Magnetic Fields Basics

5th Feb

A MAGNETIC FIELD is a region where a magnet or magetic material experiences a NON-CONTACT FORCE.

There a four magnetic materials we need to know: Nickel, Iron, Steel, Cobalt.

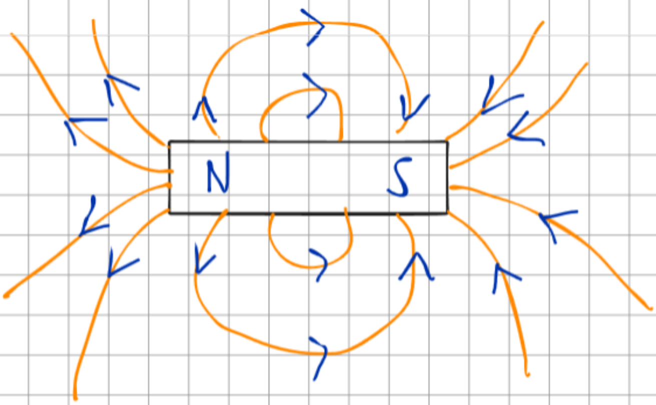
An object that stays magnetic for a long time is called a PERMANENT MAGNET; they generate their own field.

An object that becomes temporarily magnetic when placed in a magnetic field is called an INDUCED MAGNET.

The force between two permanent magnets can be attractive (if opposite poles are placed near each other) or repulsive (for like poles).

The force between a permanent magnet and an induced one is always attractive.

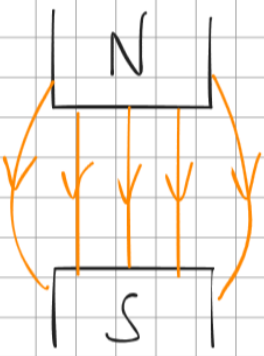
Drawing Fields

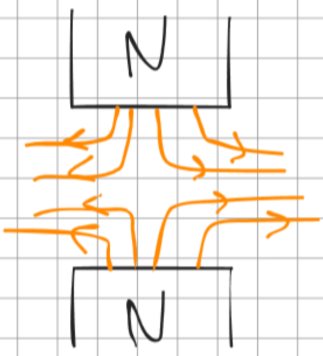


Shape: field lines, continuous

Strength: the closer the lines are together, the stronger the field

Direction: arrows show the direction of the force a NORTH POLE would experience if it was put on the line; the direction a compass would point if placed on the line.



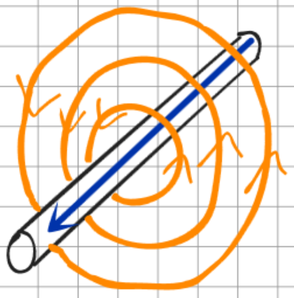


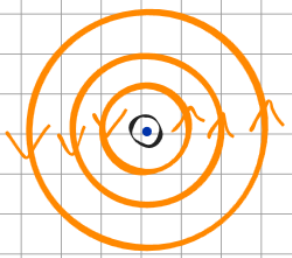
Electromagnets

10th Feb

Whenever an electric flows through a conductor, a magnetic field is created around that conductor.

These fields can be turned on and off, their direction changed and their strength increased or decreased. This is unlike permanent magnets.





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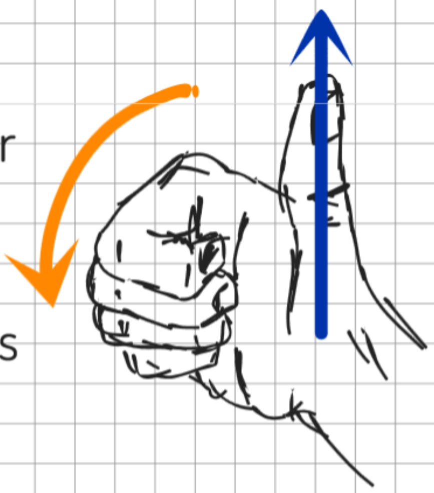
Around a straight current carrying wire we produce a circular field. We can use the RIGHT HAND THUMB RULE to determine the direction of the field.

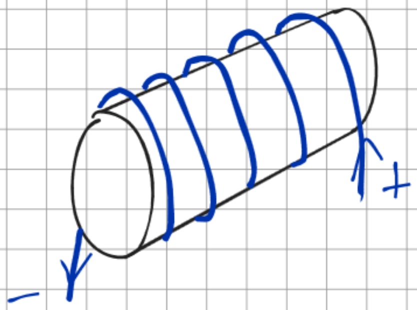


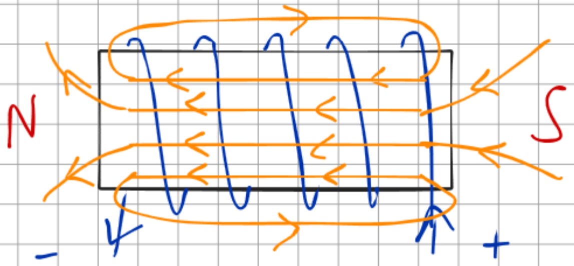
The curl of your fingers shows the direction of the field lines

Thumb shows the direction of current flow (from + to –)

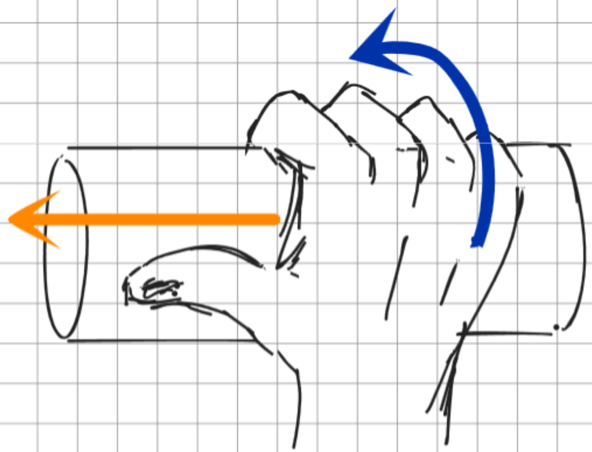
To increase the strength of a field around a wire we must INCREASE the CURRENT flowing through it. However high currents can increase the risk of electric shock and lead to lots of energy being dissipated to the surroundings.

If we wind the wire into a coil shape called a SOLENOID then this also creates a much stronger field.





The field inside the solenoid is STRONG and UNIFORM (the same strength everywhere). We can determine the direction of the field using the RIGHT HAND GRIP RULE.



The curl of your fingers shows the direction of the CURRENT AROUND the solenoid.

The thumb shows the direction of the FIELD INSIDE the solenoid (and points to the end of the solenoid we can label as a NORTH POLE).

The Motor Effect

13th Feb

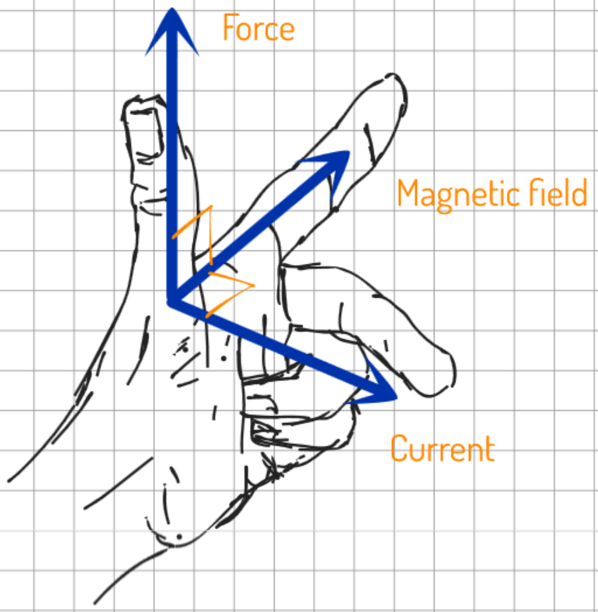
When a conductor carries a current it has a magnetic field around it.

If this conductor is placed in another magnetic field, then the TWO FIELDS INTERACT.

This interaction causes a FORCE.

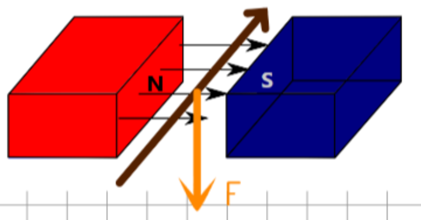
This is called the MOTOR EFFECT.

We can determine the direction of this force using FLEMING'S LEFT HAND RULE.



- Point your INDEX FINGER in the direction of the permanent magnetic field (N to S)
- Rotate your left hand until your MIDDLE FINGER points in the direction of the CURRENT in the wire (+ to –)
- Your THUMB then shows the direction of the FORCE ON THE WIRE.

Example:



We can calculate the magnitude of the force on the wire using:

Force = magnetic flux density x current x length

similar to field strength (magnetic flux density)

length of wire in the field (length)

$$F = BIL$$

F: in newtons, N

B: in tesla, T

I: in amps, A

L: in metres, m

The DC Motor

24th Feb

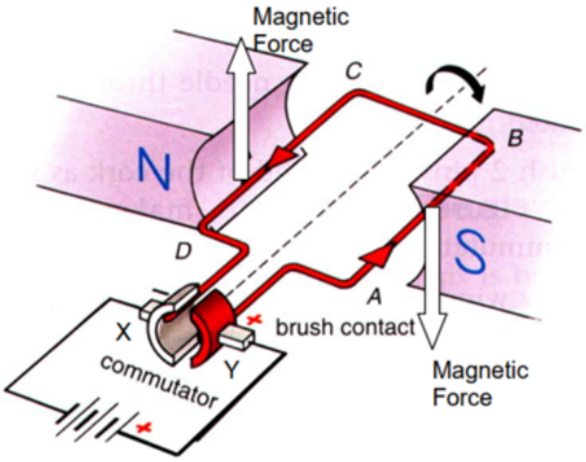


Figure 2.1: A DC Motor with magnetic forces

When a current flows through the loop of wire a MAGNETIC FIELD is created around the wire.

This field INTERACTS with the permanent magnetic field and creates a FORCE.

The current flows in OPPOSITE directions on each side of the loop, so each side experiences FORCES in OPPOSITE directions

This causes the loop of wire to ROTATE.

The current is disconnected when the loop has turned 90 degrees, and the loop's momentum means it continues to rotate.

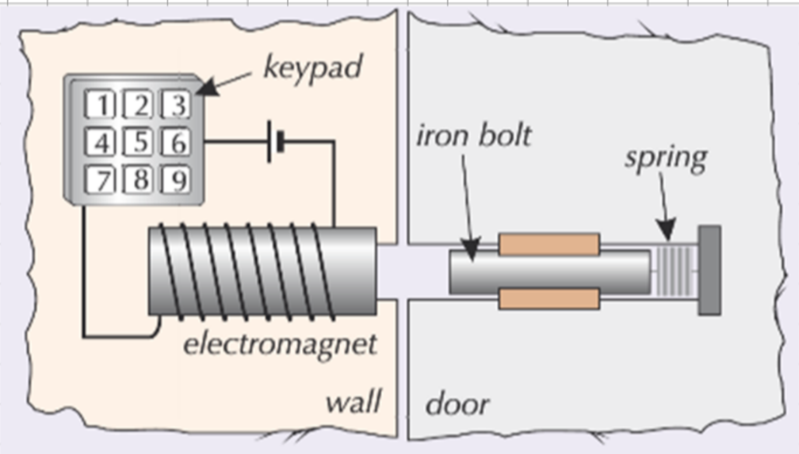
The SPLIT RING COMMUTATOR then means the sides of the loop SWAP POLARITY (connection to the power supply). This reverses the direction of the CURRENT and the FORCES. This keeps the MOMENT on the loop in the SAME DIRECTION.

Uses of Electromagnets

26th Feb

Electromagnets have many uses ranging from magnetic cranes, door locks, MRI scanners, electric bells, car starter circuits etc

Generally these uses all involve passing a current through a solenoid and creating a magnetic field around it. This field usually then exerts a force on a magnetic material to start some form of action.



In this door lock a current magnetises the electromagnet, creating a magnetic field.

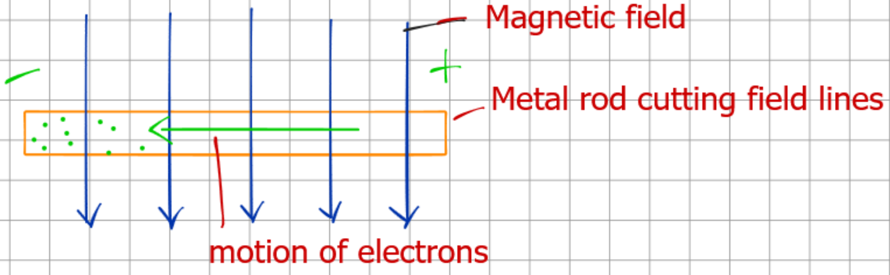
This attracts the iron bolt and locks the door.

The Generator Effect

6th March

If a conductor moves through a magnetic field (or vice versa), then the conductor cuts through magnetic field lines.

This exerts a force on the charged particles in the conductor, and causes electrons to move.

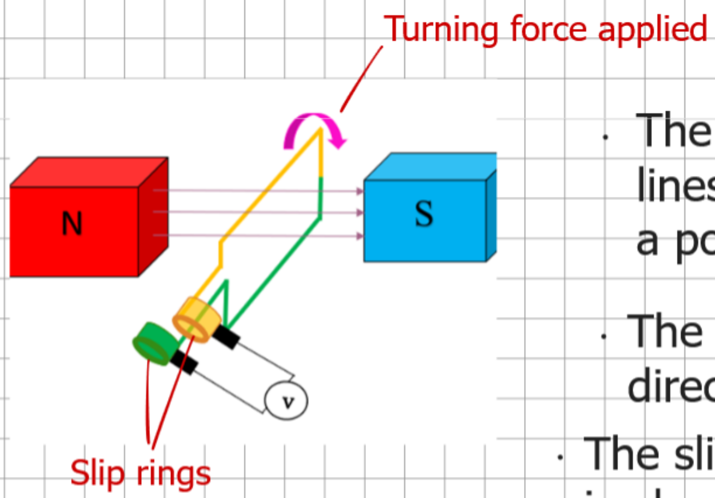


This INDUCES a POTENTIAL DIFFERENCE across the conductor.

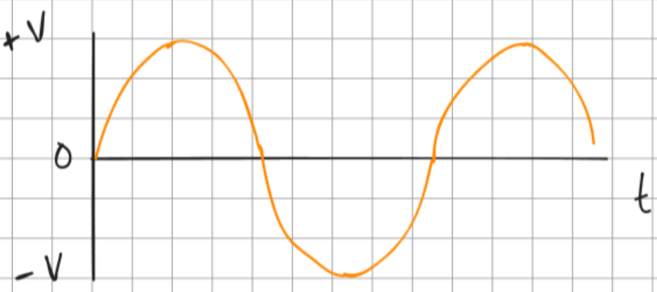
If the conductor is part of a COMPLETE CIRCUIT, then we also INDUCE A CURRENT.

Alternators and Dynamos

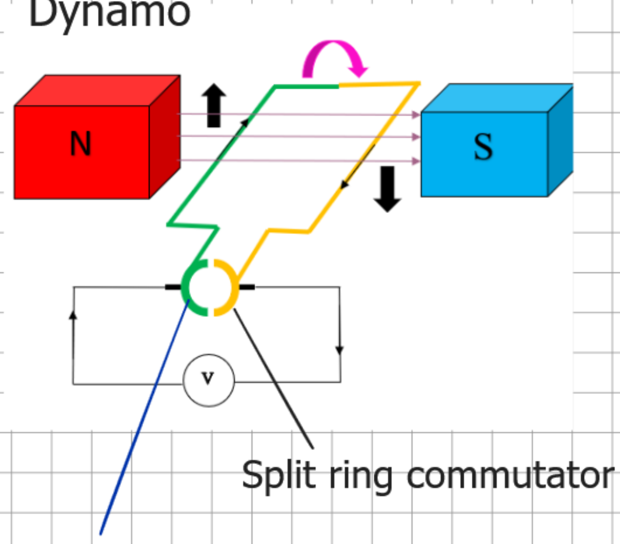
10th March



- The loop of wire cuts magnetic field lines when we turn it. This induces a potential difference across the loop.
- The loop cuts the field in a different direction each half turn.
- The slip rings mean each side of the loop is alway connected to the same side of the voltmeter.
- So the potential difference swaps direction each half turn too.



Dynamo



the side cutting 'upwards' is always connected to the same side of the voltmeter

- In a dynamo when the direction of motion of the loop through the field changes, a split ring commutator also swaps the connection between the loop and the circuit.
- This means we produce a DIRECT POTENTIAL DIFFERENCE (or direct current if the circuit is complete).

- We can increase the induced p.d. by:
  - having a stronger magnetic field
  - turning the coil faster
  - having more turns on the coil

When we INDUCE A CURRENT in a conductor, we also create a magnetic field around that conductor.

The field around the conductor interacts with the field we are moving it through, creating a FORCE.

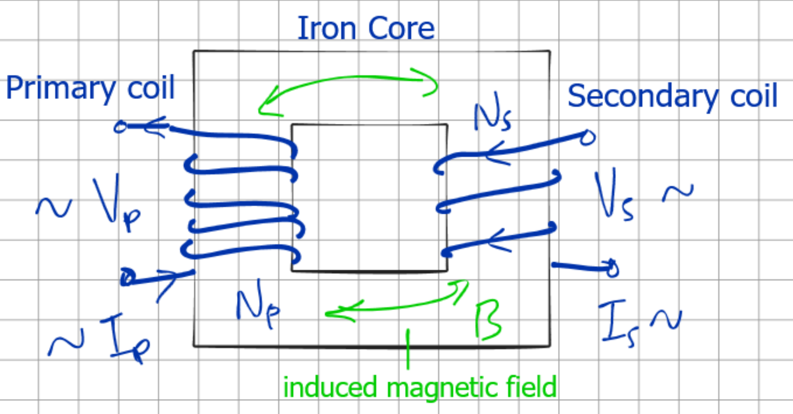
This force OPPOSES the motion of the conductor. This means when we turn a generator we experience a resistive force if the generator is part of a full circuit.

Transformers

12th March

A STEP UP transformer INCREASES POTENTIAL DIFFERENCE (and reduces current).

A STEP DOWN transformer does the opposite.



- Alternating p.d. across the primary coil creates a magnetic field that is changing direction around the coil and through the iron core.
- This means there is a changing magnetic field through the secondary coil. An alternating p.d. is induced across the coil.

The ratio of the p.d.s = the ratio of the number of turns

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

Assuming a transformer is 100% efficient then: power in = power out

$$\underbrace{V_p I_p}_{\text{power into primary}} = \underbrace{V_s I_s}_{\text{power out of secondary}}$$