ELECTRICITY AND MAGNETISM

Lesson 6

- Static electricity was discovered in Greece in the 600BCs
  - The Greeks had no scientific explanation
- Law of charges: there are two types of charges: - and +.
  - Like charges repel, opposite charges attract
  - Charges cannot be created or destroyed
  - The net amount of charges produced in any process is 0
  - Charges redistribute when objects touch

Lesson 7

- Conductivity describes how easily a charge can move through a material
- Insulators → semiconductors → conductors → conductors
  - Non-metals are insulators, metals are conductors
  - Metalloids are semiconductors: factors like temperature and light determine if a charge can be passed through the material
  - A superconductor lets charges pass with no resistance
- In conductors, electrons are not tightly linked to the nucleus, allowing them to move more freely
- Separation of charge: a charged object can cause charges to separate in another object if it is in proximity

Lesson 8

Charging by friction	When objects are rubbed, electrons are torn from one and latch on to the other, allowing it to accumulate a charge. Which one is positive and negative depends on the electrostatic series
Charging by conduction	When objects are brought close together, their charges will separate, then redistribute when the objects touch
Charging by induction	A separation of charge is created with a negative object on an object that is grounded. The separation of charge will cause the electrons to escape down the groundwire. When the groundwire is snipped, the object will have a positive charge.

- Electroscopes use the principle of separation of charge to determine if an object is charged or not

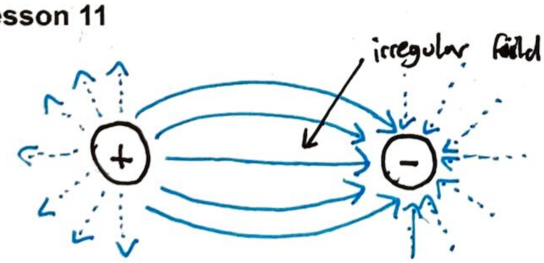
Lesson 9

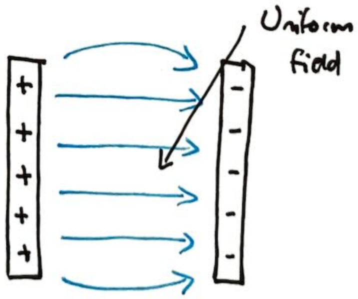
- Coulomb used a torsion balance, much like Cavendish, to measure the electric constant, which is shown as k
- Forces in between charged objects are shown by the equation $F_e = \frac{kq_1q_2}{r^2}$, where q1 and q2 are charges in coulombs
  - Whether this force is an attraction or repulsion is based on the law oh charges
- Though the coulomb is the SI unit for charge, charge is usually measured in micro-coulombs (μC) because one coulomb is very large
- The elementary charge, also denoted as e, is the charge of an electron
  - This charge is $1.6 \times 10^{-19}\ C$

Lesson 10

- Charges create electric fields around themselves that become weaker the farther away from the charge you go
  - Fields are not forces, but can exert forces
- The concept of a test charge is useful. A test charge has a value in Coulombs, but doesn't create a field. It is used to measure fields. Test charges are always positive
- Electric fields are defined by the equation $\overline{E} = \frac{F_e}{q}$ where q is a test charge
  - Electric fields are measured in N/C (newtons per coulomb)
  - Because of Coulomb's law, we know that the strength of a electric field is inversely proportional to the square of the distance from the charge
- A derived formula from this is $F_e = \frac{kq_1}{r^2}$ where q1 is the source charge
- To calculate multiple overlapping fields, treat them as vectors

Lesson 11





Lesson 12

- Charges can possess electric potential energy when they are in a field (much like gravitational potential energy in a gravitational field)
  - Like gravity, this depends in its distance from the opposite charge that it is attracted to
- Voltage is defined as the change in electric potential energy, per unit of charge
  - The unit could be called J/C, but it was instead given its own unit 𝕍
  - $\mathbb{V} = \frac{\Delta E}{q}$ �� $= \frac{\Delta E}{q}$ where q is a charge and ΔE is the change in electric potential energy
- One electron-volt (e��) is the amount of energy required to move an electron through one volt of electric potential difference
  - 1 e�� $= 1.6 \times 10^{-19}\ J$

$1\ e\mathbb{V} = 1.6 \times 10^{-19}\ J$

Lesson 13

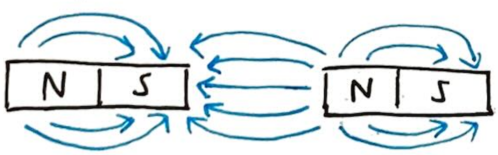
- In a uniform field, we can use the equation $\overline{E} = \frac{\Delta V}{\Delta d}$ where d is in meters
    - The direction always refers to a positive test charge
    - Thus, an electric field can be measured in V/m as well as N/C
- A uniform field is analogous to the work-energy theorem, where energy has to be exerted in order to displace a charge
- Many dynamics formulae as well as $F = ma$ can be used in questions

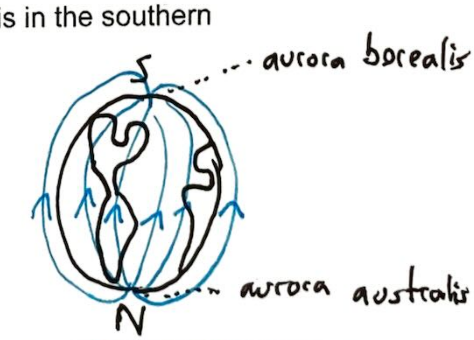
Lesson 14

- All magnets have a north and south pole
    - This is where the force exerted by the magnetic field is the strongest
    - Magnets exert forces on each other: like poles repel and opposite poles attract
- Only some metals (ferromagnetic metals) have magnetic properties
- Like electrical charges, magnets create magnetic fields around themselves

Lesson 15

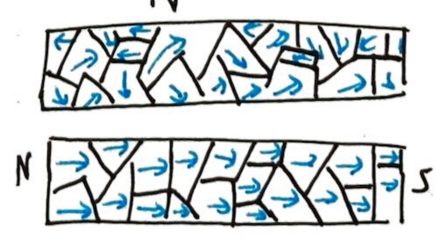
- Unlike charges, magnetic poles always come in paris of N and S
- Magnetic fields are measured in Teslas (T), and are always calculated in relation to something
    - Earth's magnetic field is $5 \times 10^{-5}\ T$, and is denoted B
- Magnetic fields always point north to south (knuckles south)
- Earth's magnetic poles are swapped: the magnetic north pole is in the southern hemisphere





Lesson 16

- In domain theory, materials are thought to be broken into many domains, which are all mini-magnets with two poles
    - Most of the time, the random alignment of the domains causes them to cancel each other out
    - The domains can't align in non-ferromagnetic materials, but can align in ferromagnetic materials if an existing magnet is used
    - When the domains align, the object turns into one large magnet with two poles
    - Depending on how a material is forged, this new magnet can be temporary or permanent
- By adding energy to a magnet (smashing it or heating it for example), you cause the domains to misalign, which weakens the magnet.



Lesson 17

Circuit diagrams always use a "conventional current" (− → +)

- An electric current can induce a magnetic field
  - The field will be induced around the wire
- When using hand rules, using your left hand means that you are using the direction that the electrons are flowing (right for "conventional")
- When representing 3D vectors in 2D, • means a vector pointing out of the page at you and x means a vector pointing into the page

First hand rule	If your thumb points in the direction of flow, wrapping your fingers will create the magnetic field around the wire
Second hand rule	When a magnet is being induced, your thumb is the north pole when your finders wrap in the direction of the electric current (solenoid)
Third hand rule	When an external magnetic field is applied to a wire, your fingers point in the direction of the field (N → S), your thumb points in the direction of the current and your palm points in the direction of the force acting on the wire

- Magnitude of the force in the third hand rule defined by the equation $F_m = IlB\ sin(\theta)$, where I is the current in Amperes, l is the length of the wire and B is the magnetic field strength, and θ is the angle between the wire and the magnetic field
  - This force is the strongest when the wire is perpendicular the field, and 0 when the wire is parallel

Lesson 18

- Charges trapped in magnetic fields follow circular motion
  - Usually expressed by the equation $F_m = F_c$
  - $F_m = qvB$
- Magnetic forces can also be balanced by gravitational forces, expressed by the equation $F_m = F_g$
- Because wires create magnetic fields, having multiple wires can create interactions in the magnetic fields
  - If the current flows in the same direction, the wires are attracted to one another
  - If the current flows in the opposite direction, the wires are repulsed by one another

Lesson 19

- A galvanometer measures things like currents by using an external magnetic field
- Electric motors use a similar technique which allows for spinning parts

Lesson 20

- A current can be induced in a wire by moving it perpendicularly to a magnetic field (Faraday's discovery)
    - The magnetic field has to be changing to produce a current (ie. moving the wire)

Lesson 21

- The induced current is always opposite to the change in the circuit or magnetic field
- <u>Lenz's law: to create electricity using a magnet, effort has to be exerted somewhere</u>
    - This effort comes from the force that it takes to push a pole into the same pole, or from tearing two opposite poles away