# Electromagnetism

Day 17

# ILOs – Day 17

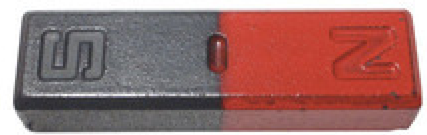
- Identify common characteristics of a magnet
- Identify the source of magnetism
- Define and understand magnetic field around a magnet
- Explain the magnetic field produced by a current carrying conductor
- Explain the magnetic field produced by a solenoid

# Magnets

- A piece of a magnet has two ends, termed as the **poles**, one of which is called a north pole (**N**), while the other is called a south pole (**S**)

# Common characteristics of a magnet

- Magnets can exist only in dipoles, i.e. it is not possible to have an isolated N pole or an isolated S pole; and the strengths of two poles of a magnet are same.




# Common characteristics of a magnet

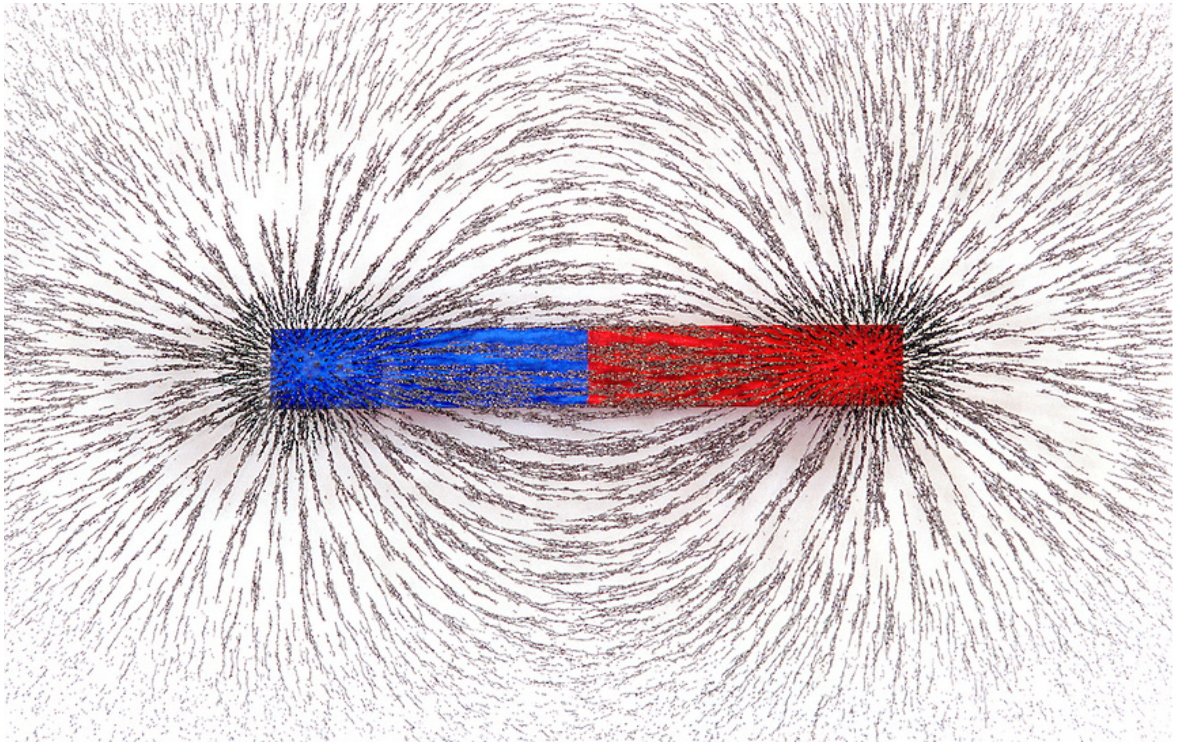
- Magnets always attract iron and its alloys (and other ferromagnetic materials such as nickel, cobalt, and alnico)

# Common characteristics of a magnet

- The north pole of one magnet attracts the south pole of a second magnet, while the north pole of one magnet repels the other magnet's north pole.
- So, the common saying is: like poles repel, while unlike poles attract each other

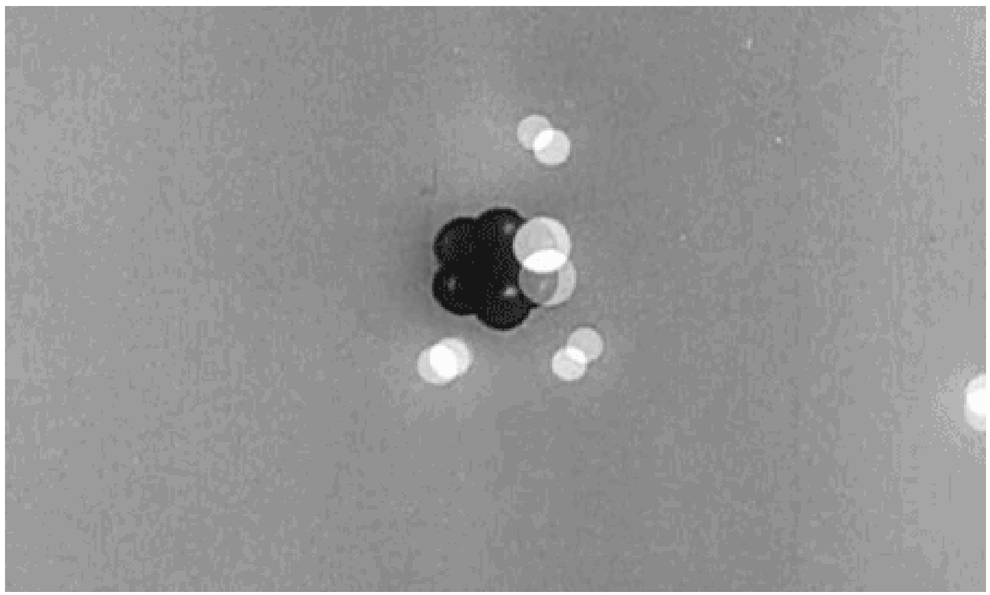
# Common characteristics of a magnet

- A magnet creates an invisible area of magnetism around it within which it exerts the force of attraction or repulsion.
- This region around the magnet where magnetic forces are present is called the **magnetic field**.



# Source of magnetism

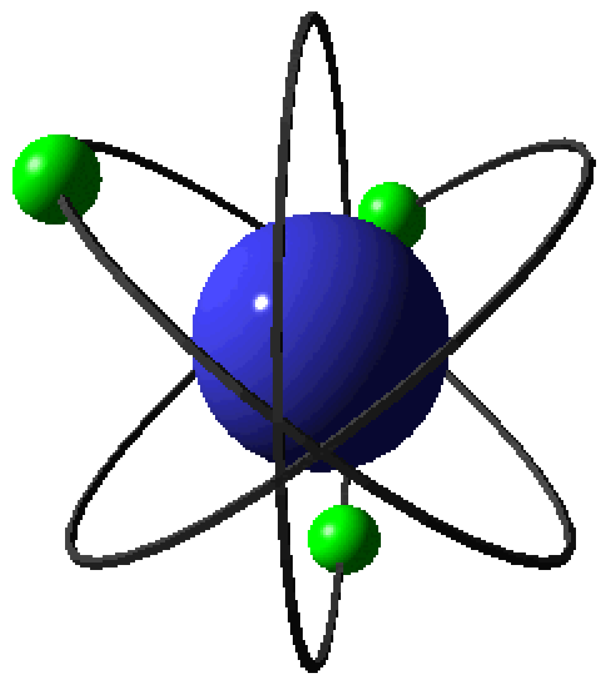
- As was discovered by H. C. Oersted in early 1800s, a moving electric charge always produces a magnetic field.
- In any material, be it a magnetic or non-magnetic, electrons orbit around the nucleus.



- Thus, due to movement of these electrons, magnetic field is produced.

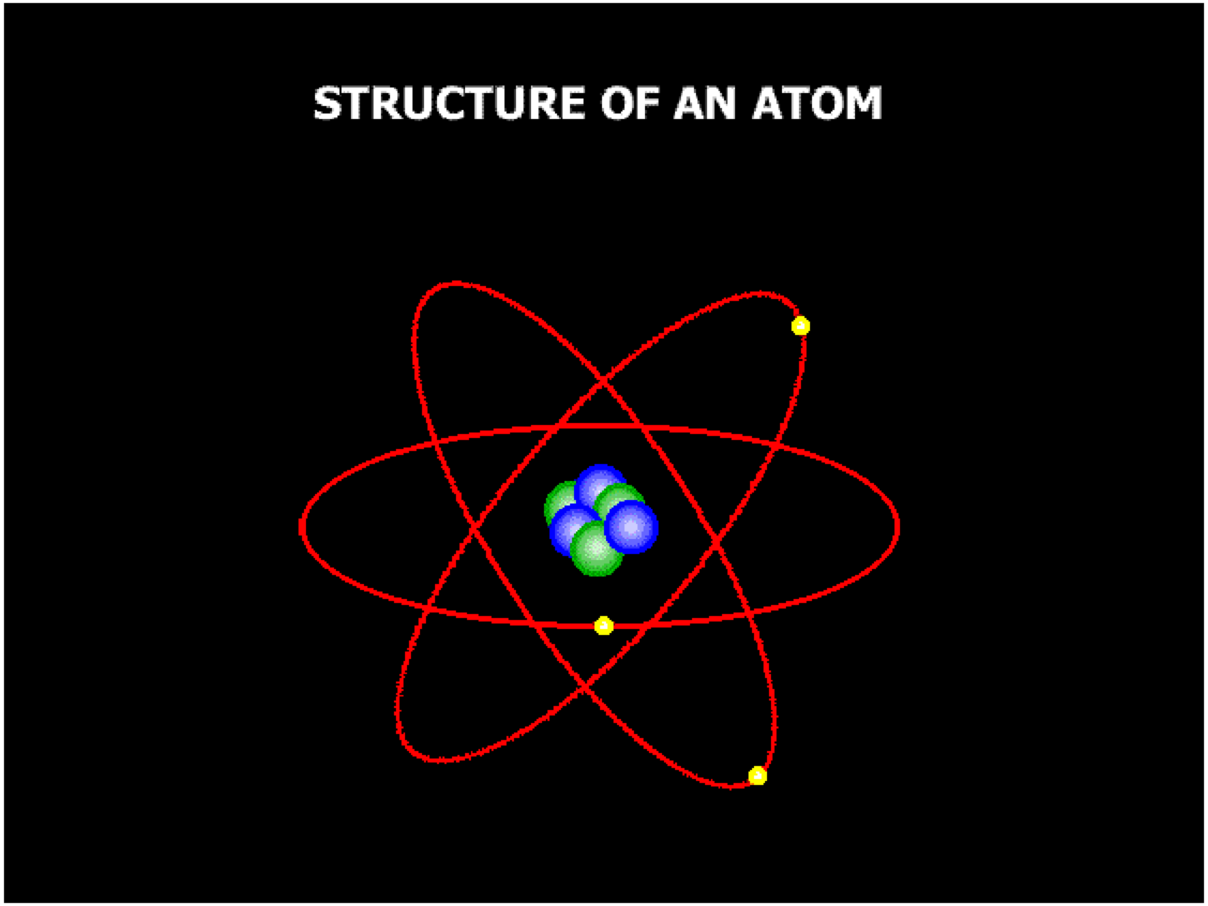
# Source of magnetism

- In certain non-magnetic materials where electrons are found to orbit in opposite  (or random) directions, their magnetic fields cancel out and the material does not display any resultant magnetic property.



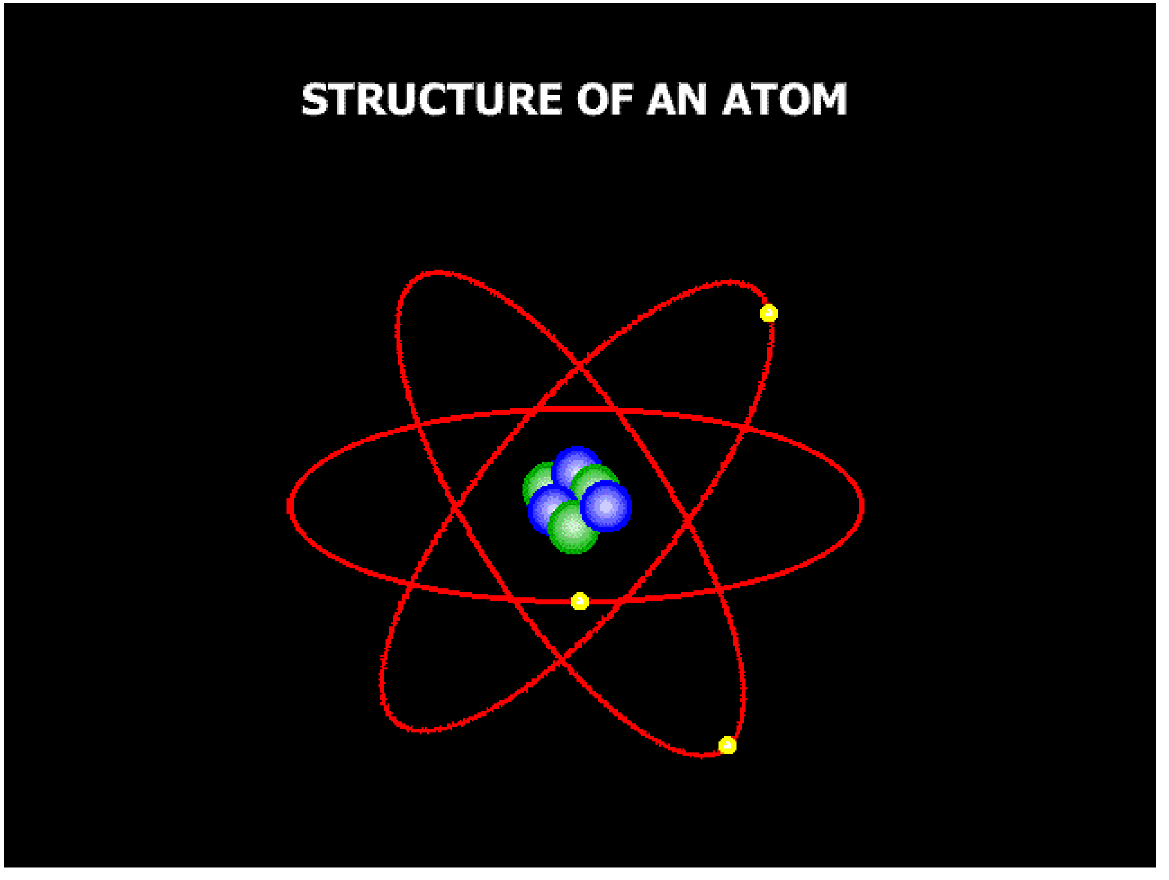
# Source of magnetism

- In some special magnetic materials, such as iron, the number of electrons orbiting in opposite directions is not same, thus producing an overall magnetic field.



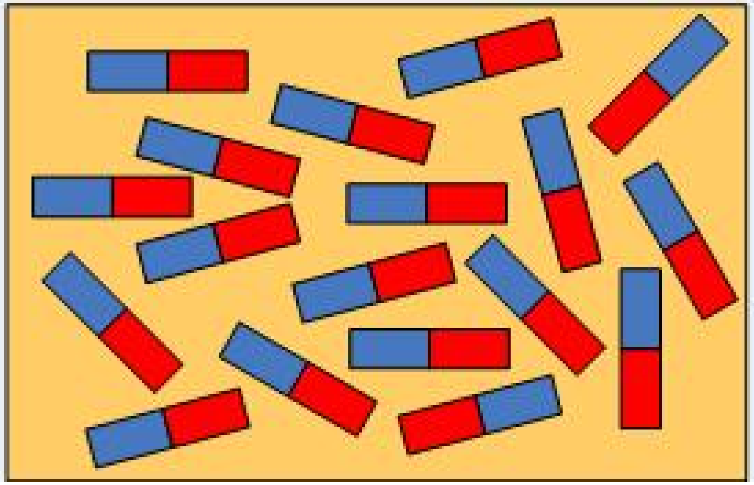
# Source of magnetism

- Each such small magnets produced inside the atom due to motion of each electron is called a magnetic **DOMAIN**.
- A block of iron will thus have a large number of such DOMAINs



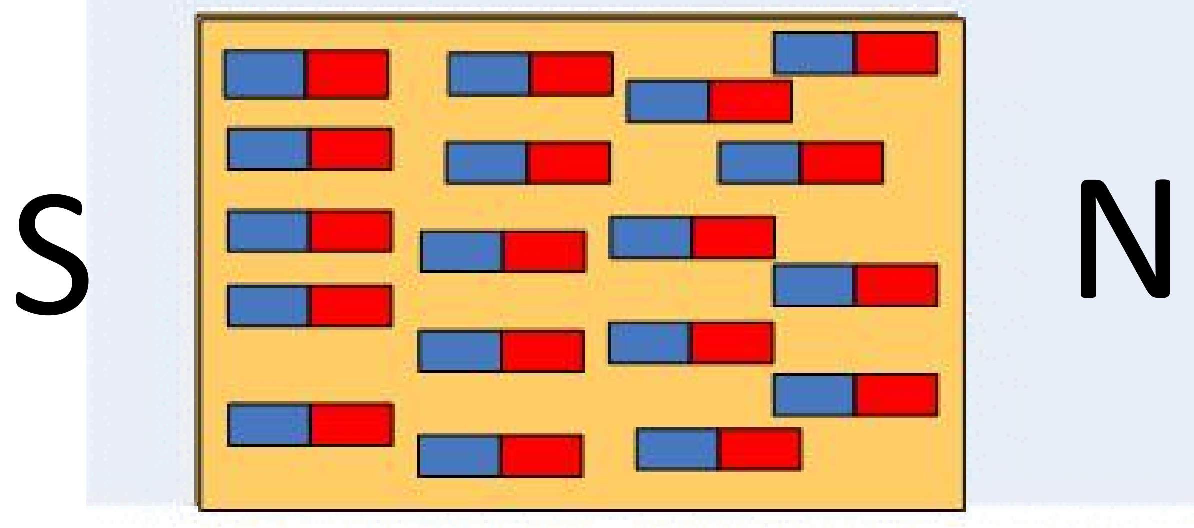
# Magnetization

- Initially un-magnetized piece of iron will have all its domains oriented randomly
- So that overall magnetic property is zero (or negligible)



# Magnetization

- As it is magnetized by an external force, all domains tend to align along the external force
- Thus overall magnetic property grows in the iron

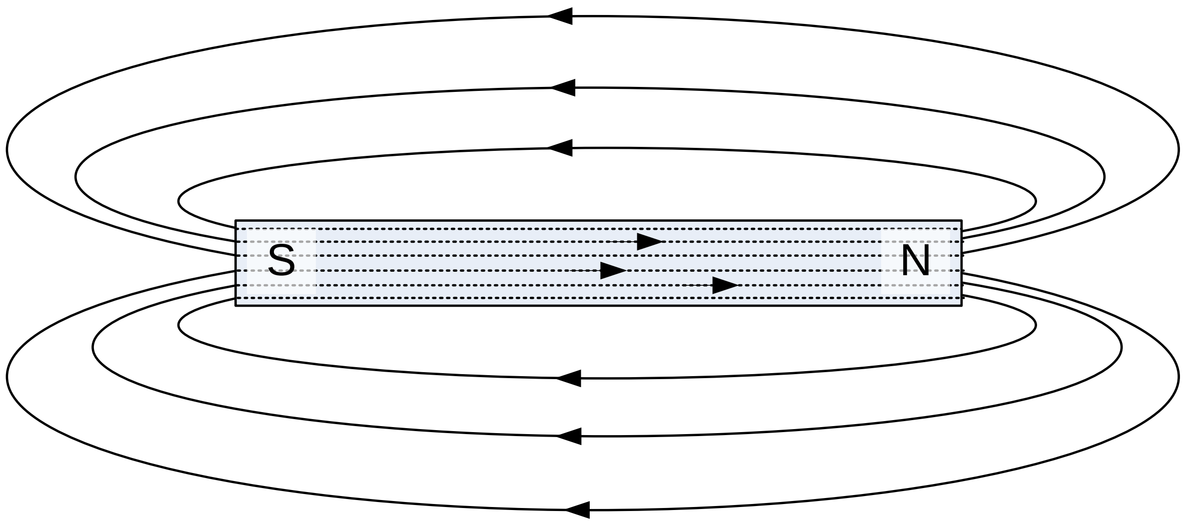


# Magnetic flux lines

- **Magnetic flux lines or magnetic lines of force** are the imaginary lines followed by a unit north pole placed in the magnetic field around a magnet
- These lines of force actually indicate the path along which a unit north pole will move under the force exerted by the magnet

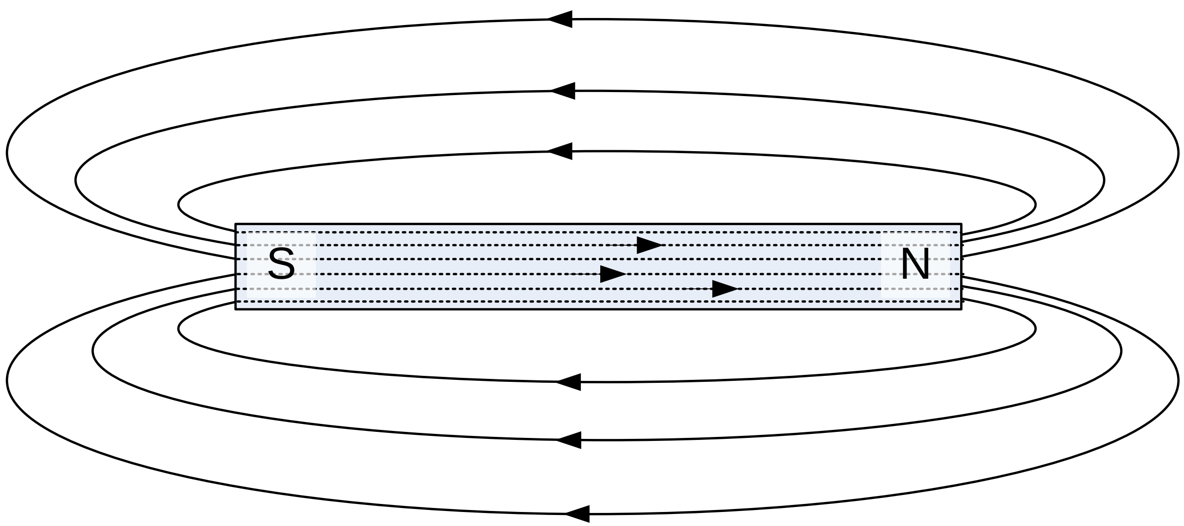
# Magnetic flux lines

- Magnetic flux lines move from N pole to S pole externally around the magnet
- and complete their closed path by passing through body of the magnet from S pole to N pole



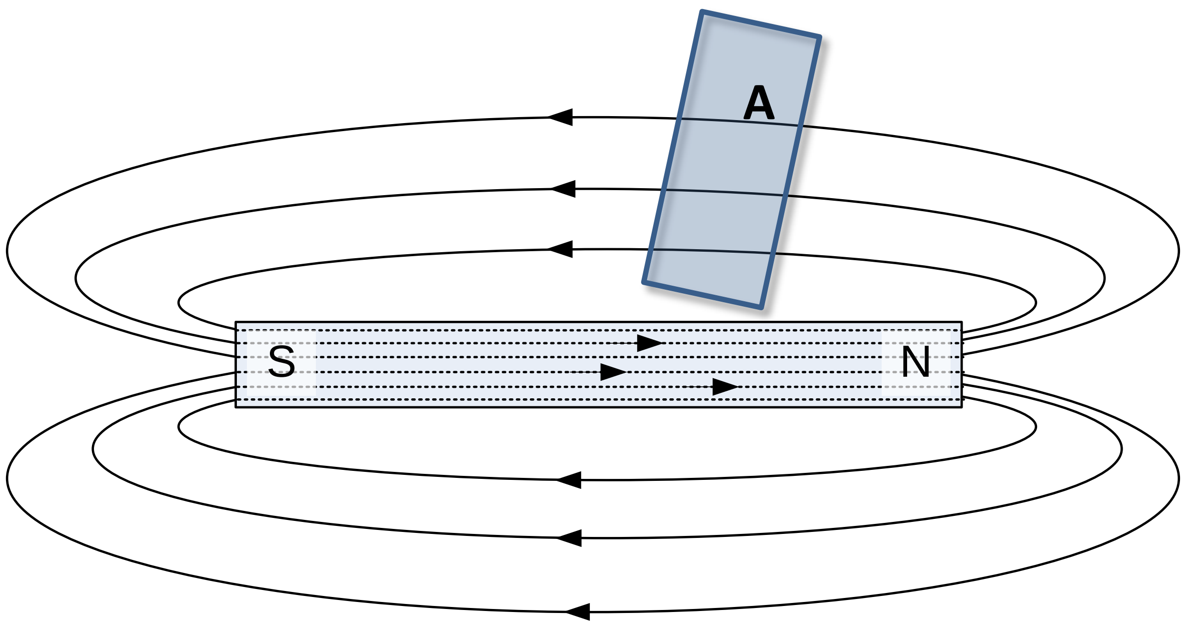
# Magnetic flux lines

- Arrowhead on the flux lines indicate the direction along which the unit north pole will travel under action of the magnet
- i.e. it indicates the **direction of force**
- Two such flux lines of a given magnet can never intersect each other (there can not be two different directions of forces)
- The number of such (imaginary) lines of force is called the total **magnetic flux** coming out of the magnet
- The unit of magnetic flux ($\phi$) is Weber [Wb]



# Magnetic flux density

- Magnetic flux density (B) is defined as the number of magnetic flux lines passing through per unit area (A) of any plane at right angles to the direction of flux.
- Magnetic flux density, also known as the *magnetic induction* is thus defined as: $$B = \frac{\phi}{A}$$
- Flux density is measured with the unit of $Wb/m^2$ or T*esla*.



# Magnetic field intensity

- Magnetic field intensity (H) at any point in the magnetic field around a magnet is defined as the force experienced by a unit North Pole placed at that point
- Magnetic field intensity (H) is also called the magnetizing force
- The unit of H is AT/m (Ampere-turns/length)
- It causes a certain value of flux density (B) to grow
- The magnetic flux density (B) and magnetic field intensity (H) are proportional, and can be expressed in free space (air or vacuum) as:

$$B = \mu_0 H$$

- Where, $\mu_0 = 4\pi\times10^{-7}$ H/m is the *magnetic permeability* of free space, or absolute permeability.

# Magnetic field intensity

- If the flux lines now pass through a material rather than free space, the magnetic flux density will attain a new value given by:

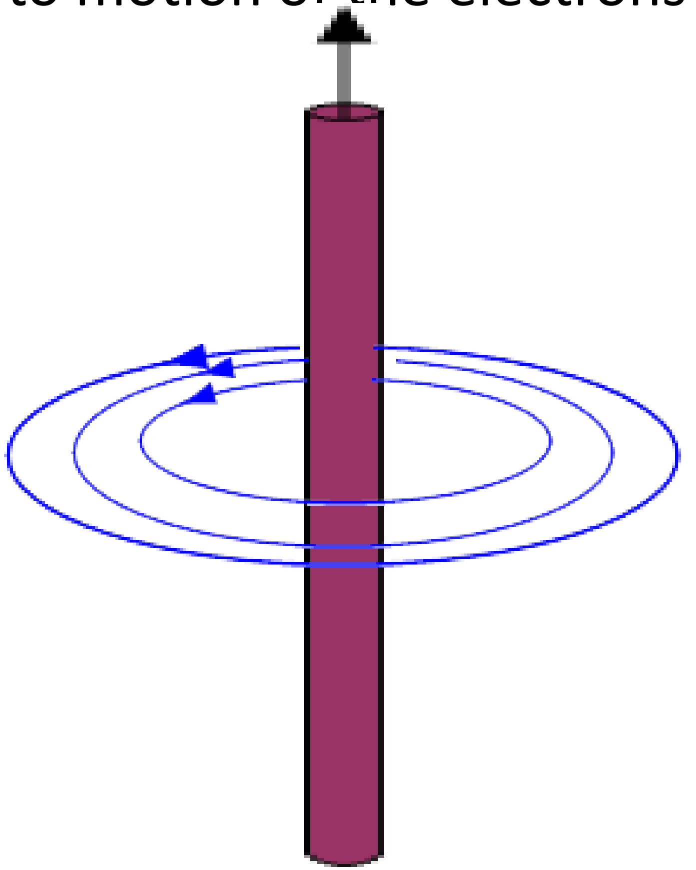
$$B = \mu_0 \mu_r H = \mu H$$

- $\mu_r$ is called the *relative permeability* of the material through which the flux is passing, and $\mu = \mu_0\mu_r$ is the effective permeability.
- The relative permeability $\mu_r$ thus indicates how good a material is in terms of its magnetic properties, i.e. how much it is *permeable* to magnetic flux
- The value of relative permeability $\mu_r = 1$ for free space (air or vacuum)
- It can have a value more than 1000 for magnetic materials like iron

# Magnetic field produced by a current carrying conductor

If electric current passes through a conductor, a magnetic field immediately builds up around it due to motion of the electrons through the conductor

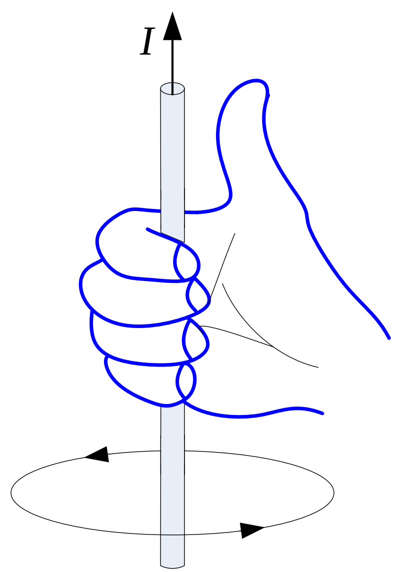
- Consider an infinitely long straight current carrying conductor
- The magnetic lines of force will be circular in shape
- Lying in a plane normal to the conductor
- Center of the circles being along axis of the conductor

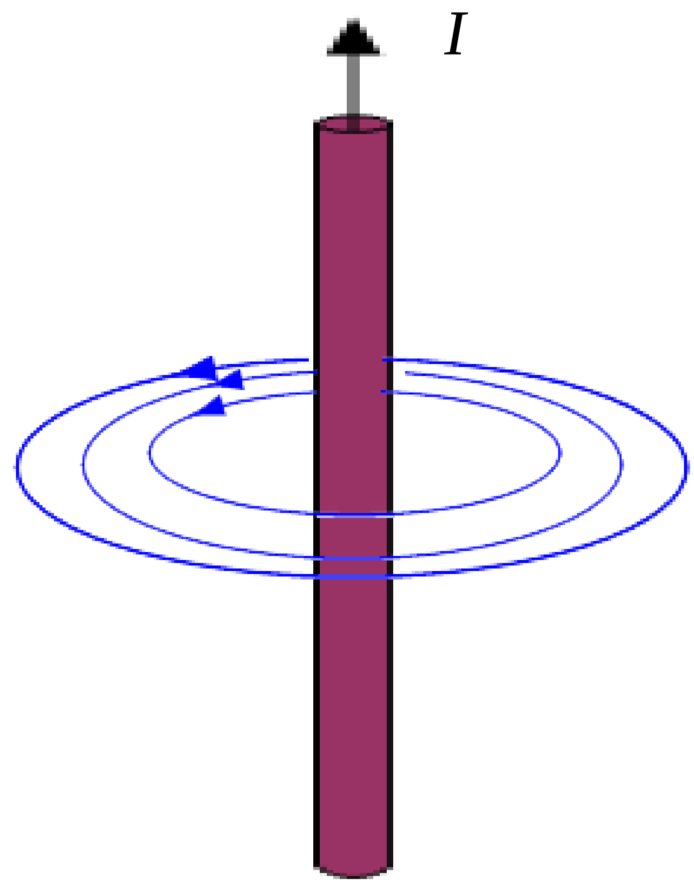


# Magnetic field produced by a current carrying conductor

The direction of lines of force, i.e. direction of the magnetic field around the conductor is determined by *right hand grip rule (or right hand thumb rule)*.

- Thumb along current
- Four fingers when bent around the conductor will point towards direction of magnetic field

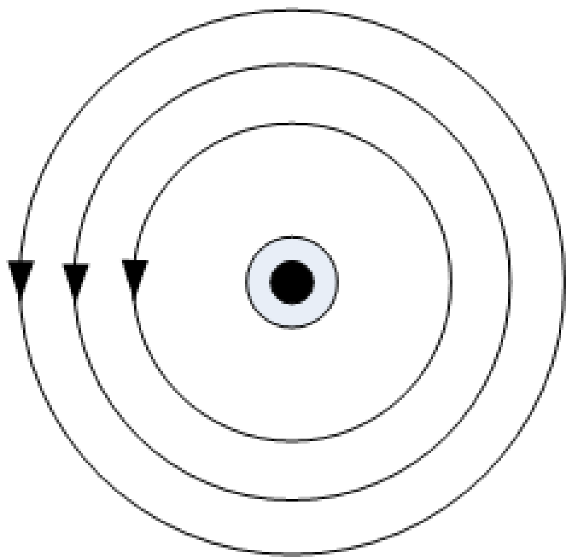


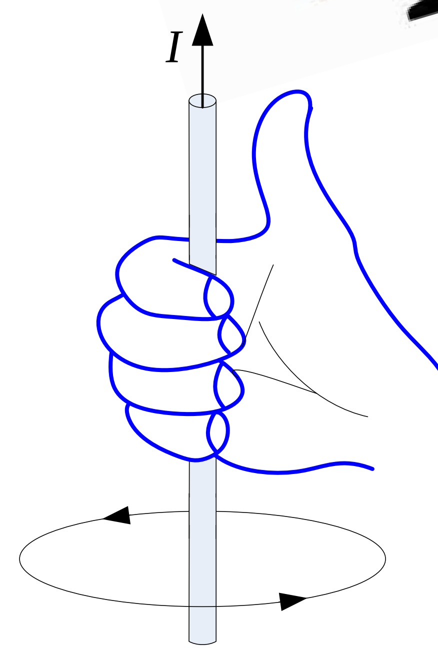



# Magnetic field produced by a current carrying conductor

**Top view**

- Current coming towards the viewer is denoted by “**dot**” – tip of an arrow

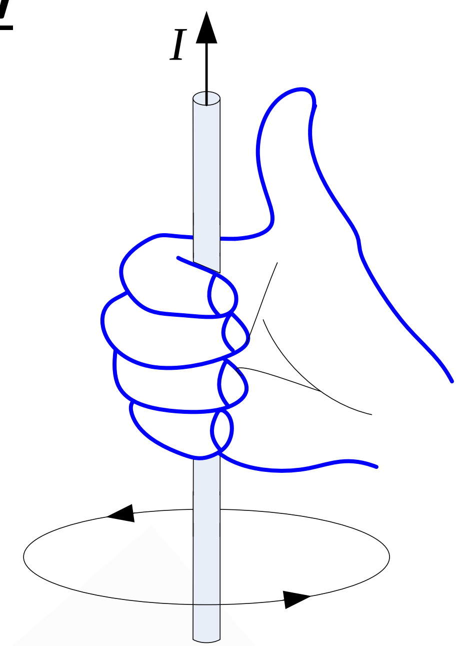




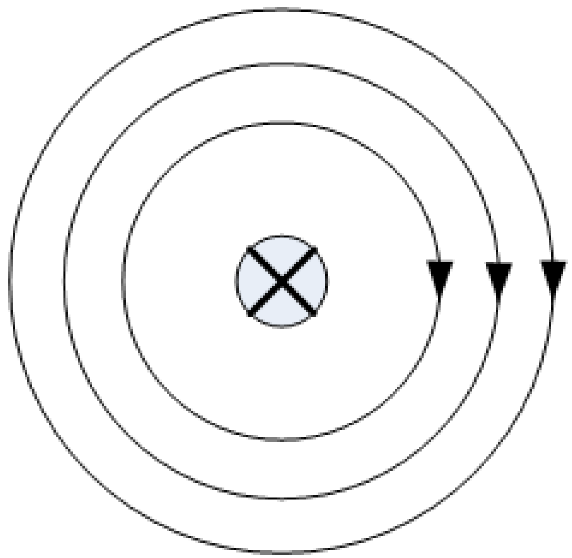

- Magnetic field is anti-clockwise

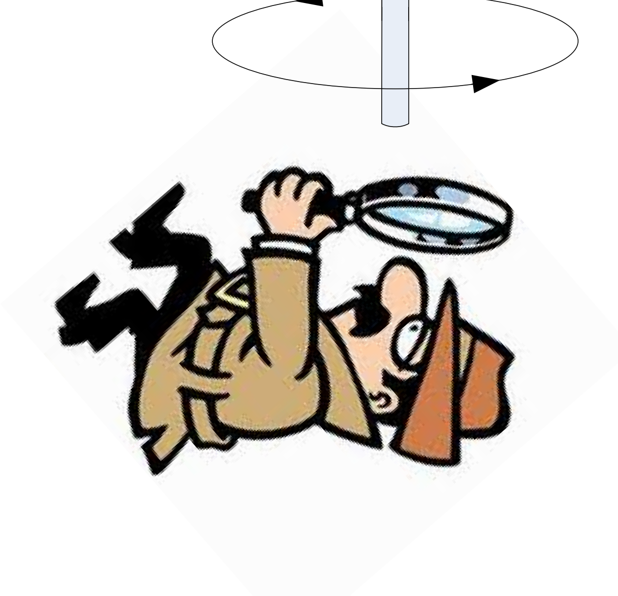
# Magnetic field produced by a current carrying conductor

**View from below**




- Current going away from the viewer is denoted by "**cross**" – tail of an arrow



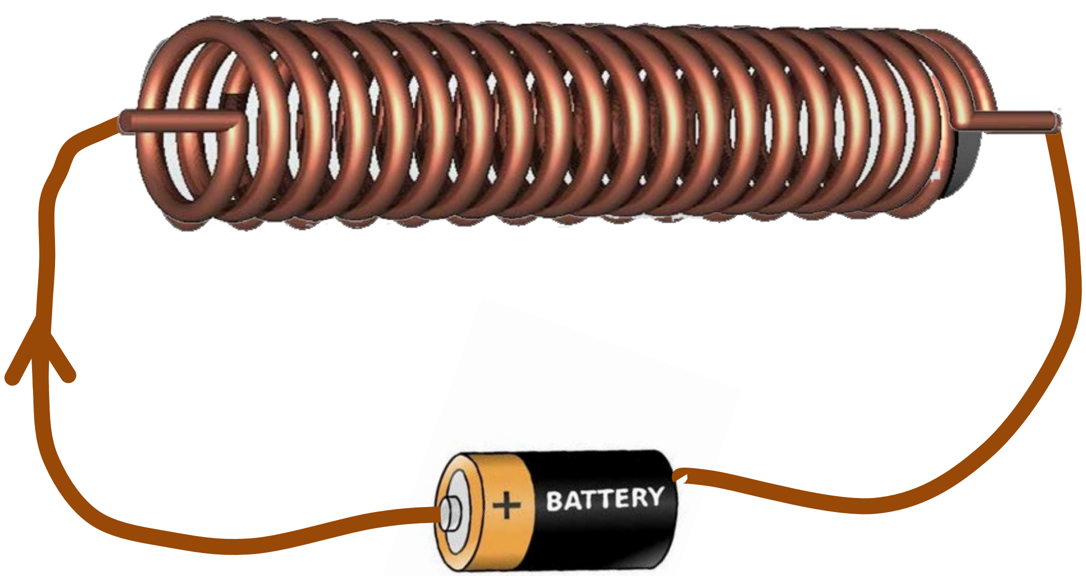


- Magnetic field is clockwise

# Electromagnet produced by a Solenoid

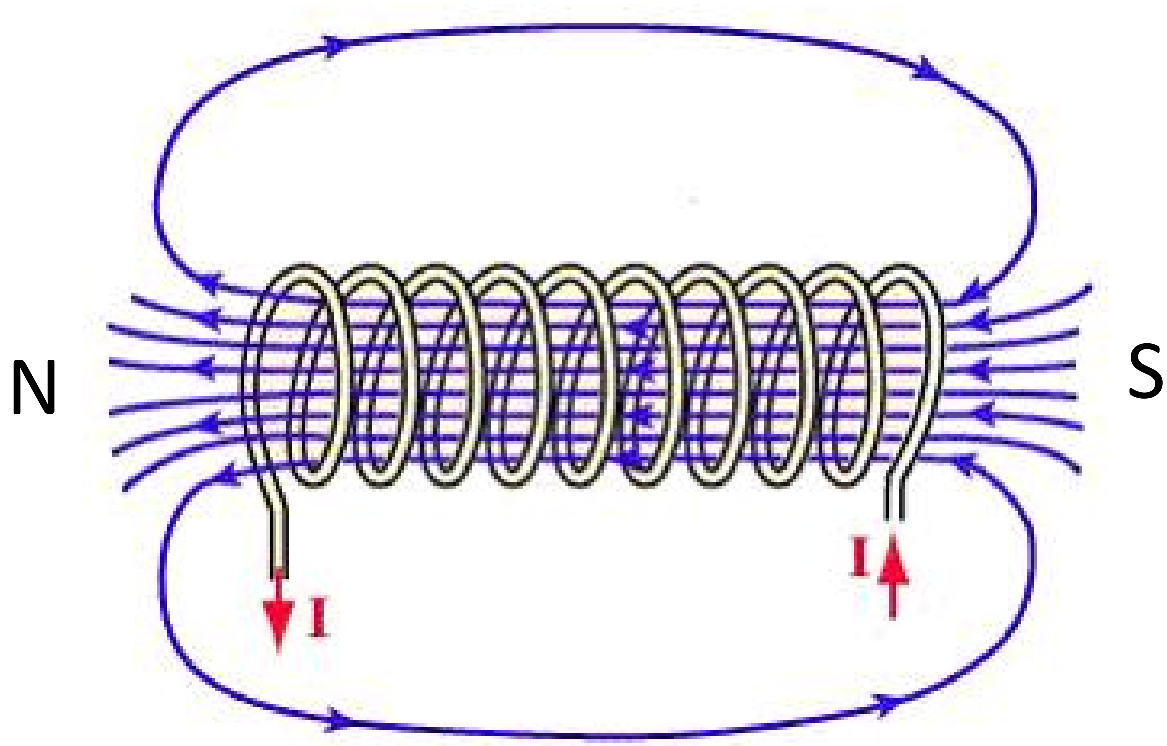
**Solenoid**

- When a conductor is wound spirally in the form of *helix* about an axis to give shape of a coil, its called a *solenoid*
- When current is passed through the coil, an electromagnet is produced
- When an iron rod is inserted in the coil, the magnetic strength increases



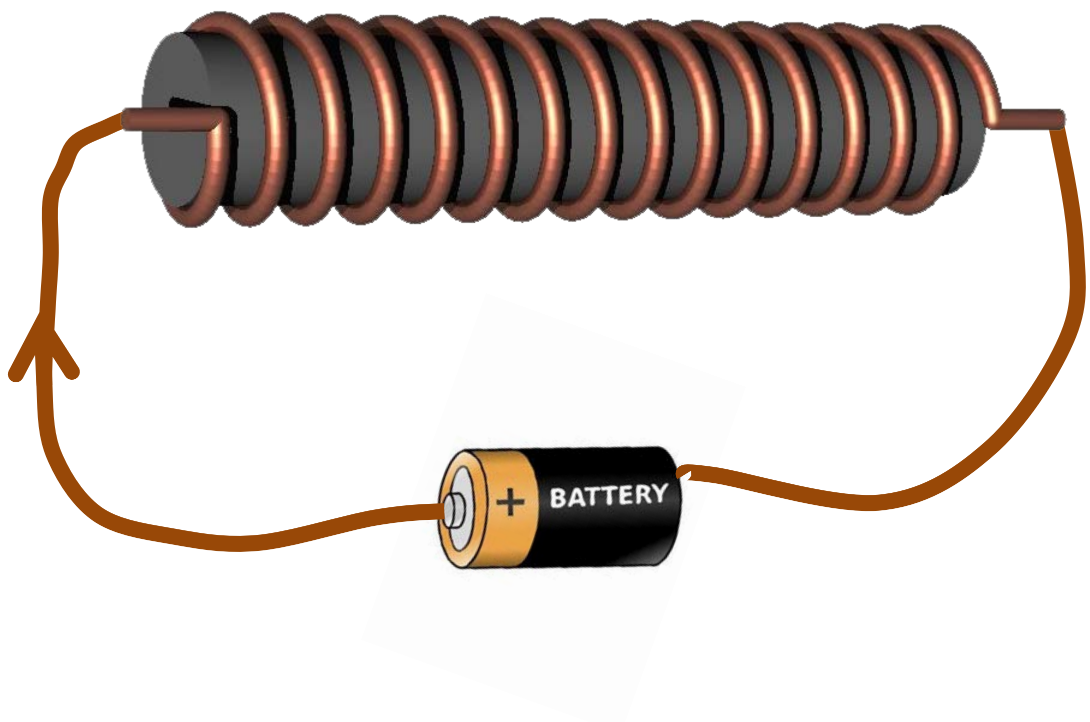
# Electromagnet produced by a Solenoid

- The solenoid acts like a bar magnet having two poles at its two ends - north pole at one end and south pole at the other end



# Electromagnet produced by a Solenoid

- Strength of the magnetic field can be increased by:
  - increasing the current in the coil
  - increasing the number of turns in the coil
  - using a soft iron core within the solenoid



# Electromagnet produced by a Solenoid

- Right-hand grip rule can be used to find the direction of the magnetic field
- Point the four wrapped fingers (along the coil) in the direction of current
- Then, the thumb will point to the direction of magnetic field created by the solenoid.