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Chapter 29. Magnetic Fields and Forces

Directions: When we use North, South, East, West directions those are merely the directions in a plane, which can be described by the positive and negative x and y directions. In addition we have to identify up and down as the directions of the z-axis.

(1.1) $\vec{F}_B = q\vec{v} \times \vec{B}$

(1.2) $d\vec{F}_B = I \ \ d\vec{s} \times \vec{B}$

(1.3) $\vec{\mu} = I\vec{A}$ = magnetic dipole moment

(1.4) $U_B = -\vec{\mu} \cdot \vec{B}\,; \vec{\tau}_B = \vec{\mu} \times \vec{B}$

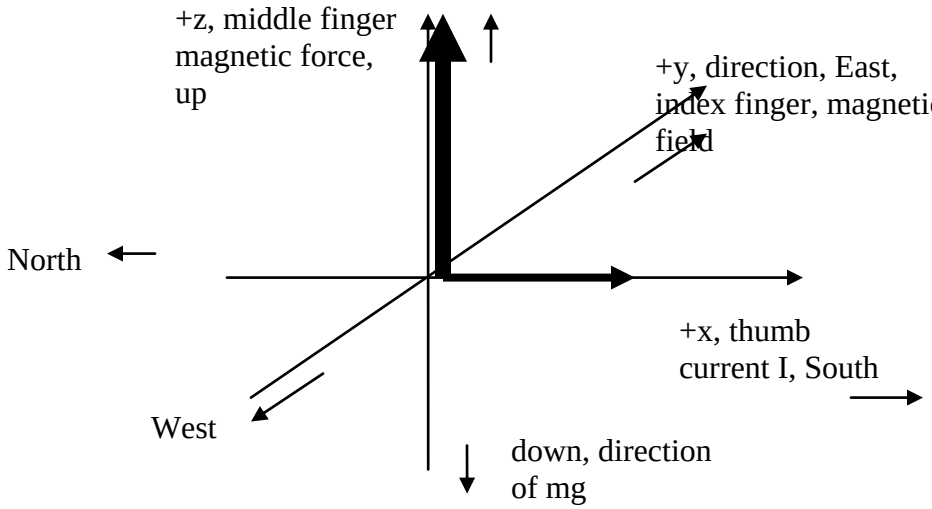
1. An electron moving along the positive x-axis perpendicular to a magnetic field experiences a magnetic deflection in the negative y-direction. What is the direction of the magnetic field? (Negative z-direction.)
2. (3) A proton moves perpendicular to a uniform magnetic field B at 1E7 m/s and experiences an acceleration of 2E13 m/s^2 in the positive x-direction when its velocity is in the +z direction. Determine the magnitude and direction of the field. (2.09E-2, -y direction).
3. (7) A proton moves with the velocity of $\vec{v} = 2\vec{i} - 4\vec{j} + \vec{k}\ \frac{m}{s}$ in a region in which the magnetic field is $\vec{B} = \vec{i} + 2\vec{j} - 3\vec{k}\ T$. What is the magnitude of the magnetic force this charge experiences? 2.34E-18 N.

Motion of a charged particle in a uniform magnetic field.

4. A proton, a deuteron (a deuteron consists of 1 proton, 1 neutron), and an alpha particle (2 protons, 2 neutrons) are accelerated through a common potential difference ΔV. Each of the particles enters a uniform magnetic field in a perpendicular fashion. All particles move in a circular fashion. Determine the radii of the particles in terms of the radius which the proton will have. (Both the alpha particle and the deuteron will have the same radius which is equal to $1.4r_p$)
5. Calculate the cyclotron frequency of a proton in a magnetic field of 5.20T.(4.98E8/s).
6. (18) Singly charged uranium-238 ions U-238 (the sum of the protons and neutrons is 238) are accelerated through a potential difference of 2.00kV and enter a uniform magnetic field of 1.20T perpendicularly. (a) Determine the radius of their circular path. (Repeat for U-235 ions.) How does the ratio of these paths depend on the accelerating voltage and on the magnitude of the magnetic field? (a: 8.28cm, b: 8.23cm) The ratio of the radii varies only with the square root of the ratio of the masses.
7. (21) A cyclotron designed to accelerate protons has a magnetic field of magnitude 0.450 T over a region of radius 1.20m. a)What are the cyclotron frequency and b) the maximum speed acquired by the protons? a: 4.31E7/s; b: 5.17E7m/s.

Magnetic Force acting on a current carrying conductor

8. (25) A wire having a mass per unit length of 0.500 g/cm carries a 2.00A current horizontally to the south. What are the direction and magnitude of the minimum magnetic field needed to lift this wire vertically upward? Hint: The magnetic field must be perpendicular to the North-South line, and to the up-down line. It can therefore only be on the East-West line. Draw a horizontal line and assign the direction to the right as the South (+x) direction (thumb). Up would be the plus z direction, which is the direction of the magnetic force. (middle finger). Your index finger points in the +y direction. 0.245T



9. (29) A cylindrical rod of mass 0.720 kg and radius 6.00 cm rests on two parallel horizontal rails which are d=12.0 cm apart and L=45.0 cm long. The rod is perpendicular to the rails and can roll on the rails without slipping. A uniform magnetic field of 0.240 T is directed perpendicular downward to the plane of the rod and the rails. The rod carries a counter clockwise current of 48.0A. If the rod starts rolling from rest (to the right), what is its speed at the end of the 45.0 cm rail.? Hint: Use energy conservation of energy; use moment of inertia. (1.07 m/s)

Torque on a current in a loop in a uniform magnetic field.

10. A small bar magnet is suspended in a uniform 0.250T magnetic field. The maximum torque experienced by the bar magnet is 4.60E-3 Nm. Calculate the magnetic moment of the bar magnet. 18.4E-3Am^2.
11. (35) A rectangular coil consists of N=100 closely wrapped turns and has dimensions a=0.400 m (vertical y-direction) and b=0.300 m (in the horizontal x-z plane). The coil is hinged along the y-axis, and its plane (the b direction) makes an angle of 30° with the x-axis. What is the magnitude of the torque exerted on the coil by a uniform magnetic field of 0.800T which is directed along the x-axis when the current is 1.20A in the direction of +y along the hinge.? What is the

expected direction of rotation of the coil? (Hint: If the plane makes an angle of 30° with the B-field, the surface vector A makes an angle of 60° with it.)
torque 9.98 Nm, clockwise.

12. The magnetic field of the earth at a certain location is directed vertically downward and has a magnitude of 50.0E-6 T. A proton is moving horizontally toward the west in the field with a speed of 6.20E 6m/s. (a) What are the direction and magnitude of the magnetic force the field exerts on this charge? (b) What is the radius of the circular arc followed by the proton? (South, 4.96E-17N, 1.29km)
13. (49) A flat copper ribbon 0.330 mm thick carries a steady current of 50.0A and is located in a uniform 1.30T magnetic field directed perpendicular to the plane of the ribbon. If a Hall voltage of 9.60E-6V is measured across the ribbon, what is the charge density of the free electrons? What effective number of free electrons per atom does this result indicate?

a) 1.28E29/m^3 versus 8.46E28 /m^3 i.e. 1.52 times as many conducting electrons as expected.