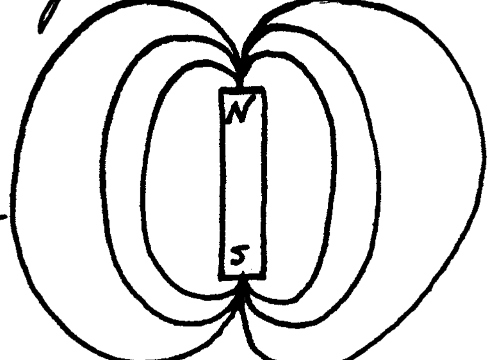
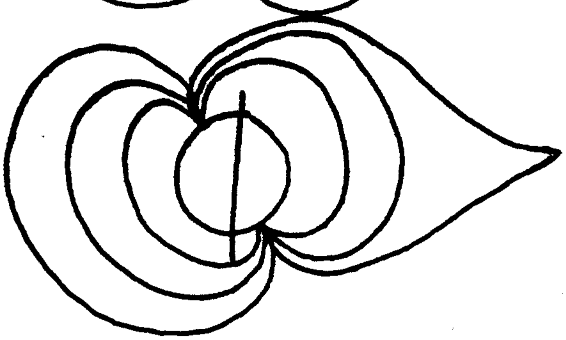
Magnetic force

Known from antiquity that iron ore found near Magnesia had property of attracting other bits of iron — magnets. The fact that magnetized pieces of metal naturally align themselves (roughly N-S) indicates that the earth itself is magnetized. If you take a bunch of iron filings and a "bar magnet" filings set up pattern following "<u>magnetic field lines</u>." Earth has North magnetic pole near north pole or axis of rotation. Use of this fact resulted in application of compass to navigation ~ 11th century. Phenomenon totally not understood until early 19th century began to realize that <u>magnetic effects are electrical</u>

BAR MAGNET



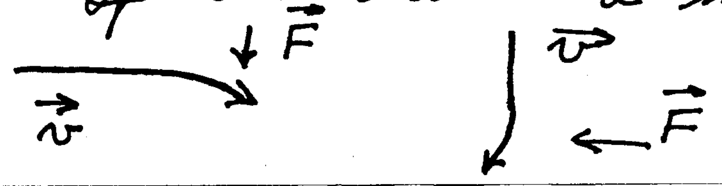


$\vec{B}$ present at that point. (We know that mag field must be produced by other chgs in motion, just as $\vec{E}$ field is produced by presence of chgd. mat'l. For now we consider $\vec{B}$ field a property of space. We'll investigate production of $\vec{B}$ field in next chapter) In general since $\vec{E}$, $\vec{B}$ are both produced by electrical charges both $\vec{E} + \vec{B}$ will be present and we speak of "<u>electro-magnetic field</u>" recognizing that electricity and magnetism are merely two aspects of same phenomenon.

$\vec{B}$ field — exists at a point in space if $\exists$ a force on a moving charge at that point

- is a vector quantity

When we discussed $\vec{E}$ field defined $\vec{E}$ to be in direction of force on positive charge — can't do that with $\vec{B}$. If we have a moving charge



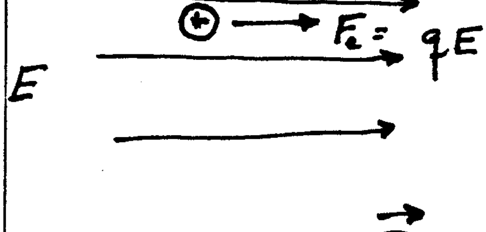
phenomena produced by (or acting upon) charges in motion

Oersted – current carrying wire attracts bar magnet

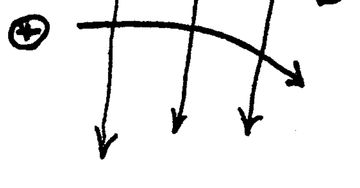
Faraday – moving magnet can
(Henry) induce current in a wire

Natural magnetic phenomena still not fully understood but result from tiny effective currents in magnetic mat'ls. atom – electrons move around nuclei + also spin on axes ⇒ all atoms exhibit magnetic effects. Some cases can align all of these little magnets within a material producing net mag field.

Magnetic field



Electrostatic field $\vec{E}$ produces force on charged particle causing acceleration

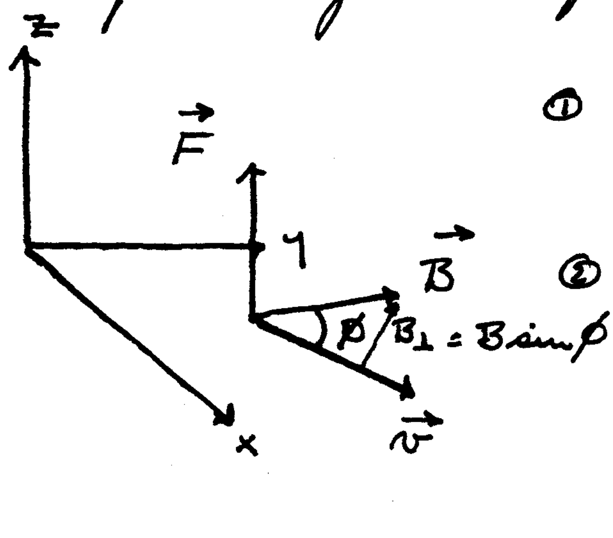


If moving charge has add'l force acting upon it we say that there is a magnetic field

$\vec{F}$ in different direction depending upon direction of velocity of charge. ① Find $\underline{\vec{F} \text{ always } \perp \vec{v}}$ and, in a given direction, $\underline{F \propto v}$.

If we look at charges moving in all possible directions we find that there is a unique direction for which no force exists. We define this unique direction as the direction of the magnetic field. W r t this definition ② Find $\underline{\vec{F} \text{ always } \perp \vec{B}}$ and in a given direction $\underline{F \propto B}$.

Now ready to write down rules of magnetic force



① $\vec{F} \perp$ plane determined by $\vec{v}$ and $\vec{B}$

② F in direction of advance of right hand screw when rotated in sense from $\vec{v}$ to $\vec{B}$ ($\overset{+}{\text{charge}}$)

③ $|\vec{F}| = q|\vec{v}|\,|\vec{B}| \sin \phi$

$F = q\, v\, B_\perp$

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

VECTOR PRODUCTS

$\vec{v} \times \vec{B}$ is vector cross product

(Sec 9-11)

- vector of magnitude

  $vB_\perp$ — $vB \sin\theta$ where θ is the angle between the two vectors

- $\perp$ to plane containing two vectors, direction in sense of r h screw rule

$$(\vec{A} \times \vec{B})_z = A_x B_y - A_y B_x$$
$$(\vec{A} \times \vec{B})_x = A_y B_z - A_z B_y$$
$$(\vec{A} \times \vec{B})_y = A_z B_x - A_x B_z$$

Recall torque

$$T = r_\perp F \quad \text{or} \quad rF\sin\theta$$
$$\vec{T} = \vec{r} \times \vec{F}$$

Angular momentum

$$\vec{L} = \vec{r} \times \vec{p}$$

— o —

$\vec{A} \cdot \vec{B}$ scalar product or dot product

- scalar of magnitude

  $A_\parallel B$ — $AB\cos\theta$ where θ is angle between two vectors

- scalar quantity - no direction