration power is it travels slowly, and can simply be stopped by the air. Since its positively charged, a travelling alpha particle will be attracted to a negatively charged cathode.

Beta particles are the same as one single electron. These electrons are not from the outer shell of the atom but derive from the nucleus. To become stable a neutron from the nucleus decays into one proton and one electron (retaining the same charge), the proton stays in the nucleus (increasing the atomic number by 1), and the electron is emitted (beta particle). It is weakly ionizing and moderately penetrating (stopped by aluminium). Since its negatively charged, its attracted to the anode.

Gamma rays are not particles, but are waves carrying large amounts of energy, and so they have very high penetration power, only being stopped by a lead block or cement. They have low ionization and they only occur after alpha or beta decay. Since it has no charge it has no electromagnetic attraction.

Alpha Radiation Example:
Uranium-238 (238 is the atomic mass when it is symbolised like that) undergoes alpha radiation to form: Thorium-222 + An alpha particle. (The atomic number and mass should be equal on both sides of the equation).
Radium-226 undergoes alpha radiation to form: Radon-222 and an alpha particle.

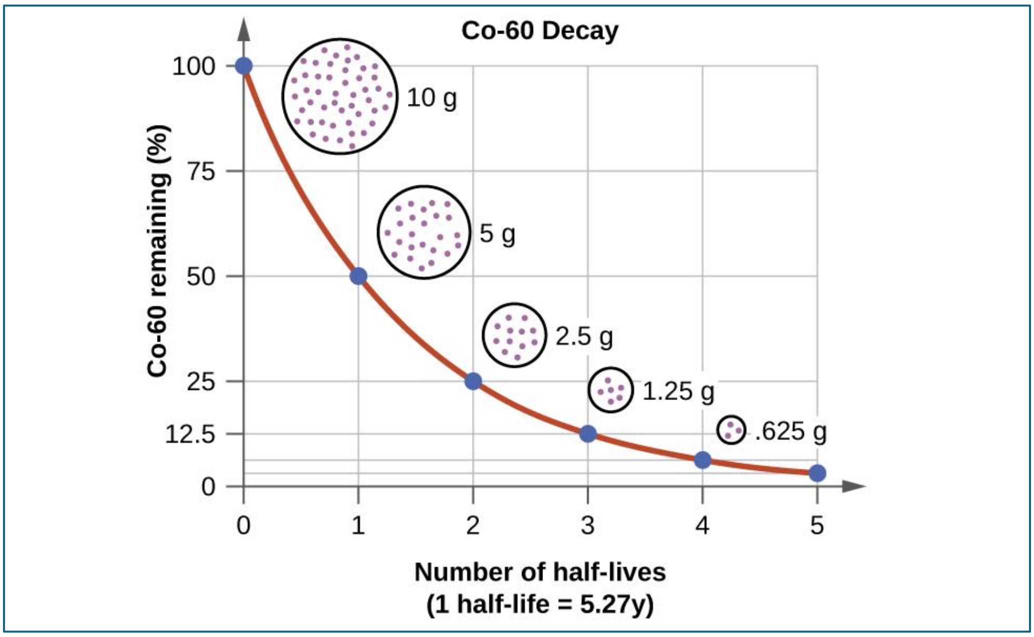
Beta Radiation Example:
Carbon-14 undergoes beta radiation to form: Nitrogen-14 + Beta particle (a neutron in the nucleus turns into a proton as mentioned earlier so atomic number increases mass number decreases).
Pottasium-40 undergoes beta radiation to form: Calcium-40 + Beta particle.

Gamma radiation example:
Thorium-234 undergoes gamma radiation to form: Thorium-234 + Gamma Rays (large amount of energy). There is no charge or mass so atomic number or mass does not change.

When an atom is unstable it emits radiation and decays, however this process is random and spontaneous, so there is no way to estimate the amount of time it will take for an atom to decay. However, a metric called Half life can help make a close enough estimate. To do this we take a large sample of the same type of nucleus.

Activity is the rate of decay of isotopes in a large sample, measured in Becquerels). 1Bq = 1 decay/1s. 600Bq, means that 600 nucleus's are radiating from the large sample.
Half life is the time taken for the total number radioactive nuclei to half (1 million nuclei are in the sample originally, half decay 500k is left, the time required for that is the half life). OR. The time taken for the activity to half (time taken for number of decays per second to half). Both definitions are correct, and both derive the same answer.

A group of nuclei can have more than one half life, theoretically there can be infinite half-lives, but after a point they become undetectable. For example, the first half life for a group of 1 million nuclei originally, will end up with 500k nuclei by the end of it. The second nuclei will have 250k by the end. Each half-life takes the same amount of time as the other. Since half life is exponential, it may or may not have another half-life. This is better illustrated in a graph.



Nuclear fusion is the process of combining nuclei, where as nuclear fission is the process of breaking down nuclei.

Nuclear fission can happen spontaneously or can happen by force. When a slow travelling neutron is sent towards an already radioactive atom, the atom absorbs the neutron, and becomes highly unstable causing it to burst into two smaller nuclei (daughter nuclei). The sum of the atomic number of the daughter nuclei is = the atomic number of the original nucleus. However, the sum of the atomic mass of the daughter nuclei is 2-3 less than the atomic mass of the original nucleus. This is to remain stability. This means that there are 2-3 extra neutrons waiting to perform nuclear fission on another atom, which is a repeated process. Fission forms two daughter nuclei, few neutrons (for more fission), and large amounts of energy (the main goal as this energy is what is harnessed in nuclear plants). However, when the chain reaction of fission is uncontrolled, it can cause mass destruction (nuclear weapons), or in some cases accidents in nuclear powerplants.

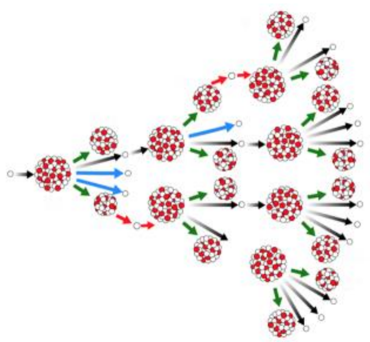


Fig 2. A Nuclear Fission Reaction. Each neutron triggers a fission reaction, which produces more neutrons, which triggers more fission reactions.

Nuclear fusion is the process of combining two smaller atoms into one larger atom (mostly only hydrogen atoms forming helium). This process is not possible in a laboratory as it requires extremely high levels of temperature and energy which is simply not attainable on Earth. Ideally, nuclear fusion is much more energy efficient than nuclear fission, however currently the input cost is greater than the energy output.
The place where nuclear fusion is most commonly occurring is the sun and other stars, as the large amount of heat turns the hydrogen atoms into helium, generating large amounts of energy.

To write fission or fusion equations properly you need to write the missing value. (Just subtract/add), atomic numbers, and then balance it until the atomic numbers and atomic masses are equal to each other.