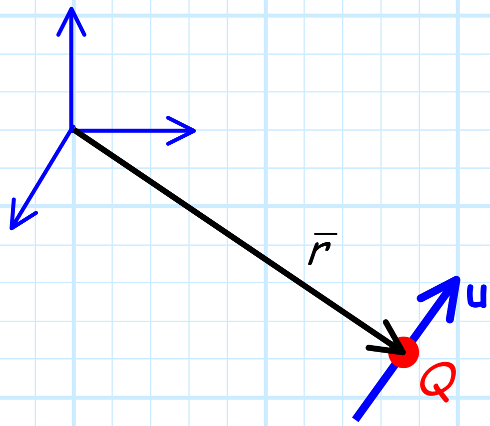
The Lorentz Force Law

Say a charge Q resides at point $\bar{r}$, and is moving at a **velocity** $\mathbf{u}$.

Somewhere, other charges and currents have generated an **electric field** $\mathbf{E}(\bar{r})$ and **magnetic flux density** $\mathbf{B}(\bar{r})$.

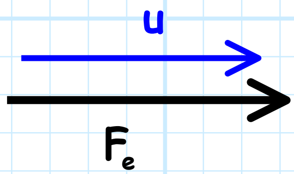


These fields exert a **force** on charge Q equal to:

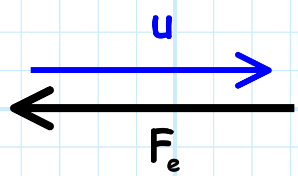
$$\mathbf{F} = Q\left(\mathbf{E}(\bar{r}) + \mathbf{u} \times \mathbf{B}(\bar{r})\right)$$

Note the force due to $\mathbf{E}(\bar{r})$ (i.e., $\mathbf{F}_e$), **could** be parallel to velocity vector $\mathbf{u}$.

For that case, $\mathbf{E}(\bar{r})$ will apply a force on the charge in the direction of its velocity. This will **speed up** (i.e., accelerate) the charge, essentially adding **kinetic energy** to the charged particle.



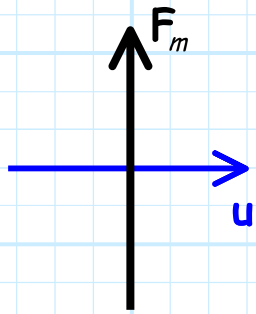
Or, the force due to $\mathbf{E}(\bar{r})$ could be **anti-parallel** to velocity vector $\mathbf{u}$. For this case, the electric field $\mathbf{E}(\bar{r})$ applies a force on the charge in the **opposite direction** of its movement. This will **slow down** the charge, essentially **extracting** kinetic energy from the charged particle.



Now, contrast this with the force applied by the **magnetic flux density**. We know that:

$$\mathbf{F_m} = \left(\mathbf{u} \times \mathbf{B}(\bar{r})\right) Q$$

Therefore, the force $\mathbf{F_m}$ is **always** orthogonal to velocity vector $\mathbf{u}$ (do **you** see why?).



As a result, the force due to the magnetic flux density $\mathbf{B}(\bar{r})$ can change the **direction** of velocity $\mathbf{u}$ (i.e., change particle path), but **not** the magnitude of the velocity $|\mathbf{u}|$.

In other words, the force $\mathbf{F_m}$ **neither** speeds up or slows down a charged particle, although it **will** change its **direction**. As a result, the magnetic flux density $\mathbf{B}(\bar{r})$ **cannot** modify the **kinetic energy** of the charged particle.