

Lorentz force, the force exerted on a charged particle q moving with velocity v through an electric E and magnetic field B . The entire electromagnetic force F on the charged particle is called the Lorentz force (after the Dutch physicist Hendrik A. Lorentz) and is given by

$$F = qE + qv \times B.$$

The first term is contributed by the electric field. The second term is the magnetic force and has a direction perpendicular to both the velocity and the magnetic field. The magnetic force is proportional to q and to the magnitude of the vector cross product $v \times B$. In terms of the angle ϕ between v and B , the magnitude of the force equals $qvB \sin \phi$. An interesting result of the Lorentz force is the motion of a charged particle in a uniform magnetic field. If v is perpendicular to B (i.e., with the angle ϕ between v and B of 90°), the particle will follow a circular trajectory with a radius of $r = mv/qB$. If the angle ϕ is less than 90° , the particle orbit will be a helix with an axis parallel to the field lines. If ϕ is zero, there will be no magnetic force on the particle, which will continue to move undeflected along the field lines.

Charged particle accelerators like cyclotrons make use of the fact that particles move in a circular orbit when v and B are at right angles. For each revolution, a carefully timed electric field gives the particles additional kinetic energy, which makes them travel in increasingly larger orbits. When the particles have acquired the desired energy, they are extracted and used in a number of different ways, from fundamental studies of the properties of matter to the medical treatment of cancer.

The magnetic force on a moving charge reveals the sign of the charge carriers in a conductor. A current flowing from right to left in a conductor can be the result of positive charge carriers moving from right to left or negative charges moving from left to right, or some combination of each. When a conductor is placed in a B field perpendicular to the current, the magnetic force on both types of charge carriers is in the same direction. This force gives rise to a small potential difference between the sides of the conductor. Known as the Hall Effect, this phenomenon (discovered by the American physicist Edwin H. Hall) results when an electric field is aligned with the direction of the magnetic force. The Hall Effect shows that electrons dominate the conduction of electricity in copper. In zinc, however, conduction is dominated by the motion of positive charge carriers. Electrons in zinc that are excited from the valence band leave holes, which are vacancies (i.e., unfilled levels) that behave like positive charge carriers. The motion of these holes accounts for most of the conduction of electricity in zinc.

If a wire with a current i is placed in an external magnetic field B , how will the force on the wire depend on the orientation of the wire? Since a current represents a movement of charges in the wire, the Lorentz force acts on the moving charges. Because these charges are bound to the conductor, the magnetic forces on the moving charges are transferred to the wire. The force on a small length dl of the wire depends on the orientation of the wire with respect to the field. The magnitude of the force is given by $idlB \sin \phi$, where ϕ is the angle between B and dl . There is no force when $\phi = 0$ or 180° , both of which correspond to a current along a direction parallel to the field. The force is at a maximum when the current and field are perpendicular to each other. The force is given by

$$dF = idl \times B.$$

Again, the vector cross product denotes a direction perpendicular to both dl and B .