Ch 27: Magnetism

Season 3 Episode 3 - preparing for boss fight

In this episode of LARC Physics 3B, we're going to . . .

- Create a foundation for solving "Magnetism" problems by
  - Determining how (moving) charges behave in magnetic fields
  - Using Ampere's Law

Lecture Review

Big Ideas: Force due to Magnetic Field and Ampere's Law

Key Words: moving charge, current, magnetic field (i.e. B-field), Ampere's Law.

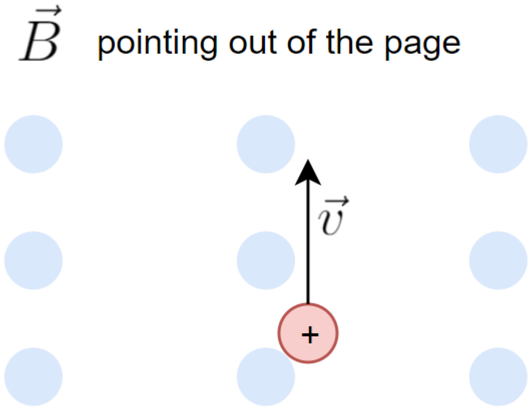
Here are some important equations/concepts:

- $F_B = q\,(\vec{v} \times \vec{B})$, magnetic force on moving point charge
- $F_B = I\,(\vec{\ell} \times \vec{B})$, magnetic force on segment of current where $\vec{\ell}$ is the direction of the current.
- Ampere's Law: $\int \vec{B} \cdot d\vec{\ell} = \mu_0\, I_{\text{enc}}$
  - Similar to Gauss' Law, we primarily rely on this equation to find the B-field.
  - Involves drawing an "Amperian loop" (like a "Gaussian surface")
  - Often reduces such that

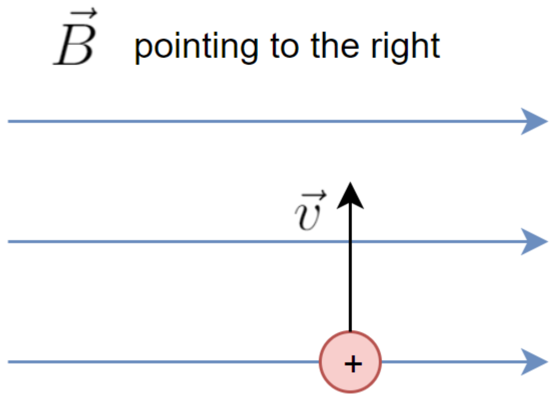
$$\int \vec{B} \cdot d\vec{\ell} = \mu_0\, I_{\text{enc}} \quad \Longrightarrow \quad B\,(2\pi r) = \mu_0\, I_{\text{enc}}, \quad \text{where } r \text{ is the radius of the Amperian loop}$$

Guided Practice

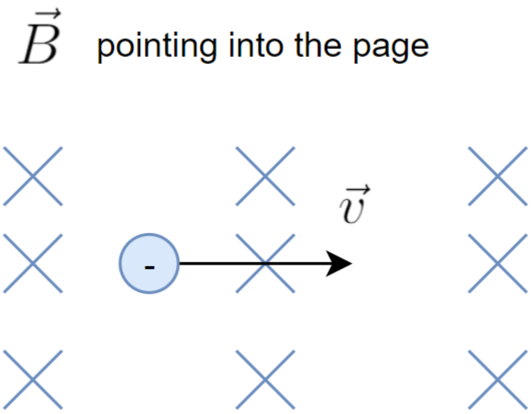
Consider the following scenarios with a given magnetic field $\vec{B}$ and a charge moving with some velocity $\vec{v}$. Determine the direction of the magnetic force acting on the charge.



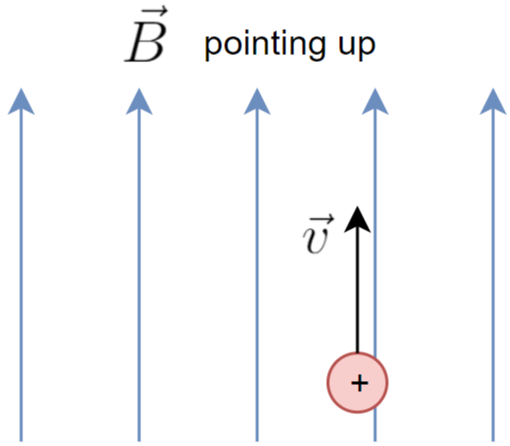
(a)



(b)



(c)



(d)

Answers:

(a) $\vec{F}_B$ points to the right

(b) $\vec{F}_B$ points into the page

(c) $\vec{F}_B$ points downwards (Left-Hand Rule for negative charges!)

(d) $\vec{F}_B$ is zero since $\vec{v}$ and $\vec{B}$ are parallel and $\sin\theta = 0$ for $\theta = 0^\circ$

Breakout-Room Activity

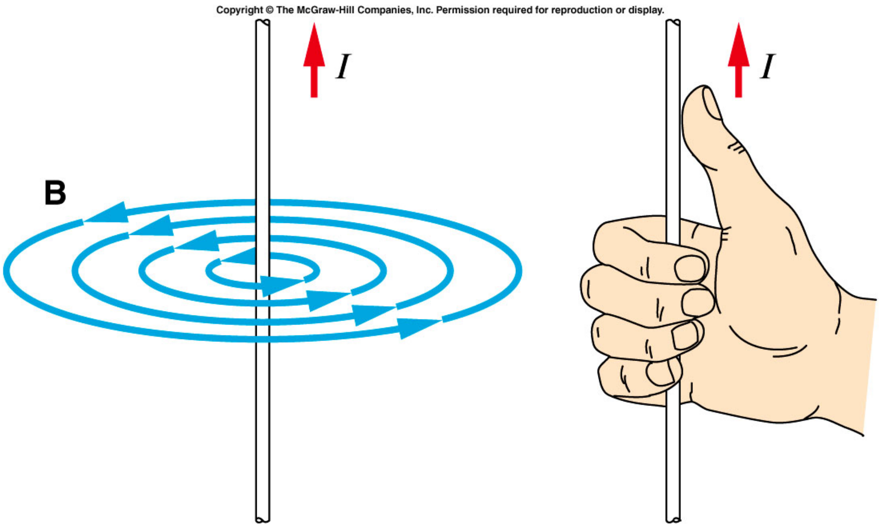
Determine the magnitude and direction of the force on an electron traveling $8.75 \times 10^5\,\mathrm{m/s}$ horizontally to the East in a vertically upward magnetic field of strength $0.45\,\mathrm{T}$.

Useful info: $q = -1.6 \times 10^{-19}\,\mathrm{C}$ for the charge of an electron.

Answer: $\vec{F}_B = 6.3 \times 10^{-14}\,\mathrm{N}(-\hat{z})$, into the page (i.e. away from you).

Breakout-Room Activity

Just as magnetic fields push moving charges; moving charges can create magnetic fields. In other words, a current may produce a magnetic field. Let's consider the scenario of current moving through a straight wire:



Derive an expression for the **magnitude of the magnetic field** $\mathbf{B} = \left|\tilde{\mathbf{B}}\right|$ at a certain radius $\mathbf{r}$ away from the wire with current I running vertically upwards as shown in the figure.

$$\text{Answer:} \qquad B = \frac{\mu_0}{2\pi}\frac{I}{r}$$

Here is an application of this concept in the case of two current-carrying wires running parallel to each other. Their individual magnetic fields cause the two wires to attract each other via the magnetic force. https://www.youtube.com/watch?v=8T_dP7Oq620