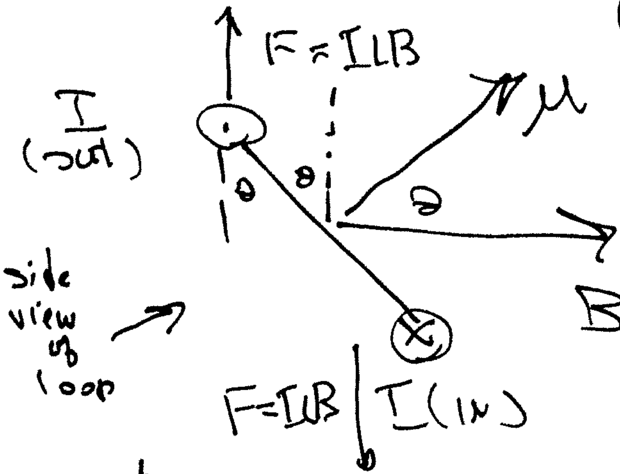
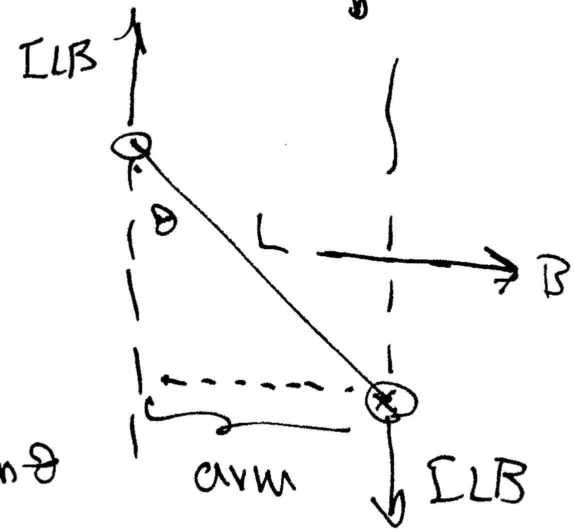
March 12, 200 ①

Torque on a current loop
(See Fig. 32.47 p. 1027)
Loop of side L (square)
+ current I



2 forces $F = ILB$ (not) acting along the same line

torque due to 'couple' is (Force)(arm)



arm = $L \sin\theta$

$$\tau = (ILB)(L\sin\theta)$$

Loop will tend to rotate CW due to the forces

$$\tau = (IL^2) B \sin\theta \qquad \mu = IA = IL^2$$

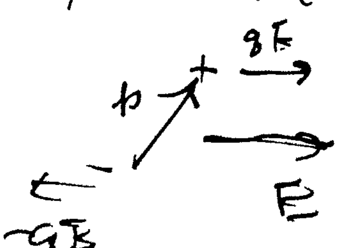
$$\tau = \mu B \sin\theta$$

$$\tau = \vec{\mu} \times \vec{B}$$ $\vec{\mu} \times \vec{B}$ is into the paper.
This means CW rotation.

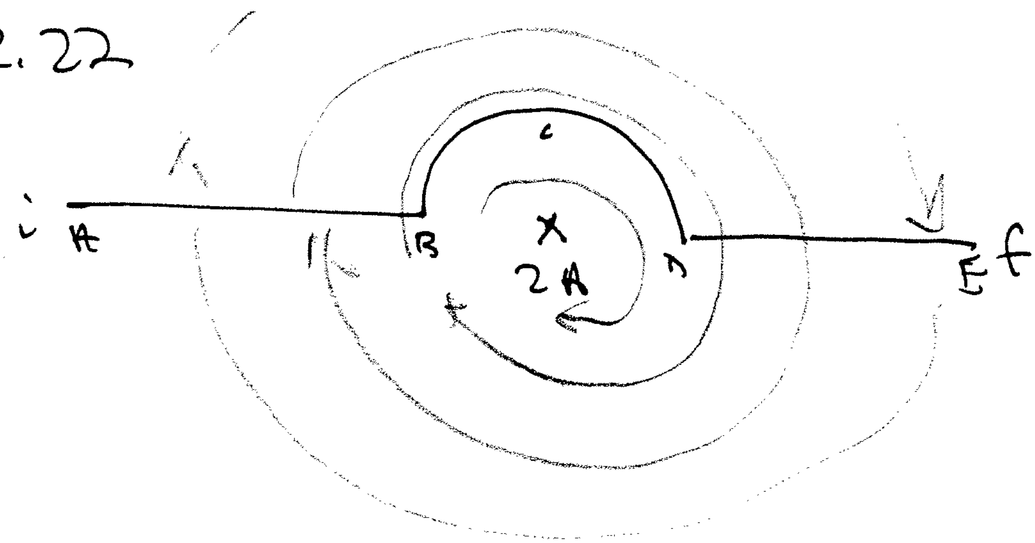
DIPOLES ALWAYS TEND TO ALIGN WITH THE FIELD

Electric dipoles too

$\tau = \vec{p} \times E$



Problem 32.22



$$\int \vec{B}\cdot d\vec{s} = \int_{AB} B\,ds\sin\theta + \int_{BCD} B\,ds\sin\theta + \int_{DE} B\,ds\sin\theta$$

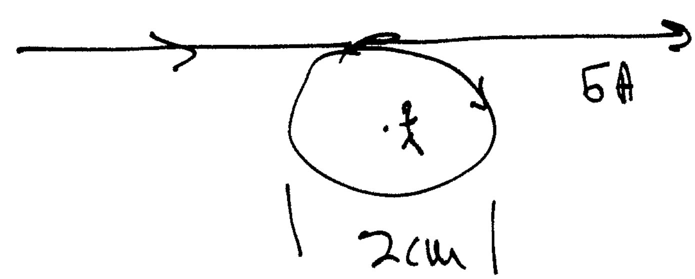
$\theta = 90°$ (AB), $\theta = 0$ (BCD), $\theta = 90°$ (DE)

$\pi r B$

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

$$\int_{BCD} \vec{B}\cdot d\vec{s} = \frac{\mu_0 I}{2} = \mu_0 \cdot 1A = 4\pi\times10^{-7}\ T\text{-}m$$

32.64

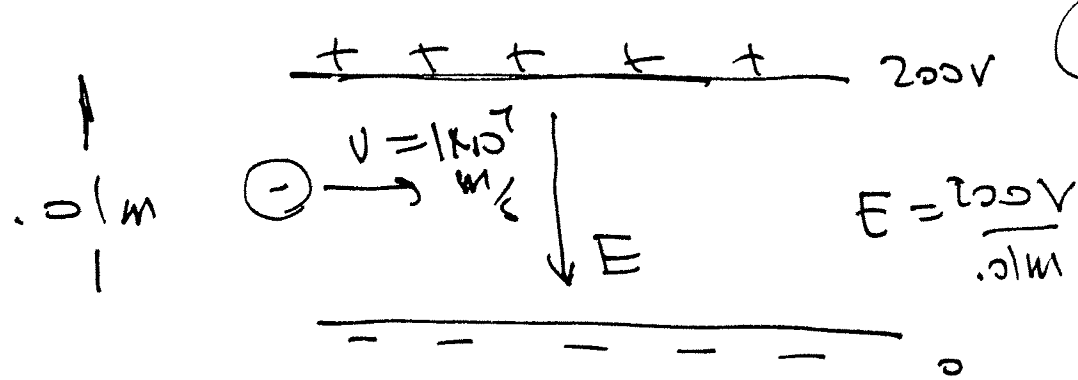


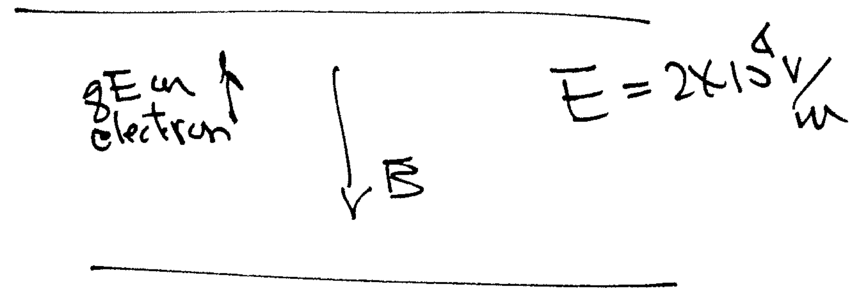
$$B_p = B_{\text{straight wire}} + B_{\odot}$$

$$B_p = \frac{\mu_0 I}{2\pi r}(\text{IN}) + \frac{\mu_0 I}{2r}(\text{IN}) = \frac{\mu_0 (5A)}{2(.01)}\left(\frac{1}{\pi}+1\right)$$

$$B_p = 4.144\times10^{-4}\ T\ (\text{IN})$$

(42)





Must add $\vec{B}$ field so

$$q\vec{E} + q\vec{v}\times\vec{B} = 0$$

and the electron goes straight

$q\,v\times B$ points down, $\vec{v}\times\vec{B}$ points up!

(q negative)

B is INTO the page

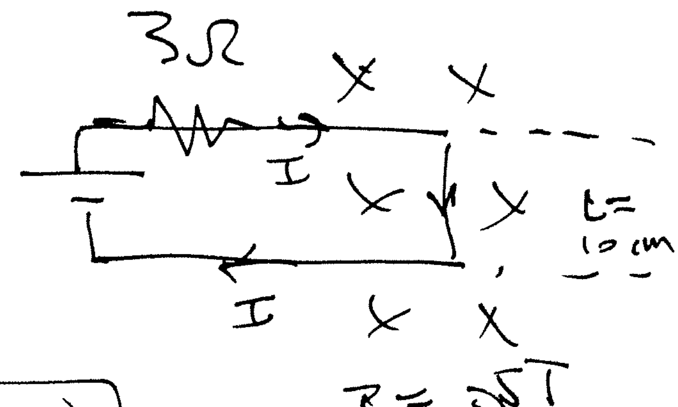
$$B = \frac{E}{v} = \frac{2\times10^{4}\ \text{V/m}}{1\times10^{7}\ \text{m/s}} = 2\times10^{-3}\ \text{T}$$

---

(37) $I = \frac{15\text{V}}{3\Omega} = 5\text{A}$

$L = 0.10\text{m}$

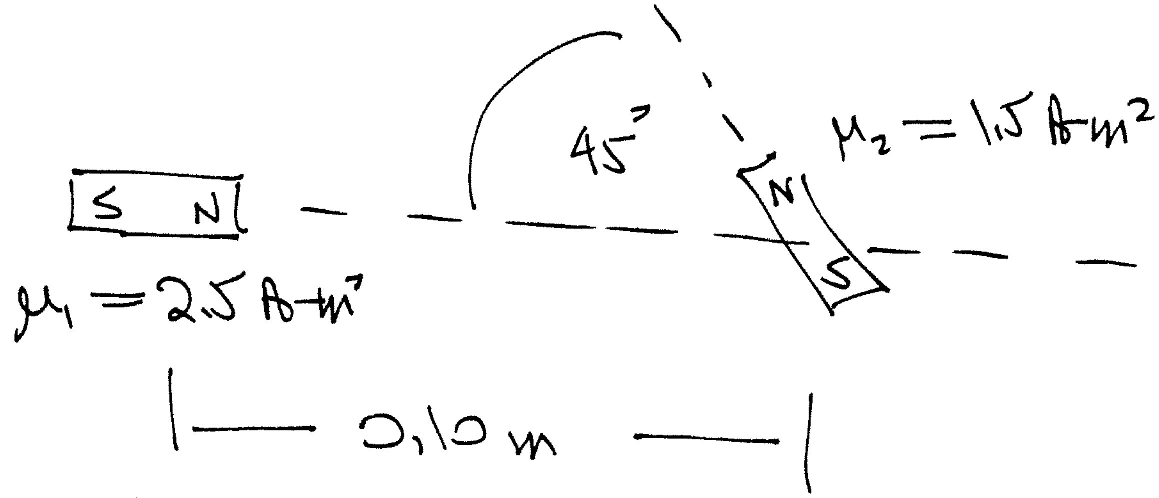
F is $I\vec{l}\times\vec{B}$ to the right



$F = (5\text{A})(.10\text{m})(.05\text{T})$

$F = .025\ \text{N}$ to right

(MJM)



τ on μ_2 due to μ_1 is $\vec{\tau} = \vec{\mu}_2 \times \vec{B}_{\text{from } \mu_1}$

$$B_{\text{axis of loop}} = \frac{\mu_0 I R^2}{2(z^2+R^2)^{3/2}} \xrightarrow[z \gg R]{} \frac{\mu_0 I R^2}{2z^3}$$

$$B_{\text{from } \mu_1} = \frac{\mu_0 (I \pi R^2)}{2\pi z^3} = \frac{\mu_0 \mu_1}{2\pi (0.10)^3}$$

$$\tau_{\text{on } \mu_2} = \mu_2 \frac{\mu_0 \mu_1}{2\pi (.10)^3} \sin 135^\circ \quad \text{(INTO PAPER)}$$

$$= \frac{(4\pi \times 10^{-7})(1.5 \times 2.5)}{2\pi (.10)^3} = 7.5 \times 10^{-4} \text{ N·m}$$

(into page)

Chapter 33

Induced emf $= -\frac{d}{dt}$(magnetic flux) p.1057

Faraday's Law

$\Phi_m = \int \vec{B} \cdot d\vec{A}$

area of loop

p.1052

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

$$\mathcal{E} = -\frac{d}{dt}\int B\,dA\cos\theta$$

Get an induced emf by changing any of
- B
- area
- angle θ

If B = constant, $\Phi_m = BA\cos\theta$

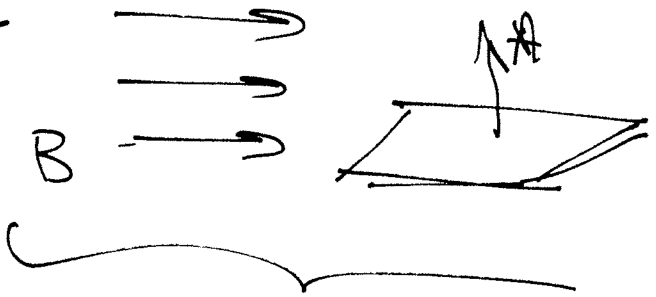
$$-\mathcal{E} = \frac{d}{dt}(BA\cos\theta) = \frac{dB}{dt}A\cos\theta + B\frac{dA}{dt}\cos\theta - BA\sin\theta\frac{d\theta}{dt}$$

- $\frac{dB}{dt}A\cos\theta$: change B only
- $B\frac{dA}{dt}\cos\theta$: change area only
- $-BA\sin\theta\frac{d\theta}{dt}$: change θ only

Magnetic flux (flux of magnetic field)

p. 1050

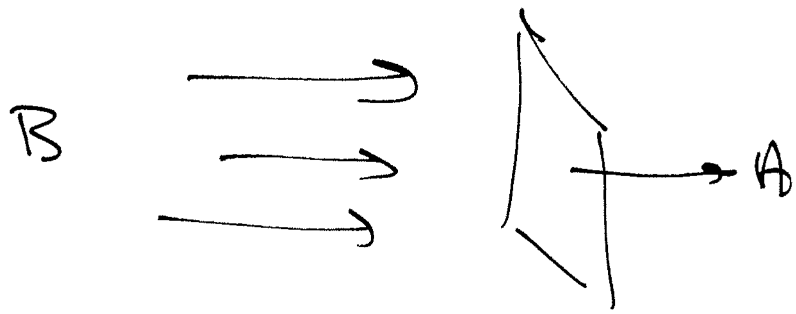
$\Phi_m = 0$



$\Phi = 0$

$\theta = \angle \vec{B}, \vec{A} = 90^\circ$

flux line slide along area



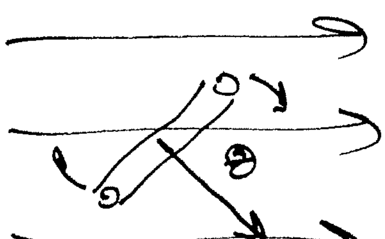
$\Phi_m = BA$

$\theta = 0^\circ$

area $\vec{A}$ at angle θ to $\vec{B}$

$\Phi_m = BA\cos\theta$

Example 33.4 p. 1051 Rotating loop



$\theta = 0$ $\Phi_m = AB$

$\theta = 30^\circ$ $\Phi_m = AB\cos 30^\circ$

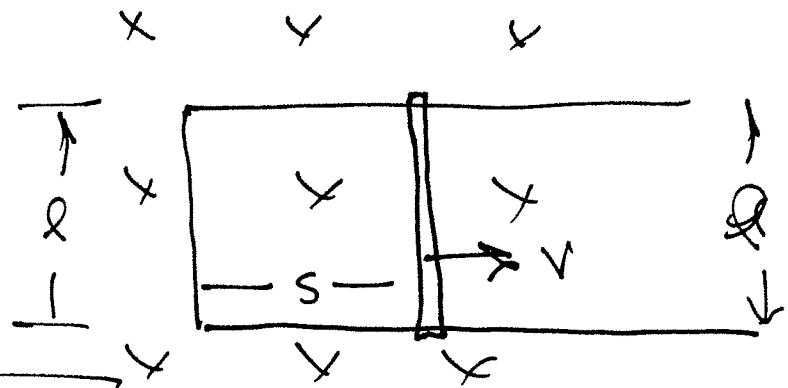
$\theta = 60^\circ$ $\Phi_m = AB\cos 60^\circ$

$\theta = 90^\circ$ $\Phi_m = 0$

Emf due to changing the area only

Fig 33.6
p. 1046

Also page 1057!



B into the page

rod of length l moves w velocity $v = \frac{ds}{dt}$

$q\vec{v}\times\vec{B}$ forces charge **up** along the rod!

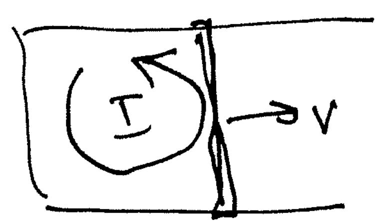
$$A = \text{area} = l \cdot s \qquad \frac{dA}{dt} = l\frac{ds}{dt} = lv$$

$$\Phi_m = BA\cos\theta \qquad \frac{d\Phi_m}{dt} = B\cos\theta\frac{dA}{dt} = B\cos\theta \cdot lv$$

$$|\mathcal{E}| = \left|\frac{d\Phi_m}{dt}\right| = Blv$$

$$I = \frac{\mathcal{E}}{R} = \frac{Blv}{R} \quad \text{(Eq 33.4)}$$

Current I flows CCW



Force on moving rod is

~~$I\vec{l}\times\vec{B}$~~ (to the left)

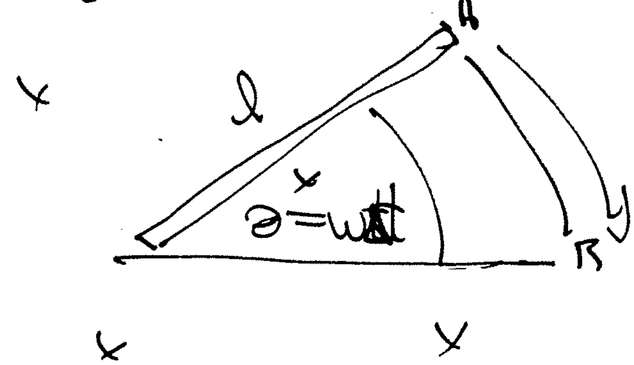
$$\vec{F} = I\,\vec{l}\times\vec{B}$$

$$F = \frac{Blv}{R}lB = \frac{vl^2B^2}{R} \quad \text{Eq 33.5}$$

Changing area (rotating bar)

$$|\mathcal{E}| = B\cos\theta \frac{dA}{dt}$$

Example 33.2



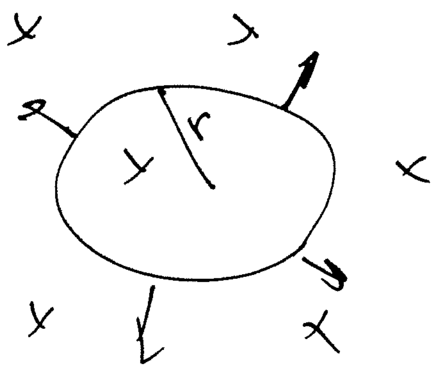
B is into the page

area swept from A to B is

$$(\pi l^2)\frac{\omega \Delta t}{2\pi} = \Delta A \rightarrow \frac{\Delta A}{\Delta t} = \frac{\omega l^2}{2}$$

$$\mathcal{E} = B\cos 0 \frac{\omega l^2}{2} = \frac{1}{2}\omega^2 l B$$ (Bottom p. 1045)

(MJM) **Expanding loop**



Let $r(t) = r_0 + at$

$$A(t) = \pi(r_0+at)^2$$

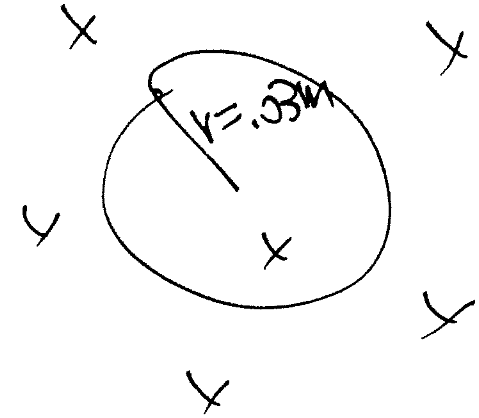
$$\frac{dA}{dt} = 2\pi(r_0+at)(a)$$

$$\mathcal{E} = B\frac{dA}{dt} = B\,2\pi(r_0+at)a$$

Changing B only

Example 33.9 p. 1058

B INTO PAGE



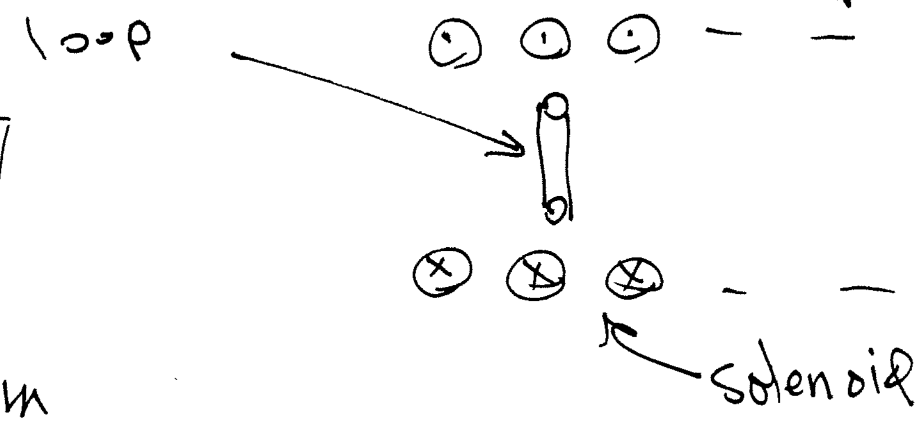
B: 1.0 T → 0.4 T in 1.2 s

$$\frac{dB}{dt} = -\frac{.6T}{1.2s} = -.5\,T/s$$

$$|\mathcal{E}| = A\frac{dB}{dt} = \frac{d}{dt}(BA\cos\theta)$$

$$|\mathcal{E}| = \pi(.03m)^2(0.5\,T/s) = 14.1\times10^{-4}\text{ volts}$$

Loop inside a solenoid p. 1058 Example 33.9



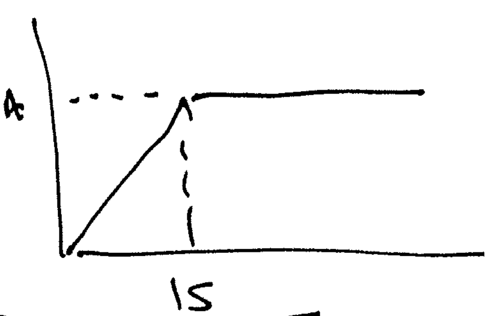
solenoid
0.20 m, 1000 turns
$n = 5000$ turns/m

$R_{solenoid} = 0.02\,m$

$R_{loop} = 0.01\,m$

$B = \mu_0 n I$

Current in solenoid ramps up at 10 A/s



$$dB/dt = \mu_0 n \frac{dI}{dt} = 4\pi\times10^{-7}\times5000\times10$$

(10 A/s)

$$= .0628\,T/s$$

$$|\mathcal{E}| = A\frac{dB}{dt} = (\pi(.01)^2)(.0628) = 1.97\times10^{-5}\,V$$