Electrodynamics-II

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Contents

6.1 Magnetization

- Types of magnetism (Chapter#6,Magnetic fields in matter)
- Torque and force on dipole (Chapter#6,Magnetic fields in matter)
- Magnetization (Chapter#6,Magnetic fields in matter)

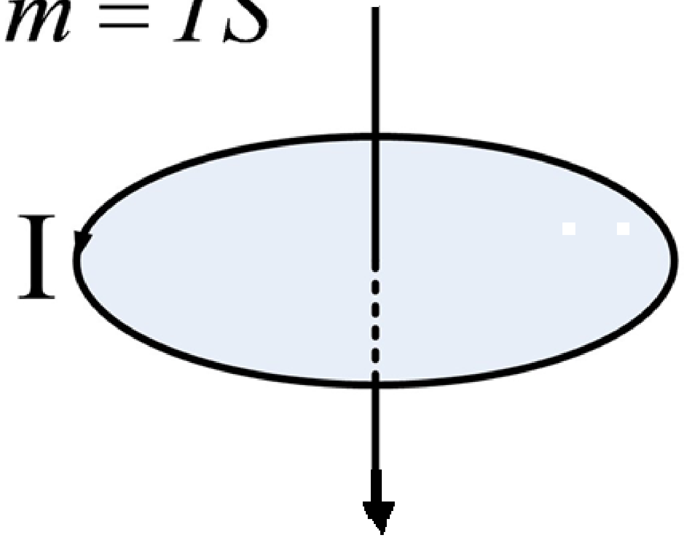
Assignment

Problem 6.1, 6.3

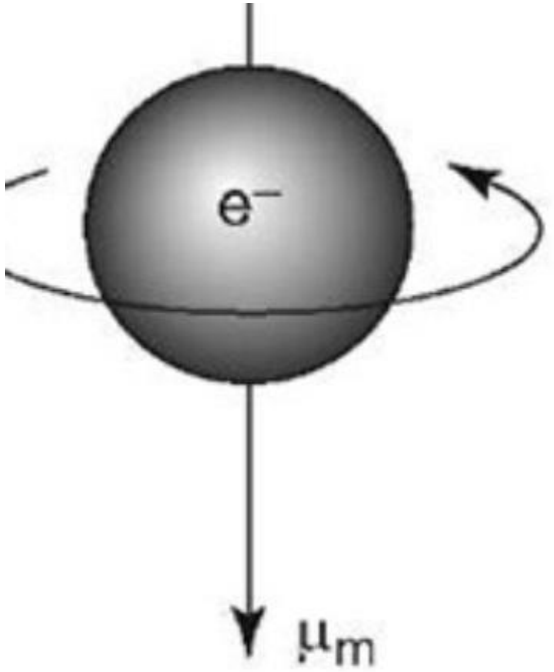
Origin of Magnetism

$$\overline{m} = I\overline{S}$$

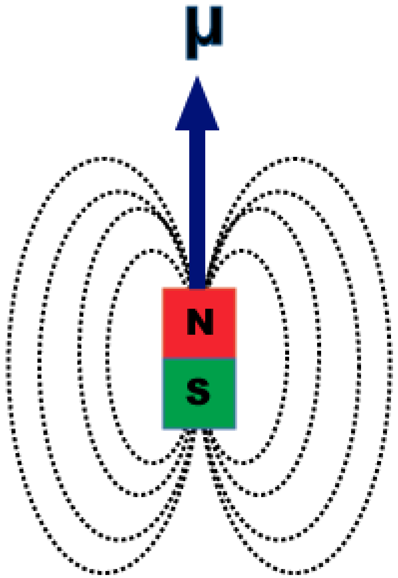
Tiny Dipole
Orbital motion
of electrons



Tiny dipole
Spin motion
of electrons



Magnetic dipole



All the magnetism arise due to spin and orbital motion of electrons.

Direction of magnetic dipole moment

Direction can be find out by Right Hand Rule.

Types of magnetism

- **Diamagnetism:** The materials in external magnetic field acquire small amount of magnetization opposite to applied external magnetic field. Such phenomenon is called diamagnetism. Such type of magnetism is present almost in all type of materials. This effect is produced by the orbital motion of electrons.
- **Paramagnetism:** Some materials acquire the magnetization in the direction of applied magnetic field. Its reason is mostly due to spin motion of electron. Therefore materials having even number of electrons does not show paramagnetic behavior and odd number of electrons show such behavior.

Types of magnetism

- **Ferromagnetism:**

Few substances retain their magnetization even after removing the external applied magnetic field. Such materials are call ferromagnets and such phenomenon is called ferromagnetism. For example iron

6.1.2 Torque, forces on magnetic dipole

We will discuss the above topic for

- Uniform applied external magnetic field
- Non uniform applied external magnetic field

Uniform applied external magnetic field

- **Torque**

Let $\vec{B}$ point in z direction(fig6.2), the forces on two sloping sides cancel and the forces on horizontal sides are likewise equal and opposite they are also cancelled but the do generate torque:

$$\vec{N} = \vec{r} \times \vec{F} = rF\ sin\theta$$

On left side

$$\vec{N} = \vec{r} \times \vec{F} = \frac{a}{2}F\ sin\theta\hat{x}$$

On right side

$$\vec{N} = \vec{r} \times \vec{F} = \frac{a}{2}F\ sin\theta\hat{x}$$

Total torque

$$\vec{N} = \vec{r} \times \vec{F} = \frac{a}{2} F\ sin\theta \hat{x} + \frac{a}{2} F\ sin\theta \hat{x}$$

$$\vec{N} = aF\ sin\theta \hat{x}$$

And magnitude of force acting on each side is

$$F = IBb$$

Then

$$\vec{N} = aIBb\ sin\theta \hat{x} = IB(ab) sin\theta \hat{x} = IB(area) sin\theta \hat{x}$$

$$\vec{N} = mB sin\theta \hat{x}$$

$$\vec{N} = \vec{m} \times \vec{B}$$

Magnetic force on magnetic dipole in non uniform magnetic field

In uniform magnetic field net force acting on the magnetic dipole is zero while in non uniform magnetic field net force acting on the dipole is

$$\mathbf{F} = \nabla(\mathbf{m} \cdot \mathbf{B})$$

Torque and force on current carrying loop

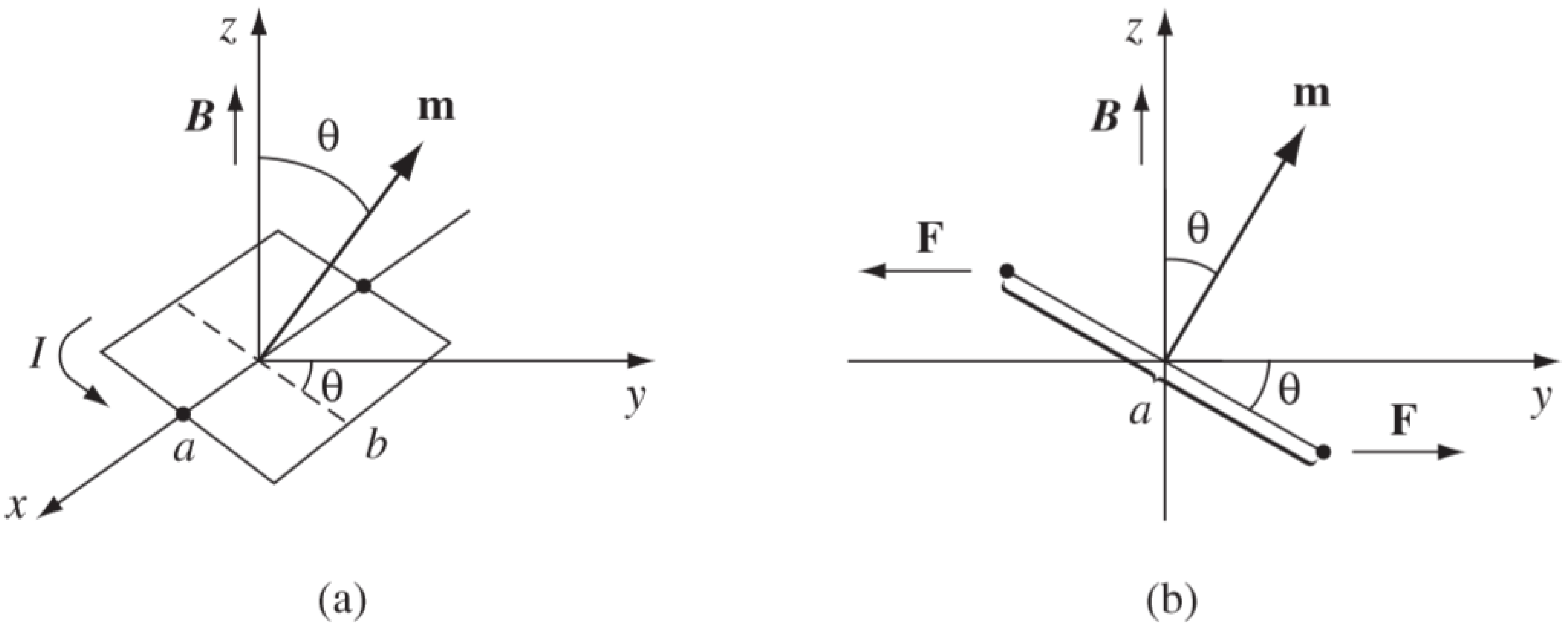
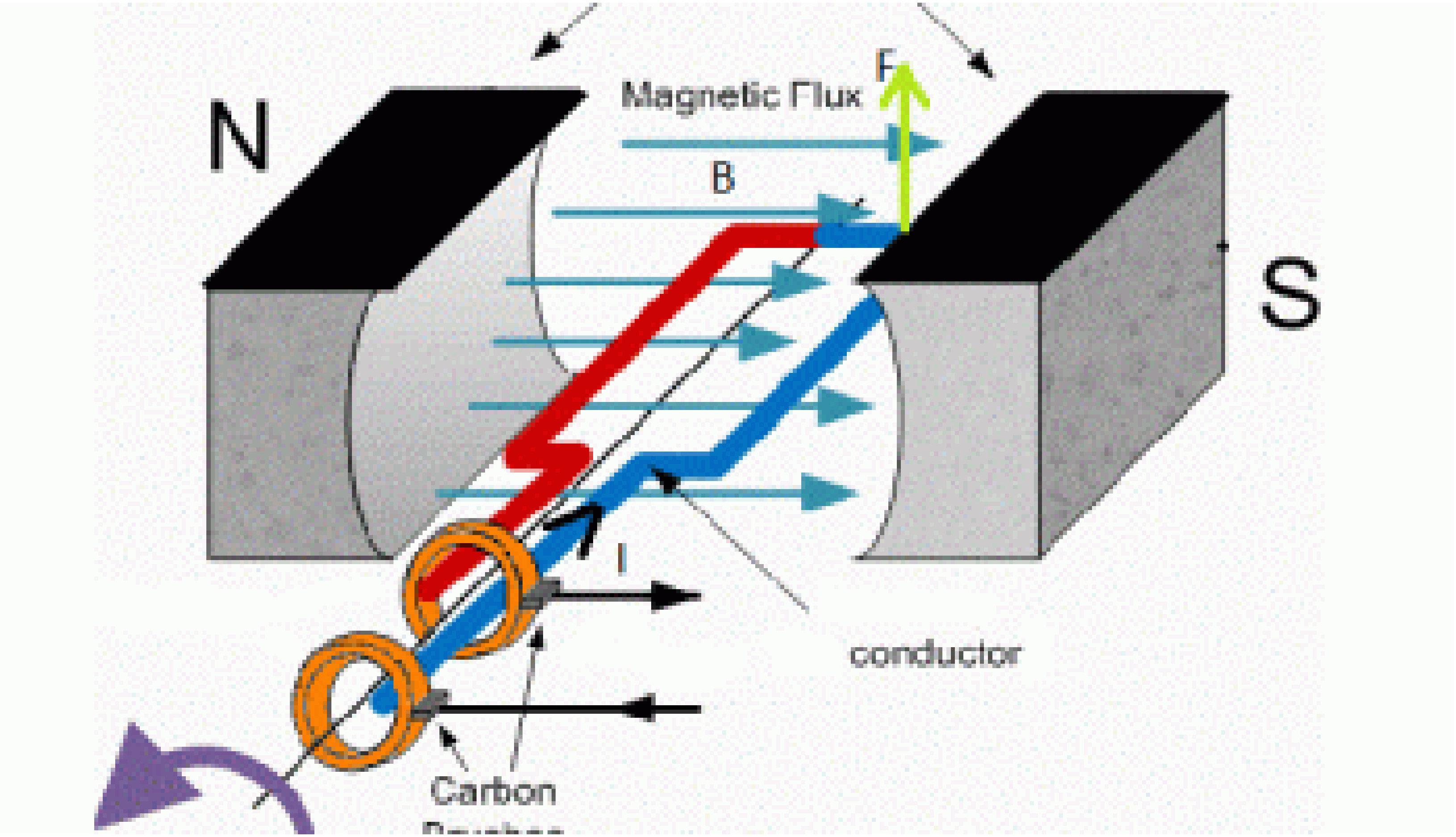
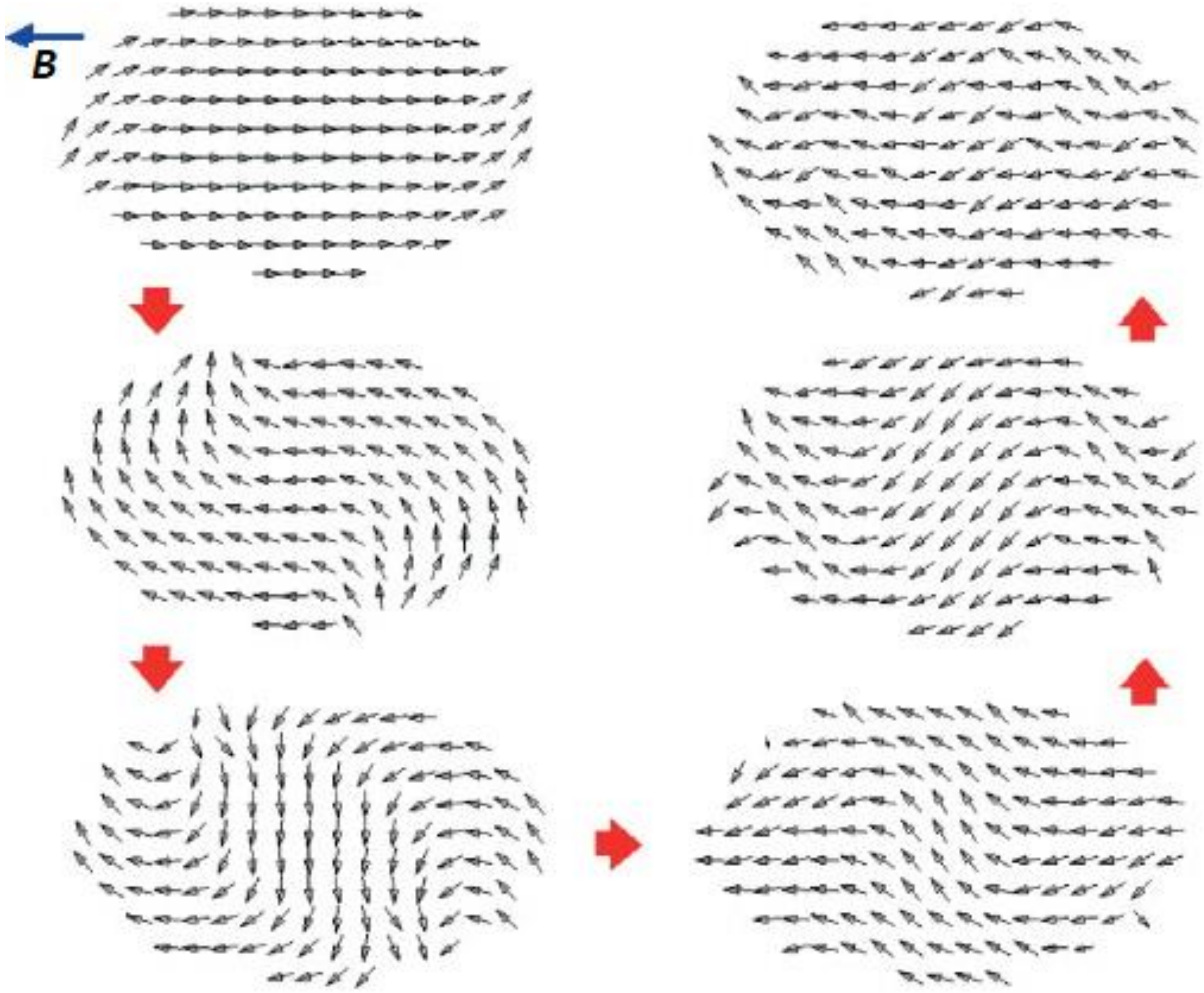


FIGURE 6.2

Application: Electric motor



What is effect of external magnetic field on magnetic dipoles.



As you increase the magnetic Field, magnetic dipoles tend align the external magnetic field

Magnetization

We have discussed mechanisms that account for magnetic polarization

- Paramagnetism
- Diamagnetism

Magnetic polarization is defined as

Magnetic dipole moment per unit volume

Information

North pole of magnet attract the paramagnetic substance and in contrast it repels the diamagnetic substance.