Tues: Supp Ex 61, 62, 63, 64

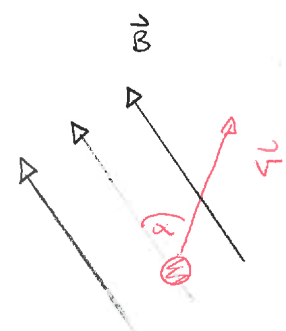
Ch 24 Q 19, 24

Ch 24 Prob 23, 33

Weds: PRELABS

Force exerted by magnetic fields on moving charges

The general rule for the force that a magnetic field exerts on a charged particle is



* the magnitude of the force is

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

* the direction is given by the right-hand rule

thumb ⇝ $\vec{v}$

index ⇝ $\vec{B}$

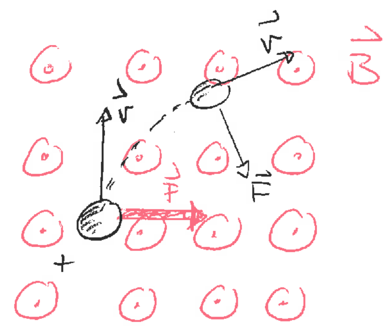
middle finger ⇝ $\vec{F}$ if charge is positive

opposite to $\vec{F}$ if charge is negative.

We can use this together with Newton's laws to describe the motion of any charged particle in a field.

Particle in a uniform magnetic field.

The simplest type of motion to analyze is that of a particle in a uniform magnetic field. A uniform magnetic field is one which has the same magnitude and direction at each location in space. Consider a positively charged particle which at some initial moment moves perpendicular to the field. Then the force law gives:



1) the force is perpendicular to the velocity.

2) the force changes the direction in which the particle moves but not the speed of the particle.

3) the magnitude of the force stays constant but its direction changes.

The particle will move in a circle with constant speed. So

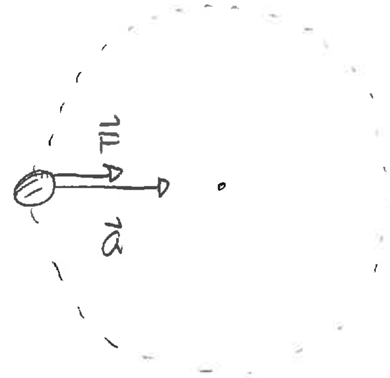
> A particle that moves perpendicular to a magnetic field undergoes uniform circular motion.

Quiz 1 70%

We can apply Newton's Second Law to analyze this situation.

Let q = particle charge
m = particle mass
v = particle speed
r = radius of orbit

Then * $\sum \vec{F} = m\vec{a}$



* the acceleration is centripetal

$$a = v^2/r$$

* the only force is magnetic

$$F = |q| v B \sin 90^\circ = |q| v B$$

These imply

$$|q| v B = m v^2/r \Rightarrow |q| B = \frac{mv}{r}$$

or

$$\frac{|q|}{m} = \frac{v}{rB}$$

Warm Up 1

Certain aspects of this circular motion are apparent even when the field is not uniform. It is generally typical that the charged particle tends to orbit magnetic field lines. Some applications are:

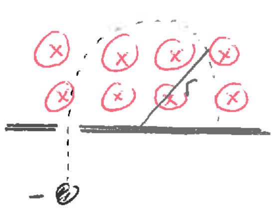
1) detection of charged particles - the field can be used to give $|q|/m$

Demo - bubble chamber

2) motion of charged particles in Earth's magnetic field

Demo: NCAR animation (requires Flash)

3) mass spectrometer. - fire charged ionized particle into region
- follows circular path. Can get mass



$$m = \frac{|q| B r}{v}$$

Force exerted by a magnetic field on a current

The fact that magnetic fields can exert a force on moving charges also implies:

Magnetic fields can exert forces on currents.

We consider the current in a wire.

Quiz 2 10%

Suppose that the current consists of positively charged particles. We can determine the force on each charge.
We can then aggregate these to give:

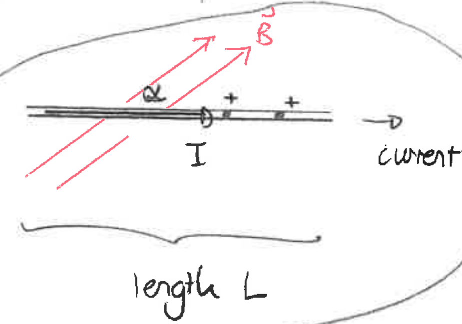
The force exerted by a magnetic field on a wire:

* has magnitude

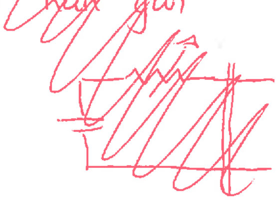
$$F = ILB\sin\alpha$$

* direction given by r.h. rule.

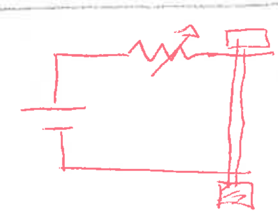
thumb → current
index → magnetic field
middle → force



~~Demo: Rail gun~~



Demo: Rail gun



Quiz 3

Demo this