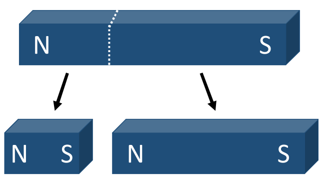
Magnetism

Magnetic "charges"
- Called poles
- Two types, North and South
- Like poles repel each other
- Opposite poles attract each other
- Found only in North/South pairs (Dipoles)

Magnetism

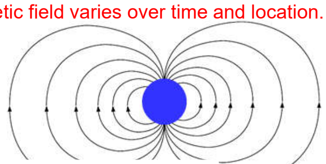
Magnetic poles
- Found only in North/South pairs

Cutting a magnet in two will not isolate the poles.
Cutting a magnet in two produces two magnets.



Earth as a Magnet

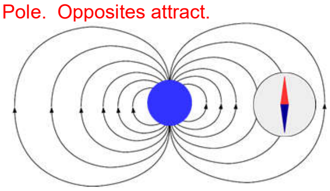
The strength and orientation of the earth's magnetic field varies over time and location.



(Currently $0.25 - 0.65\text{G}, 1\text{G} = 10^{-4}\text{T}$)
The earth's magnetic poles are "near" the geographic poles (where the axis of rotation intersects the earth's surface).

Earth as a Magnet

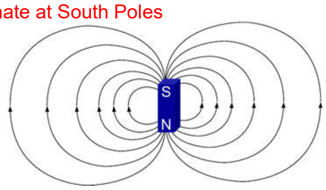
North Pole of compass points towards Geographic North Pole. Opposites attract.



Geographic North Pole is (near) Magnetic South Pole and Geographic South Pole is (near) Magnetic North Pole.

Magnetic Field Lines

Originate at North Poles
Terminate at South Poles



Magnetic Forces

Magnetic fields can produce forces

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

- No forces on particles at rest
- No forces on particles moving parallel to field
- Force is perpendicular to field
- Force is perpendicular to particle's velocity

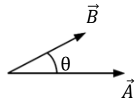
Cross Product Review

$\vec{A} \times \vec{B}$

Magnitude of cross product is the product of perpendicular components.

$$|\vec{A} \times \vec{B}| = AB \sin\theta$$

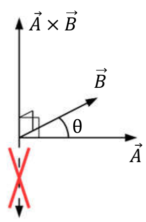
where θ is the angle between $\vec{A}$ and $\vec{B}$.



Cross Product Review

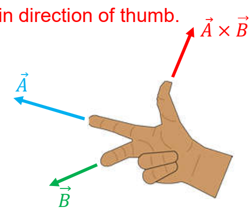
$\vec{A} \times \vec{B}$

Direction of cross product is the direction perpendicular to both $\vec{A}$ and $\vec{B}$ with the ambiguity removed by application of the "Right Hand Rule".

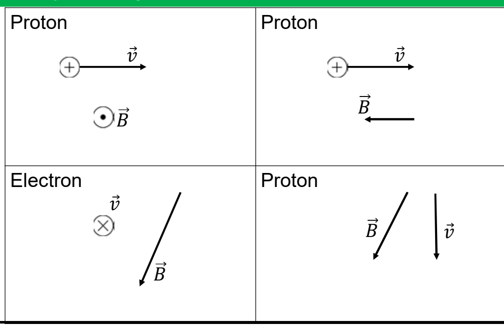


Cross Product Review
Right Hand Rule

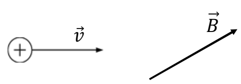
Point 1st finger in direction of $\vec{A}$.
Point 2nd finger in direction of $\vec{B}$.
Cross product is in direction of thumb.



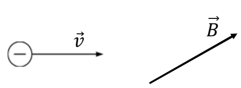
Examples: Determine the direction of the force for each combination of charge, velocity and magnetic field.



Example: Determine the force acting on a proton moving with speed $v_0 = 200\text{m}/s$ at an angle of 30° relative to a magnetic field, $B = 0.04\text{T}$.



Example: Determine the force acting on an electron moving with speed $v_0 = 200\text{m}/s$ at an angle of 30° relative to a magnetic field, $B = 0.04\text{T}$.



Cross Product Review
Multiplying Components

$$\vec{A}\times\vec{B} = \begin{vmatrix} A_x & A_y & A_z \\ B_x & B_y & B_z \\ \hat{\imath} & \hat{\jmath} & \hat{k} \end{vmatrix}$$

$$= (A_yB_z - A_zB_y)\hat{\imath} + (A_zB_x - A_xB_z)\hat{\jmath} + (A_xB_y - A_yB_x)\hat{k}$$

Cross Product Review
Multiplying Components

$$\vec{A}\times\vec{B} = \begin{vmatrix} A_x & A_y & A_z \\ B_x & B_y & B_z \\ \hat{\imath} & \hat{\jmath} & \hat{k} \end{vmatrix}$$

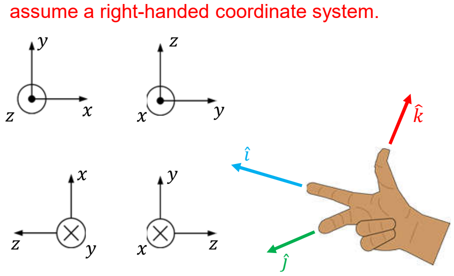
$$= (A_yB_z - A_zB_y)\hat{\imath} + (A_zB_x - A_xB_z)\hat{\jmath} + (A_xB_y - A_yB_x)\hat{k}$$

Note that $\hat{\imath}\times\hat{\jmath} = \hat{k}$ $\quad \hat{\jmath}\times\hat{k} = \hat{\imath}$ $\quad \hat{k}\times\hat{\imath} = \hat{\jmath}$

$\hat{\jmath}\times\hat{\imath} = -\hat{k}$ $\quad \hat{k}\times\hat{\jmath} = -\hat{\imath}$ $\quad \hat{\imath}\times\hat{k} = -\hat{\jmath}$

Cross Product Review

All versions of determining the cross product assume a right-handed coordinate system.



Example: An object with charge, $q = 5\text{C}$, is moving with initial velocity, $\vec{v}_0 = 2(\text{m/s})\hat{\imath} - 3(\text{m/s})\hat{\jmath}$, in a region with a uniform magnetic field, $\vec{B} = -4\text{T}\hat{\imath} + 4\text{T}\hat{\jmath} + 5\text{T}\hat{k}$. Determine the initial force on the object.

Example: An electron entering a region of uniform magnetic field, $\vec{B} = 0.50\text{T}\hat{\jmath}$, experiences a force, $\vec{F} = 3.28 \times 10^{-13}\text{N}\hat{k}$. Determine the initial velocity of the electron.