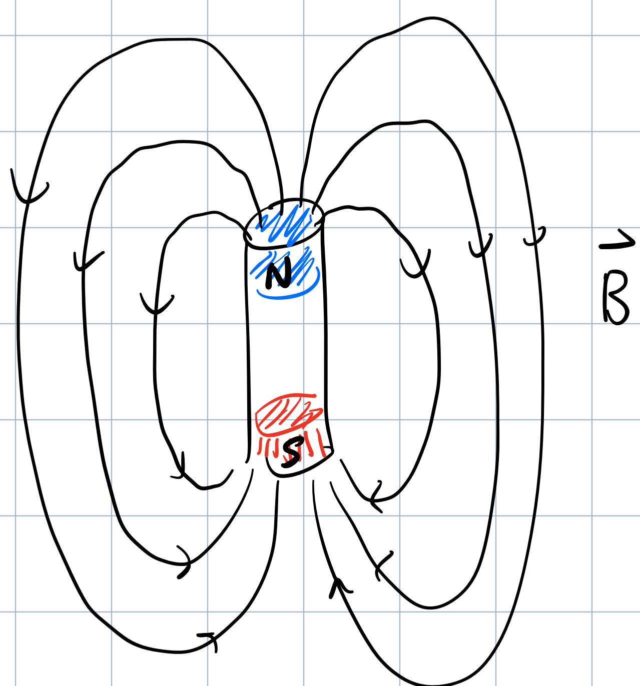
PHYS 121 March 15, 2024

- Complete Prairie Learn HW by 23:59 today
- Complete Pre-Lab #7 before the start of Lab #7
- Quiz #2 will be on Wednesday, March 20

  ⇒ See course website for details.

Last Time:

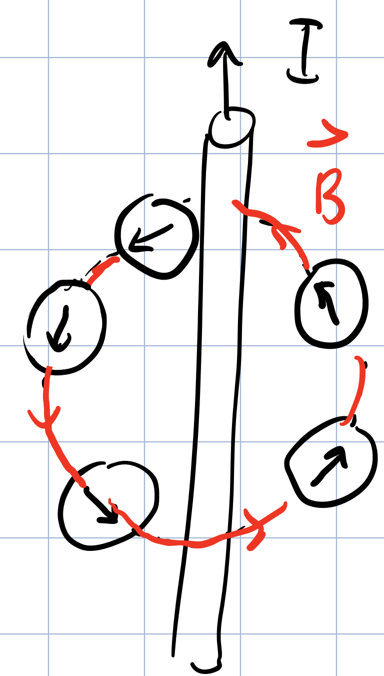
Magnets always come in pairs of N & S poles → no isolated poles or monopoles



Magnetic field lines $\vec{B}$ exit North poles & enter South poles.

- Current or moving charges are a source of magnetic fields. Static or stationary charges do not create magnetic fields.

Continue with thinking about a compass next to a wire with a curret I.



The current creates a magnetic field $\vec{B}$ that loops around the wire.

This magnetic field causes the compass needle to align with the field due to the current.

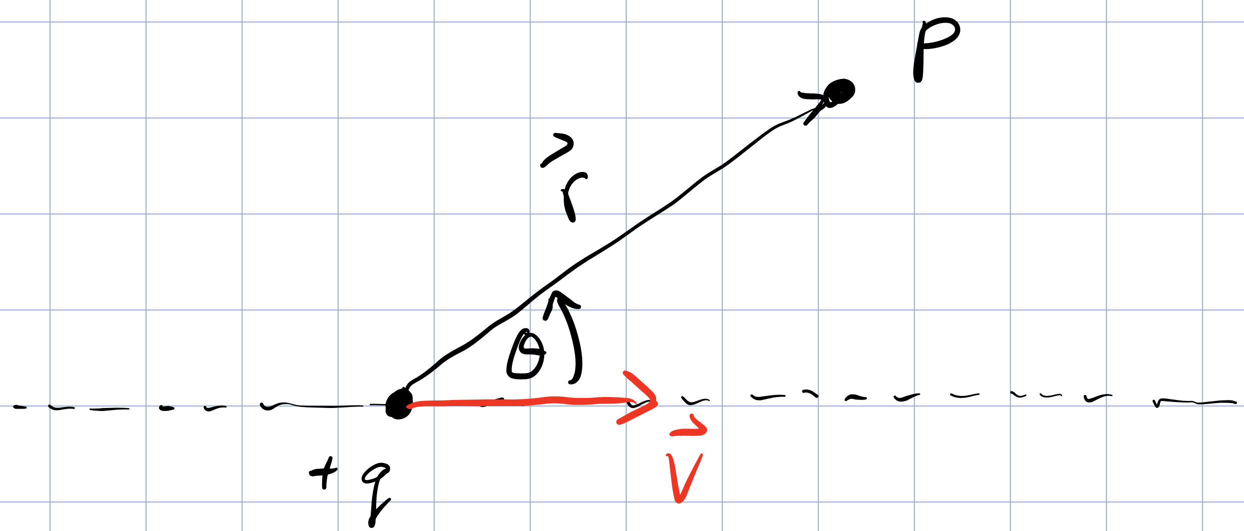
If we reverse the dir'n of I, the magnetic field changes dir'n & compass needles would rotate by 180°.

To find the correct dir'n of $\vec{B}$ due to a current, we use the right hand rule (RHR)

1. Pt. thumb of right hand in the dir'n of I.

2. Fingers naturally curl in dir'n of resulting $\vec{B}$-field.

Imagine a pt. charge q moving in a straight line with velocity $\vec{v}$.



What is $\vec{B}$ at P due to moving charge?

Find that the strength of magnetic field $\vec{B}$ at P is proportional to:

- the charge q
- the speed $|\vec{v}|$ of the charge.
- $\frac{1}{r^2}$
- $\sin\theta$ (perhaps a little surprizing)

$$B \propto \frac{qv}{r^2}\sin\theta$$

$\theta = 90°$

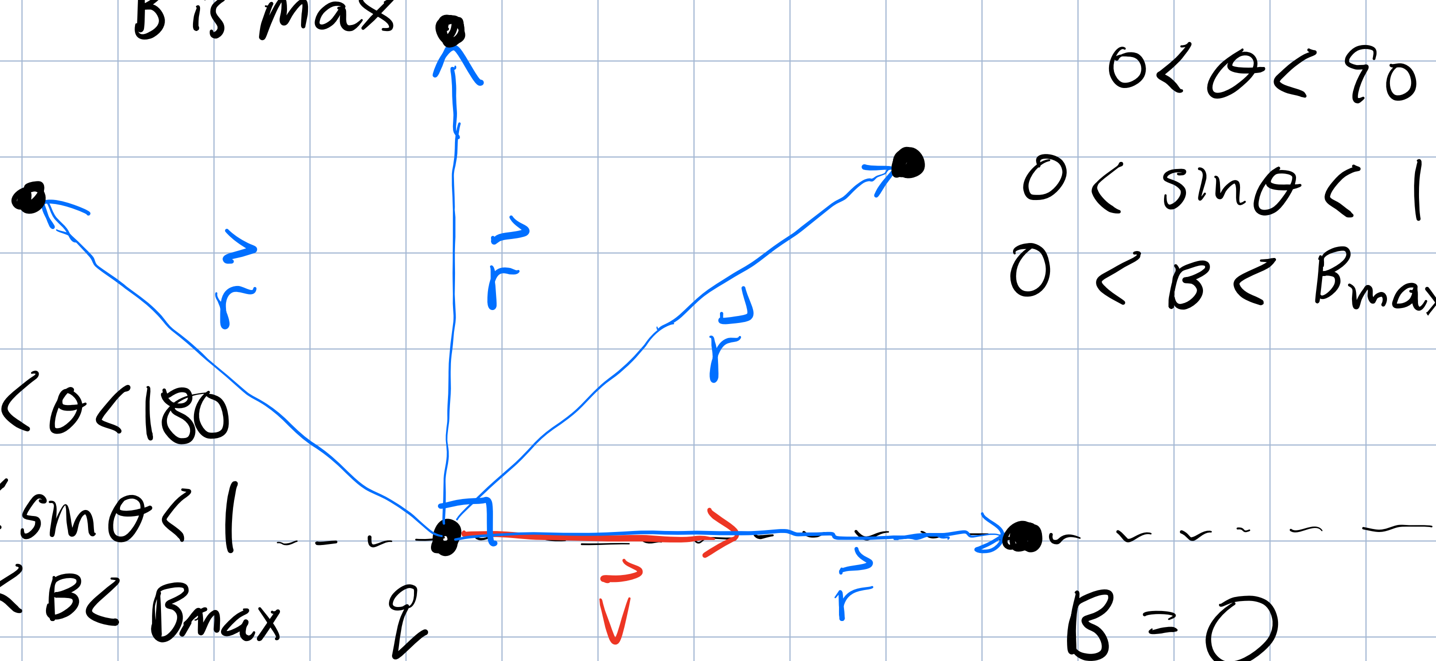
$\sin\theta = 1$ (max)

B is max

$0 < \theta < 90°$

$0 < \sin\theta < 1$

$0 < B < B_{max}$



$90 < \theta < 180$

$0 < \sin\theta < 1$

$0 < B < B_{max}$

$B = 0$

b/c $\theta = 0$

& $\sin\theta = 0$

Through careful measurements, we can find the constant of proportionality:

$$\boxed{B = \underbrace{\frac{\mu_0}{4\pi}}_{\text{constant of proportionality}} \frac{qv\sin\theta}{r^2}}$$

μ_0 is called the "permeability of free space".

$$\mu_0 = 4\pi \times 10^{-7} \ \frac{T \cdot m}{A}$$

$$\frac{\mu_0}{4\pi} = 1 \times 10^{-7} \ \frac{T \cdot m}{A}$$

$$[B] = [\mu_0] \left[\frac{q\, v}{r^2} \right]$$

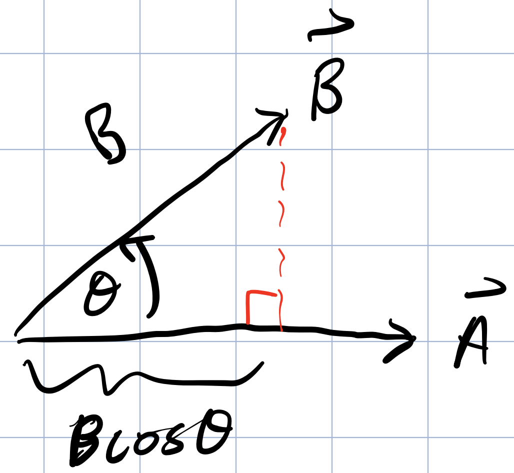
$$= \frac{T \cdot \cancel{m}}{\cancel{A}} \ \cancel{C} \ \frac{\cancel{m}}{\cancel{s}} \ \frac{1}{\cancel{m^2}} = T$$

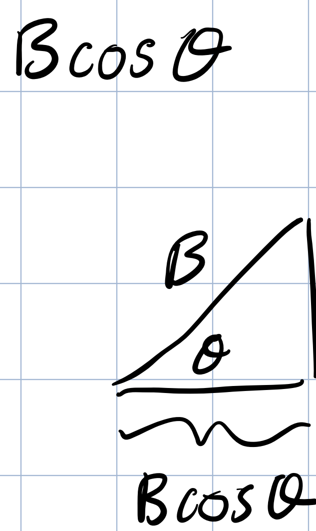
Magnetic fields are measured in units of Tesla (T).

Cross-Product

The cross-product is a product between two vectors.

First, recall the dot product between two vectors



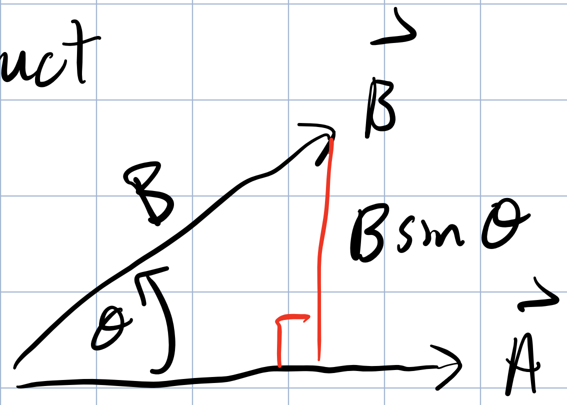


$$\vec{A}\cdot\vec{B} = |\vec{A}||\vec{B}|\cos\theta$$
$$= AB\cos\theta$$

Note that result of $\vec{A}\cdot\vec{B}$ is a scalar (a number).

The dot product selects the component of $\vec{B}$ that is parallel to $\vec{A}$

Cross Product



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

just the magnitude of the cross product.

not ordinary multiplication

The cross product selects the component of $\vec{B}$ that is $\perp$ to $\vec{A}$.

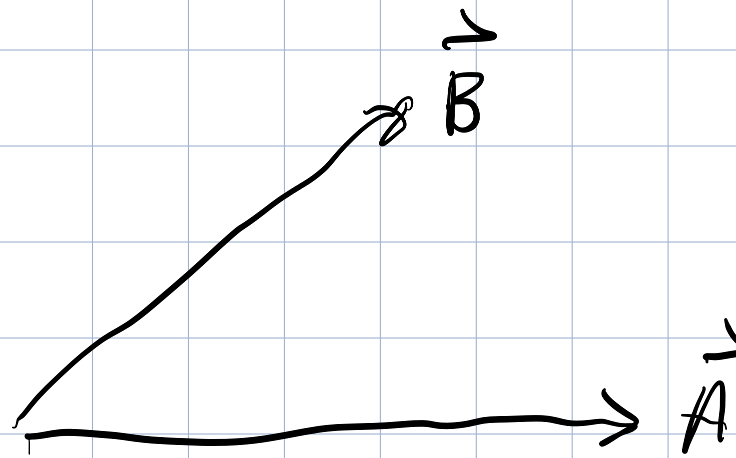
One important difference between dot & cross products is that the result of the cross product is another vector.

In general

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

$$|\vec{C}| = AB\sin\theta$$

Vectors $\vec{A}$ & $\vec{B}$ lie in a plane.



In this the plane is the screen.

$\vec{C}$ will be $\perp$ to this plane or (equivalently) $\vec{C}$ is $\perp$ to both $\vec{A}$ & $\vec{B}$.

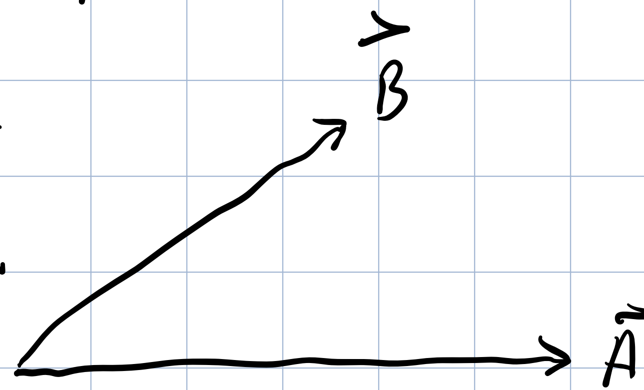
To determine whether $\vec{C}$ is into or out of the screen, we use a second RHR.

- Place right hand/arm in dir'n of $\vec{A}$ (the first vector in the cross product)

- Curl fingers of right hand so that they are parallel to $\vec{B}$ (second vector in the cross product)

- Thumb points in the dir'n of $\vec{C}$.

$\vec{C} = \vec{A} \times \vec{B}$ points out of the screen.



$\vec{D} = \vec{B} \times \vec{A}$ points into the screen.