Physics Notes:
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Electric Fields (Static Electricity):

Laws of Electrostatics:

- There are positive and negative charges
- Unit of charge is the coulomb, equivalent to 6.25 x 10^18 electrons
- The amount of charge on an electron is approximately 1.6 x 10^-19 Coulombs
- Like charges repel and unlike charges attract
- The electric force between point charges is proportional to the product of the charges and inversely proportional to the square of the distance between them

Principles of Electrostatics:

- Conductors: materials with free charge carriers
- Insulators: do not have free charge carriers
- Note: graphite is a conductor due to the free electrons present to act as charge carriers
- Charge is conserved and cannot be destroyed or created
- Atoms have an equal number of electrons and protons (electrically neutral)
    - Ionized when electrons are lost (positive charge) or when gained (negative charge)
- Electrons can move and transfer to another body, but not protons

Charging Objects:

- Charging by **Friction**:
    - Two different insulators are rubbed together, electrons transfer from one insulator to another
    - The two bodies have an equal amount of the opposite net charge (+ = -)
    - Reason: some materials have a stronger hold on their electrons compared to others
- Charging by **induction**:
    - Charging a conductor without any contact with the charging body
    - To make an insulated conductor positively charged:
        - Bring negatively charged rod near the conductor so free electrons are repelled by the negatively charged rod and move away from the rod
        - Touch the conductor with an earthed wire to allow electrons to flow out
        - Remove the wire and the conductor will be positively charged
        - Remove rod and the electrons in the conductor redistribute evenly on the surface of the conductor
    - To make two conductors have equal and opposite charges
        - Bring two uncharged conductors into contact
        - Bring a negatively charged rod near one conductor and electrons are repelled and move to the far end of the other conductor
        - Separate the conductors and they will carry equal and opposite charges
- Charging by **contact**
    - When a charged conductor contacts an uncharged conductor, the excess charge will be shared between both conductors, not necessarily equally

Discharging objects:

- Meaning:
    - Remove excess charge from a charged body so that it has an equal amount of positive and negative charges
- Discharging charged insulators:
    - Excess charge leaks away in highly ionized surroundings
    - Ions in the air are transferred to the insulators to discharge them
    - Highly ionized: moisture or intense heat

- Discharging charged conductors:
  - Earthing
    - For negatively charged metal objects electrons flow to the earth
    - For positively charged metal objects electrons flow from earth

Electrostatic hazards:

- Lightning
  - Thunderclouds are charged by friction between the water molecules and air molecules
  - Excess charge is sufficiently large, it can ionize the surrounding air and provides a conducting path for a huge quantity of charge to be discharged to the ground
  - Lightning conductor is connected to a thick copper late in the ground, and a positive charge in induced on the spikes, which attract and remove electrons from the air molecules and produce positive ions
  - Positive ions are attracted to the negatively charged cloud and neutralize negatively charged cloud and reduces chance of lightning strike
  - If lightning strikes, charges flow to the earth through the copper strip
- Fires
  - Friction between moving lorry and surrounding air charges the lorry, and sparks produced by discharge may cause explosion with combustion of petrol vapour
  - Sometime, metal chains hang from the lorry to the ground to allow charges toe scape to the earth and prevents formation of sparks
  - In aeroplane, excess charges build up on a plane as well, sparks may develop as the plane lands, so tyres made from conducting rubber conduct sparks to ground during touchdown

Applications of Electrostatics:

- <u>Photocopier</u>
  - Surface of drum is charged by rotating it near metal rod
  - Light reflects off the page into the drum and white parts of the page reflect more light, making these areas conducting and losing their charge. Other parts correspond to black parts and receive no light.
  - Black parts hold on to their charge and the drums ends up with exact copy of the pattern of printing on the original page
  - Carbon powder is attracted to the charged area of the drum and printed onto paper
  - Heat melts the powder and fixes it onto the surface
- Spray paint
  - Dry plastic powders are charged when emerging from spray gun
  - Charged particles are attracted to the grounded object and the powder coating is heated to creating a smooth layer
  - Good adhesion of paint to every corner of the object to give uniform layer of paint
  - Benefit: increase efficiency and reduce paint usage
- Precipitator
  - Located within the chimneys of homes
  - Wires are negatively charged to create charges on the dust and smoke particles when passing through
  - Collector plates are positively charged to attract and collect the particles
  - Plates are shaken to remove dust and smoke

Electric Field:

- <u>Electric field: electric force around an electric charge (magnitude and direction represented by field lines)</u>
- Direction of the force acting on a positive test charge can be obtained by drawing a tangent to the field line at that point
- Vector quantity: magnitude and direction present
- Electric field lines which are closer together indicate a stronger electric field

- Field lines cannot cross nor touch each other
- <u>Positive charge: field lines directed away</u>
- <u>Negative charge: field lines directed towards</u>
- <u>Two opposing charges: point from positive to negative charge</u>
- <u>Two positive charges: directed away from each other</u>
- <u>Uniformly charged parallel plates</u>
    - Every point in the field experiences the same charge

Additional Notes:

- Some atoms hold onto electrons more tightly, and this depends on the triboelectric series
- If a material is more apt to give up electrons when in contact, it is more positive
- If material is likely to capture electrons, it is more negative in the triboelectric series
- Relative positions on the series tells us how two materials will act when brought in contact (who becomes positively charged and who becomes negatively charged)
- Note: ONLY applies to insulators

Electroscope Detective:

- Gold leaf is used to detect charges and test for the sign of charges
- Bringing a charged object to the metal cap of the electroscope: gold leaf deflects from the metal rod
    - Example: negative object induces positive charge in cap, negative charge in rod and leaf, thus repulsion between the two
- Place finger on the metal cap: gold leaf moves back (since discharging takes place and electrons transferred from electroscope to hand)
- Remove finger and rod: deflection occurs again

Current Electricity:

Important Information:

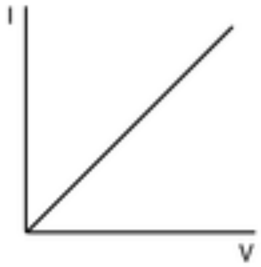
- Electric Current: flow of electric charge that occurs when there is a potential difference across the ends of an electric conductor
- Current: rate of flow of charges with respect to time (I=Q/t)
    - 1 Ampere is the current produced when 1 coulomb of charge passes a point in a conductor in one second
    - Conventional current: direction that the positive charges would move, flows in the opposite direction of electron show (therefore, from + to -)
    - Ammeter: measures the current in a circuit, and should have zero resistance to current flow
        - Must be connected in series to the circuit
- Electromotive Force (source): work done by the source in driving a unit charge around a complete circuit (E=W/Q)
- Potential Difference (load): work done to drive a unit charge through the component (V=W/Q)
    - Volt: unit for measuring electromotive force and potential difference
    - Why does it exist? All charges move from a higher electric potential region to a lower electric potential region (potential difference drives the movement of charges)
    - Voltmeter: measures voltage in a circuit, and should have infinite resistance to current flow
        - Must be connected in parallel to the circuit
- Resistance of a resistor: ratio of the potential difference, V, across the resistor to the current, I, flowing through the resistor (R=V/I)
    - Resistors: components or devices placed in circuits designed to hinder the flow of charge so that electrical energy is lost, which is converted into other forms of energy
    - Ohm: unit for measuring resistance
    - Note: often the resistance of wires is deemed to be negligible since conductors have low resistivity, and thus low resistance
- Ohm Law: potential difference, V, across an ideal conductor is directly proportional to the current, I, through it, provided temperature and other physical conditions remain constant (V=IR)
    - This means that the resistance should theoretically remain constant
- Resistance: measured by formula (pl)/A (resistivity x length / surface area)
    - The greater the length of the conductor, the more resistance there will be
    - Charges are able to flow through a conductor with a larger cross-sectional area more easily
- Effect of temperature on resistance of metallic conductor
    - Increase in temperature leads to an increase in the atomic vibrations within the conductor
    - Resistance occurs due to collision of the charge carriers with the atoms, so there will be more collisions to hinder the flow of electrons, hence leading to a larger resistance
    - At extremely low temperatures, some materials have no measurable resistance, this is known as superconductivity
- Rheostat: variable resistor
    - Allows resistance to be altered by turning a shaft or sliding a contact
    - Allows current to be controlled as well
    - Used in brightness controls for light, or sound controls in radio and TV sets

Differences between Potential Difference and EMF

EMF	Potential Difference
Energy transfer from non-electrical forms to electrical forms when one coulomb of charge passes through the cell	Energy transfer from electrical to non-electrical forms when one coulomb of charge passes through the components
Only applicable to a source	Applicable to components
Exists in a cell even when it is not in used	Exists across a component only when it is in use

I-V Graphs:

1. Metallic conductor
    a. The metallic conductor will have a constant resistance if at constant temperature
2. Filament Lamp
    a. As current increases, the heating effect on the lamp increases (since electrical energy is converted to light and some heat energy) and resistance increases
3. Semiconductor Diode
    a. Diodes only allow current to flow in one direction, when the diode is in forward-biased mode, current flows through easily and the resistance is low
    b. Reverse potential difference is applied, negligible current flows through it thus resistance is high
4. Thermistor
    a. Increased potential difference across the thermistor leads to increased current and temperature rise
    b. Positive temperature coefficient: higher resistance (less steep gradient)
    c. Negative temperature coefficient: lower resistance (more steep gradient)
5. More Information:
    a. A steeper gradient on an I-V graph implies a smaller resistance
    b. A less steep gradient implies a larger resistance
        i. For the filament lamp with a constantly decreasing gradient, the resistance increases



Metallic conductor

Semiconductor diode

Filament lamp

Extra Facts and Questions:

- Why is it safe to touch a 100 000V and not a 240V power supply?
    - 100 000V means a higher electromotive force, but electrons are supplied in waves
    - For 240V, there is a constant supply of electrons due to the presence of a current, thus the current flowing through the body kills the individual, not one single wave of electrons
- Why can birds stand safely on power lines while humans are electrocuted?
    - Birds place both their legs on the power line simultaneously and electricity chooses the path of least resistance: the wire itself
    - For humans, we provide a new path for the electricity to travel to the ground, thus humans will get electrocuted

Direct Current Circuits:

Series Circuit:

- Current at every point in the circuit is the same (I1=I2=I3)
- The sum of the p.d. across each component is equal to the p.d. across the whole circuit (V=V1+V2)
- Effective resistance is the sum of resistance of all components (R1+R2+…)

Parallel Circuit:

- Total current from the source is the sum of currents in each of the n branches (I=I1+I2+… In)
- The potential difference across each separate parallel branch is the same
- The effective resistance for n resistors is 1/R =1/R1 +1/R2 +…1/Rn

Internal Resistance:

- Reason: batteries that are in use will also heat up, thus resulting in increased resistance of the battery itself (heat energy is produced since energy conversion is not 100% efficient into electrical energy from chemical energy in the battery)
- Internal resistance resists the flow of current, and can be measured as the potential difference across the battery

Potential Divider Circuit:

- Consists of a number of resistors usually arranged in series to achieve an output p.d. that is a fraction of the emf of the battery (required supply is less than the provided supply)
- Divide the emf and measure the pd required for the additional component

Thermistor and Light-dependent resistor

- Many devices known as input transducers can convert different forms of energy (through readings) into a signal that can be read
- Use of thermistor: Thermostat
  - Allow for temperature control using the circuit to switch on or off heating or cooling appliances like heaters, fan or air-conditioning
  - Thermostats can have a positive or negative temperature coefficient
- The resistance of LDR is normally very high, but when it is illuminated with light, the resistance drops dramatically, LDR is used to detect the presence or the level of light, needed to turn on street lamps

Additional Information:

Series and Parallel Circuits:

- If two components were connected in series and one failed, the circuit becomes open and the other components cannot function (in order for the devices in series to work, all must work)
- By adding more components to a series circuit, the overall resistance of the circuit increases, and decreases the current passing through the circuit, so the efficiency of each component decreases
- If two components were connected in parallel and one fails, current still flows through the other component without affecting its power
- By adding more components to a parallel circuit, the overall current increases, but current through each branch remains the same (due to similar resistance), increase in overall current due to reduction in effective resistance
- Disadvantage of parallel: more current is drawn from the source when more components are added, it can become hazardous (and if the source cannot supply enough current, components cannot work)

Connection of Batteries:

- If cells are connected in series, there is an increased emf because charges gain energy from each cell when they pass through all cells (emf is the sum of all sources)

- In parallel, the charges flowing round the circuit will split into each branch and each charge passes through one cell only, thus the gain in energy for any charge is only from one of the cells (combined emf is small)
- Advantage of parallel: cells will last longer

Practical Electricity:

Power and Energy:

- Power is the rate of converting energy or the rate of doing work with respect to time
- P = E/t = VQ/t = VIt/t = VI
- P = VI = I^2R = V^2/R
- Power is measured in watt (or usually kilowatt, 10^3)
- Amount of electrical energy (multiply the quantities of power and time)
- Electrical Energy is measured in Joules
- Note: The kilowatt hour is the most common unit to measure use of energy
    - 1 Kilowatt of power in one hour (1kWh is 3.6 x 10^6 J)

Electrical Wiring:

- Electricity supply in a normal home is an alternating current with a potential difference of 240V
- Live wire (brown/red) at 240V potential and carries current between the mains supply and the electrical appliance during normal operation
- Neutral wire (blue) is usually at 0V and carries current from electrical appliance to main supply
- Earth wire (yellow and green stripes) is a low resistance wire at 0V and usually has no current flowing through
    - It is connected to the metal casing of electrical appliances for safety purposes, and protects users from an electric shock, by carrying leakage current from the metal casing to the Earth instead of through the human body
- Switches: break or complete an electrical circuit
    - Must be fitted onto the live wire, so that “switching off” will disconnect the high voltage to the appliance
- Fuse: Safety device inserted to protect the appliance and wiring against excessive current flow
    - Particularly important when the socket is overloaded with too much current
    - Short, thin piece of wire which becomes hot and melts when the current through it is greater than its rated value
    - Always connected to live wire, with rating slightly higher than current flow into appliance
- EXAM INFORMATION (contacts in socket):
    - Live wire is always next to the switch, on the right pin
    - Neutral wire is always on the left pin (opposite live)
    - Earth wire is always at the top
- Consumer Unit: distribution point of household electricity supply
    - Lighting circuit: connected in parallel so each lamp receives 240V
    - Ring Main Circuit: supplies electricity to all wall sockets, with an added earth wire for safety

Dangers of Electricity: electric shocks and fires

- Causes:
    - Damp conditions
    - Damaged insulation
    - Overheating of cables
    - Poor and loose connections
- Electric Shocks:
    - The human body can withstand about 50mA of electricity
    - Resistance comprises of resistance of dry skin and resistance of the body itself: dry skin is about 100 kilo-ohms while the body is a few hundred ohms (damp conditions=shocks)
    - Damp conditions reduce resistance of the body and increases the current flowing through it
    - Cause: deterioration of insulation covering live wire
- Fires:

    - Overheating of cables with too much current flowing in it
    - Live and neutral wires may touch and cause short circuit in loose connections
    - Poor contacts can create high potential differences between contacts, causing charges to jump across contacts and produce sparks
- Solutions:
    - Earth Leakage Circuit Breaker: compares the amount of current flowing through live and neutral wires
        - Current leakage above 30mA, ELCB cuts off power supply
    - Miniature Circuit Breaker: switch which operates when electric current exceeds certain value
        - When tripped, power supply is cut off
    - Earth Wire: if appliance becomes live, current flows through earth wire instead of person
    - Double Insulation: Some appliances do not have earth wire
        - Insulation covering the wires and internal components
        - If a fault occurs, a non-conducting casing prevents users from shocks

Other Information:

- Solar cell converts solar radiation into electrical energy
- Clean energy causes little or no harm to the environment
- Renewable energy is generated by eternally present sources (wind, tides, geothermal)
- Singapore:
    - Wind speeds too low to use wind turbines
    - Tidal energy limited since sea space is used for ports, anchorage and shipping lanes
    - No chance for hydro or geothermal technologies due to geographical reasons
    - Increased energy consumption in Singapore (cause for concern)

Magnetic Fields:

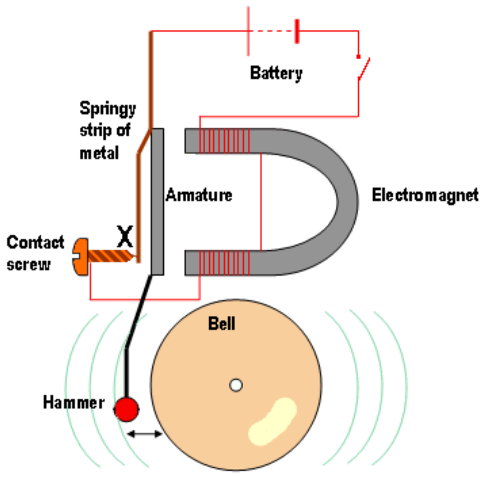
Magnetic Principles:

- A freely suspended magnet always settles with poles pointing in the North South Direction
  - Pole pointing towards geographical North is the North Pole (since geographical North would be the magnetic South Pole)
- Like poles repel and unlike poles attract
  - To test for magnets: a magnet must repel another object (which must be a magnet)
  - Attraction between magnet and object does not show the object is a magnet
- Any material places near a magnet becomes an induced magnet
- Magnetic vs Non-Magnetic Materials:
  - Magnetic Materials: Iron, cobalt, nickel, steel
  - Composed of magnetic domains
  - When randomly arranged (haphazard), the material does not act like a magnet
  - When most domains are lined up with their north and south poles in the same direction, the material then acts like a magnet
  - Therefore, if a magnet is broken into smaller pieces, each will become a magnet as well
  - Non-magnetic materials do not have magnetic domains
  - Explanation: magnets are strongest at the poles since it is the sum of all the domains pointing in the same direction through the entire magnet
  - Reasons: due to the magnetic spins of the electron orbiting around the nuclei of atoms and the configuration of certain metals
- Magnetic Saturation:
  - Every magnet has a maximum strength
  - Happens when all the magnetic domains are pointing in the same direction and the magnet cannot become any stronger
- Electrical method of Magnetization:
  - Place a magnetic material in a dc circuit within a solenoid
  - The magnetic domains will be aligned in one direction
  - The polarity of the magnet is the same as the polarity of the coil
- Other Forms of Magnetization:
  - By stroking: using a magnet
    - The end of the steel bar where the stroke ends has the opposite polarity to the end of the stroking magnet
    - The magnet must be lifted high after each stroke
- Electrical method of Demagnetization:
  - Definition: Demagnetization is the process of removing the magnetic properties of a magnet
    - Can be done by heating and subjecting to physical impact as well (hammering)
  - Magnet is placed in a solenoid carrying alternating current
  - Magnet is removed in an east-west direction to randomize arrangement of magnetic domains
- Storage of Magnets
  - Magnets are stored in pairs by using soft iron keepers across the ends of the bar magnets
  - Magnets become weather after some time due to the 'free poles' near the ends of magnets which repel one another if placed side by side
- Iron vs Steel:
  - Iron: easier to magnetize but loses magnetism easily (soft magnetic material)
    - Used more often in electromagnets
  - Steel: harder to magnetize but retains magnetism (hard magnetic material)
    - Used to make permanent magnets
- Magnetic Fields:

- Definition: region in which a magnet or magnetic material experiences a magnetic force
- The direction of the field at a given point is defined as the direction of the force that acts on a north magnetic pole placed at that point
- Note: The Earth has a weak magnetic field caused by electric currents circulated within the core of the Earth (inducing a magnetic field)
  - The magnetic field also acts as a protective shield over the surface of Earth by catching projectiles flying towards the Earth and trapping them in the field
- Magnetic Shielding: use soft magnetic materials to divert magnetic field lines
- Plotting:
  - Plotting compass is used and placed from head to tail with each other to show the direction of force
  - A magnetic field line joins up all the different forces (summation)
- Magnetic Field Lines:
  - Always drawn from the North to the South Pole
  - Away from the North Pole, towards the South Pole
  - Field lines which are closer together indicates a stronger magnetic fields, thus there are more field lines at the poles of the magnets
  - Field lines cannot cross each other
- Bar Magnet Pattern:
  - Direction from North to South
  - Between two opposite poles: flows from North to South
  - Between two similar poles: null point at the spot which experiences no net force
    - Lines bend away from the null point
- Straight Wire Pattern:
  - Right Hand Corkscrew Rule: direction of current and magnetic field
  - Two parallel wires with current in opposite direction: repulsion
  - Two parallel wires with current in same direction: attraction
- Flat circular coil Pattern:
  - Right hand grip rule for the position of the poles (given the direction of current)
- Long solenoid Pattern:
  - Right hand grip rule for the position of the poles
  - If a ferrous core is placed within the solenoid and magnetized, magnitude of the magnetic field is the sum of core and the solenoid
  - Increase strength of magnetic field around solenoid:
    - Increase current passing through solenoid
    - Add more coil of wire per unit length around the solenoid
    - Use magnetic material within the solenoid
- Principles (current-carrying conductors):
  - When the magnitude of the current increases, the strength of magnetic field increases
  - When the direction of the current is reversed, direction of magnetic field reverses

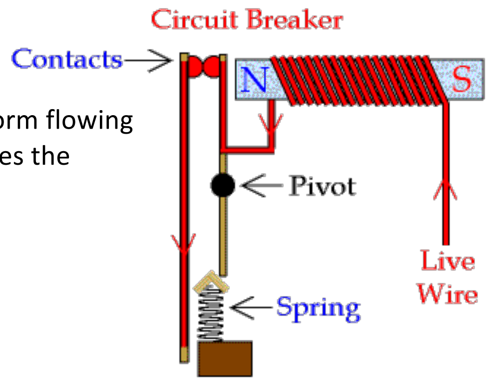
Applications:

- Electric Bell
  - The switch closes when the bell is pressed, closing the circuit and the electromagnet attracts the iron armature, causing the hammer to strike the bell
  - Contact breaks and the circuit is open and the magnet demagnetized, so the armature is no longer



attracted, remaking the contact and completing the circuit again

- Circuit Breaker
  - When the current is too high, the electromagnet becomes strong to attract the iron catch
  - The contacts are separated due to the pull of the spring and the circuit is broken to stop the current form flowing
  - The reset button connects the contacts and completes the circuit again



Electromagnetism:

Principle:

- Fleming's Left Hand Rule
  - When a current-carrying conductor is placed in a magnetic field, it experiences a force that is perpendicular to the plane with the conductor and the direction of the magnetic field
    - Therefore, force, current and field are mutually perpendicular
  - The force is maximum when the magnetic field and direction of current is perpendicular
  - The force is zero when parallel to one another
  - Predicts the relative direction of force acting on a charge
- Force on Moving Charge in Magnetic Field
  - Moving charged particles constitute charged particles
  - Positive charges move in the same direction as the current (negative charges move in the opposite direction)
  - Initial movement: either up or down
- Force between parallel conductors
  - The wires attract each other when they carry currents in the same direction
  - The wires repel each other when they carry currents in the opposite direction
  - Use the Right Hand Grip Rule to find the direction of magnetic field around conductor
- Exam Tips
  - Often used in conjunction with Right Hand Grip/Corkscrew Rule
  - X in magnetic field means its acting into the page
  - O in magnetic field means its acting out of the page

Motor Effect and DC Motors:

- Turning Effect:
  - Current-carrying coil placed in a magnetic field will have an upwards force on one end and downwards force on the other end (due to the opposing flow of current)
  - Turning effect occurs due to moments acting on the coil
  - As the angle increases, the coil cuts through fewer and fewer magnetic field lines
  - At 90 degrees, the coil is parallel to the magnetic field but momentums carries on the movement of the coil
- Purpose:
  - Converts electrical energy from direct current into motion (kinetic energy)
  - Carbon brush: conduct electricity from the external circuit into the coil and allow commutator rotate continuously (since the brush is carbon, it conducts electricity)
- Factors affecting turning effect
  - Increase the number of turns per unit length of the coil
  - Increase the magnitude of the current
  - Presence of external magnetic field strength
  - Length of the current-carrying conductor
  - Winding the coil onto a soft-iron cylinder
- Split-Ring Commutator
  - Reverses the current in the coil every half-rotation when the coil is perpendicular to the magnetic field, so the coil can rotate in the same direction
- Galvanometer
  - Moving coil that is able to detect electric current
  - When current passes through coil in the magnetic field, the coil experiences a torque proportional to the current
  - If the coil's movement is opposed by the coil spring, then the amount of deflection of needle attached to the coil is proportional to the current passing through the coil

- Loudspeaker
  - Converts electrical signals into sound
  - A movable coil is wrapped around center magnet with electrical signets sent through the coil
  - Due to external magnetic fields, the coil moves in and out of the central magnet
  - Motion of the coil results in vibration of the cone, producing sound
- Practical Motors
  - An increased and constant turning effect is enabled
  - Curved north and south poles produce a radial magnetic field
  - An iron armature concentrates and intensifies the magnetic field onto the coil
  - There are many coils at different orientations, each with many turns

Electromagnetic Induction:

Principles:

- Faraday's Law of Electromagnetic Induction
  - States that the magnitude of the induced emf is proportional to the rate of change of magnetic flux linkage or the rate at which the field lines of forces are cut
  - Requires a changing magnetic flux, it cannot be a stationary object with no force and effect on the magnetic flux
- Factors affecting magnitude of induced current
  - Speed of the magnet or object moving
  - Use of stronger magnet (strong magnetic field)
  - Number of turns per unit length in coil
- Lenz's Law
  - States that the induced current is always in a direction to oppose the change in magnetic flux linkage producing it
  - This induced current then produces its own force (which will oppose the original force creating the change in magnetic flux linkage)
  - Conservation of Energy: energy can only be converted from one form to another
  - Newton's Third Law of Motion: Every action must have an equal and opposite reaction
- Fleming's Right Hand Rule
  - Direction of induced current in a conductor

Alternating Current Generator:

- Important application of electromagnetic induction: generation of electricity
- Transforms mechanical energy into electrical energy
- Principle:
  - Consists of rectangular coil and permanent magnet
  - When coil rotates, it cuts through magnetic field lines and induces emf and thus current
  - Current flows through slip rings to the electrical load (slip rings contact with carbon brushes)
  - When the coil rotates 180 degrees, the sides of the coil switches places and induced emf will reverse and current flow reverses
  - Since current flow changes directions, the current will alternate at ()Hz based on rotations
  - No current is induced if the coil does not cut any magnetic field lines, so no change in flux
- Explanation
  - Rate at which coil cuts magnetic field lines greatest is when coil is horizontal (maximum emf)
  - Rate at which coil cuts the fewest field lines is when coil is vertical (minimum emf)
- Slip Rings
  - Prevents the twisting of wires
  - Enables the continuous rotation of the coil
- Factors
  - Speed of rotation of coil (affects the frequency and amplitude of the current)
  - Number of turns per unit length of coil (amplitudes increases with more wires cutting magnetic field lines)
  - Winding coil on a soft iron core (concentrates the magnetic field strength)
  - Use of stronger magnets (amplitude increases due to larger change in magnetic flux linakge)
- Practical Design
  - Fixed coil generator fixes coil and rotates magnet around it
  - Rotating magnetic field cuts the coil to produce an induced emf
  - Slip rings and carbon brushes are not used as output terminals of the coil are fixed
- Reasons for Design over Theory:
  - Carbon brushes wear and tear easily and must be replaced frequently, thus increasing cost

    - The connection with slip ring becomes loose when the carbon brush erodes
        - Loose connection increases resistance at the connection point, causing heating
    - Fixed coil design is more compact and space saving

Eddy Currents:

- Induced current circulating in a solid conductor when there is a change in magnetic flux linkage
- Treated as unwanted current because it leads to undesirable heating which represents power loss
- They always oppose the motion of a solid conductor in the magnetic field
    - Copper plate experiment: swings back and forth to change magnetic flux inducing emf , causing the free electrons in the plate to move, producing swirling eddy currents which have directions that oppose change that causes them
    - Eddy currents produce magnetic poles on the plate to repel poles of the magnet
    - Leads to repulsive force that opposes the motion of plate and reduces its movement

Alternating Current:

Transformers:

- One coil of wire is wound on each side of an iron core
  - Iron is the preferred material since it conducts electricity well and can be magnetized easily
- Principle:
  - When the switch is closed, the current increases in the primary coil, increasing the magnetic field within the core, and the changing magnetic flux induces an emf and current in the secondary coil
  - Once the current in the primary coil is steady, there is no more change in magnetic flux linkage, thus no more induced emf in the secondary coil
  - Therefore, an alternating current supply is used in the primary coil, continually changing the magnetic field, which constantly induces an emf in the secondary coil
- Increasing efficiency
  - Special core design to ensure magnetic field produced by the primary coil is completely linked to the secondary coil
  - Core made of a soft magnetic material
  - Laminated core used to reduce eddy current
  - Using thick copper wire with lower resistance
- Equations:
  - Vsec/Vpri = Number of turns (sec) / Number of turns (primary)
  - VsIs = VpIp
    - In an ideal transformer that is entirely efficiency
    - Therefore, current is inversely proportional to voltage
  - Efficiency = (Output/Input) x 100%
- Types of transformers
  - Step up: higher output voltage than input voltage by having more turns in secondary coil
  - Step down: lower output voltage by having more turns in the primary coil
- Reasons:
  - Alternating current Is sued so the voltage can be stepped up or down in transformers
  - Electricity generated is stepped up to very high voltage in transformers to power lines
  - High voltage reduces power loss in transmission cables (power loss = I^2 x R)

Half-Wave Rectification:

- Diode conducts current only in one direction when the potential difference applied is forward bias
- For reverse bias, the resistance of the diode is very high, reducing current
- Rectification: process of changing alternating current to direct current
- Principle:
  - For the first half of cycle, the diode is forward bias and there is current through the diode
  - For second half, the diode is reverse bias and there is negligible current