Physics Unit 4: Physics on the Move

Further mechanics

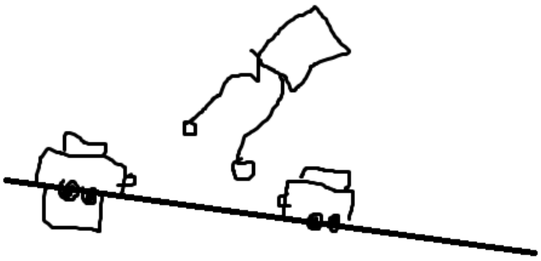
Use the expression p = mv

- → Momentum = mass x velocity
- → Unit for momentum is $kgms^{-1}$ or Ns
- → Momentum is a vector because velocity is a vector

Investigate and apply the principle of conservation of linear momentum to problems in one dimension

- → Momentum is conserved in interactions between bodies

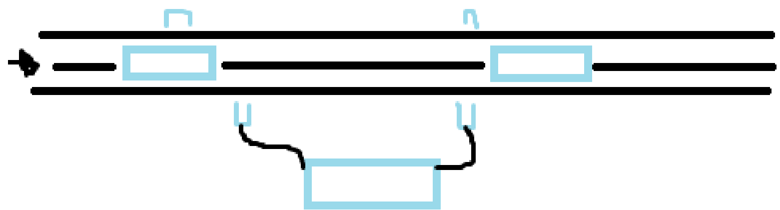
A simple collision between trolleys on a friction compensated slope:



1. Trolley A is given a given a push so that after release it the interrupter card cuts the light beam
2. The trolley will be moving at a constant velocity down a friction compensated slope
3. The time the light beam is interrupted is recorded on the computer and you can work out initial velocity "u"
4. Trolley A has a cork with a pin sticking out so that it couples with the cork on trolley B (both trolleys of same mass)
5. When trolley A is released it then attaches to B and both move off together at a new constant velocity
6. This can be measured when the interrupter card on a cuts a second light beam
7. If momentum is conserved then $m_a u$ should equal $(m_a + m_b)v$ the final velocity should be ½ the initial velocity

Investigate and relate net force to rate of change of momentum in situations where mass is constant

- → Collision experiments can also be simulated using gliders on linear air track where friction is negligible.
- → To get the gliders to stick together a bit of blue tac can be where they strike each other
- → 2 gliders can be fitted with small magnetic buffers that are set to repel
- → When they collide they bounce apart, so if the computer records the initial velocity of the gliders moving towards each other and then when the move apart the principle of conservation of momentum can be tested.



Derive and use the expression $E_k = \frac{p^2}{2m}$ for the kinetic energy of a non-relativistic particle

- → $E_k = \frac{1}{2}mv^2$
- → $p = mv$
- → $p^2 = m^2v^2 \text{ and } v^2 = \frac{2E_k}{m}$
- → $p^2 = m^2 \times \frac{2E_k}{m}$
- → $p = \sqrt{m^2 \times \frac{2E_k}{m}}$
- → $\therefore\ E_k = \frac{p^2}{2m}$

Explain and apply the principle of conservation of energy, and determine whether a collision is elastic or inelastic.

- → Collisions where the kinetic energy is not conserved but momentum is are called inelastic
- → Collisions where Kinetic energy and momentum are conserved are called elastic
- → Energy cannot be lost but is transferred from one form to another. The loss of kinetic energy is equal to the gain in internal energy

Express angular displacement in radians and in degrees, and convert between those units

$$\text{degrees} = \text{radians} \times \frac{180}{\pi}$$

$$\text{radians} = \text{degrees} \times \frac{\pi}{180}$$

- $\omega = \frac{\Delta\theta}{\Delta t}$
- When describing how an object is moving in a circle we could use the terms revelations per second, but in physics we use revelations per radians. This is called angular velocity.

Explain the concept of angular velocity, and recognise and use the relationships $v = \omega r$ and $T = 2\pi/\omega$

- $v = r\omega$
- From this equation we can explain why on a meri-go-round everyone on it has the same angular velocity but people standing further are travelling faster because the radius is larger.
- $T = \frac{2\pi}{\omega}$ enables you to calculate the angular velocity of the spinning earth

Explain that a resultant force (centripetal force) is required to produce and maintain circular motion

- Centripetal acceleration is produced by the centripetal force and there are 2 equations for centripetal force
- If you remove the centripetal force the object would fly off at a tangent.
- $a = \frac{v^2}{r}$
- $a = \omega r$
- $F = \frac{mv^2}{r}$
- $F = \omega^2 r$

Particle physics

Use the terms nucleon number (mass number) and proton number (atomic number)

- → The **proton number** or the atomic number denotes the number of protons in the nucleus of the element (Z)
- → The **neutron number** is the number of neutrons in the nucleus of an atom (A-Z)
- → **Nucleon number** the total number of protons and neutrons in the nucleus of an atom (A)

$$^{A}_{Z}X$$

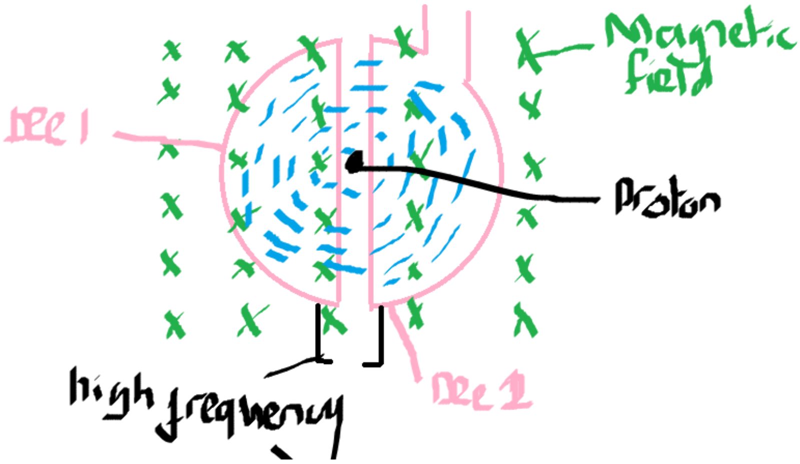
Describe how large-angle alpha particle scattering gives evidence for a nuclear atom

- → The material of the nucleus is very dense $(10^{16} kgm^{-3})$
- → The fact that the atom was mainly empty space was first established when alpha particles from a naturally radioactive source were fired at a thin sheet of gold
- → Some of the alpha particles are deflected back through significant angles, so the centre of the atom must be tiny but contain a lot of mass.
- → The alpha particles were repelled, so the nucleus must have a positive charge.
- → Atoms are neutral overall so the electrons must be on the outside if the atom separating one atom from the next.

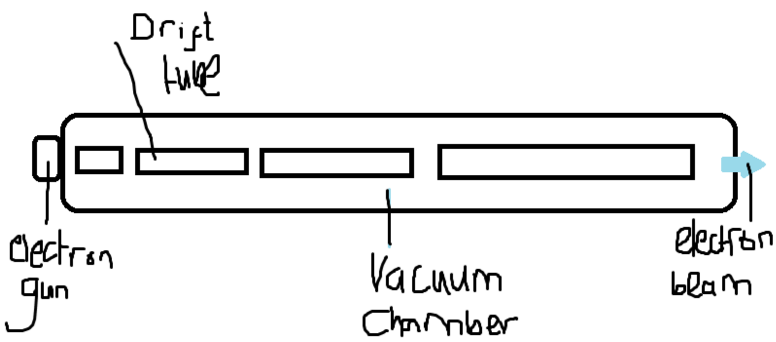
Recall that electrons are released in the process of thermionic emission and explain how they can be accelerated by electric and magnetic fields

- → When metal is heated to high temperatures, negatively charged electrons leave the surface of the metal.
- → They are however attracted back by the positive surface they leave behind
- → If a positively charged plate is placed near the metal in the vacuum electrons accelerate towards it and can be made into a narrow beam
- → This arrangement is called the electron gun.

Explain the role of electric and magnetic fields in particle accelerators (linac and Cyclotron) and detectors (general principles of ionisation and deflection only)



→ A source of protons (ionised hydrogen atoms) is placed at the centre of the two Dee's.
→ The Dee's are connected to a high frequency alternating voltage and are situated in strong vertical magnetic fields
→ Some protons emerge from the central source entering D1.
→ Inside the Dee it follows a semi-circular path under the action of a magnetic field
→ When they arrive at the narrow gap between the D's the second D has the opposite charge and this means the proton is accelerated across by an electric field
→ They enter the second D with extra eV.



→ Electrons are given energy as they pass between charged metal plates
→ Energy is given to a particle by an electric field
→ Tubes are connected to high frequency alternating voltage
→ Length of tubes is calculated so that there is always a positive charge on the next tube. Therefore the length of the tube increases
→ Inside the tube the electrons travel at a steady speed because there I no electric field inside the tube. This is why they drift

- → Energetic charged particles cause ionisation in any material they pass through. The **cloud chamber** makes use of ionisation in super saturated air and in a **Bubble chamber** ionisation of super saturated liquid hydrogen.
- → Molecules leave a path of **liquid water** drops in a cloud chamber and gas bubbles of hydrogen in bubble chambers
- → These tracks can then be detected by taking illuminated photographs

Recognise and use the expression *r = p/BQ* for a charged particle in a magnetic field

- → $\frac{mv^2}{r} = Bev$
- → $mv = Ber$
- → $mv = p \; and \; p = Ber$
- → $r = \frac{p}{Be}$

Recall and use the fact that charge, energy and momentum are always conserved in interactions between particles and hence interpret records of particle tracks

- → A charged particle in a magnetic field will experience a force making the particle follow a curved track. The radius of the curved track is equal to momentum divided by magnetic field strength times the charge on the particle.
- → Positive and negative particles curve in other ways which can be worked out using Fleming's left hand rule. You see spirals because interactions with the detector decrease the energy and therefore momentum.
- → Neutral particles only show up when they decay.
- → Cloud and bubble chambers are no longer used. Detectors used give out electrical signals that are sent straight to a computer.

Explain why high energies are required to break particles into their constituents and to see fine structure

- → Quarks are bound together tightly and in order to break the quarks apart very high energy bombarding electrons are needed.

Recognise and use the expression Δ*E* = *c*2Δ*m* in situations involving the creation and annihilation of matter and antimatter particles.

- → C= the speed of light in a vacuum 3×10^8
- → M= tells us that particles have mass when they are at rest, this mass increase as the energy a particle has increases.
- → Einstein's principle of the conservation of mass-energy says that mass and energy are interchangeable

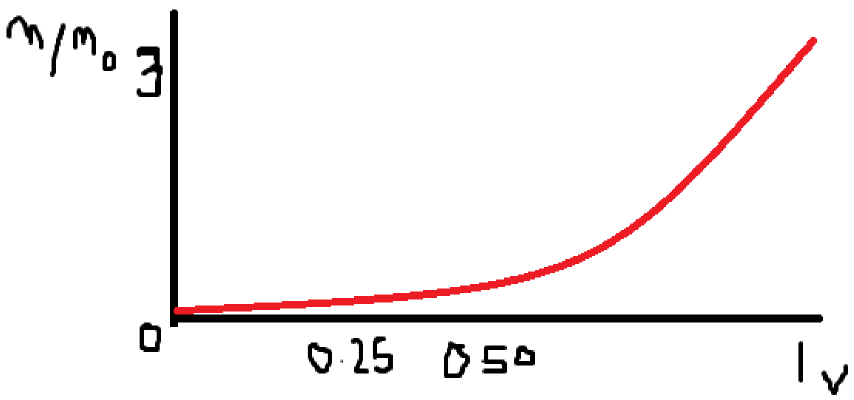
Use the non-SI units MeV and GeV (energy) and MeV/c2, GeV/c2 (mass) and atomic mass unit u, and convert between these and SI units

- → Unified atomic mass, u is useful in nuclear physics
- → It measures masses on the scale where the isotope for carbon $^{12}_{6}C$ is 12u
- → 1u= 1.66×10^{-27}

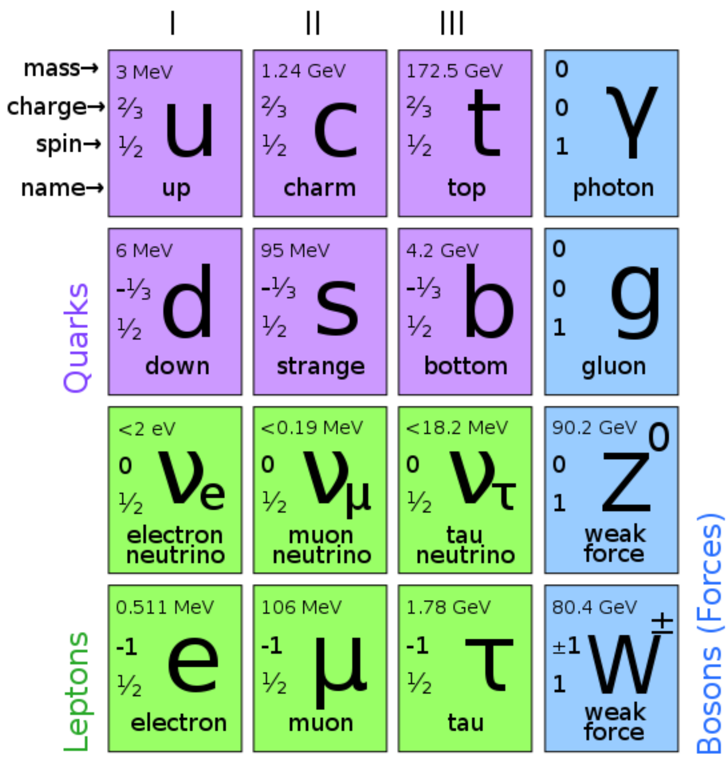
	kg	u	MeV/c^2
1kg	1	6.02×10^26	5.62×10^{29}
1u	1.66×10^{-27}	1	1.07×10^{-3}
1MeV/c^2	1.78×10^{-30}	934	1

Be aware of relativistic effects and that these need to be taken into account at speeds near that of light (use of relativistic equations not required)

- → The faster particles travel the heavier they become



Recall that in the standard quark-lepton model each particle has a corresponding antiparticle, that baryons (e.g. neutrons and protons) are made from three quarks, and mesons (e.g. pions) from a quark and an antiquark, and that the symmetry of the model predicted the top and bottom quark.



- → **Hadrons** are particles that feel a force called the strong interaction. There are two types of hadrons. They are baryons and mesons.
- → Particles made up of three quarks are called **baryons**. Protons and neutrons are examples of baryons. A protons quark structure is up, up down. A neutrons quark structure is up, down, down. The proton is the only stable baryon.
- → **Mesons** are made up of a quark and an anti-quark. All mesons are unstable. Pions are the lightest mesons and there are three versions with different electric charges: plus, minus and neutral. Kaons are heaver and more unstable and you get different ones like plus, minus and neutral kaons. Mesons interact with baryons via the strong interaction.
- → **Leptons** are fundamental particles and they do not feel the strong interaction force. The only way they can interact with other particles is via the weak interaction, gravity and the electromagnetic force if they are charged.
- → Electrons are stable and there are two other leptons. The two other leptons are muons and taus and they are unstable and are just like heavier electrons. Muons and taus eventually decay into ordinary electrons. The 3 leptons have their own neutrino and have zero mass or electric charge.
- → Neutrons decay into protons.

Write and interpret equations using standard nuclear notation and standard particle symbols (e.g. π+, e-)

Use de Broglie's wave equation λ = *h*/p

- → $Planks\ constant\ h = 6.63 \times 10^{-34}$
- → Particles with mass such as electrons cab behave like waves
- → Planks constant links energy with wavelengths for electromagnetic waves and wavelength with momentum

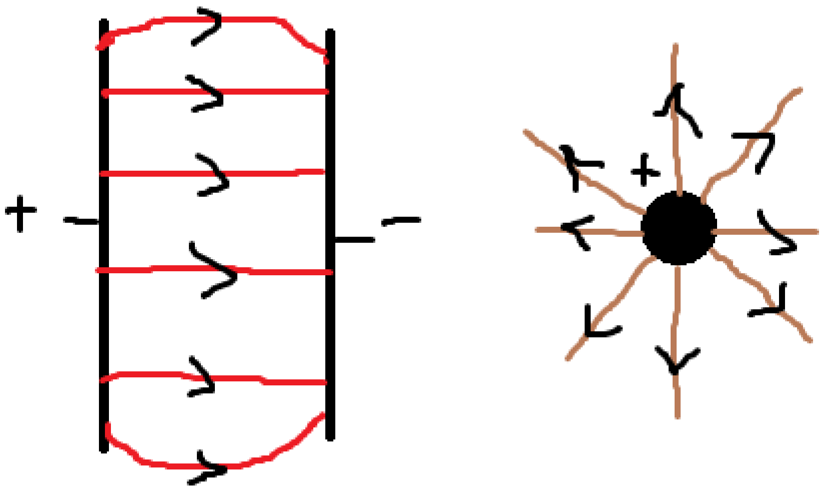
Electric Fields

Explain what is meant by an electric field and recognise and use the expression electric field strength *E = F/Q*

- → An electric field is a region of space where a charged particle experiences a force.
- → $E = \frac{F}{Q}$ electric field strength ='s force per unit charge

→ Unit for electric field strength is NC^{-1}

Draw and interpret diagrams using lines of force to describe radial and uniform electric fields qualitatively



→ Two oppositely charged plates produce a uniform electric field

→ In a uniform field the line are equally spaced out and are parallel and when a small charged object is moved around in a uniform electric field it experience the same force everywhere.

Use the expression F = kQ1Q2/r2, where k = 1/4πε0 and derive and use the expression E = kQ/r2 for the electric field due to a point charge

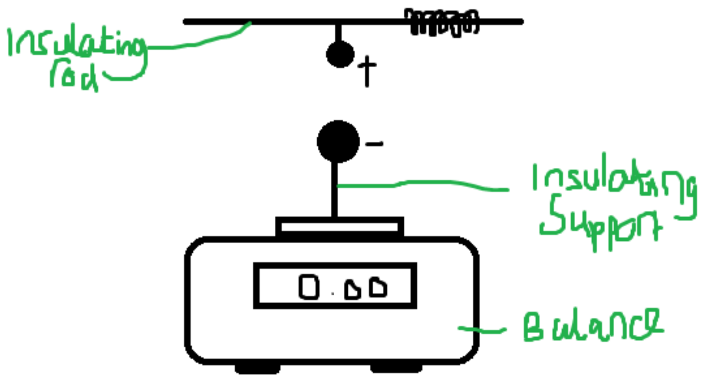
→ $F = \frac{kQ1Q2}{r^2}$

→ The above equation is coulombs law describing the force between two point charges. This is an example of an inverse square law dependent on the radius

→ $\frac{F}{Q} = \frac{kQ}{r^2}$ $E = \frac{F}{Q}$

→ $E = \frac{kq}{r^2}$

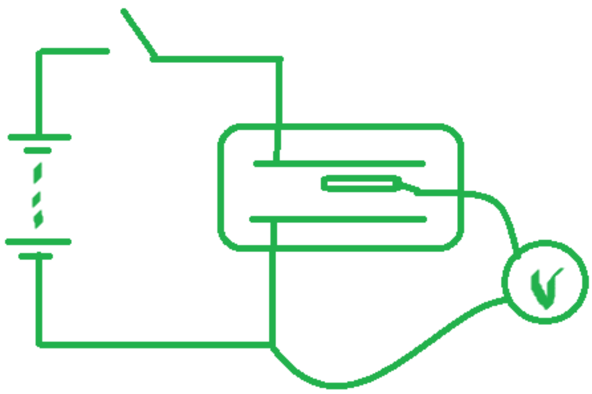
Testing coulomb's inverse square law for the force between two charges



- → Forces are going to be small, so a sensitive measuring device is needed to register changes in force
- → Electric top pan registers changes to 0.01g
- → Two conducting spheres are charged (make sure the charged spheres are insulated so they don't lose charge during the experiment)
- → The reading m is taken at different distances between the spheres.

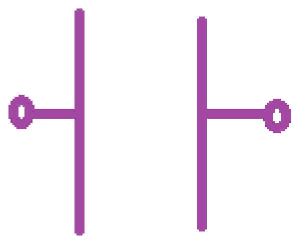
Investigate and recall that applying a potential difference to two parallel plates produces a uniform electric field in the central region between them, and recognise and use the expression *E = V/d*

- → In a uniform field, the size of the electric field strength can also be expressed as $E = \frac{V}{d}$
- → Two counducting plates are linned up parallel to each other in a shallow solution of copper sulfate
- → A metal probe Is connected to the negative terminal of a power supply via a digital voltmeter
- → When the switch is closed there is an uniform electric field produced between the plates
- → When the probe is placed in the liquid it will register a reading on the voltmeter

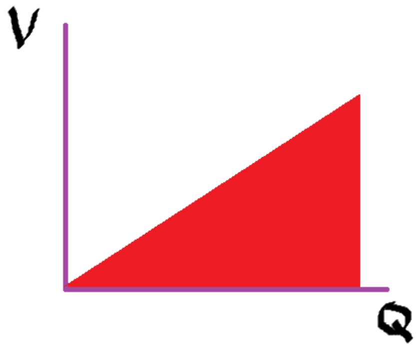


Investigate and use the expression C = Q/V Use a Coulometer to measure charge stored

- → $Q = CV$
- → When you apply a potential difference to the plates of a capacitor they become charged
- → Capacitance is measured in Farads

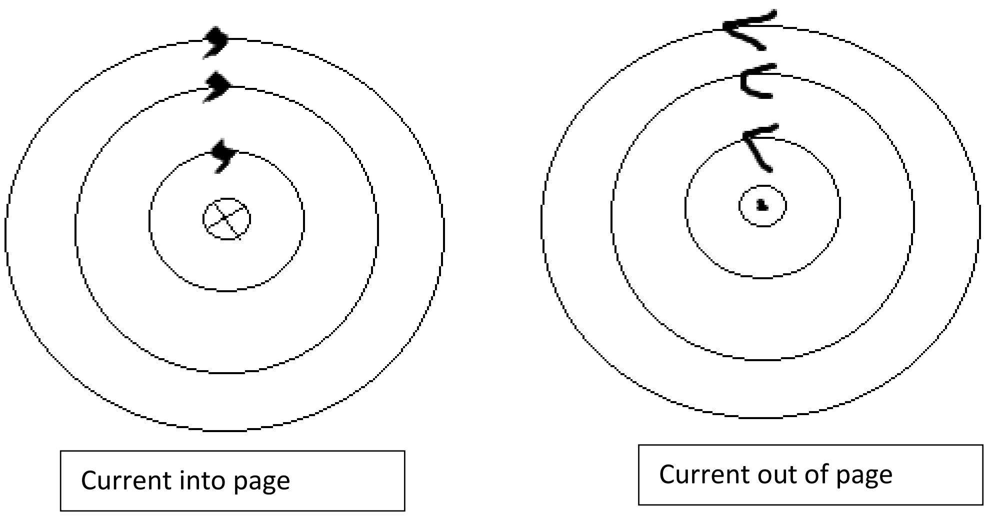


Recognise and use the expression $W = \frac{1}{2} QV$ for the energy stored by a capacitor, derive the expression from the area under a graph of potential difference against charge stored, and derive and use related expressions, for example, $W = \frac{1}{2} CV2$



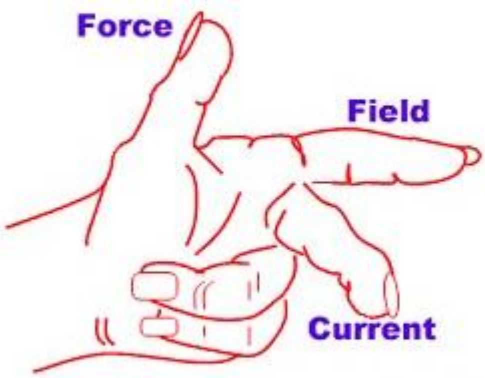
Explore and use the terms magnetic flux density B, flux Φ and flux linkage $N\Phi$

- → Around a magnet there is a region where objects made of iron or containing iron would feel a force pulling them towards a magnet
- → You can investigate the shape of a magnetic field by sprinkling iron fillings on a piece of paper placed over a magnet
- → When the field lines are closest together the magnetic field strength is the strongest



- → When a current carrying wire is placed at right angles to a uniform magnetic field, the magnetic fields interact producing a force on the wire
- → The force depends on the current in the wire and the length of wire
- → Strength of the magnetic field is called the magnetic flux density.
- → $F = BIl sin\theta$ where B is the magnetic field strength
- → Φ is the symbol for magnetic flux
- → $Magnetic\ flux = BA$ the product of magnetic flux density and the are through which it acts

Investigate, recognise and apply Fleming's left hand rule to currents



Investigate and explain qualitatively the factors affecting the emf induced in a coil when there is relative motion between the coil and a permanent magnet and when there is a change of current in a primary coil linked with it

- → Lenz's law states the induced e.m.f is always in such a direction as to oppose the change that caused it.
- → You can change the voltage induced in the coil by changing the following factors.
- → The angle between the coil and the field.
- → Number of turns of the coil.
- → Area of the coil.
- → Magnetic field strength (flux density).
- → Angular speed off the coil.

Investigate, recognise and use the expression $\varepsilon = -d(N\Phi)/dt$ and explain how it is a consequence of Faraday's and Lenz's laws

$$\varepsilon = -d(N\Phi)/dt$$

→ ε is the induced emf in a circuit when the average rate of change of magnetic flux is Φ/t

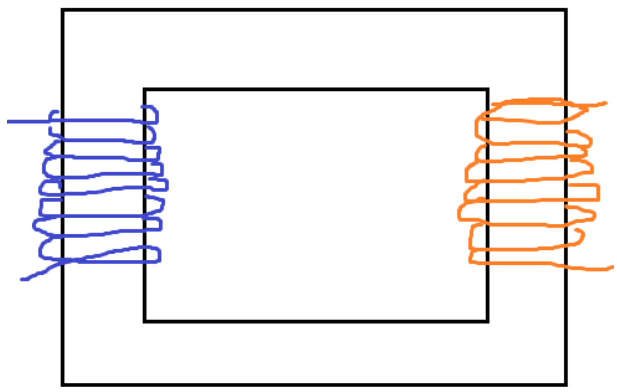
→ N is greater than one when there are many turns on a coil because emf is induced in each coil

→ **Faraday's Law**: the induced emf in a circuit is equal in size to the rate of change of magnetic flux linkage through a circuit

→ The minus sign in the equation shows that the induced emf could send an induced current around the circuit that would set up a magnetic field that would oppose the change in magnetic flux causing the induced emf. This is **Lenz's law**

Transformers

→ Transformers work by electromagnetic induction. An alternating current flowing in the primary coil produces a magnetic flux. The magnetic field is passed through the iron core to the secondary coil, where it induces an alternating voltage of the same frequency.



→ Step up transformers increase voltage by having more secondary coils.

→ Step down transformers reduce the voltage by having fewer coils in the secondary coil.