Lecture 22

20 OCT 2014

Ch. 28 - Magnetic fields

Magnetic field produces a magnetic force on a moving charged particle

Applications of magnetic fields are everywhere:

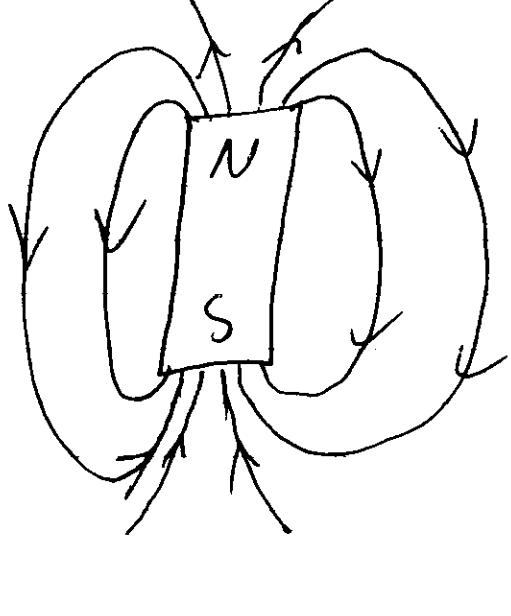
- magnets control DVDs & CD players & computer hard drives
- modern cars have magnets for automatic window control, windshield wipers, etc.
- security alarm systems

How are magnetic fields produced?

1. moving charges
2. [redacted] some particles have an intrinsic magnetic field around them, due to a property called spin (these fields can add to make a net field)

no such thing as a "magnetic charge" or "magnetic monopole"

can think about magnetic field around a bar magnet:



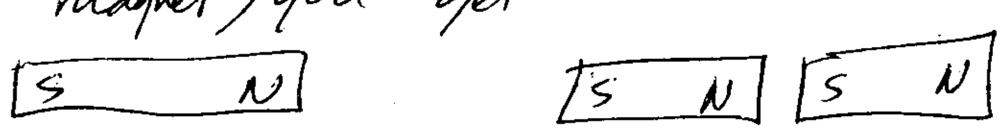
looks like field for a dipole, but all loops are actually closed magnetic field has no sources or sinks (unlike G-field or E-field)

magnets have poles, usually labeled as N and S.

opposite poles attract:

like poles repel:

magnetic poles always come in pairs. So if you break a bar magnet, you get



Earth itself has a magnetic field.
caused by a difference in rotation
between its solid inner core &
the liquid outer core.

Helpful for

1) navigation
2) protection from sun flares

How to determine magnetic field?

For electric field, we just placed
a test charge somewhere, calculated
force, & divided out by the
charge.

We cannot do this for the
magnetic field due to lack of
magnetic charges.

To determine it at some point, consider a positive test charge q,

1) measure the force on it when @ rest. This gives $\vec{E}$.

2) Now measure the force on it when velocity is $\vec{v}$. Keep doing this ~~when~~ with $\vec{v}$ in other directions.

What is found is always consistent w/ the Lorentz force law:

$$\vec{F} = q\left(\vec{E} + \vec{v} \times \vec{B}\right)$$

where $\vec{B}$ is magnetic field.

So we can say that the total force $\vec{F}$ has 2 contributions: $\vec{F}_E + \vec{F}_B$ so that $\vec{F} = \vec{F}_E + \vec{F}_B$

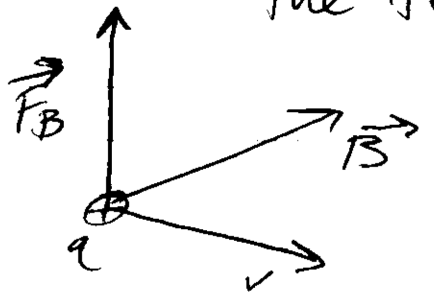
Experimentally, it is found that

- the magnetic force vanishes ($= 0$) when $\vec{v}$ is parallel to $\vec{B}$
- direction of $\vec{F}_B$ is perpendicular to the plane formed by $\vec{v}$ & $\vec{B}$.
& magnitude is $v B \sin\theta$ where θ is angle between $\vec{v}$ & $\vec{B}$.

So this is consistent w/

$$\vec{F}_B = q\,(\vec{v} \times \vec{B})$$

sign change for the charge switches the direction of the force.



(right hand rule)

$\vec{F}_B$ is always perpendicular to $\vec{v}$ + $\vec{B}$ + thus cannot change the speed of a particle (but it can change its direction)

As a result, magnetic field does no work on a moving particle:

$$dW = \vec{F}_B \cdot d\vec{s} = q(\vec{v} \times \vec{B}) \cdot \vec{v}\,dt$$

$$= q(\vec{v} \times \vec{v}) \cdot \vec{B}\,dt = 0$$

units for magnetic field

$$F_B = qvB\sin\theta$$

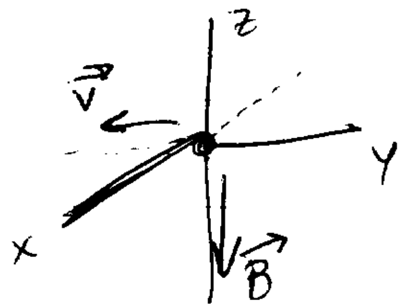
$$\Rightarrow \quad B\sin\theta = \frac{F_B}{qv}$$

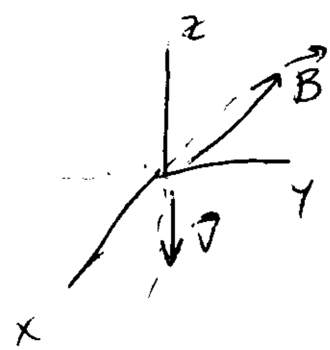
So units are $\dfrac{N}{C \cdot m/s} = T$

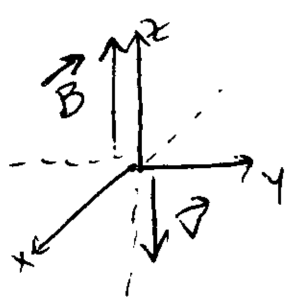
(Tesla)

QUESTION:

What is direction & magnitude of $\vec{F}_B$ for





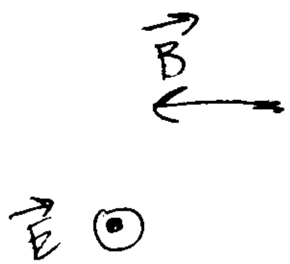


QUESTION:

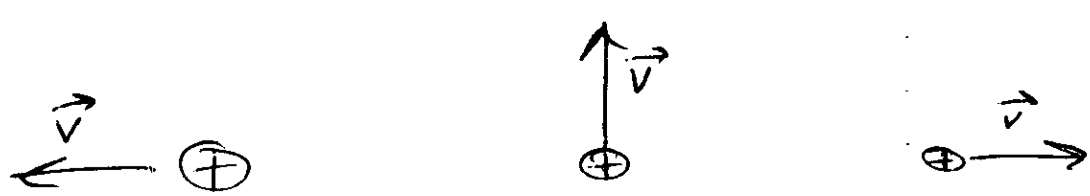
Suppose both E-field & B-field

$\vec{E}$ coming out of page &

$\vec{B}$ going left



Which velocity vector results in highest net force?



Which way to make $\vec{v}$ point in order to possibly have a net force of zero?