L8 Magnetic forces

Lecture outline:
- Force on a current.
- Torques and forces on magnetic dipoles.
- Potential energy of magnetic dipoles.
- Applications of magnetic forces.
- Atomic magnetic dipole moments.

L8.1 : Magnetic forces

The magnetic force on a current: \( dF_B = i dl \times B \)

Consider a wire bent into a loop:

The field looks like that from a magnet, with north and south poles – a dipole field.

So the loop is called a magnetic dipole.

L8.2 : Magnetic forces

Forces and Torques on magnetic dipoles.

Any loop can be considered to be made up of a number of rectangular loops.

Consider the torque on a rectangular current loop

\( \tau = iB \sin \theta \)

(If B is different on each side, there is a net force.)

L8.3 : Magnetic forces

The torque = \( \tau_B = Is_1 \sin \theta \quad \text{i.e.} \quad B = Is_2 B \)

Then \( \tau_B = (Is_1s_2)B \sin \theta \quad \text{i} = \mu B \sin \theta \quad \text{i} \)

Direction of \( \mu \) is perpendicular to the loop given by a right hand rule with respect to the direction of the current.

The magnitude of \( \mu \) is \( \mu = Is_1s_2 = 1 \text{ Amp m}^2 \), where \( A = s_1s_2 \) is the area of the loop. \( \mu \) is called the magnetic dipole moment of the loop.

L8.4 : Magnetic forces

The torque acts to line the dipole up with the magnetic field. The dipole therefore has potential energy \( U \) in the magnetic field: as for the electric dipole,

\[
U = -\int_0^{\phi} \mu B \sin \theta d\theta = -\mu B \cos \theta
\]

\( \mu B \) is the magnetic dipole moment of the loop.

L8.5 : Magnetic forces

Examples:
The DC motor: current produces mechanical rotational motion. Loudspeaker – example of transducer.
Atomic magnetic dipole moments.

Consider an electron revolving around a nucleus:

The current is \( I = \frac{e}{T} \) where \( T \) is the period, so \( \mu = \frac{e}{T} \pi r^2 \).

The orbital angular momentum is \( L = mvr \), and \( T = \frac{2\pi r}{v} \) so \( \mu = \frac{e}{(2\pi r/v) \pi r^2} = \frac{e vr}{2} = \frac{e}{2m} L \).

The electron also spins with angular momentum \( S \), so it has a spin magnetic moment \( \mu_s = 2\frac{e}{2m} S \). The factor 2 comes from quantum physics.