Chapter 22 Magnetism

Outline

22-1 The Magnetic Field

22-2 The Magnetic Force on Moving Charges

22-3 The Motion of Charges Particles in Magnetic Field

22-4 The Magnetic Force Exert on a Current-Carrying Wire

22-5 Loops of Current and Magnetic Torque

22-6 Electric Current, Magnetic Fields, and Ampère's Law

22-7 Electric Loops and Solenoid

22-1 The Magnetic Field

Permanent Magnets

Permanent magnet: the magnetism is permanently exist, such as bar magnets, the Earth (two poles)

- A magnet always consists of two poles: North Pole (N) and South Pole (S).

- Opposite poles attract; Like poles repel.

Magnetic Field Lines

Magnetic field is Very similar with Electric field of point charge.

1) Direction:

   The direction of the magnetic field, at a given location, is the direction in which the north pole of a compass points.

2) Magnetic field lines begin from the north pole and end at the south pole (*close loop*).

3) Dense lines have higher magnitude.

Magnetic Field Lines

Figure 22-4
Magnetic Field Lines for a Bar Magnet

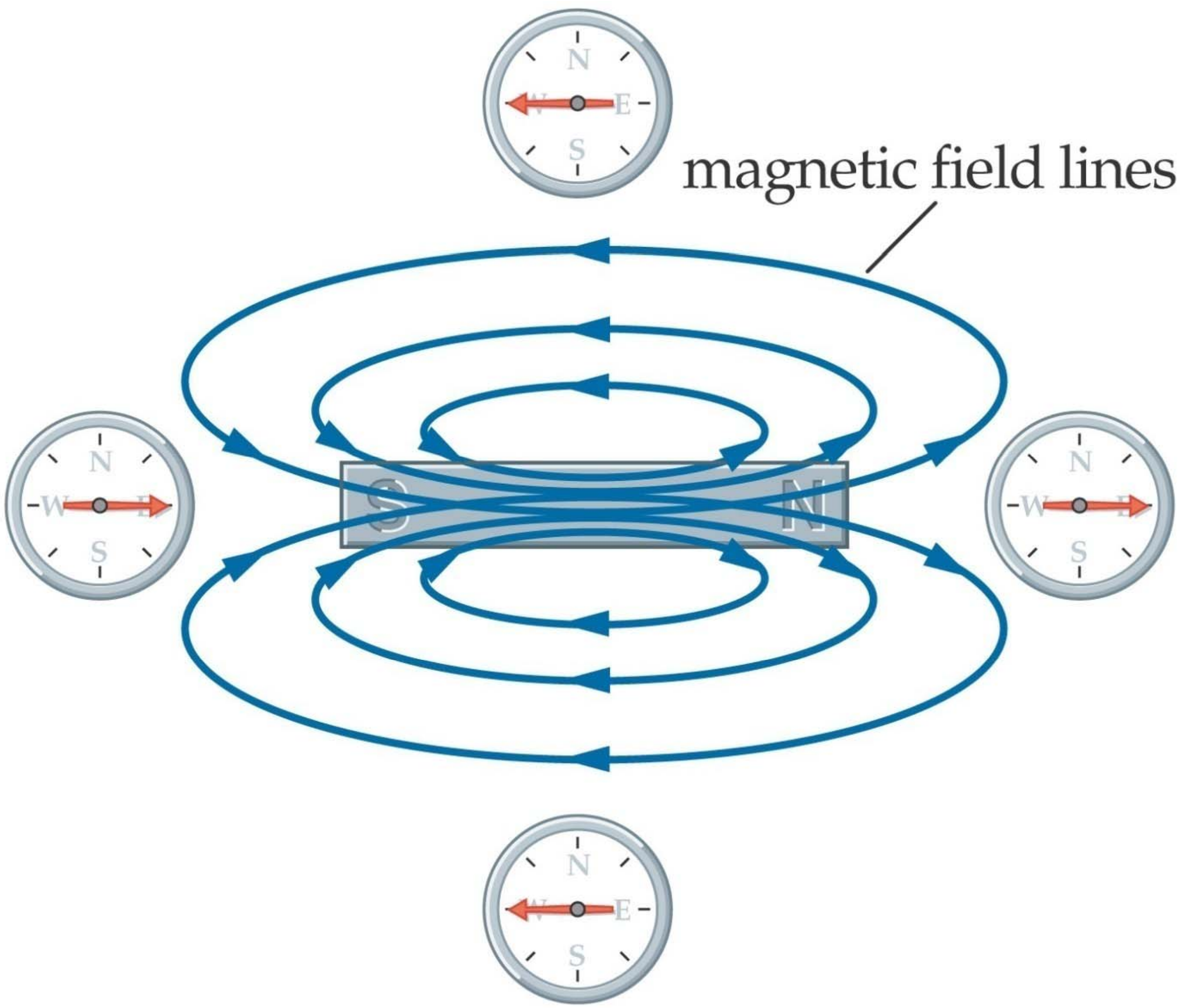
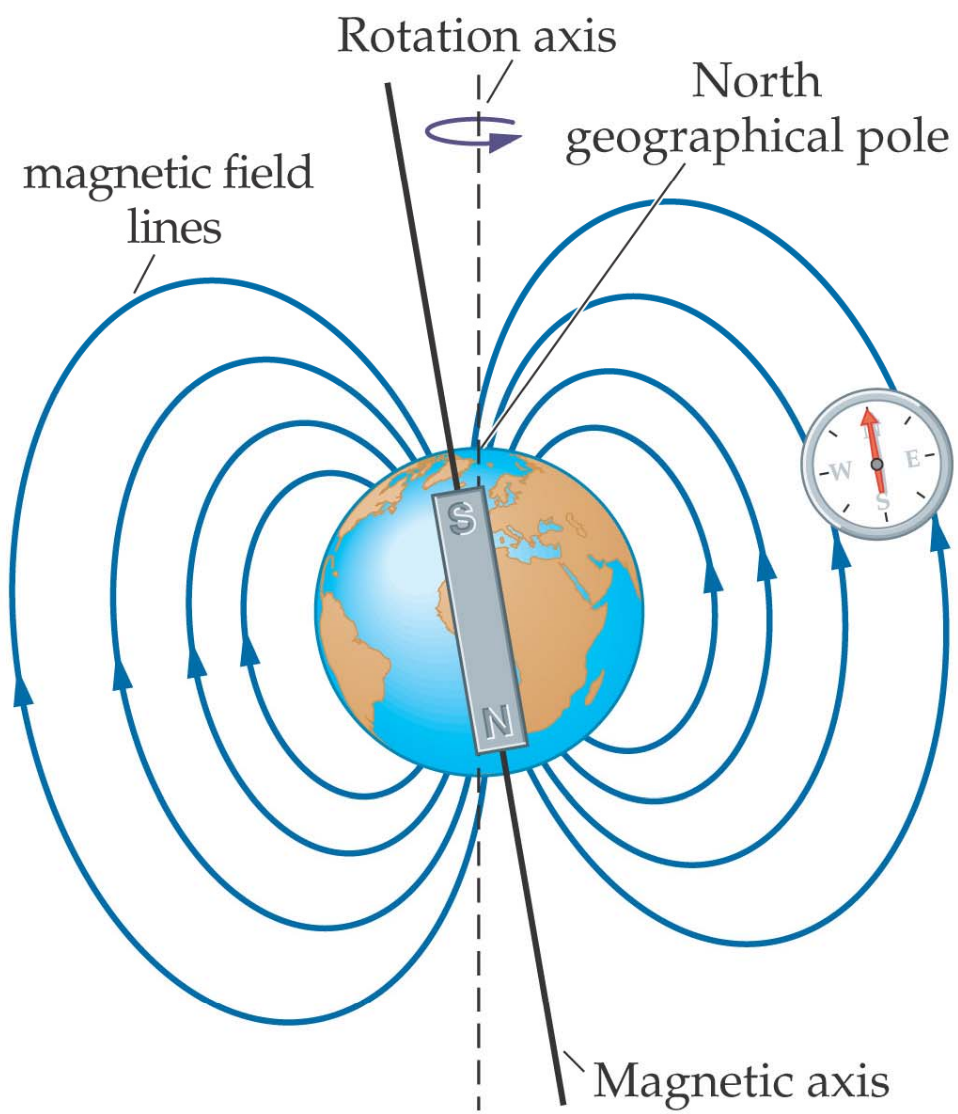


Figure 22-6
Magnetic Field of the Earth



CONCEPTUAL CHECKPOINT 22–1

Can magnetic field lines cross one another?

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Reasoning and Discussion

Recall that the direction in which a compass points at any given location is the direction of the magnetic field at that point. Since a compass can point in only one direction, there must be only one direction for the field $\vec{\mathbf{B}}$. If field lines were to cross, however, there would be two directions for $\vec{\mathbf{B}}$ at the crossing point, and this is not allowed.

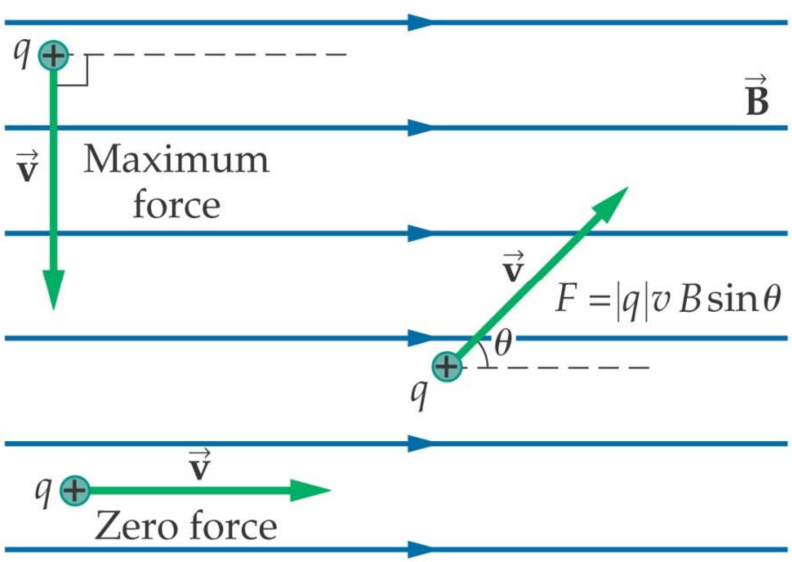
Answer:

No. Magnetic field lines never cross.

22-2 The Magnetic Force on Moving Charges

Magnitude of the magnetic Force

Consider a magnetic filed $\vec{B}$. A particle of charge q moves through with a velocity $\vec{v}$. The velocity $\vec{v}$ and the magnetic field $\vec{B}$ has an angle of θ ,



$\vec{F}$

+

The Magnetic Force on a Moving Charged Particle

Magnitude of the magnetic force , F, is

$$F = |q| vB \sin\theta \qquad (22-1)$$

SI unit: newton

Definition of the magnitude of the magnetic field. B

$$B = \frac{F}{|q| v \sin\theta} \qquad (22-2)$$

SI unit: 1 tesla = 1 T =1 N / (A·m)

1 Gauss = 1 G = 10^{-4} T

Problem 22-5 **Electromagnetic Force**

A 0.32-μC particle moves with a speed of 16m/s through a region where the magnetic field has a strength of 0.95 T. At what angle to the field is the particle moving if the force applied on it is

(a) $4.8\text{x}10^{-6}$N , **(b)** $3.0\text{x}10^{-6}$ N.

Magnetic Force Right-Hand Rule (RHR)

Magnetic Force Right-Hand Rule

To find the direction of the magnetic force on positive charge, start by pointing the fingers of your right hand in the direction of the velocity $\vec{v}$. Now curl your fingers toward the direction of $\vec{B}$, as shown in Figure. Your thumb will point in the direction of $\vec{F}$;

If the charge is negative, the force points opposite to the direction of your thumb.

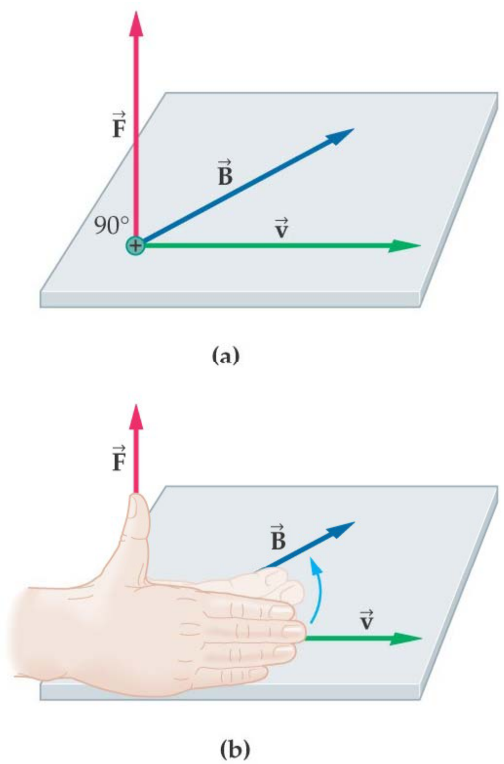


Figure 22-8
The Magnetic Force Right-Hand Rule

The relationship can be mathematically expressed in terms of the vector ***cross product***,

$$\overrightarrow{F} = q\vec{v} \times \vec{B}$$

We use the symbols to indicate a vector that point into or out of page:

- Circle with point: a vector points out of the page.
- Circle with cross: a vector points into the page.

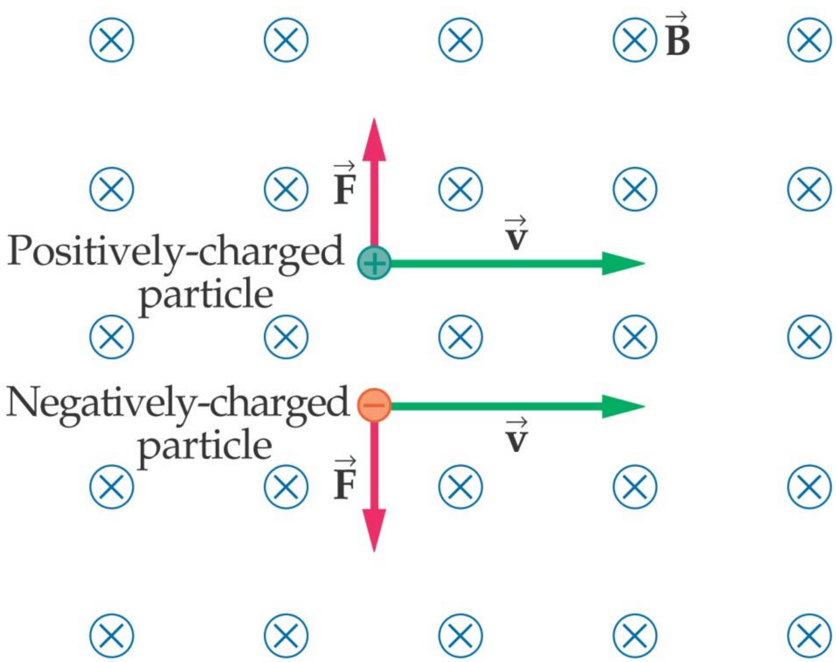
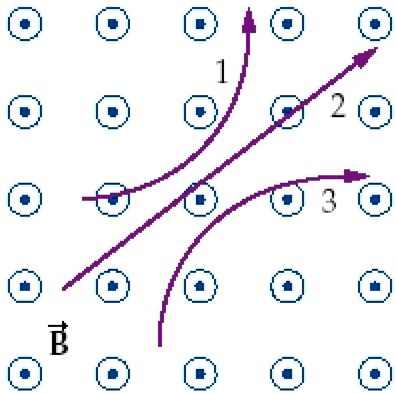
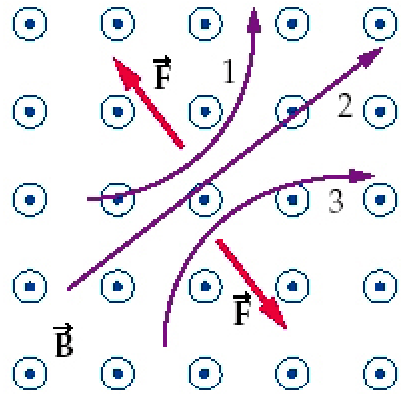


Figure 22-9
The Magnetic Force for Positive and Negative Charges

CONCEPTUAL CHECKPOINT 22–2

Three particles travel through a region of space where the magnetic field is out of the page, as shown below in the sketch to the left. For each of the three particles, state whether the particle's charge is positive, negative, or zero.





Problem 22-11 **Electromagnetic force**

When at rest, a proton experiences a net electromagnetic force of magnitude 8.0×10^{-13} N pointing in the positive x direction. When the proton moves with a speed of 1.5×10^{6} m/s in the positive y direction, the net electromagnetic force on it decreases in magnitude to 7.5×10^{-13} N, still pointing in the positive x direction.

Find the magnitude and direction of

(a) The electric field and **(b)** the magnetic field.

Summary

1) Magnetism

Opposite poles attract; Like poles repel.

1) Magnitude of magnetic force

$$F = |q| vB \sin\theta \qquad (22-1)$$

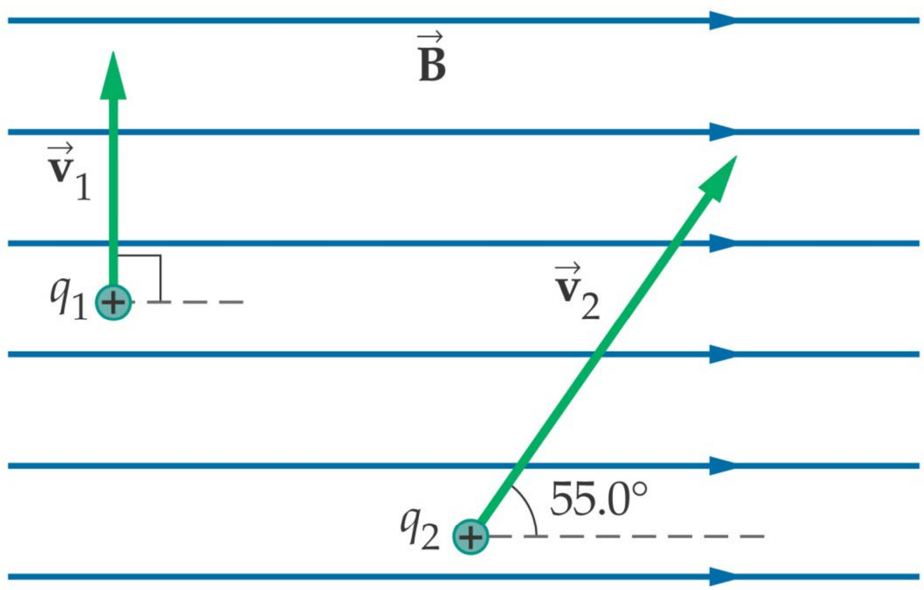
3) Right-Hand Rule (RHR): direction of magnetic force

$$\vec{F} = q\vec{v} \times \vec{B}$$

Example 22-1 **Two Charges**

Particle 1, with a charge q_1=3.6 uC and a speed v_1= 862 m/s, travel at right angle to a uniform magnetic field. The magnetic force on particle 1 is 4.25x10^{-3} N. Particle 2, with a charge q1= 53.0 uC and a speed v_2= 1.3x10^3 m/s, move at a angle of 55.0˚ to the same magnetic field.

Find (a) the strength of the magnetic field; (b) magnitude of the magnetic force exerted on particle 2.



Example 22-1
A Tale of Two Charges

Part (a)

$$F = |q| vB \sin\theta$$

$$4.25 \times 10^{-3} N = (3.60 \times 10^{-6} C)(862 m/s)B(\sin 90°)$$

$$B = 1.37 \quad T$$

Part (b)

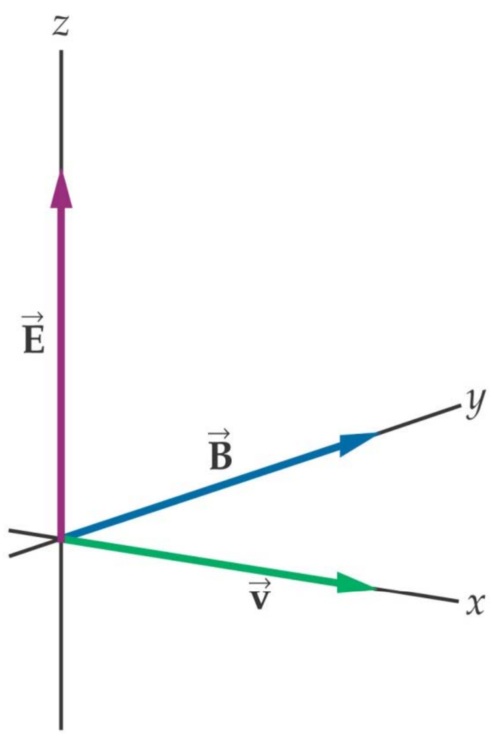
$$F = |q| vB \sin\theta$$

$$= (53.0 \times 10^{-6} C)(1.30 \times 10^{3} m/s)(1.37T)\sin 55.0°$$

$$= 0.0773 \quad N$$

Example 22-2 **Electric and Magnetic Field**

A particle with a charge of 7.70 μC and speed 435 m/s is acted on by both en electric and a magnetic field. The particle moves along x axis in positive direction. The magnetic field has a strength of 3.2 T and points in the positive y direction, and the electric field points in the positive z direction with a magnitude of $8.10x10^3$ N/C. Find the magnitude and direction of the net force acting on the particle.



Example 22-2
Electric and Magnetic Fields

Solution

1) Calculate the magnitude of the electric force on the particle

$$F_E = qE$$
$$= (7.70\times10^{-6}\,C)(8.10\times10^{3}\,N/C) = 6.24\times10^{-2} \quad N$$

2) Calculate the magnitude of the magnetic force

$$F = |q| vB \sin\theta$$
$$= (7.7\times10^{-6}\,C)(435\,m/s)(3.20\,T)\sin 90^\circ = 1.07\times10^{-2} \quad N$$

3) Both forces are in positive z direction, and can be added directly

$$F_{net} = F_E + F_B = (6.24\times10^{-2} \quad N) + (1.07\times10^{-2} \quad N)$$
$$= 7.31\times10^{-2} \quad N$$