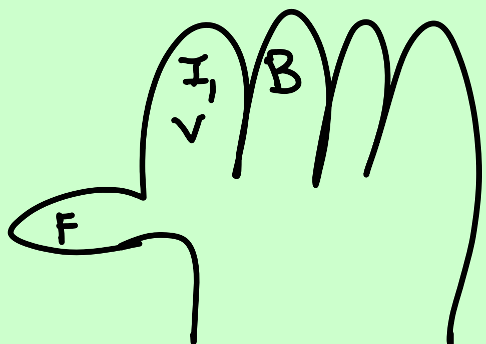
Magnetism Review

This partly esthetic judgment by a nerdish physicist (Maxwell), entire unknown except to a few other academic scientists, has done more to shape our civilization than any ten recent presidents and prime ministers. *Sagan*

Eisenhower expressed astonishment and alarm on discovering that fully half of all American have below average intelligence.

Force on Moving Charge

- Charge moving in a B-field
  - F = $q v \times B$
  - F = $I \ell \times B$
  - RHR



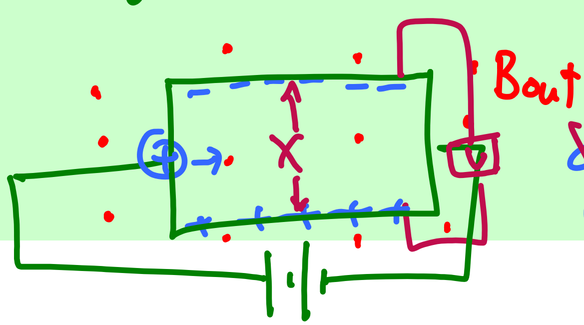
  - Separation of charge (Hall Effect)

No deflection

$qE = qvB$

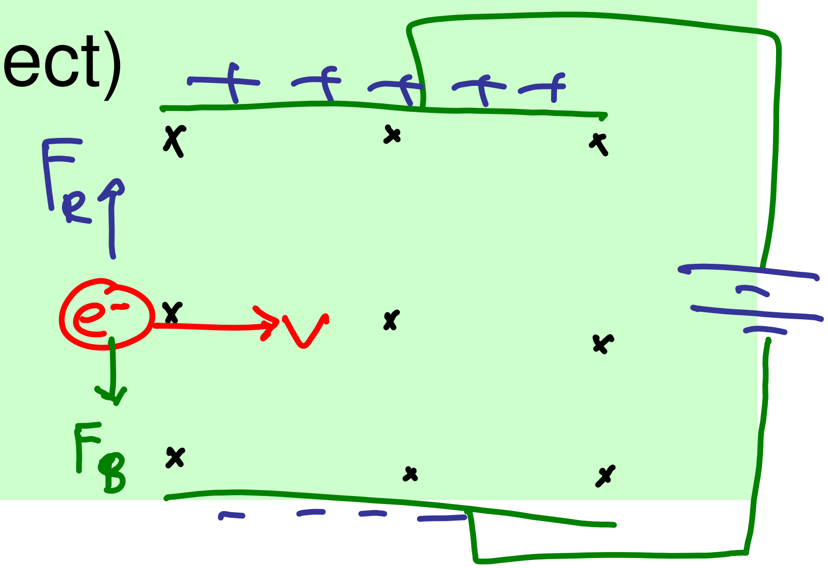
$\Delta V = \int E \cdot ds$

$\Delta V = E \cdot x$



$qvB = qE$

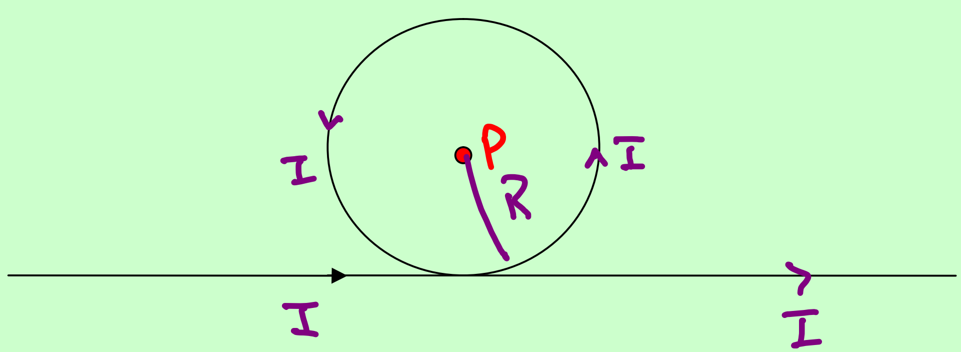
$vB = E$



Charge Distribution

- Biot-Savart: $B = \frac{\mu_0 I}{4\pi} \int \frac{d\vec{s} \times \hat{r}}{r^2}$

  - ❖ Finite wire $B = \frac{\mu_0 I}{4\pi a} (\cos\theta_1 - \cos\theta_2)$
  - ❖ Arc length $B = \frac{\mu_0 I}{4\pi R} \theta$
  - ❖ Example: wire and circle of current



$B_P = \frac{\mu_0 I}{2\pi R} + \frac{\mu_0 I}{4\pi R}(2\pi)$

Ampere's Law

- Flux: $\Phi_B = B \cdot A = \int B \cdot dA$

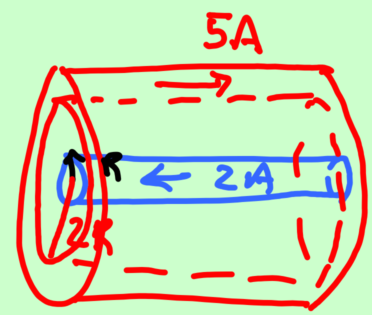
- Ampere's Law: $\oint B \cdot ds = \mu_0 I + \mu_0 \epsilon_0 \frac{d\Phi_E}{dt}$

❖ Wire/coaxial

$r < R$

$R < r < 2R$

$r > 2R$



$r < R$, $\oint B \cdot ds = \mu_0 I$

$B(2\pi r) = \mu_0 \left(\frac{\pi r^2}{\pi R^2} 2\right)$

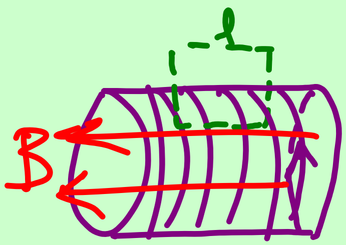
$R < r < 2R$

$B = \frac{\mu_0 I}{2\pi r}$, $I = 2A$

$r > 2R$

$B(2\pi r) = \mu_0 (-3A)$

❖ Solenoid



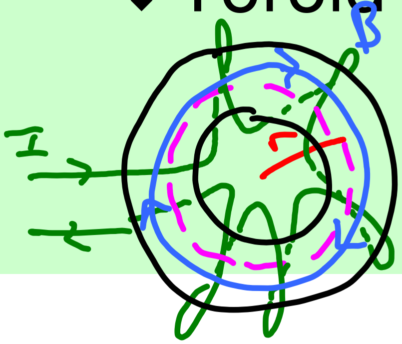
$\oint B \cdot ds = \mu_0 I$

$Bl = \mu_0 N I$

$B = \mu_0 \frac{N}{l} I$

$B = \mu_0 n I$

❖ Toroid



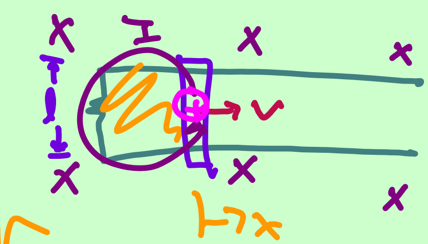
$\oint B \cdot ds = \mu_0 I$

$B(2\pi r) = \mu_0 N I$

$B = \frac{\mu_0 N I}{2\pi r}$

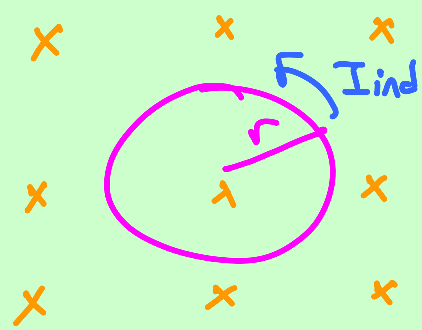
Faraday's Law

- Faraday's Law $\mathcal{E} = -N\frac{d\Phi_B}{dt} = -\oint E \cdot ds$
- Lenz's Law B_{ind} opposes $\Delta\Phi_B$
- Examples $\mathcal{E} = \frac{d\Phi_B}{dt} = Bl\frac{dx}{dt} = Blv$



$I = \frac{Blv}{R}$

  - Bar on rails or moving through B-field



$\frac{dB}{dt} = 2\frac{T}{s}$

$\mathcal{E} = \pi r^2 \left(\frac{dB}{dt}\right)$

  - Coil in B-field
  - Calculate emf, I, F and E-field

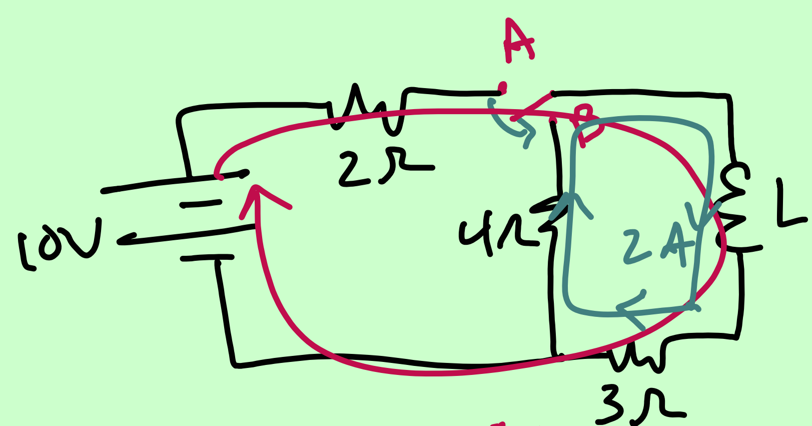
$\mathcal{E} = IR$ $\quad F = Il \times B$ $\quad \mathcal{E} = -\int E \cdot ds$

Inductors

- $\varepsilon_L = -L\frac{dI}{dt}$
- Time constant: $\tau = \frac{L}{R}$
- Natural frequency: $\omega = \frac{1}{\sqrt{LC}}$ for LC
- $U = \frac{1}{2}LI^2$
- At $t = 0$, inductors acts like opposing battery
- At $t = \infty$, inductors acts like wire

Test in room ~~140~~ 142

- 10 MC
  - Force on charge 1
  - Ampere 1
  - Faraday: 3
  - RL Circuits: 4
  - Maxwell's equations: 1
- 2 FR
  - Ampere and Faraday
  - Circuits with inductors



@ t=0 switch moved to A

$I = 0$

$I(\infty) = \frac{10}{5} = 2A$

move to B

$I = 2A$ immediately after