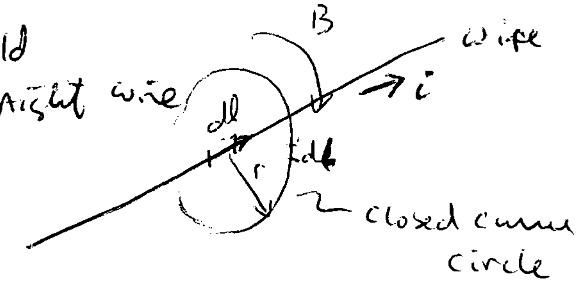
Using Ampere's Law

What is B field around STRAIGHT wire



$$\int \vec{B}\cdot d\vec{l} = \mu_0 I_{encl}$$

Use Biot-Savart law to Think about direction of B and path along which B is CONSTANT

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{i\,\vec{dl}\times\hat{r}}{r^2}$$

Keep your dl's STRAIGHT!

B is a fn of r only!

B goes in direction show

⟹ Put right thumb along i – fingers curl in direction of $\vec{B}$

$$\vec{B}\cdot d\vec{l} = B\,dl$$

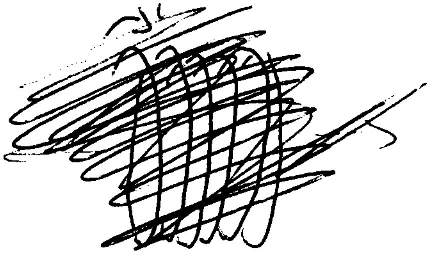
$$\int \vec{B}\cdot d\vec{l} = B\int dl = \mu_0 i$$

$$B\,2\pi r = \mu_0 i$$

$$\boxed{B = \frac{\mu_0 i}{2\pi r}}$$

Right Hand rule
B around current bearing wire!

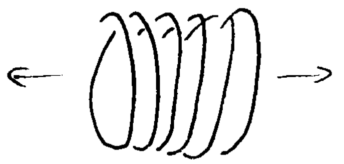
~~Field of a Solenoid an a Stenoid~~



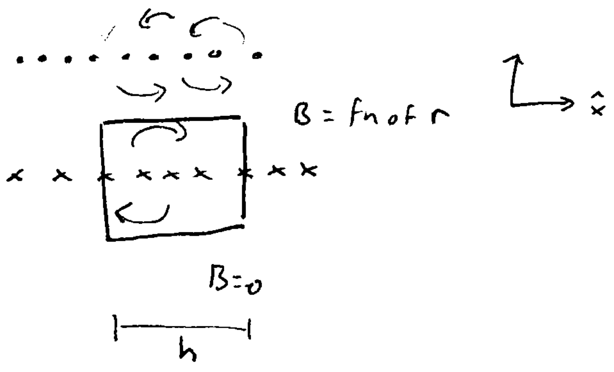
~~In Magnetostatics plays the role of a ∥ plate capacitor for Electrostatics~~

Slinky

Field of an infinite Solenoid Tightly Packed n loops/unit length



Slinky



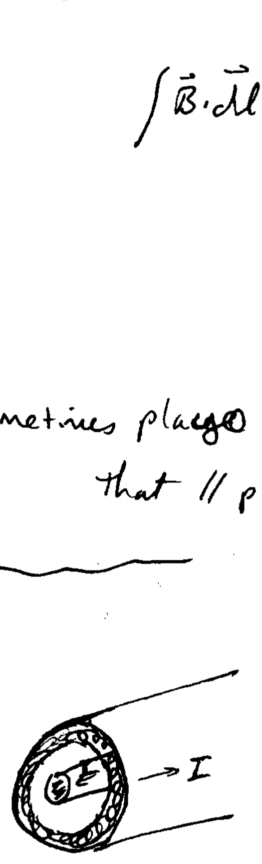
$$\int \vec{B}\cdot d\vec{l} = Bh = \mu_0 i = \mu_0 n h i$$

$$\vec{B} = \mu_0 n i \hat{x}$$ inside

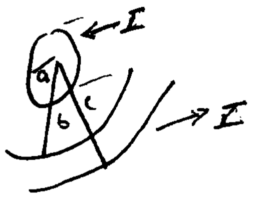
$$\vec{B} = 0$$ outside

~ Sometimes plays role in Magnetostatics that // plate capacitor plays in Electrostatics

Long Coaxial cable
Concentric conductors - each w/ i



Find B
$r < a$
$b > r > a$
$c > r > b$
$r > c$



Assume I is uniformly distributed thruout conductor

$r < a$

$$\int \vec{B} \cdot d\vec{l} = 2\pi r B = \mu_0 i_{encl}$$

$$i_{encl} = \frac{\pi r^2}{\pi R^2} I$$

use thumb/fingers to get direction

$$|\vec{B}| = \frac{\mu_0}{2\pi r} \frac{\pi r^2}{\pi R^2} I = \frac{\mu_0 r I}{2\pi R^2}$$

$a < r < b$

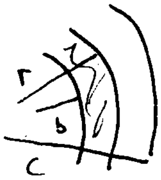
$$\int B \cdot dl = \mu_0 I_{enc} \longrightarrow$$

$$2\pi r B = \mu_0 I$$

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

$b < r < c$

$$\int B \cdot dl = 2\pi r B = \mu_0 i_{encl} = \mu_0 \left[I - \frac{I}{\pi(c^2-b^2)} \pi(r^2-b^2) \right]$$



Area current density in outer conductor is

$$\frac{I}{(\pi c^2 - \pi b^2)} = \frac{I}{\pi(c^2-b^2)}$$

$$B = \frac{\mu_0 I}{2\pi r} \left[1 - \frac{\cancel{\pi}(r^2-b^2)}{(c^2-b^2)} \right]$$

Note $r = c \Rightarrow B \to 0$

$r > c$

$B = 0$ ⇝ because $i_{encl} = 0$ for Amperian loop w/ $r > c$!

$$\int \vec{B} \cdot d\vec{l} = i_{encl} \mu_0$$

Magnetic Induction

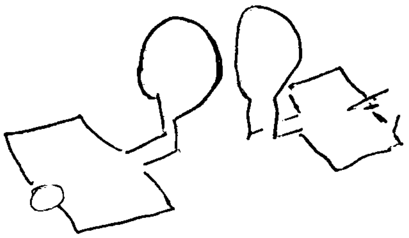
do demos

1830's Michael Faraday (England)
Joseph Henry (US)

⇒ do demo(s)

Induction - A changing magnetic field induces A changing electric field

⇒ induced EMF's, induced currents



observe a current due to induced EMF

No changing fields
Magnetostatics

Kirchoff's rules

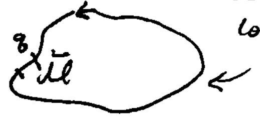
$$\sum V \Big|_{\substack{\text{closed}\\ \text{loop}}} = 0$$

Also true in free space

$$\oint_C \vec{E}\cdot d\vec{l} = 0$$

line integral

Work to Move charge About A closed loop



With changing Magnetic field

$$\mathcal{E} = \oint \vec{E}\cdot d\vec{l} = -\frac{d\Phi_M}{dt}$$

Faraday's Law

True in Wires/material
or
free space !!

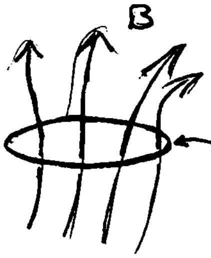
$\mathcal{E}$ True only instantaneously!

unless $\frac{d\Phi_M}{dt}$ is constant

So, Think abt wire loop $\qquad \mathcal{E} = \oint \vec{B} \cdot d\vec{l} = -\dfrac{d\Phi_m}{dt}$

Δ'ing geometry of loop

Δ'ing B magnitude or Angle will cause Δ in Magnetic flux



changing B flux thru loop induces $\mathcal{E}$

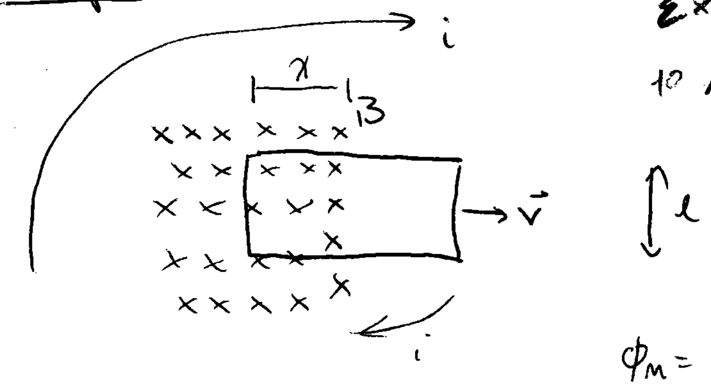
i or current in wire loop

So we have induced $\mathcal{E}$ .... current flows in loop
→ induced current

What direction? ⇝ NOTE the "-" in Faraday's law

Lenz's Law - An induced current in a closed conducting loop will appear in such a ~~way~~ direction that it opposes the change that produced it!

EXAMPLES



Explain Φ_M — induced i wants to ↑ increase — means it goes in what direction? wave arms

$$\Phi_M = Blx$$

$$\mathcal{E} = -\frac{d\Phi_m}{dt} = -Bl\frac{dx}{dt} = -Blv$$

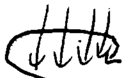
Sets up a current $|i| = \dfrac{Blv}{R}$ — loop resistance

Clockwise — why?

3 ways to look at —

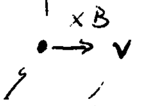
① Φ_M being reduced

induced i creates B that increased Φ_M



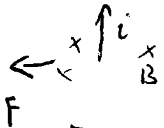
B of loop

② Motional EMF



F on "conductor q" due to V

③



F produced by current works to slow down $\vec{v}$