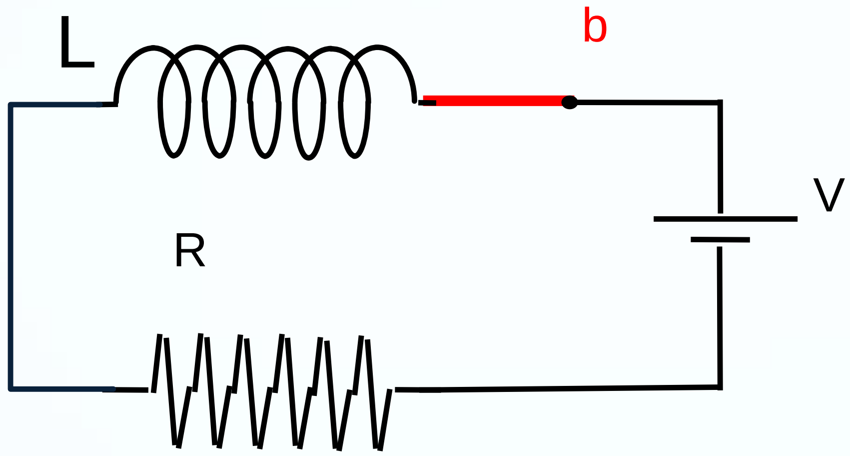
Electricity and Magnetism

- Physics 259 – L02
- Lecture 49

Chapter 29: Magnetic field due to current

30.6: R-L Circuit



$$V - L\frac{di}{dt} - iR = 0$$

If the switch is moved to position b, to initiate the current flow, what happens?

Faraday's law applies and so the change in the Magnetic Field in the inductor L means there is a back EMF induced in L.

The components have all been connected for a very long time. At t=0 the switch S is opened. The current through R_1 and R are 0 and $\varepsilon/_R$

Using the loop rules

$$-L\frac{di}{dt}-iR=0$$

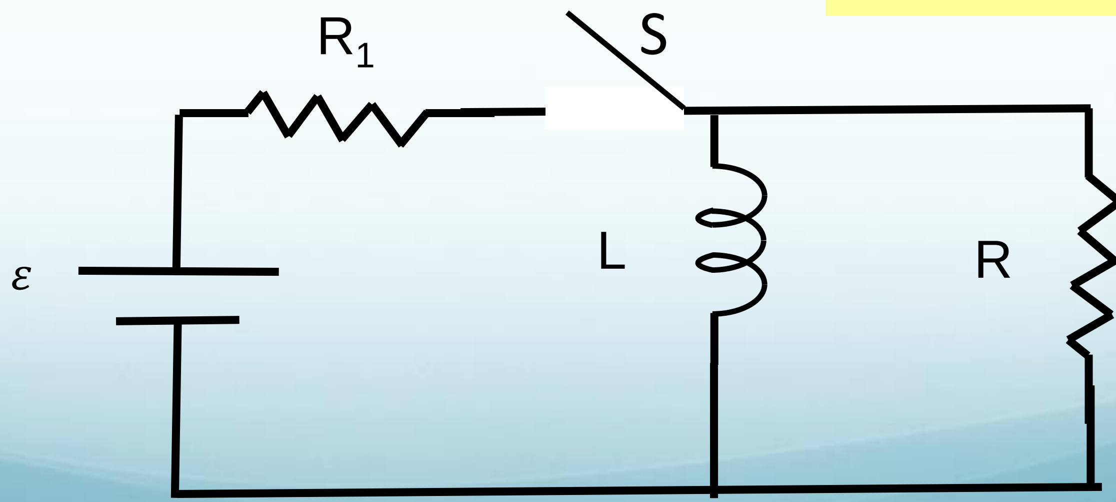
Solving with the method we used for a discharging capacitor

So in this case at t = 0, $i(0) = 0$. Inductor acts like a BATTERY

After a long time, i= V/R

Inductor acts like a WIRE

$$i(t)=i(0)\mathrm{e}^{-\left(\frac{Rt}{L}\right)}$$



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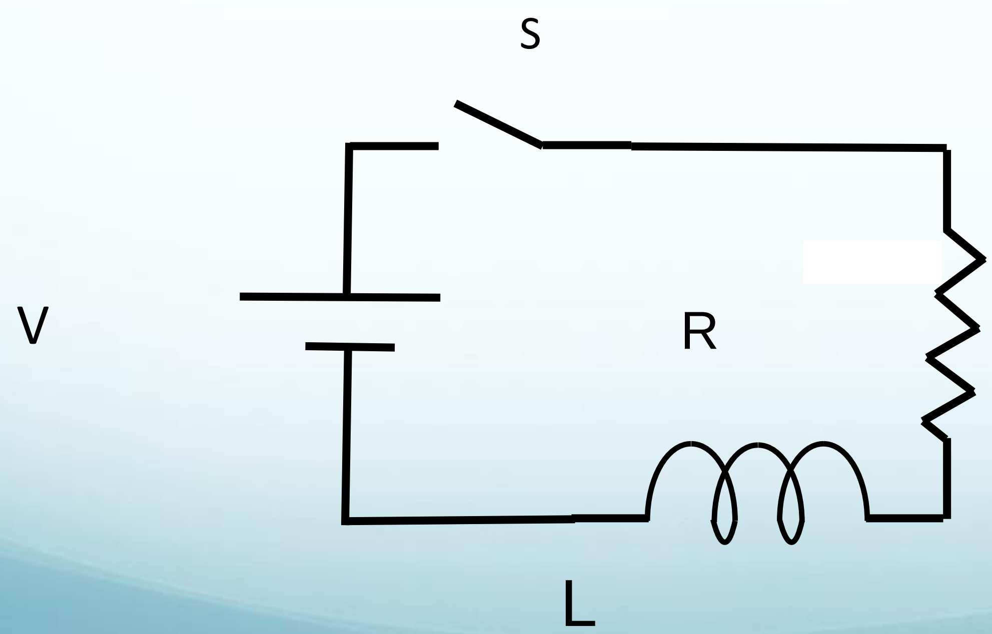
At t=0 the switch S is closed.

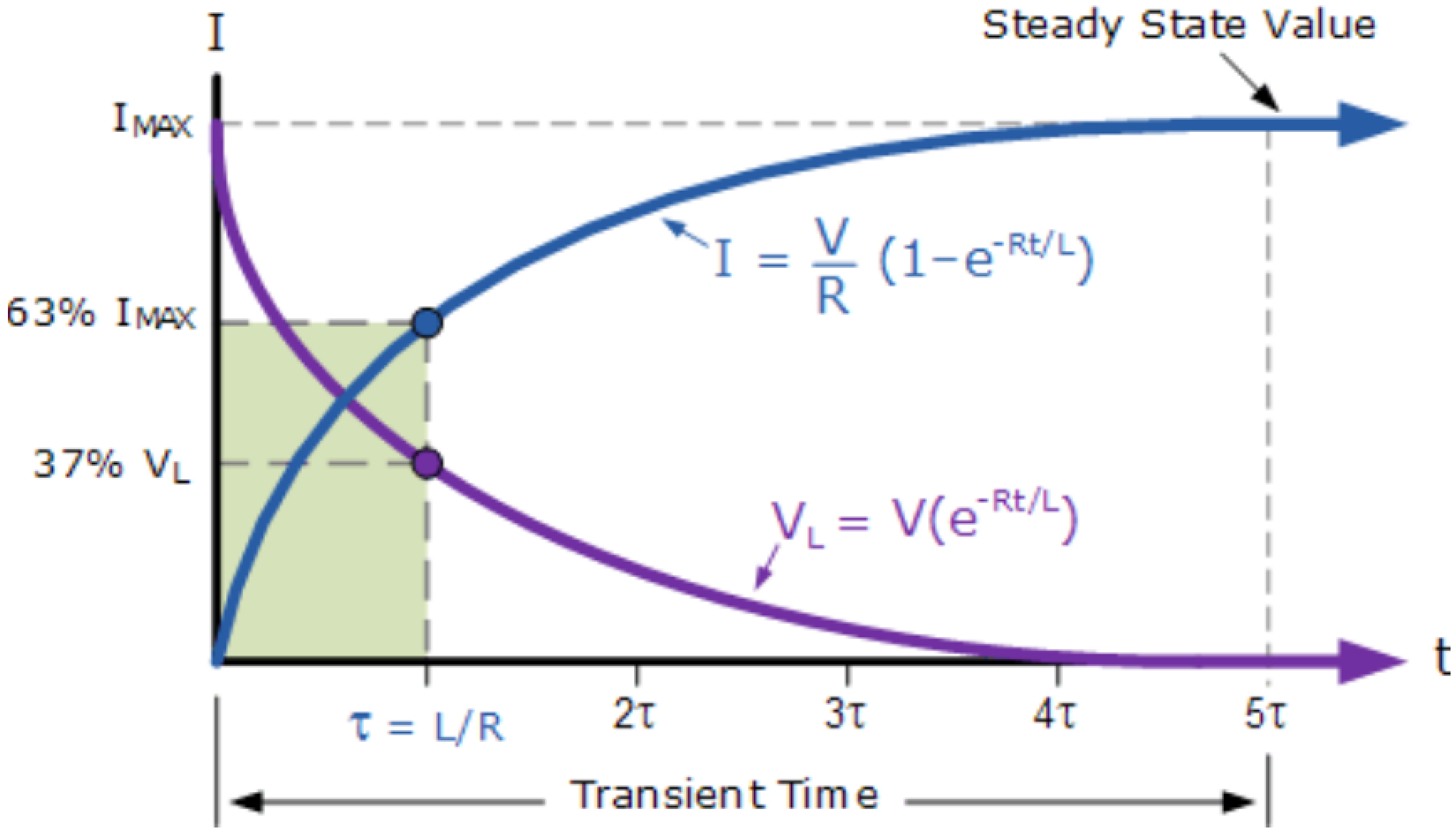
Using the loop rules

$$V - iR - L\frac{di}{dt} = 0$$

Solving using the method we used for the charging capacitor



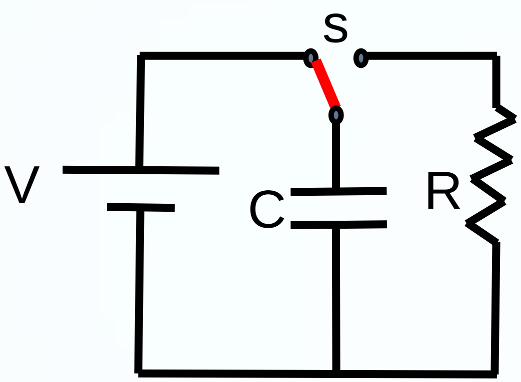
$$i(t) = i_{\max}\left(1 - e^{-\left(\frac{Rt}{L}\right)}\right)$$



https://tinyurl.com/msfn7b5

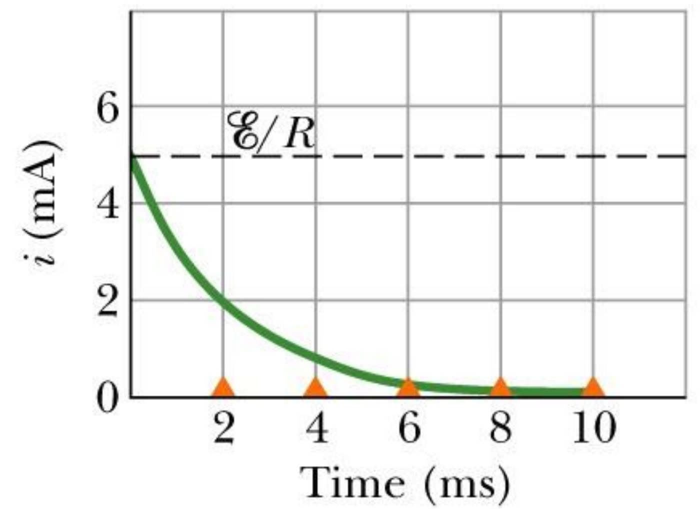
Final review

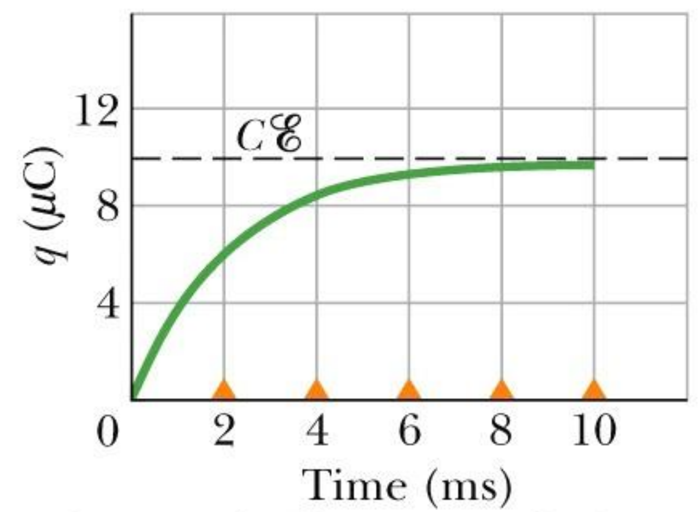
RC circuit: Charging a capacitor



$$i = i_0 e^{-t/RC}$$

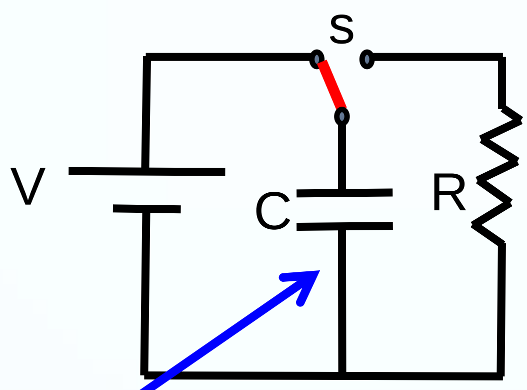
$$q = \varepsilon C\left(1 - e^{-t/RC}\right) = Q_f\left(1 - e^{-t/RC}\right)$$





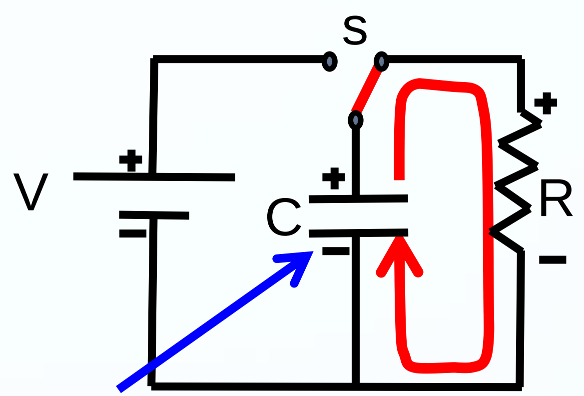
RC circuit: Discharging a capacitor

Switch is connected to the left for a long time until t=0-



Capacitor charges up to voltage V

Switch is suddenly flipped to the right at t=0+

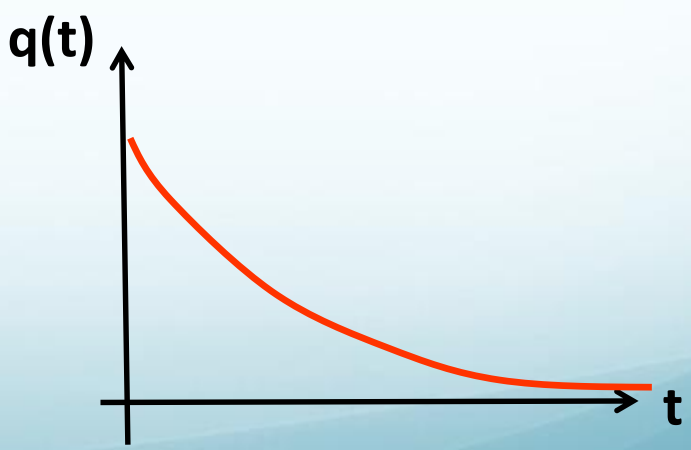


Capacitor discharges

$$\boxed{q(t) = q_0 e^{-t/RC}}$$

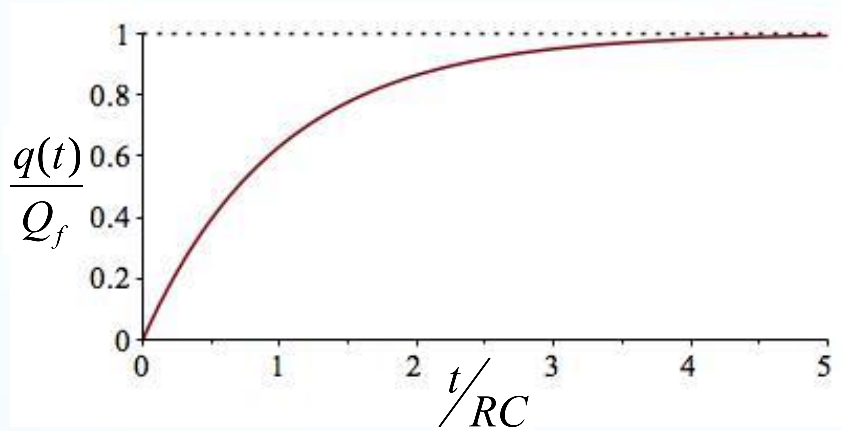
$$\boxed{i(t) = i_0 e^{-t/RC}}$$

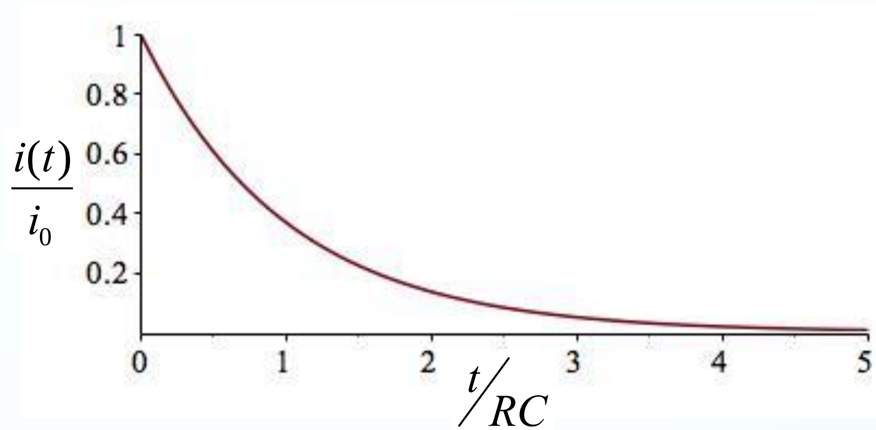
$$q_0 = CV$$



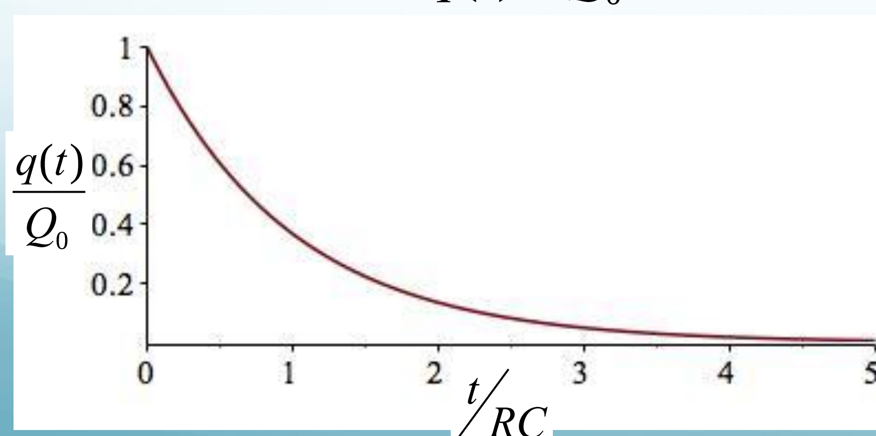
Charging/Discharging Capacitors

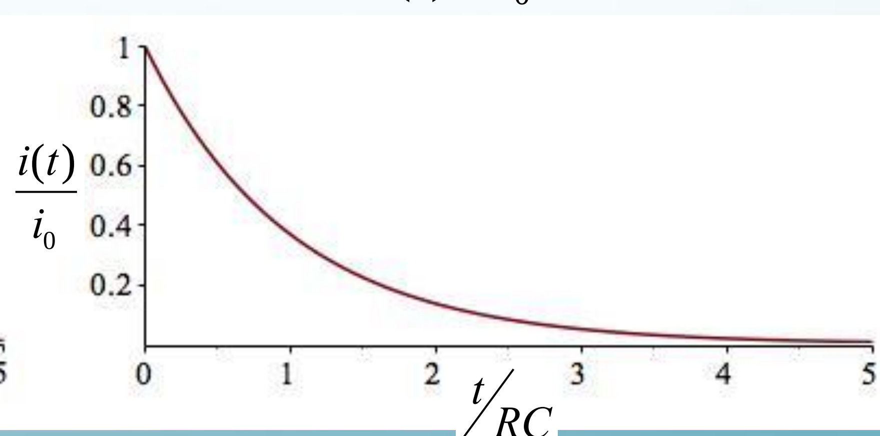
Charging: $q(t)=Q_f\left(1-e^{-\frac{t}{RC}}\right)$ $\qquad$ $i(t)=i_0 e^{-\frac{t}{RC}}$





Discharging: $q(t)=Q_0 e^{-\frac{t}{RC}}$ $\qquad$ $i(t)=i_0 e^{-\frac{t}{RC}}$





The RC time constant

The constant RC pops up in the exponential factor for both charging and discharging capacitors. What does it represent?

The units of RC is seconds: $$[RC] = \frac{V}{A}\frac{C}{V} = \frac{C}{C/s} = s$$

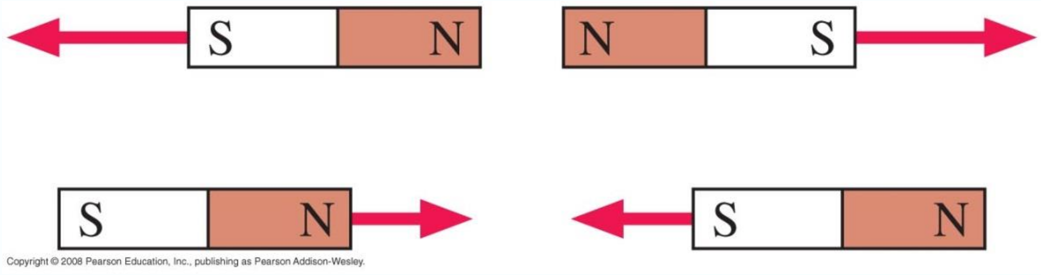
We call RC the "**RC time constant**" and it tells us how quickly a capacitor can charge or discharge.

$$\boxed{RC \equiv \tau}$$

After a time τ, the charge on a discharging capacitor is reduced by a factor of 1/e. After a time $N\tau$, it is reduced by a factor of $1/e^N$

$$\boxed{q(t) = Q_0 e^{-\frac{t}{\tau}}}$$

28.1: Magnetic fields

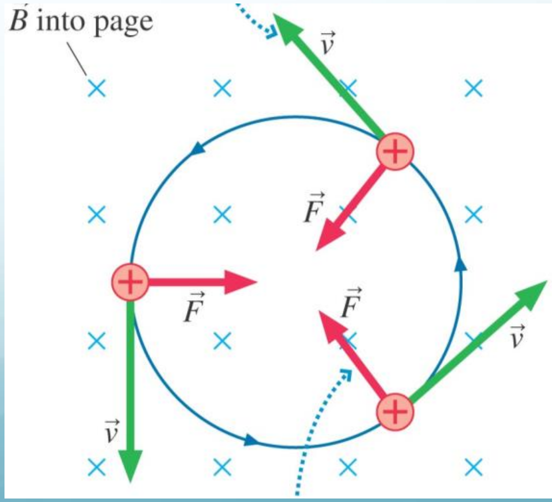


Magnetic force acts only on a moving charge.

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

The Tesla
The Gauss

28.4: A circulating charged particle

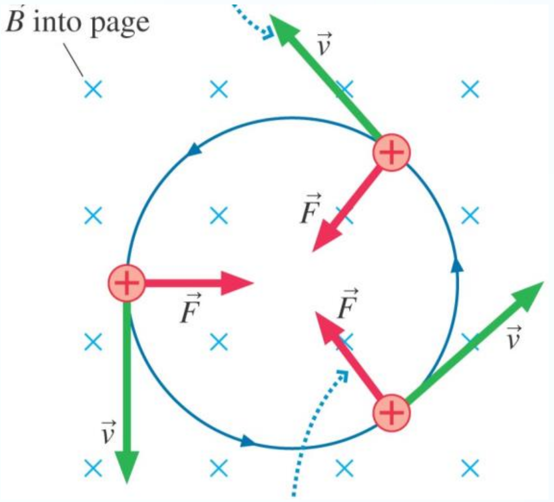


28.4: A circulating charged particle

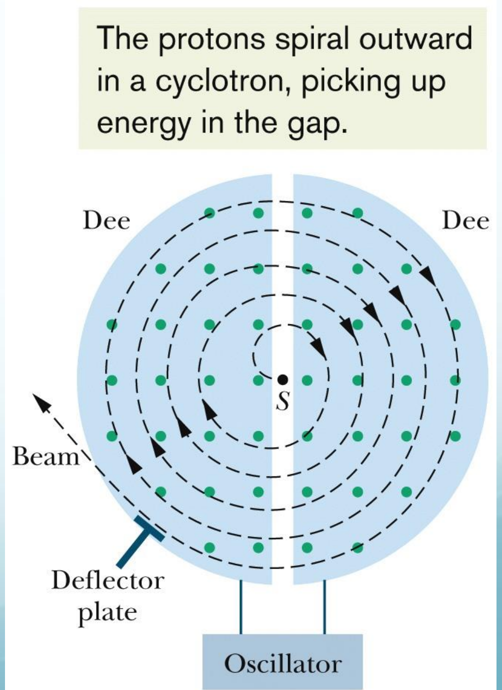
$$R = \frac{mv}{|q|B}$$

$$T_{cyc} = \frac{2pm}{|q|B}$$

$$f_{cyc} = \frac{|q|B}{2pm}$$



28.5: Cyclotrons and Synchrotrons

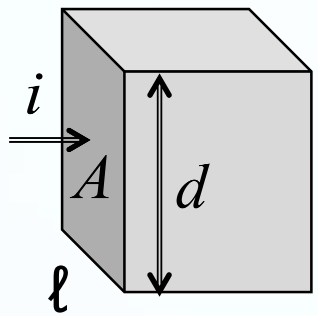


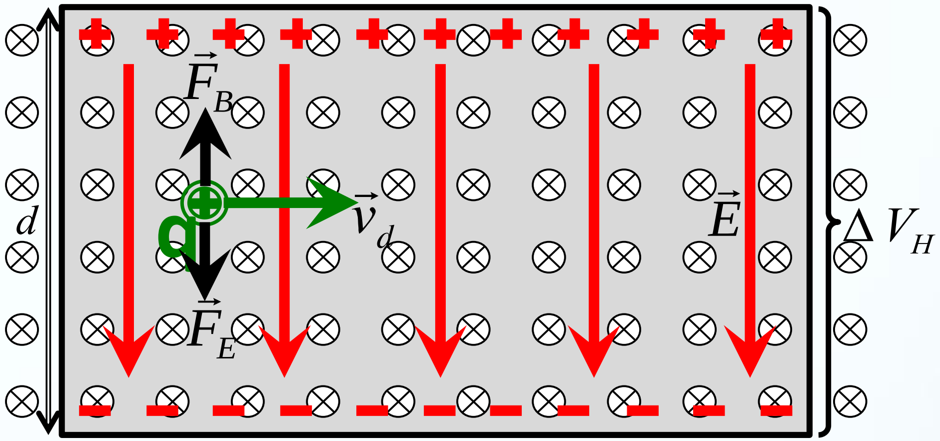
Application: Mass Spectrometer

$$R = \frac{mv}{|q|B}$$

28-2 Crossed Fields: Discovery of The Electron

28-3 Crossed Fields: The Hall Effect





$$F_B = q v_d B$$

$$v_d = \frac{i}{neA} \qquad A = \ell d$$

$$\boxed{\Delta V_H = v_d B d}$$

$$\boxed{B = \frac{ne\ell}{i} \Delta V_H}$$

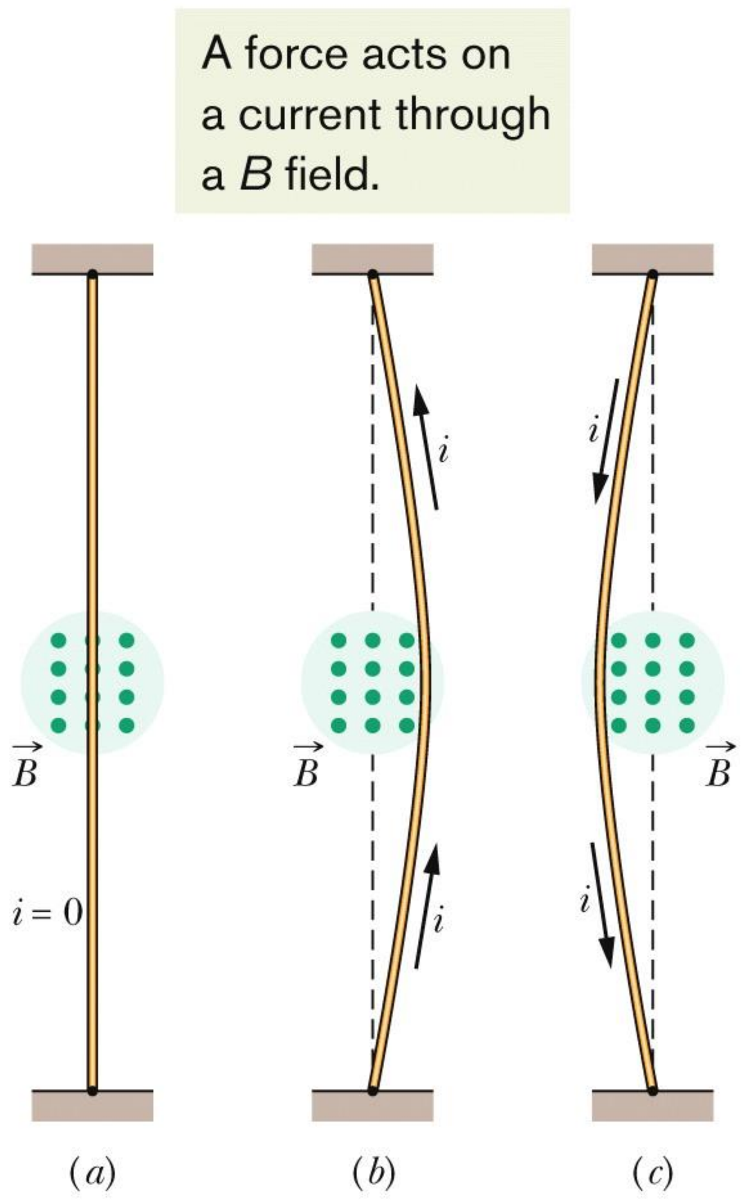
n is a material property

28-6 Magnetic Force on a Current-Carrying Wire

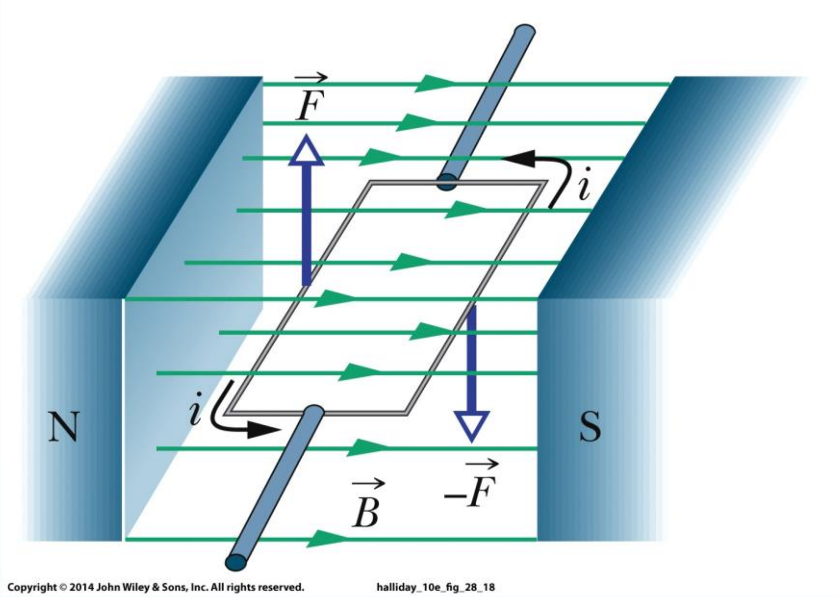
A straight wire carrying a current *i* in a uniform magnetic field experiences a sideways force

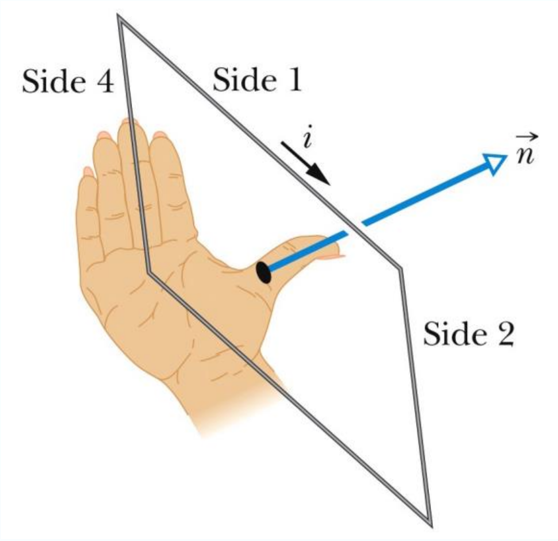
$$\vec{F}_B = i\vec{L} \times \vec{B} \quad \text{(force on a current).}$$

Here ***L*** is a length vector that has magnitude *L* and is directed along the wire segment in the direction of the (conventional) current.



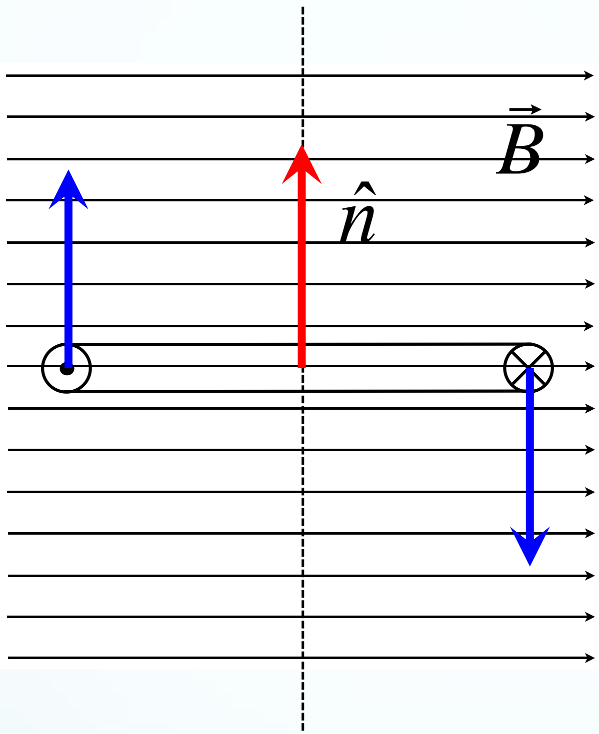
28-7 Torque on a Current Loop



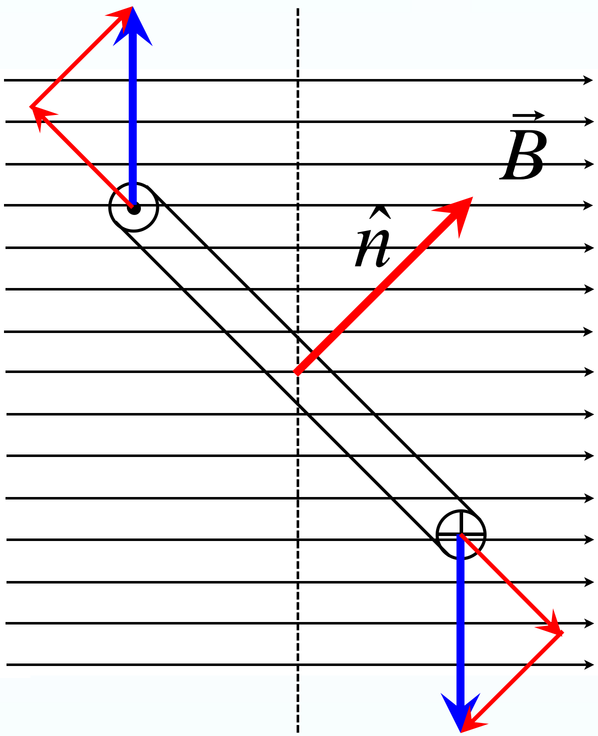


$$\vec{F}_B = i\vec{L} \times \vec{B} \quad \text{(force on a current).}$$

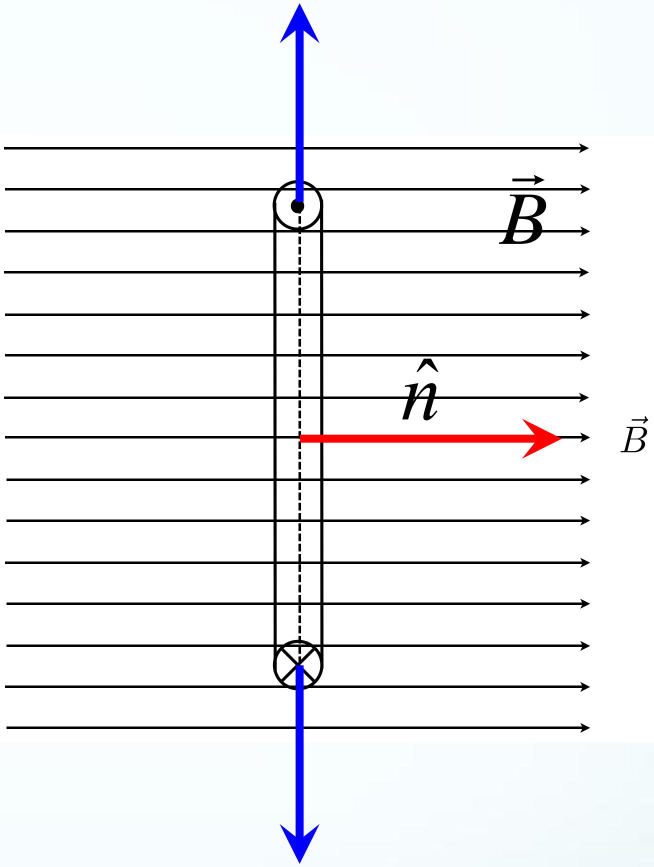
$$\tau = NiAB \sin \theta,$$



The normal vector is at right angles to the B-field: all magnetic force causes rotation of the loop

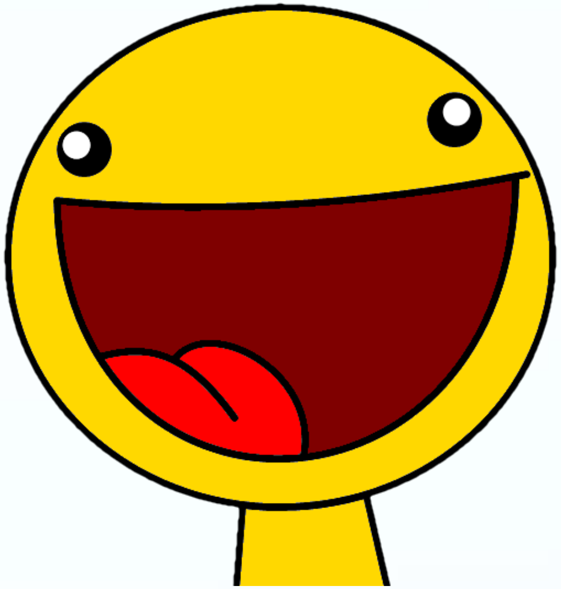


The normal vector is at some angle to the B-field: some of the magnetic force causes rotation of the loop



The normal vector is parallel to the B-field: none of the magnetic force causes rotation of the loop

Conclusion: components of magnetic force (anti)parallel to normal vector cause torque



For a single charge→ $\boxed{\vec{F}_B = q\vec{v}_d \times \vec{B}}$

For N charges moving through the wire (current carrying wire)→ $\boxed{\vec{F}_B = i\vec{\ell} \times \vec{B}}$

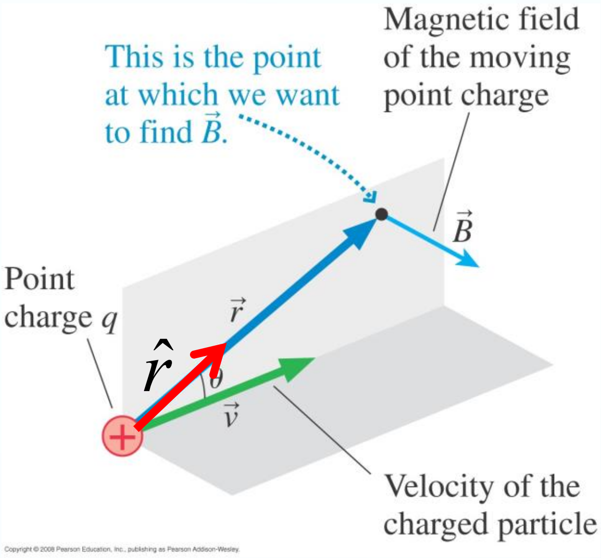
The Biot-Savart Law

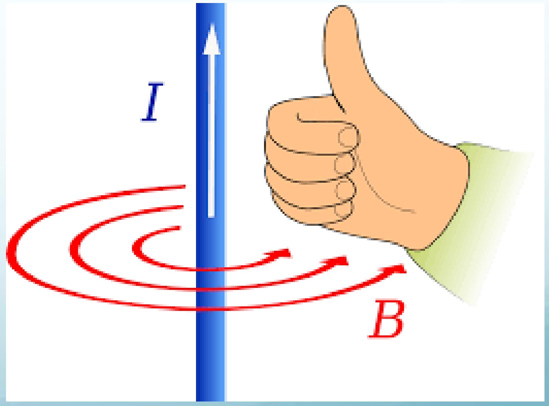
Magnetic fields are caused by **moving charges**.*

$$\vec{B}_{\text{point charge}} = \frac{\mu_0}{4\pi}\frac{q\vec{v}\times\hat{r}}{r^2}$$

$$\vec{B}_{\text{point charge}} = \frac{\mu_0}{4\pi}\frac{q\vec{v}\times\vec{r}}{r^3}$$

$$\vec{B}_{\text{current segment}} = \frac{\mu_0}{4\pi}\frac{I\,\Delta\vec{s}\times\hat{r}}{r^2}$$





This section we talked about:

Chapter 30

See you on Monday