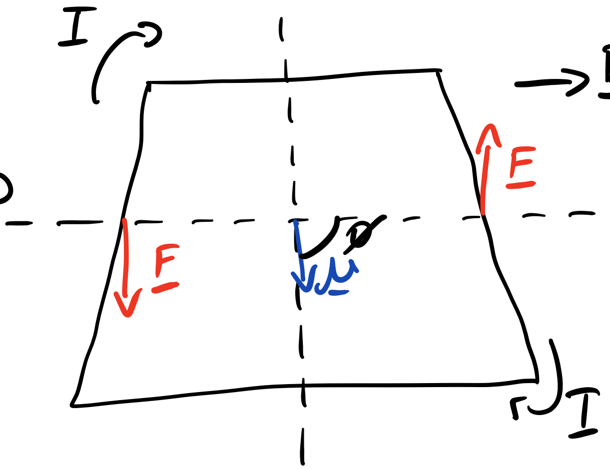
Motors

Motors use electrical energy to do mechanical work.

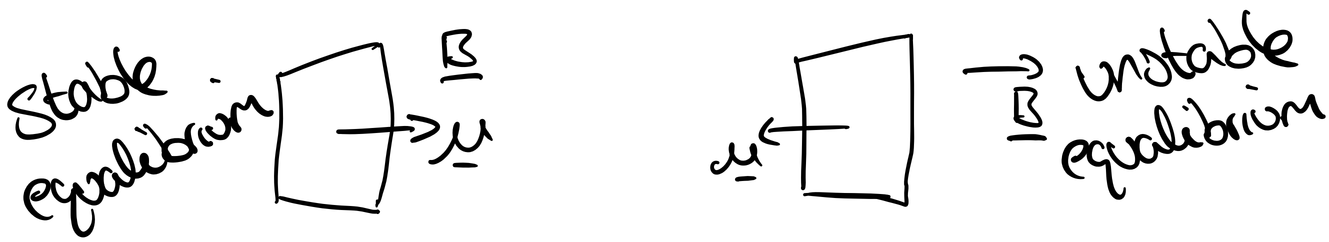
As the loop rotates, it does work.



- $\underline{\mu}$ points down
- $\emptyset$ is angle between $\underline{\mu}$ & $\underline{B}$

$$\text{Work} = \int \Gamma \, d\emptyset = \int |\underline{\mu}||\underline{B}| \sin\emptyset \, d\emptyset$$

There are positions with no torque.



To form a motor we have to change the direction of current every half rotation. This is done using a commutator. This keeps the direction of torque in a useful direction.

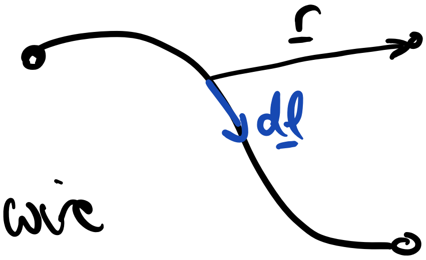
Moving Charges Form Magnetic Fields

Biot-Savart Law

General expression for a magnetic field formed from a current element.

$$\underline{B} = \frac{\mu_0 I}{4\pi} \int_L \frac{d\underline{l} \times \hat{r}}{|\underline{r}|^2}$$

This is for a magnetic field at position $\underline{r}$ due to a current in direction $I d\underline{l}$.



If we instead only look at the field due to a single point of wire

$$d\underline{B} = \frac{\mu_0 I}{4\pi} \cdot \frac{d\underline{l} \times \hat{r}}{|\underline{r}|^2}$$

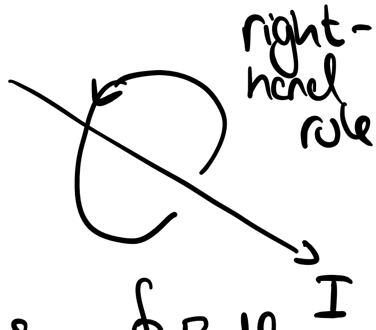
Biot-Savart Law

Ampere's Law

$$\oint \underline{B} \cdot d\underline{l} = \mu_0 I$$

This is for any closed loop where $I = \iint_S \underline{j} \cdot d\underline{S}$

It is only valid when there is no time-varying electric field.



We can use stoke's theorem $\iint_S \nabla \times \underline{B} \cdot d\underline{S} = \oint_{\partial S} \underline{B} \cdot d\underline{l}$ to get

$$\iint_S \nabla \times \underline{B} \cdot d\underline{S} = \mu_0 \iint_S \underline{j} \cdot d\underline{S}$$

$\therefore$ for any surface we can write

$$\nabla \times \underline{B} = \mu_0 \underline{j}$$

This is nearly one of maxwell's equations. Maxwell added two terms - see later.