Physics 10-02 Magnetic Fields and Force on a Moving Charge

**Magnetic Fields**

- Around a magnet is a magnetic ____________ (B-field)
- At ____________ point in ____________ there is a magnetic ____________
- Can be seen with a ____________
- Unit is ____________ (T)

**Magnetic Field Lines**

- Magnetic fields can be ____________ with field ____________.
- Start at ____________ pole and end at ____________ pole
- The more lines in one area means ____________ field

**Force on a Moving Charge**

- Since currents (moving charges) make ____________, then other B-fields apply a ____________ to ____________ charges.
- For a moving charge to experience a ____________
  - Charge must be ____________
  - The ____________ vector of the charge must have a ____________ ____________ to the ____________
- \( \vec{F} = q\vec{v}\vec{B} \sin \theta \)
  - Where \( F \) = force, \( q \) = charge, \( v \) = speed of charge, \( B \) = magnetic field, \( \theta \) = angle between \( v \) and \( B \)

**Direction of force on positive moving charge**

**Right Hand Rule**

- Fingers point in direction of ____________
- Thumb in direction of ____________
- Palm faces direction of ____________ on ____________ charge
- Force will be ____________ if \( v \) and \( B \) are parallel, so a moving charge will be unaffected

**Motion of moving charged particle in uniform B-field**

- ____________
- \[ r = \frac{mv}{q\vec{B}} \]

A particle with a charge of \(-1.6 \times 10^{-19}\) C and mass \(9.11 \times 10^{-31}\) kg moves along the positive x-axis from left to right. It enters a 3 T B-field is in the x-y plane and points at 45° above the positive x-axis.

What is the direction of the force on the particle?

After it has been in the B-field, the particle moves in a circle. If the radius of its path is \(2 \times 10^{-10}\) m, what is the speed of the particle?

What is the magnitude of the force on the particle?
1. Is the Earth's magnetic field parallel to the ground at all locations? If not, where is it parallel to the surface? Is its strength the same at all locations? If not, where is it greatest?
2. If a charged particle moves in a straight line through some region of space, can you say that the magnetic field in that region is necessarily zero?
3. How can the motion of a charged particle be used to distinguish between a magnetic and an electric field?
4. What are the signs of the charges on the particles in Figure 1?
5. Which of the particles in Figure 2 has the greatest velocity, assuming they have identical charges and masses?
6. Which of the particles in Figure 2 has the greatest mass, assuming all have identical charges and velocities?
7. What is the direction of the magnetic force on a positive charge that moves as shown in each of the six cases shown in Figure 3? (OpenStax 22.1) left, into, up, no, right, down
8. Repeat Exercise 7 for a negative charge. (OpenStax 22.2) right, out, down, no, left, up
9. What is the direction of the velocity of a negative charge that experiences the magnetic force shown in each of the three cases in Figure 4, assuming it moves perpendicular to \( B \)? (OpenStax 22.3) right, into, down
10. Repeat Exercise 9 for a positive charge. (OpenStax 22.4) left, out, up
11. What is the direction of the magnetic field that produces the magnetic force on a positive charge as shown in each of the three cases in the Figure 5, assuming \( B \) is perpendicular to \( v \)? (OpenStax 22.5) into, left, out
12. Repeat Exercise 11 for a negative charge. (OpenStax 22.6) out, right, into
13. What is the maximum force on an aluminum rod with a 0.100 \( \mu \)C charge that you pass between the poles of a 1.50-T permanent magnet at a speed of 5.00 m/s? In what direction is the force? (OpenStax 22.7) \( 7.50 \times 10^{-7} \) N, \( \perp \)
14. (a) Aircraft sometimes acquire small static charges. Suppose a supersonic jet has a 0.500 \( \mu \)C charge and flies due west at a speed of 660 m/s over the Earth's south magnetic pole, where the 8.00 \( \times 10^{-5} \) T magnetic field points straight down. What are the direction and the magnitude of the magnetic force on the plane? (b) Discuss whether the value obtained in part (a) implies this is a significant or negligible effect. (OpenStax 22.8) \( 2.64 \times 10^{-8} \) N, south, negligible
15. (a) A cosmic ray proton moving toward the Earth at \( 5.00 \times 10^7 \) m/s experiences a magnetic force of \( 1.70 \times 10^{-16} \) N. What is the strength of the magnetic field if there is a 45° angle between it and the proton's velocity? (b) Is the value obtained in part (a) consistent with the known strength of the Earth's magnetic field on its surface? Discuss. (OpenStax 22.9) \( 3.61 \times 10^{-5} \) T, yes
16. A cosmic ray electron moves at \( 7.50 \times 10^6 \) m/s perpendicular to the Earth's magnetic field at an altitude where field strength is \( 1.00 \times 10^{-5} \) T. What is the radius of the circular path the electron follows? (OpenStax 22.12) \( 4.27 \) m
17. A proton moves at \( 7.50 \times 10^7 \) m/s perpendicular to a magnetic field. The field causes the proton to travel in a circular path of radius 0.800 m. What is the field strength? (OpenStax 22.13) \( 0.979 \) T
18. (a) Viewers of Star Trek hear of an antimatter drive on the Starship Enterprise. One possibility for such a futuristic energy source is to store antimatter charged particles in a vacuum chamber, circulating in a magnetic field, and then extract them as needed. Antimatter annihilates with normal matter, producing pure energy. What strength magnetic field is needed to hold antiprotons, moving at \( 5.00 \times 10^7 \) m/s in a circular path 2.00 m in radius? Antiprotons have the same mass as protons but the opposite (negative) charge. (b) Is this field strength obtainable with today's technology or is it a futuristic possibility? (OpenStax 22.14) \( 0.261 \) T, yes
19. (a) An oxygen-16 ion with a mass of \( 2.66 \times 10^{-26} \) kg travels at \( 5.00 \times 10^6 \) m/s perpendicular to a 1.20-T magnetic field, which makes it move in a circular arc with a 0.231-m radius. What positive charge is on the ion? (b) What is the ratio of this charge to the charge of an electron? (c) Discuss why the ratio found in (b) should be an integer. (OpenStax 22.15) \( 4.80 \times 10^{-19} \) C, 3