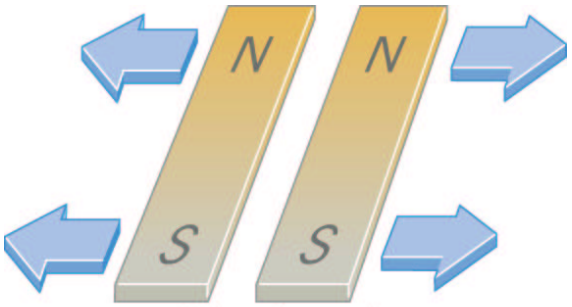
Chapter 21

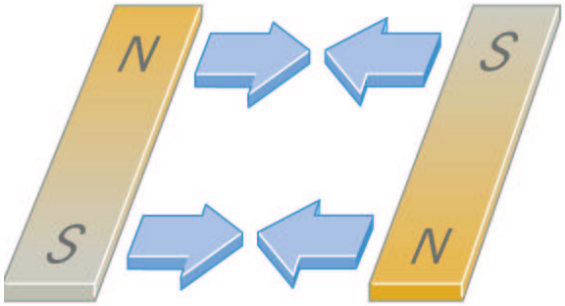
Magnetic Forces and Magnetic Fields

Magnetic Fields



Like poles repel

(*a*)



Unlike poles attract

(*b*)

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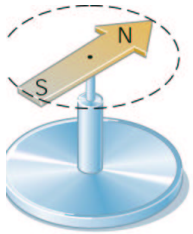
Figure 21.02 (W0820)
C M Y K

Permanent magnets have what is known as a north pole and a south pole.

If you take two magnets and try to push the north poles together, you would find this difficult to do.

Like poles of a magnet repel each other. Unlike poles attract each other.



Cutnell & Johnson
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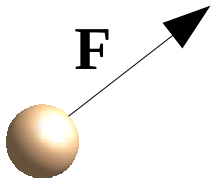
Figure 21.01 (W0819)
C M Y K

A compass works because it always points toward the Earth's magnetic north pole.

Since a compass always aligns with the magnetic field, you can use it to map out the field.

Magnetic Force

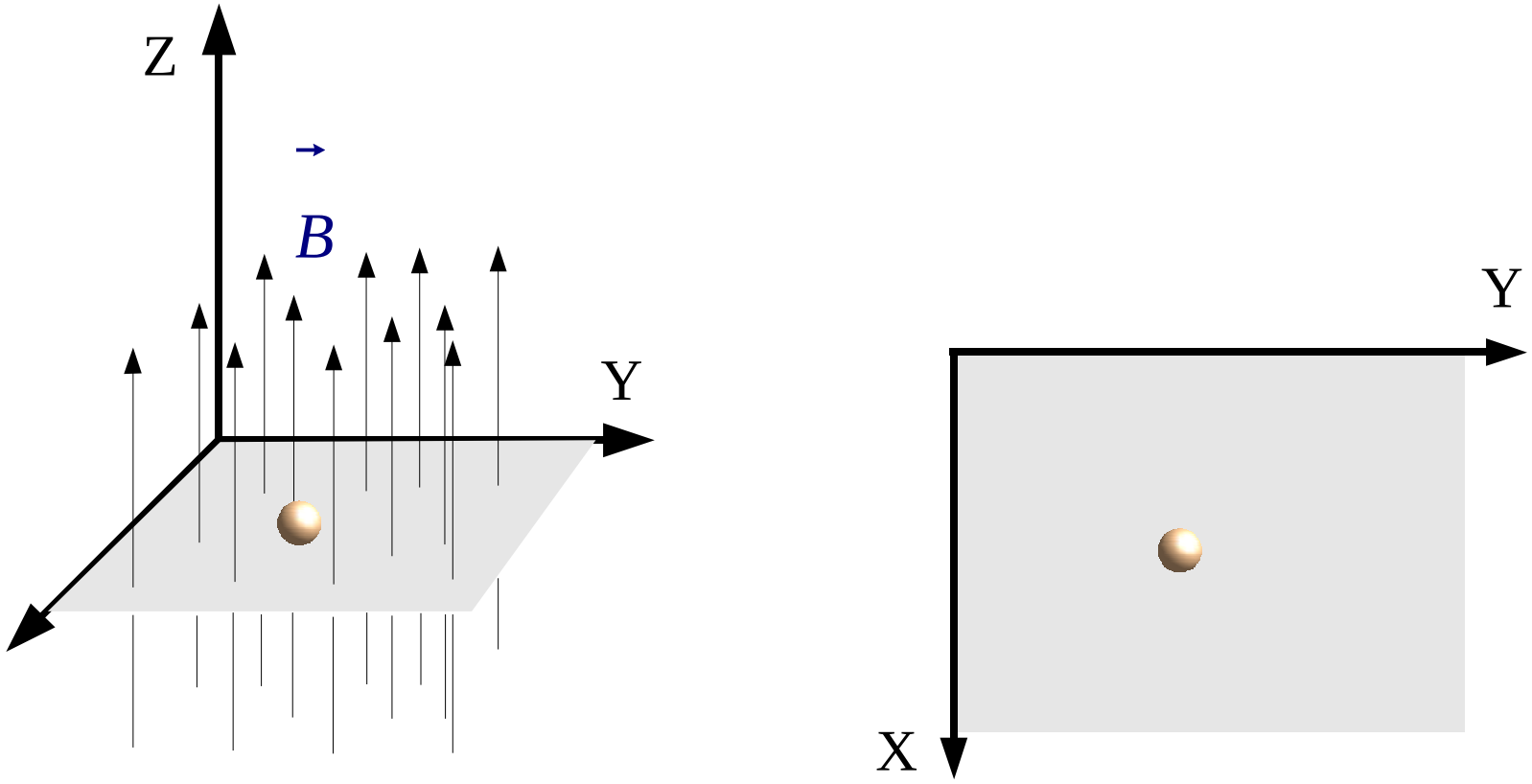


This force only operates on charged particles. Particles which have no net electric charge are not effected by a magnetic field.

Like other forces, this force causes particles to accelerate (Newton's 2nd Law, F = ma).

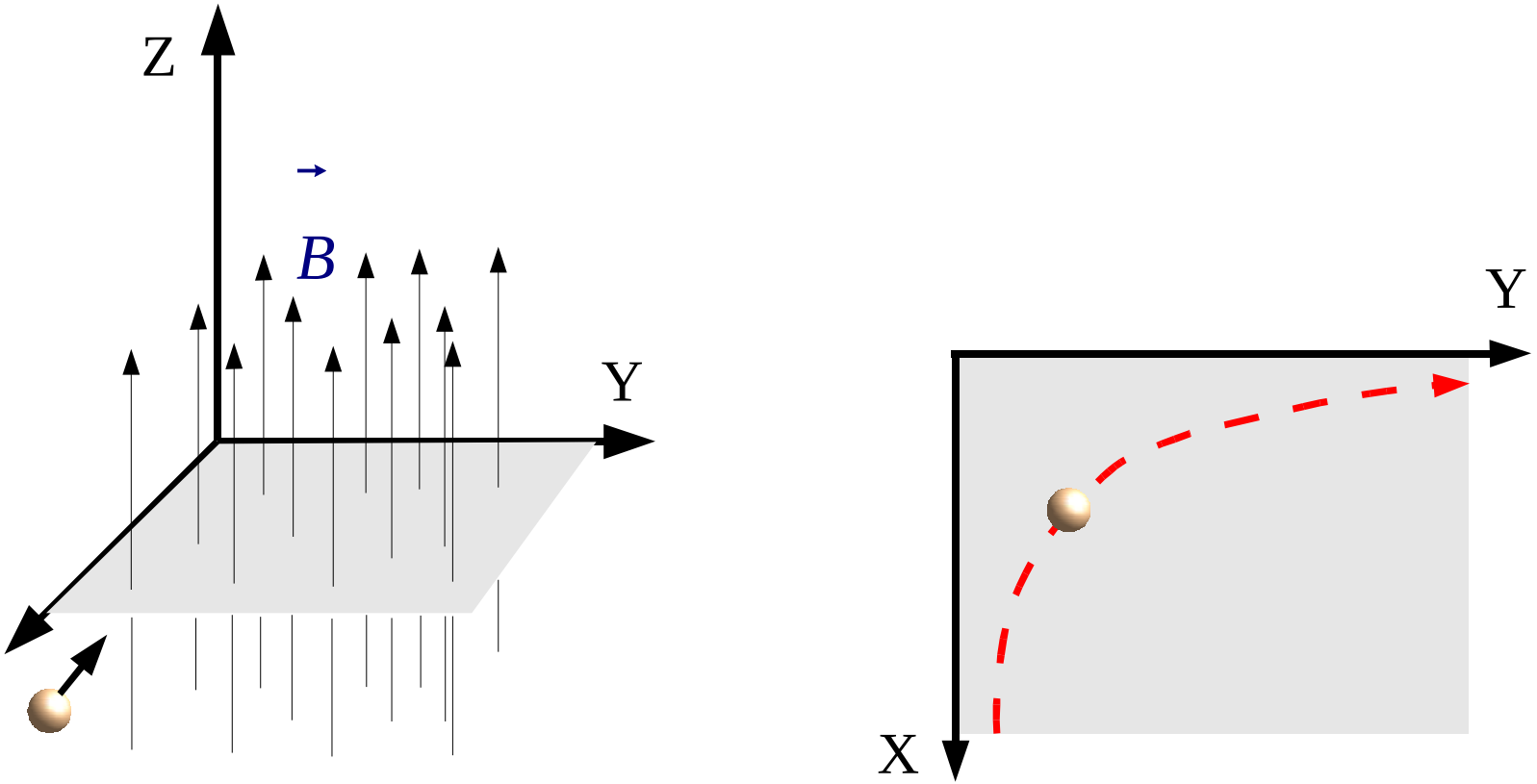
Unlike other forces, the charged particle must be moving through the field. More specifically, there must be a component of the velocity perpendicular to the magnetic field for any force to be realized.

Magnetic Field (2)



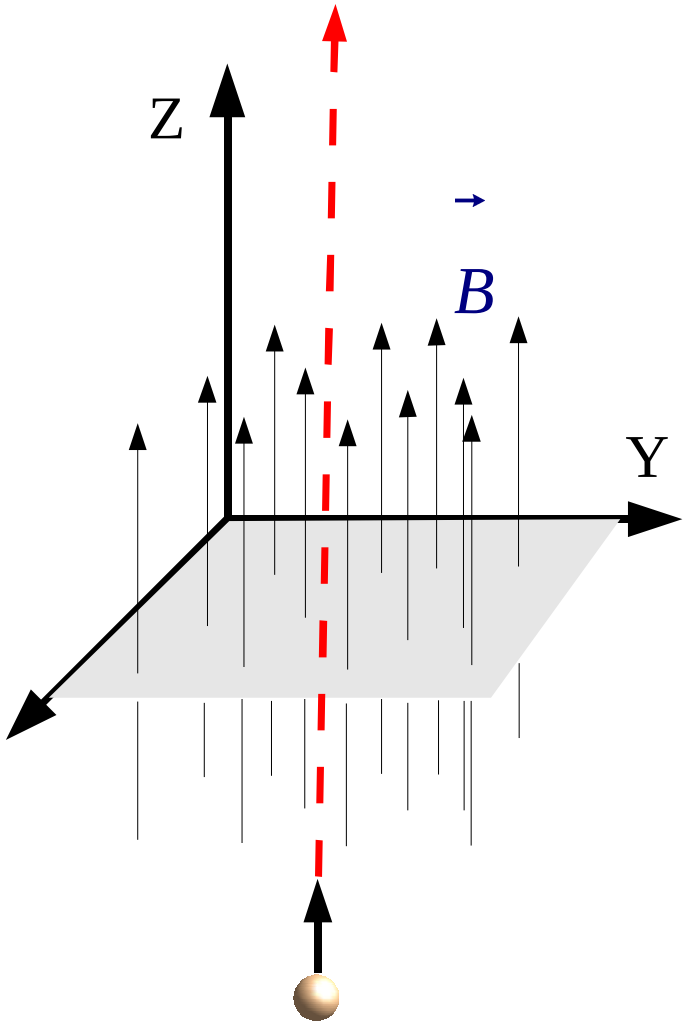
Stationary particle is place in the magnetic field. No force acts on it.

Magnetic Force (3)



Moving Particle enters the magnetic field with a velocity perpendicular to the field.

Magnetic Force (4)



If the particle enters the field with a velocity parallel to the magnetic field, there is no force acting on the particle and it continues along its original path.

Definition of the Magnetic Field

Recall the electric force was defined to be: $\boldsymbol{E} = \dfrac{\boldsymbol{F}}{q_0}$

The magnitude of the magnetic field is also defined in terms of a force:

$$B = \frac{F}{q_0 \left(v \sin \theta \right)}$$

where v is the particles velocity and

θ is the angle between the velocity and the magnetic field

In terms of the force, $\boldsymbol{F} = q_0 \left(\boldsymbol{v} \times \boldsymbol{B} \right)$

The $\times$ symbol is not a simple multiplication but a type of vector multiplication called the cross-product. This is where the sin θ term comes from. It is also from this we get the direction of the force. The direction is given by the “ Right Hand Rule”.

Magnetic Field Units

The magnetic field carries units known as the Tesla. This unit is named after Nikola Tesla (1856-1943) and is a derived unit based on base units given by:

$$1\,Tesla = 1\,T = 1\,\frac{N \cdot s}{C \cdot m}$$

Commonly, fields are much smaller than this. In fact, the Earth's magnetic field near the surface of the Earth is only about 10^{-4} T. You may find magnetic fields with units of the gauss defined as:

$$1\,Gauss = 10^{-4}\,Tesla$$