* Magnet fields require a *moving* charge, which produces the magnetic field
* Second current or moving charge responds to the magnetic field

**Magnetism**

**- Permanent Magnets** – Exert forces on each other as well as unmagnetized iron, which also becomes magnetized when in contact with a magnet

- Opposite poles attract, like poles repel

- Unmagnetized iron is attracted to either pole

- Earth is a magnet; geographic north is magnetic south, geographic south is magnetic north

- Magnetic field lines: Direction a compass would point at any point in the field

Magnetic Poles Versus Electric Charge

* Isolated magnetic poles cannot exist
* A magnetized body has coordinated motion of electrons
* Electric and magnetic interactions are closely related though

**Magnetic Field**

* Electric field:
  + Distribution of electric charge at rest creates electric field in surrounding space
  + Electric field exerts force on any other charge present in field
* Magnetic field:
  + Moving charge/current creates magnetic field in surrounding space
  + Exerts force F on any other moving charge or current present in field

Magnetic field is also a vector field.

Magnetic Forces on Moving Charges

4 key characteristics:

* 1) Magnitude proportional to magnitude of charge
* 2) Magnitude of force proportional to strength of field
* 3) Magnetic force depends on particles velocity
* 4) Magnetic force is always perpendicular to magnetic field B and velocity v.

Right Hand Rule:

1. velocity and magnetic field vectors are placed tail to tail
2. V rotates toward B through smaller angle
3. Curl fingers in direction of the rotation. The direction of your thumb is direction force acts in

* Force is opposite direction for negative charge
* Units are Tesla = 1T = 1N/A(m) or Gauss = 10^-4 Tesla or magnetic field of earth

Measuring Magnetic Fields With Test Charges

* Deflection of an electron beam shows the strength of a magnetic field
* Direction and magnitude of deflection determine direction and magnitude of magnetic field
* It is possible for both a magnetic and electric field to exert force on a particle

**Magnetic Field Lines and Magnetic Flux**

* magnetic field lines used to represent any magnetic field
* Line through any point is tangeant to the magnetic field vector at that point
* When field lines are close, magnitude large
* Field lines never intersect
* They do NOT point in direction of force, which is always perpendicular to the magnetic field
* Direction of force depends on velocity and sign of charge of the particle going through the magnetic field
* Dot used for going out of the plane, cross used to represent going into the plane

Magnetic Flux and Gauss’s Law for Magnetism

**-Magnetic flux** through surface defind same as electric flux.

- Look at elements of the magnetic field vector that are perpendicular to the surface.

- Magnetic flux is scalar.

- Unit is Weber = 1T(m^2)

- Since there is no magnetic monopole, **The total magnetic flux through a closed surface is always zero.**

- Magnetic field lines have no ends. They continue through the material and create a closed loop

- For magnetism, Gauss’s law can often apply to open surfaces with boundary lines

**Motion of Charged Particles in a Magnetic Field**

* Because force always perpendicular to v, the force can’t change the magnitude of velocity, only the direction
* Magnetic force never has component parallel to particle motion
* **Motion of charged particle under action of magnetic field always has constant speed**
* Number of revolutions per unit time is called **cyclotron frequency**
* If there is a velocity component parallel to the field, it remains constant
* Non-uniform magnetic field can create magnetic bottle which traps particles, similar to that of the earth.

**Applications of Motion of Charged Particles**

Velocity Selector

* Charged particles of different velocities enter electric and magnetic fields that are parallel
* For particular value v, the magnetic and electric forces will be equal

Mass Spectrometers

* Ions pass through velocity selector first
* Ions then pass through magnetic field that is perpendicular to the figure
* Different mass ions strike detector at different points based on radius R
* This leaves mass m as only unknown

**Magnetic Force on a current-carrying Conductor**

* Magnets exert force on all moving charges
* Magnet field lines are directed into plane that a wire resides on
* We calculate the totalforce on all the moving charges in a wire of length l.
* This simplifies to current(length) x magnetic field
* Integrals can be used if the line isn’t straight
* These equations are valid for both positive and negative charges, because the signs cancel out

**Force and Torque on a Current Loop**

* The total force acting on a current loop is zero, but there can be a net torque
* In a uniform electric field, the current will travel in opposite directions in the loop and the forces will cancel each other out
* Torque varies depending on magnet fields position within the loop
* IA is **magnet dipole moment**

Magnetic Torque: Vector Form

* Magnetic torque can also be defined in vector form
* Torque vector is always perpendicular to the plane of the loop and uses right hand rule based on direction of current flow around the loop

Potential Energy for a Magnetic Dipole

* If a magnetic dipole changes orientation, the field does work on it.
* Work is a product of torque times difference in angle, and potential energy changes
* Torque for electric dipole matches equation for that of magnetic dipole