Brief Note on Magnetic Fields in Applied Physics

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Commentary

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ABOUT THE STUDY

A magnetic field is a vector field that describes the magnetic influence on moving electric charges, currents, and magnetic materials. A moving charge in a magnetic field is subjected to a force that is perpendicular to both its own velocity and the magnetic field. The magnetic field of a permanent magnet attracts or repels other magnets and pulls on ferromagnetic materials such as iron. Furthermore, a varying magnetic field exerts a force on a variety of nonmagnetic materials by influencing the motion of their outer atomic electrons. Magnetic fields envelop magnetized materials and are generated by electric currents such as those used in electromagnets and by time-varying electric fields. Because the strength and direction of a magnetic field vary with location, it is mathematically described by a function that assigns a vector to each point of space, known as a vector field. The term "magnetic field" refers to two distinct but closely related vector fields denoted by the symbols B and H in electromagnetics. H, magnetic field strength, is measured in SI base units of ampere per meter (A/m) in the International System of Units.

Magnetic flux density (B) is measured in tesla (in SI base units: kilogram per second^2 per ampere), which is equivalent to newton per meter per ampere. The way H and B account for magnetization differs. Moving electric charges and the intrinsic magnetic moments of elementary particles associated with a fundamental quantum property, their spin, generate magnetic fields. Magnetic and electric fields are inextricably linked and are both components of the electromagnetic force, one of nature's four fundamental forces. Magnetic fields are used in many areas of modern technology, most notably electrical engineering and electro mechanics. Electric motors and generators both use rotating magnetic fields. Magnetic circuits are used to conceptualize and investigate the interaction of magnetic fields in electric devices such as transformers. The Hall Effect, which is caused by magnetic forces, provides information about the charge carriers in a material. The Earth generates its own magnetic field, which protects the Earth's ozone layer from solar wind and is important in navigation. The force on an electric charge is determined by its location, speed, and direction; two vector fields are used to describe this force. The first is the electric field, which describes the force acting on a stationary charge and gives the component of the force that is independent of motion. The magnetic field, on the other hand, describes the component of force that is proportional to both the speed and direction of charged particles. The field is defined by the Lorentz force law and is perpendicular to both the charge's motion and the force it experiences at any given instant. A set of magnetic field lines that follow the direction of the field at each point can be used to visualize the field. The lines can be built by taking measurements of the strength and direction of the magnetic field at a large number of points (or at every point in space). Then, at each location, draw an arrow (called a vector) pointing in the direction of the local magnetic field, with a magnitude proportional to the magnetic field's strength. By connecting these arrows, a set of magnetic field lines is formed. The magnetic field direction at any point is parallel to the direction of nearby field lines, and the local density of field lines is proportional to its strength. Several phenomena "display" magnetic field lines as if they were physical phenomena. Iron filings, for example, form lines that correspond to "field lines" when placed in a magnetic field. Magnetic field "lines" are also visible in polar auroras, where plasma particle dipole interactions produce visible streaks of light that align with the local direction of the Earth's magnetic field. Magnetic forces can be visualized using field lines as a qualitative tool. Magnetic forces in ferromagnetic substances such as iron and plasmas can be understood by imagining that field lines exert tension (like a rubber band) along their length and pressure perpendicular to their length on neighboring field lines.