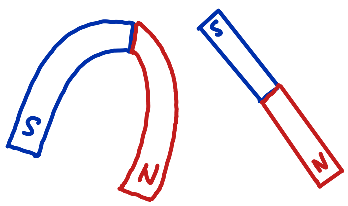
MAGNETIC FIELD

Definition

↳ A magnetic field is a region of space in which a magnetic pole will experience a force. Referred to as a B-field

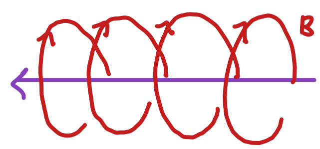
A magnetic field is created either by

↳ permanent / hard magnet



↳ temporary / soft magnet

(Moving electric charge)



Property of magnet

↳ same pole (repel)

↳ unlike charge (attract)

↳ atoms inside the material are align

* magnetism : A property of iron and certain other feromagnetic materials such as cobalt, nickel, gadolinium, alloy

Components that has voltage but no current flowing

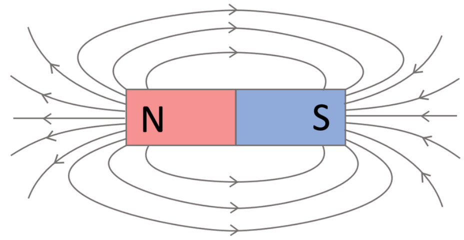
↳ battery

↳ capacitor

Comparison between magnetic fields and electric fields

Magnetic Fields (temporary)	Electric fields
Produced by current	Produced by voltage
Created when electric current flows: the greater the current, the stronger the magnetic field	Created by differences in voltage: the higher the voltage, the stronger will bet he resultant field
If a current does flow, the strength of the magnetic field will vary with the power consumption	An electric field will exist even when there is no current flowing.
Measured in gauss (G) @ Tesla (T), 1 T = 1×10^4 G	Measured in volts per meter (V/m) @ N/C
Not easily shielded (weakened)	Easily shielded (weakened) by conducting objects, such as metal, trees and buildings

Magnetic field lines

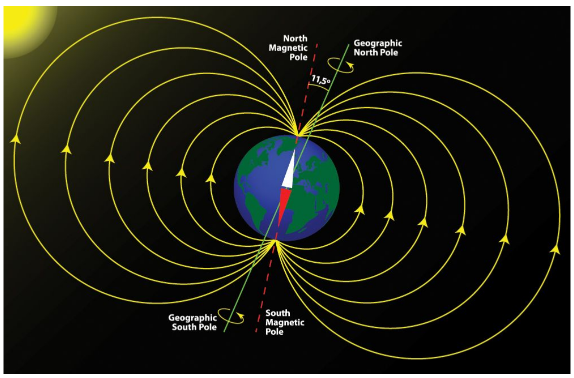


↳ point from north pole to south pole

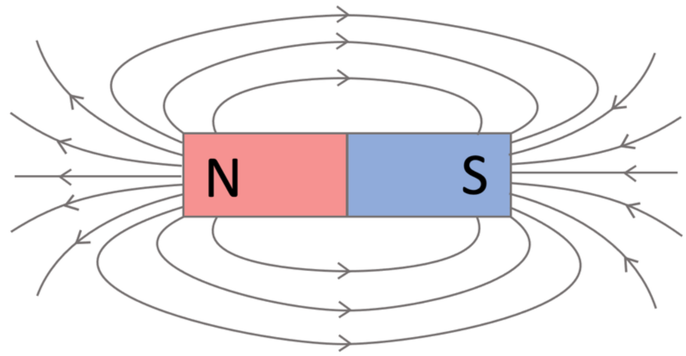
↳ density of lines = strength of the field

Magnetic Field Pattern

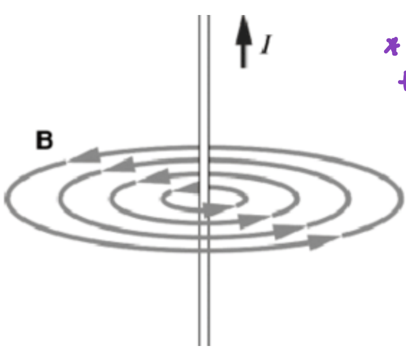
1. Earth magnetic pole



2. Magnet bar (permanent)

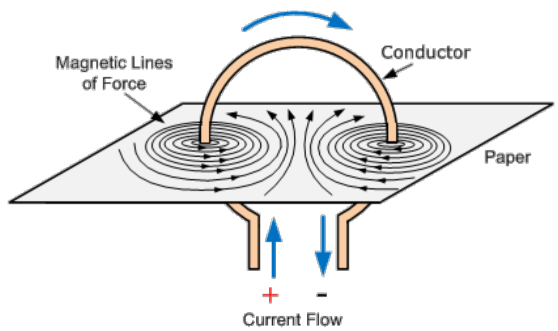


3. Along a straight wire-carrying current

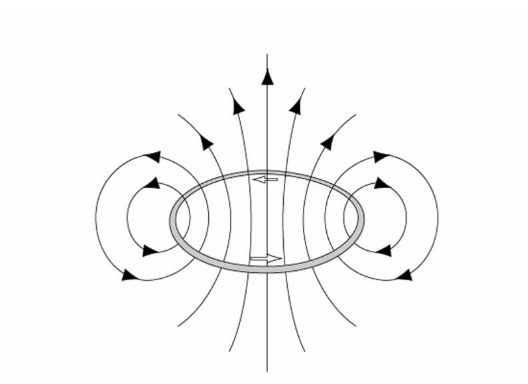


* determine by the right-hand rule

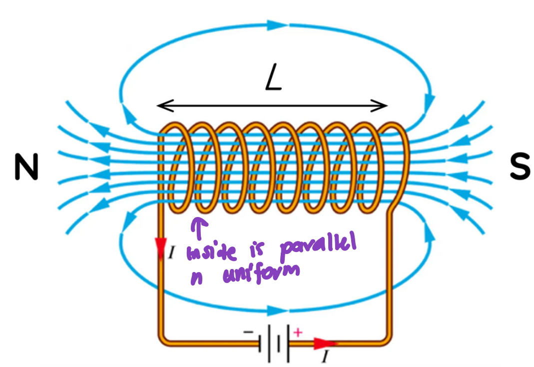
4. Current in a single loop



5. Flat circular coil



6. Solenoid



* MF inside of solenoid can be increased by:

↳ Increase current flow

↳ Increase number of coil

↳ Insert soft iron core in the coil

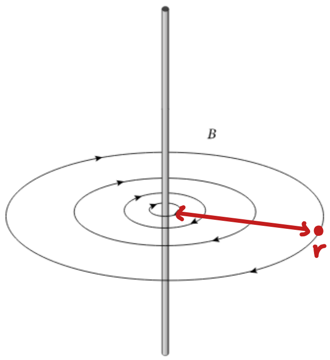
Differences between magnetic and electric field

- A magnet does not feel a force when placed in an electric field.
- A positive charge does not feel a force when placed stationary in a magnetic field.
- Isolated charges exist whereas isolated poles do not.
- The Earth itself has a magnetic field. It turns out to be similar to that of a bar magnet with a magnetic South pole near the geographic North pole

Magnetic Field, B

1. Due to a straight wire

↳ The field pattern around a long straight wire shows that as one moves away from the wire, the strength of the field get weaker



$B \propto I$

$B \propto \frac{1}{r}$ (If distance away doubled the magnetic field will halved)

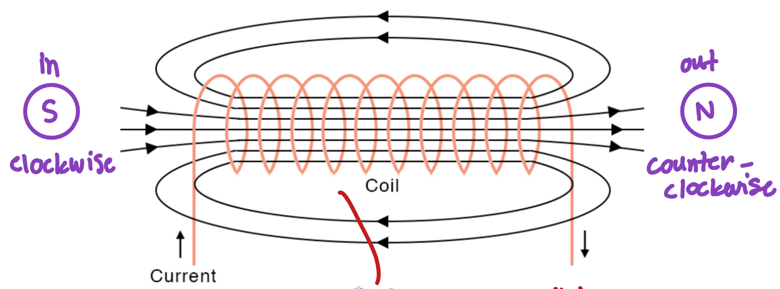
* The field also depends on the medium around the wire

$B = \frac{\mu_0 I}{2\pi r}$ (μ_0 - permeability of free space $= 4\pi \times 10^{-7}$ Tm/A)

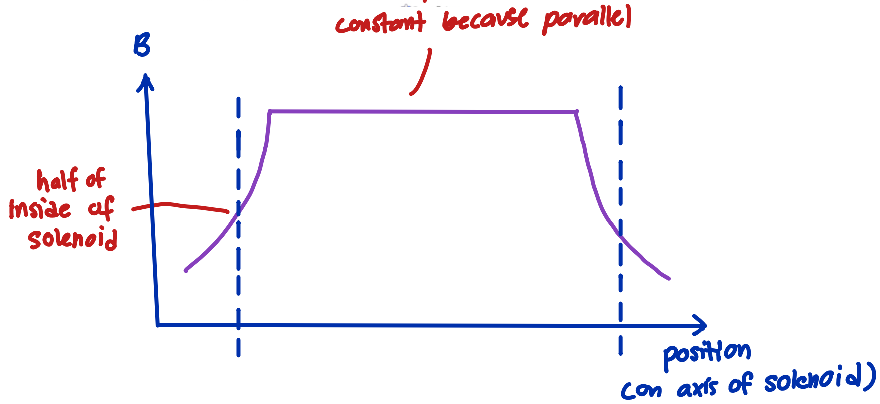
2. In solenoid

↳ Behave like permanent magnet bar, the magnetic field inside the solenoid is constant

$B = \mu n I$



constant because parallel



↳ The strength of magnetic field, B at any point inside a solenoid of length l with N (number of turns carrying current) given by:

$B = \mu_0 \left(\frac{N}{l}\right) I$ @ $B = \mu_0 n I$, $n = \left(\frac{N}{l}\right)$

* N is the number of turns

Magnetic Force in a current-carrying conductor

Definition of Magnetic force on a current-carrying wire

↳ The force experienced by a wire carrying current in a magnetic field, perpendicular to both the current and the magnetic field.

↳ The wire experience force

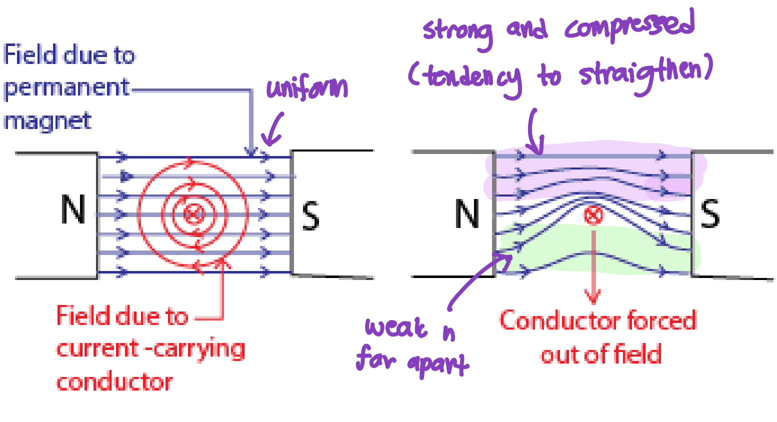
↳ known as the motor effect

↳ This is the principle behind the operation of all electric motors

↳ Electrical energy → mechanical energy

Motor effect

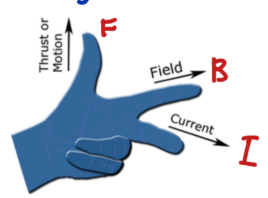
↳ A conductor carrying an electric current may experience a force when placed in a magnetic field.



(a) Individual fields

(b) Combined field causing force on conductor

Flemming left-hand rule



To increase the force:

↳ Increase the current

↳ Increase the number of coils

↳ Increase the strength of magnet

↳ Increase length of conductor in the field

To reverse the force:

↳ reverse direction of the force

↳ reverse direction of the (permanent) magnet

* note: conductor parallel to the field, nothing happen (tak cut)

$F = BIL \sin\theta \Rightarrow B = \dfrac{F}{IL \sin\theta}$

L - length of the current

θ - angle between the force and current

I - current

↳ Direction of F is always ⊥ to the direction of the current and also perpendicular to the direction of the magnetic field, B

If $\theta = 90°$, then $F_{max} = ILB$

If $\theta = 0°$, then $F = 0$

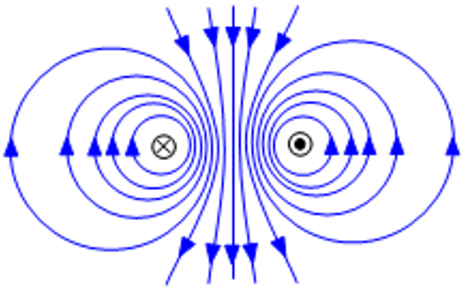
↳ SI unit for B is Tesla (T)

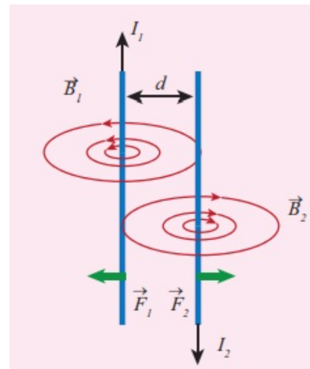
↳ T defined to be equal to $1\ N A^{-1} m^{-1}$ @ $1\ T = 1\ Wbm^{-2}$ (weiber - unit of flux)

↳ Cgs [cm gs] unit : Gauss (G), $1\ G = 1 \times 10^{-4}\ T$ (used by the Brits)

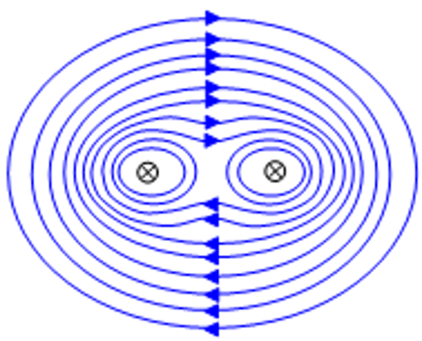
Magnetic Force between 2 parallel Conductors

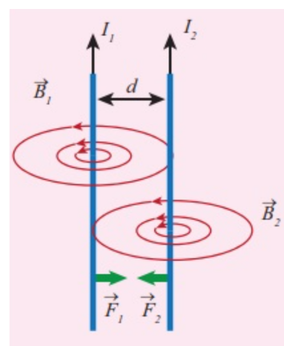
1) Opposite direction





2) Same direction





Parallel wires carrying currents exert forces on each other due to their magnetic fields. This force can be either repulsive or attractive

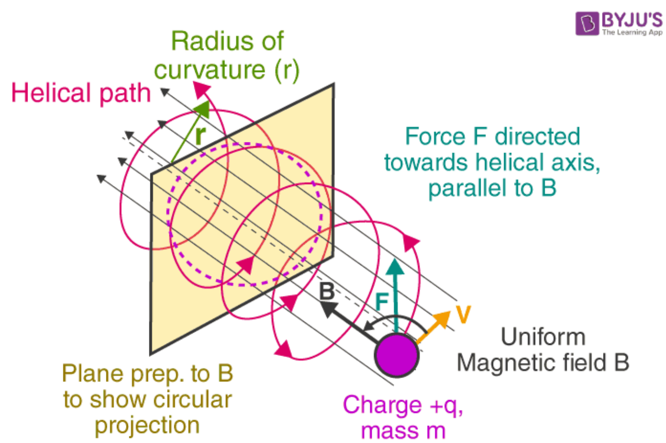
- ↳ The force per unit length is given by $\frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi r}$
- ↳ Attractive force when currents flow in the same direction
- ↳ Repulsive force when currents flow in the opposite direction

On a moving charge

↳ When a charged particle moves through a magnetic field, it experience a force that's always ⊥ to both its velocity and the magnetic field

Definition of Magnetic force on a moving charge

↳ The force experienced by a moving charged particle in a magnetic field



In this case, the force on a moving charge is proportional to:

↳ the magnitude of the magnetic field, B

↳ the magnitude of the charge, q

↳ the velocity of the charge, V

↳ the sine of the angle, θ, between the velocity of the charge and the field

so, $F = BqV \sin\theta \Rightarrow B = \frac{F}{qV\sin\theta}$

↳ When $\theta = 90°$, and $\vec{B}$ is uniform, the particle will undergo uniform circular motion.

↳ if $\theta = 0°$ (parallel to the field lines), $\therefore F = 0$

Radius of Circular Motion

↳ can be derived by equating the magnetic force to the centripetal force

$$r = \frac{mv}{qB}$$

Time Period of Circular Motion

$$T = \frac{2\pi m}{qB}$$

m - particle's mass

q - particle's charge

B - Magnetic field

* Doesn't depend on velocity

↳ Frequency of revolution

$$f = \frac{1}{T} = \frac{qB}{2\pi m}$$