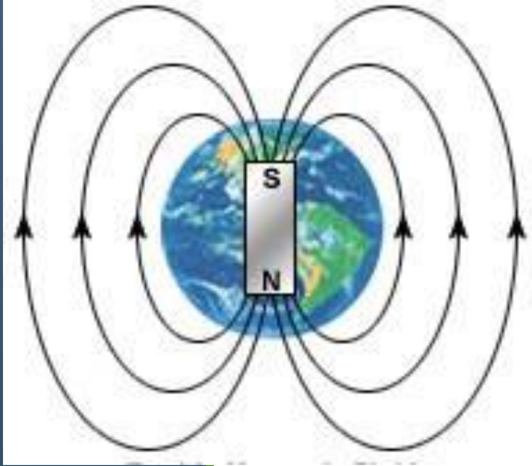
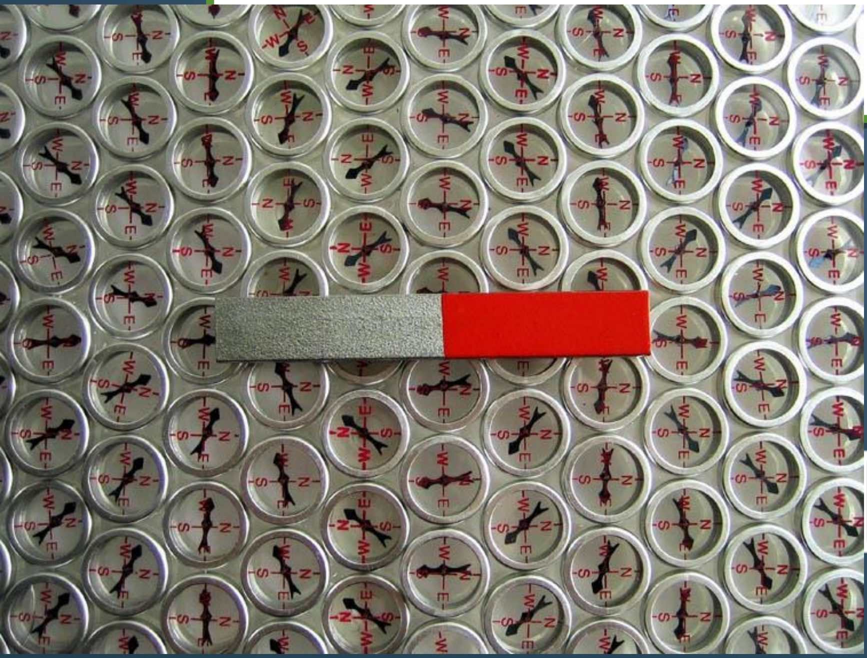
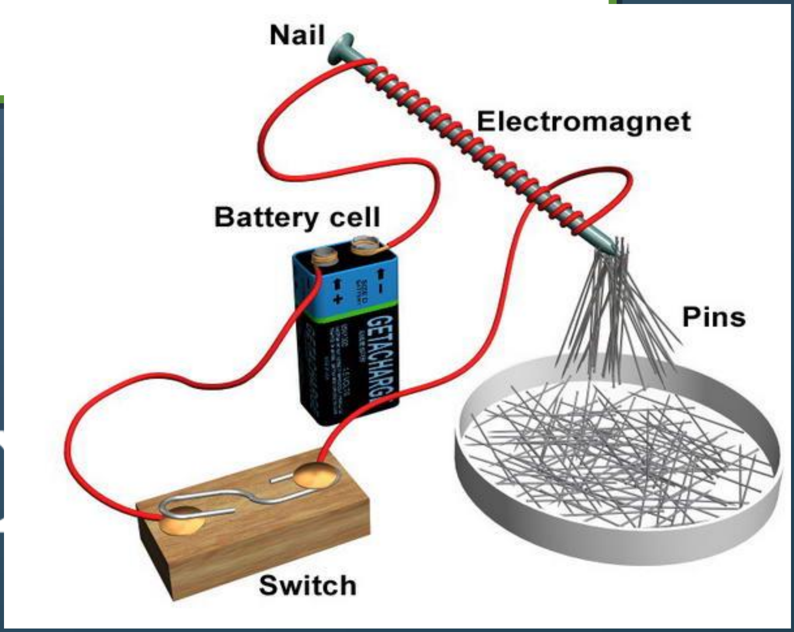


Chapter 28

Magnetic Fields





28-2 Magnetic Fields and the Definition of *B*

Learning Objectives

28.01 Distinguish an electromagnet from a permanent magnet.

28.02 Identify that a magnetic field is a vector quantity and thus has both magnitude and direction.

28.03 Explain how a magnetic field can be defined in terms of what happens to a charged particle moving through the field.

28.04 For a charged particle moving through a uniform magnetic field, apply the relationship between the force on the charge F_B, charge q, speed v, field magnitude B, and the angle Φ between the directions of the velocity vector v and the magnetic field vector B.

28.05 For a charged particle sent through a uniform magnetic field, find the direction of the magnetic force F_B by (1) applying the right-hand rule to find the direction of the cross product $\boldsymbol{v}\times\boldsymbol{B}$ and (2) determining what effect the charge q has on the direction.

28-2 Magnetic Fields and the Definition of *B*

Learning Objectives (Contd.)

28.06 Find the magnetic force F_B acting on a moving charged particle by evaluating the cross product $q\,(\boldsymbol{v}\times\boldsymbol{B})$ in unit-vector notation and magnitude-angle notation.

28.07 Identify that the magnetic force vector F_B must always be perpendicular to both the velocity vector ***v*** and the magnetic field vector ***B***.

28.08 Identify the effect of the magnetic force on the particle's speed and kinetic energy.

28.09 Identify a magnet as being a magnetic dipole.

28.10 Identify that opposite magnetic poles attract each other and like magnetic poles repel each other.

28.11 Explain magnetic field lines, including where they originate and terminate and what their spacing represents.

28-4 Crossed Fields: Discovery of The Electron

Learning Objectives

28.12 Describe the experiment of J. J. Thomson.

28.13 For a charged particle moving through a magnetic field and an electric field, determine the net force on the particle in both magnitude-angle notation and unit-vector notation.

28.14 In situations where the magnetic force and electric force on a particle are in opposite directions, determine the speed at which these forces cancel, the speeds at which the magnetic force dominates, and the speeds at which the electric force dominates.

28-5 Crossed Fields: The Hall Effect

Learning Objectives

28.15 Describe the Hall effect for a metal strip carrying current, explaining how the electric field is set up and what limits its magnitude.

28.16 For a conducting strip in a Hall-effect situation, draw the vectors for the magnetic field and electric field. For the conduction electrons, draw the vectors for the velocity, magnetic force, and electric force.

28.17 Apply the relationship between the Hall potential difference *V*, the electric field magnitude *E*, and the width of the strip *d*.

28.18 Apply the relationship between charge-carrier number density *n*, magnetic field magnitude *B*, current *i*, and Hall-effect potential difference *V*.

28.19 Apply the Hall-effect results to a conducting object moving through a uniform magnetic field, identifying the width across which a Hall-effect potential difference *V* is set up and calculating *V*.

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28-6 A Circulating Charged Particle

Learning Objectives

28.20 For a charged particle moving through a uniform magnetic field, identify under what conditions it will travel in a straight line, in a circular path, and in a helical path.

28.21 For a charged particle in uniform circular motion due to a magnetic force, start with Newton's second law and derive an expression for the orbital radius r in terms of the field magnitude B and the particle's mass m, charge magnitude q, and speed v.

28.22 For a charged particle moving along a circular path in a magnetic field, calculate and relate speed, centripetal force, centripetal acceleration, radius, period, frequency, and angular frequency, and identify which of the quantities do not depend on speed.

28.23 For a positive particle and a negative particle moving along a circular path in a uniform magnetic field, sketch the path and indicate the magnetic field vector, the velocity vector, the result of the cross product of the velocity and field vectors, and the magnetic force vector.

Learning Objectives (Contd.)

28.24 For a charged particle moving in a helical path in a magnetic field, sketch the path and indicate the magnetic field, the pitch, the radius of curvature, the velocity component parallel to the field, and the velocity component perpendicular to the field

28.25 For helical motion in a magnetic field, apply the relationship between the radius of curvature and one of the velocity components.

28.26 For helical motion in a magnetic field, identify pitch *p* and relate it to one of the velocity components.

28-8 Magnetic Force on Current-Carrying Wire

Learning Objectives

28.31 For the situation where a current is perpendicular to a magnetic field, sketch the current, the direction of the magnetic field, and the direction of the magnetic force on the current (or wire carrying the current).

28.32 For a current in a magnetic field, apply the relationship between the magnetic force magnitude F_B, the current i, the length of the wire L, and the angle f between the length vector $\mathbf{L}$ and the field vector $\mathbf{B}$.

28.33 Apply the right-hand rule for cross products to find the direction of the magnetic force on a current in a magnetic field.

28.34 For a current in a magnetic field, calculate the magnetic force $\mathbf{F}_B$ with a cross product of the length vector $\mathbf{L}$ and the field vector $\mathbf{B}$, in magnitude-angle and unit-vector notations.

28.35 Describe the procedure for calculating the force on a current-carrying wire in a magnetic field if the wire is not straight or if the field is not uniform.

28-9 Torque on a Current Loop

Learning Objectives

28.36 Sketch a rectangular loop of current in a magnetic field, indicating the magnetic forces on the four sides, the direction of the current, the normal vector $\boldsymbol{n}$, and the direction in which a torque from the forces tends to rotate the loop.

28.37 For a current-carrying coil in a magnetic field, apply the relationship between the torque magnitude τ, the number of turns N, the area of each turn A, the current i, the magnetic field magnitude B, and the angle θ between the normal vector $\boldsymbol{n}$ and the magnetic field vector $\boldsymbol{B}$.

28-10 The Magnetic Dipole Moment

Learning Objectives

28.38 Identify that a current-carrying coil is a magnetic dipole with a magnetic dipole moment ***μ*** that has the direction of the normal vector ***n***, as given by a right-hand rule.

28.39 For a current-carrying coil, apply the relationship between the magnitude *μ* of the magnetic dipole moment, the number of turns *N*, the area *A* of each turn, and the current *i*.

28.40 On a sketch of a current-carrying coil, draw the direction of the current, and then use a right-hand rule to determine the direction of the magnetic dipole moment vector ***μ***.

28.41 For a magnetic dipole in an external magnetic field, apply the relationship between the torque magnitude *τ*, the dipole moment magnitude *μ*, the magnetic field magnitude ***B***, and the angle *θ* between the dipole moment vector ***μ*** and the magnetic field vector ***B***.

28.42 Identify the convention of assigning a plus or minus sign to a torque according to the direction of rotation.

28-10 The Magnetic Dipole Moment

Learning Objectives (Contd.)

28.43 Calculate the torque on a magnetic dipole by evaluating a cross product of the dipole moment vector $\boldsymbol{\mu}$ and the external magnetic field vector $\boldsymbol{B}$, in magnitude-angle notation and unit-vector notation.

28.44 For a magnetic dipole in an external magnetic field, identify the dipole orientations at which the torque magnitude is minimum and maximum.

28.45 For a magnetic dipole in an external magnetic field, apply the relationship between the orientation energy U, the dipole moment magnitude μ, the external magnetic field magnitude $\boldsymbol{B}$, and the angle θ between the dipole moment vector μ and the magnetic field vector $\boldsymbol{B}$.

28.46 Calculate the orientation energy U by taking a dot product of the dipole moment vector $\boldsymbol{\mu}$ and the external magnetic field vector $\boldsymbol{B}$, in magnitude-angle and unit-vector notations.

28-10 The Magnetic Dipole Moment

Learning Objectives (Contd.)

28.47 Identify the orientations of a magnetic dipole in an external magnetic field that give the minimum and maximum orientation energies.

28.48 For a magnetic dipole in a magnetic field, relate the orientation energy U to the work W_a done by an external torque as the dipole rotates in the magnetic field.