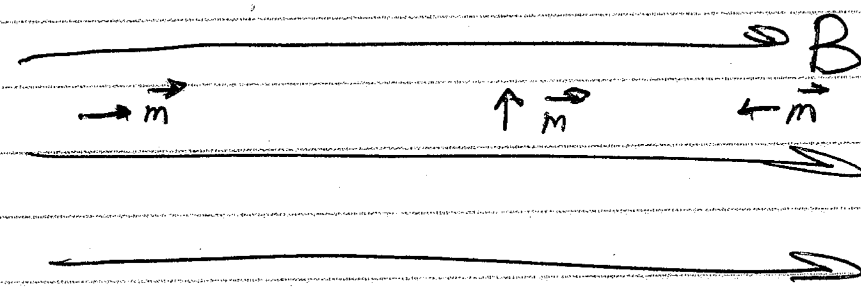
1 Phys 1402 2015-10-06 Lec 12

Effects of Magnetism - magnetic moment

Example: Compass needle
Small bar magnet
Small coil or solenoid

Potential Energy $PE = -\vec{m} \cdot \vec{B}$

- Dot prod is big when vectors are in the same direction
- PE is negative when $\vec{m} \parallel \vec{B}$

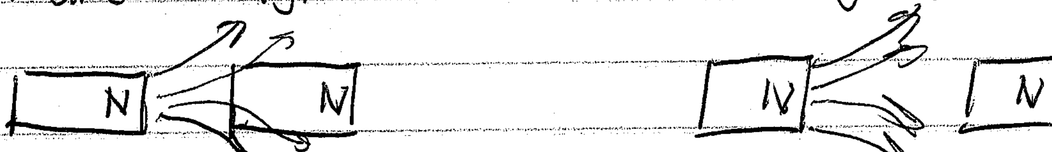


Low-energy (negative PE) | Zero PE | High PE (positive)

Results:

- Compass needle aligns with $\vec{B}$
- Makes magnets attract when aligned.

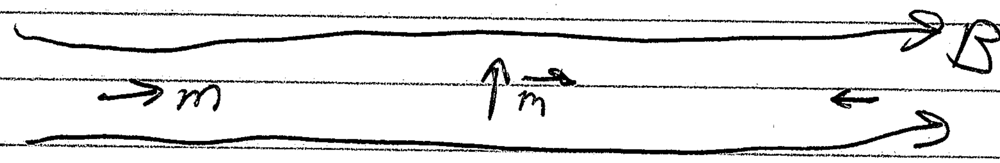
Left magnet makes $\vec{B}$
Right magnet is $\vec{m}$



Low (negative) Energy | Higher (Less Neg) Energy

Torque due to magnetic field

$$\tau = mB\sin\theta$$



$\tau = 0$ $\quad$ τ = strong $= mB$ $\quad$ $\tau = 0$ (unstable)

An electromagnet is a magnetic moment

$m = IA$ (single loop)
$m = NAI$ (multi loop)

In a motor, we control I, which determines m, which makes torque.

$$\max \tau = NBAI$$

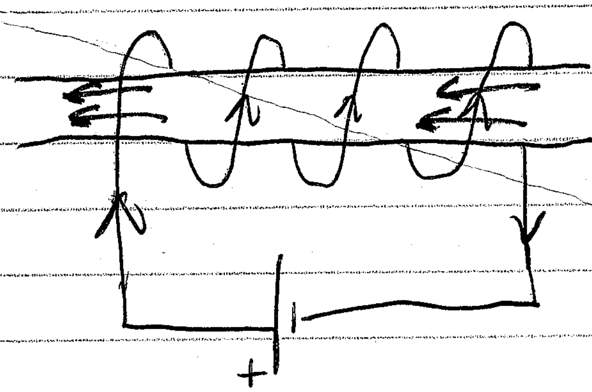
1402 (3)

Sources of Magnetic Field

Solenoid Coil

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

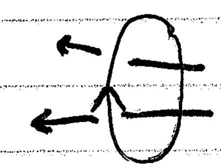
(inside the solenoid)

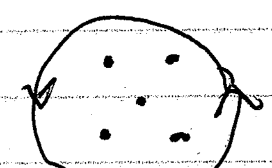


RHR for a coil:

- Curl fingers in dir of current
- Thumb points in dir of B (inside the coil)

Simple Coil (Or a single loop)





$$B = \frac{\mu_0 N I}{2R}$$

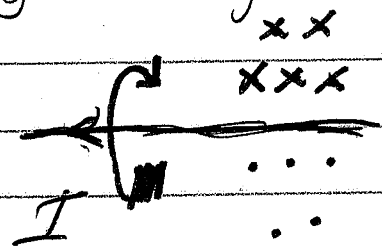
Up in front
Down in back

Left view
$\vec{B}$ = "out of page"

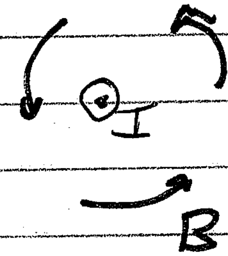
Directions:

→	←	↑	↓	•	X
+x	−x	+y	−y	+z	−z

Long straight wire



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



r = dist from wire

RHR For a wire:
- Thumb along current
- Fingers curl in dir of B.

Ex Wires are 6 cm apart,

B_2

$I_1 = 2A$ $\quad$ $B = ?$ $\quad$ $I_2 = 2A$

I_1: $\quad B_1 = \frac{\mu_0 I}{2\pi r} = \frac{\mu_0 (2A)}{2\pi (0.03\,m)} =$

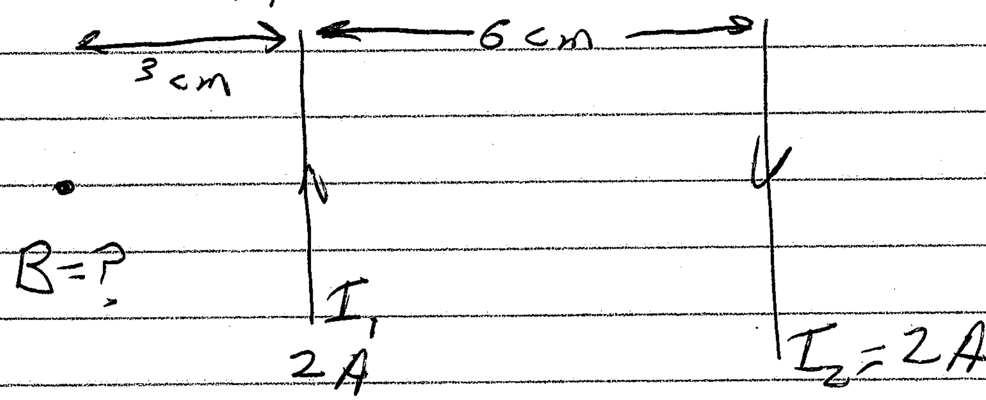
$= 13.3\ \mu T$ (up)

I_2: $\quad B_2 = 13.3\ \mu T$ (down)

Tot: $\quad B = 0$

1402 ⑤

Currents in opposite directions



I_1: $B_1 = \dfrac{\mu_0 (2A)}{2\pi (0.03m)} = 13.3\ \mu T$ (out)

I_2: $B_2 = \dfrac{\mu_0 (2A)}{2\pi (0.09m)} = 4.4\ \mu T$ (in)

Tot: $B = 8.9\ \mu T$ (out)

↑ Dir of "strong" contribution

In component form

$B_z = B_{1z} + B_{2z}$

$= (+13.3\ \mu T) + (-4.4\ \mu T)$

$= +8.9\ \mu T$

what if the wires are only 1 mm apart?

$B_1 = 13.3\ \mu T$ (out)

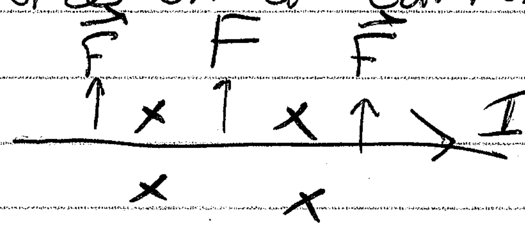
$B_2 = \dfrac{\mu_0 I}{2\pi (0.031m)} = 12.9\ \mu T$ (in)

Tot $B = 0.4\ \mu T$ (out)

Effects of magnetic Fields

- Torque on a mag. moment.
- Force on mag moment toward or away from strong field.

- Force on a current

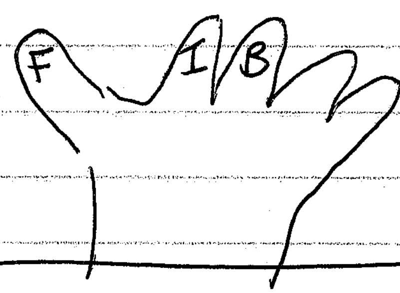


Force is up.

B = into page (caused externally)

Observations: $\vec{F} \perp I$ (always)
$\vec{F} \perp \vec{B}$ (always)

$$\vec{F} = I\vec{l} \otimes \vec{B}$$



- Index = I
- Middle = B
- Thumb = F

Drop an electron ⇒ $\vec{v}$ = down → I = up
$\vec{B}$ points north. B = north
Initial force?
Result: F = west