# Lecture #22

Magnetic Torque

&

Hall Effect

&

Magnetic Materials

total

**What is the ~~direction of~~ magnetic force on this ~~wire?~~** circuit?

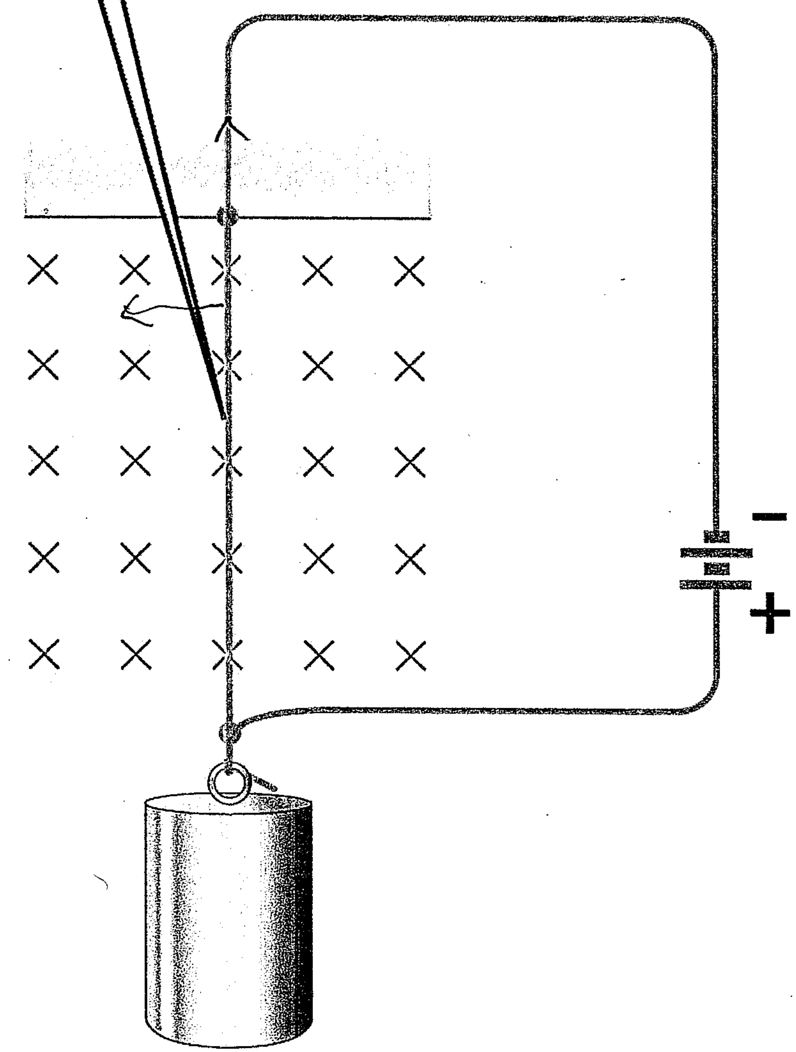



Figure 30-12 Physics for Engineers and Scientists 3/e



(1) Non-zero

(2) Zero

# Torque on a Loop

Is there a torque on this loop?

a) yes b) no

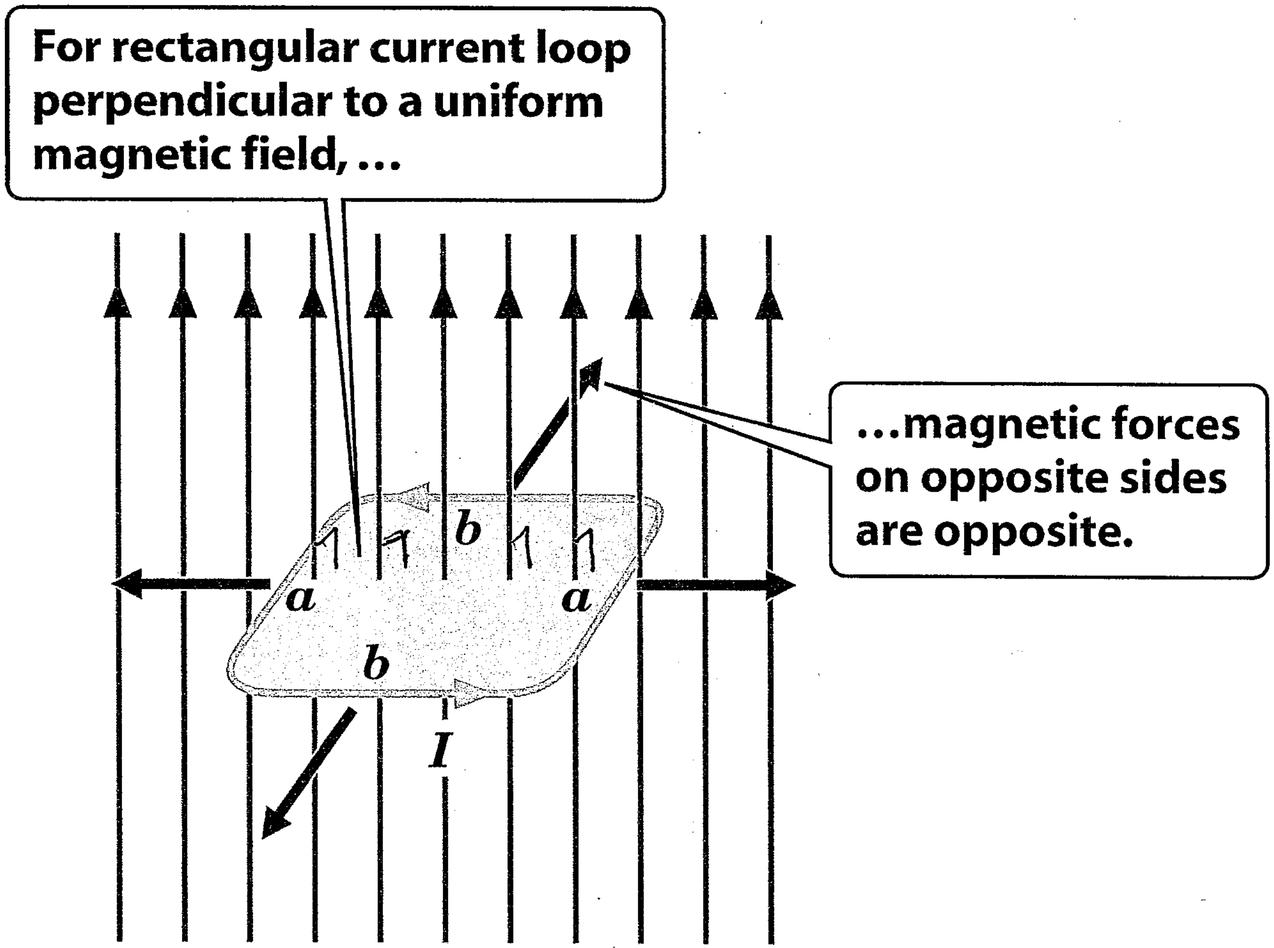
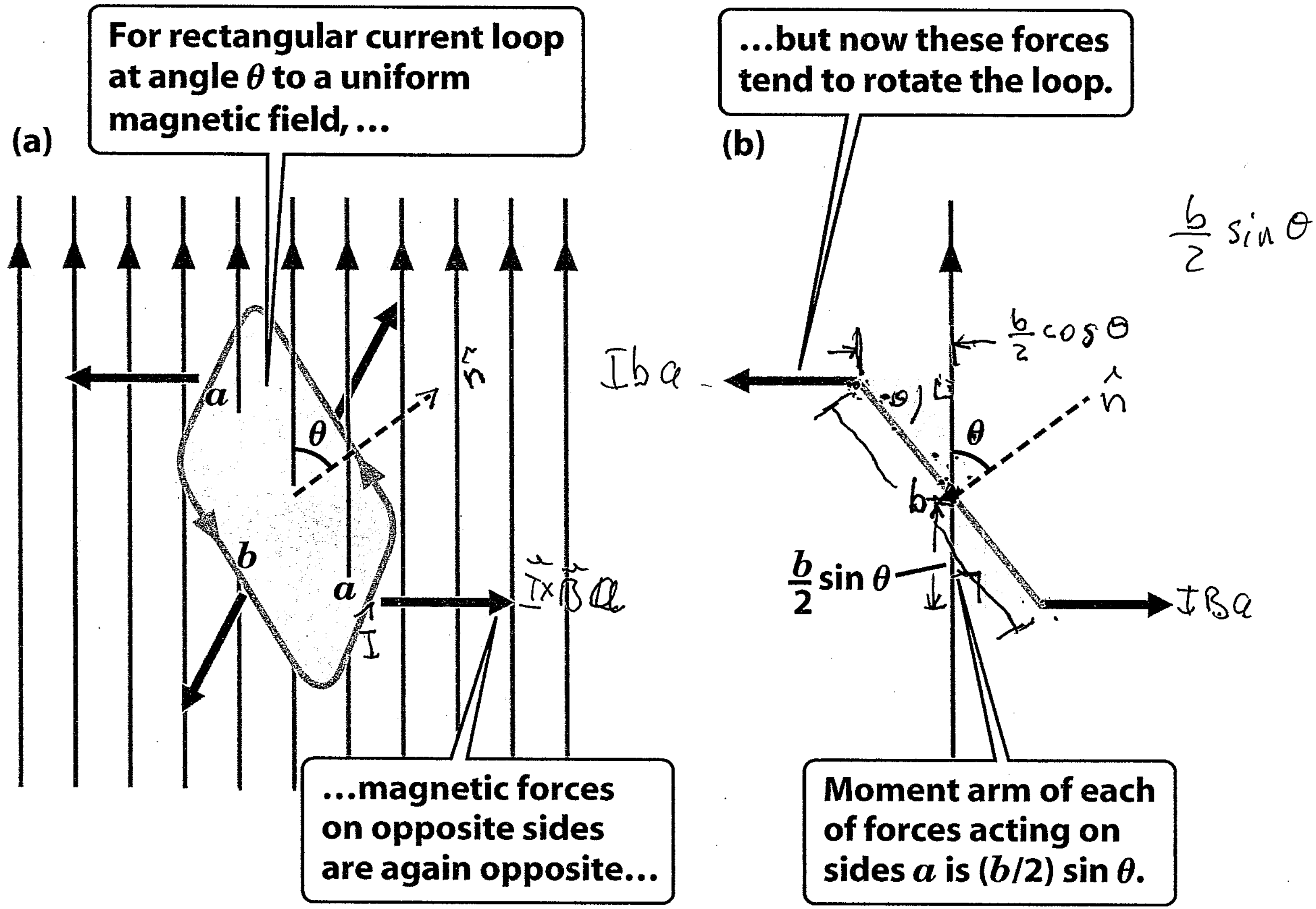



Figure 30-13 Physics for Engineers and Scientists 3/e

# Torque on a Loop

$\tau = BIA\sin\theta$






$ab = A$

$\tau = F\,l_f = 2IBa\frac{b}{2}\sin\theta$

$= IbaB\sin\theta = BIA\sin\theta$ (3)

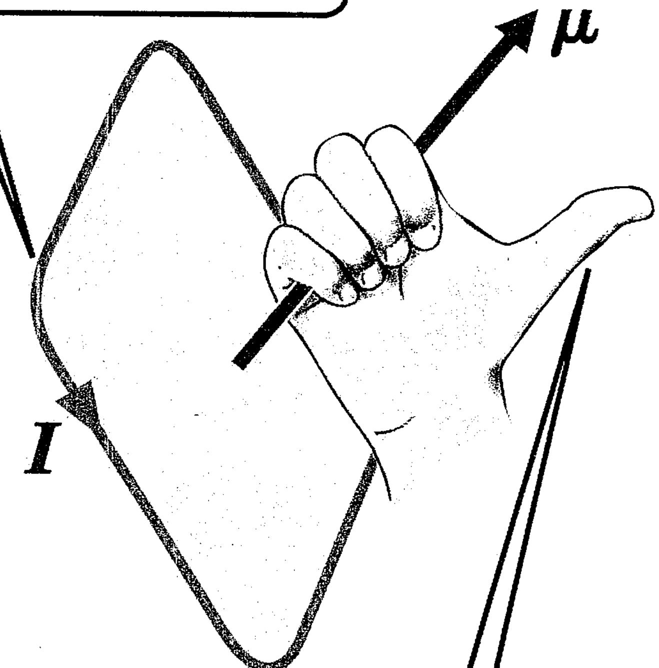
$\tau = \underbrace{IA}_{\mu} B \sin\theta$

$\mu \equiv IA$

**If you curl fingers of your right hand around in direction of current…**

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

$\vec{\mu} = I\Delta\vec{A}$




$\vec{\tau} = \vec{\mu} \times \vec{B}$

$\vec{\mu} \parallel \vec{A}$

**…then your thumb points in direction of magnetic moment $\mu$.**

Figure 30-15 Physics for Engineers and Scientists 3/e

Magnetic Moment of individual electron

# BOHR MAGNETON

$$\mu_B = \frac{eh}{4\pi m_e} = 9.27 \times 10^{-24}\,\mathrm{J/T}$$

$h \approx$ planck's constant

$\approx 6.63 \times 10^{-34}$ Joule-s

Equation 30-23 Physics for Engineers and Scientists 3/e

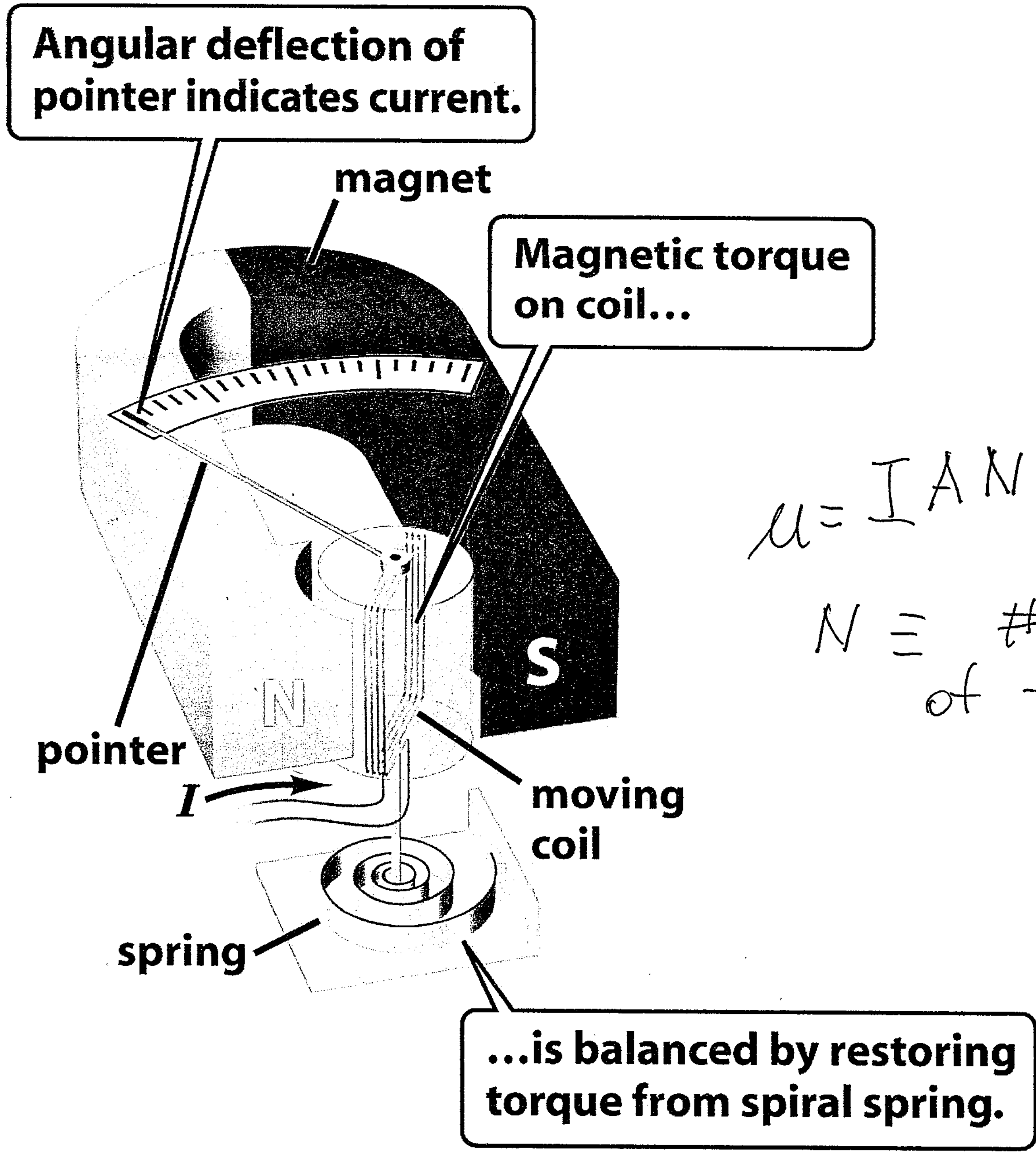



Figure 30-18 Physics for Engineers and Scientists 3/e


$\mu = IAN$

$N \equiv$ # loops of the coil

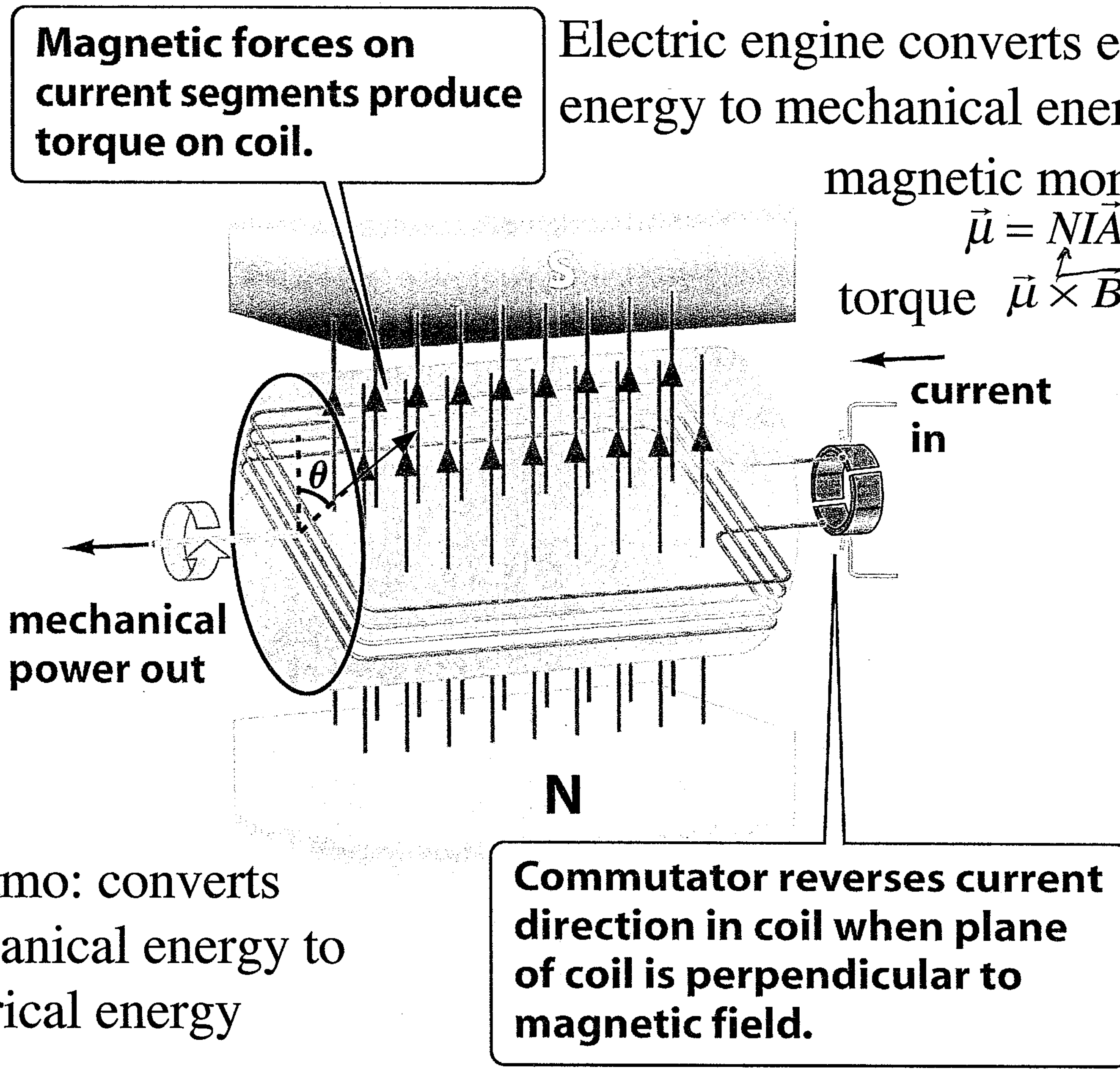
Electric engine converts electrical energy to mechanical energy

magnetic moment

$$\vec{\mu} = N I \vec{A}$$

(N: # of turns of coil)

torque $\vec{\mu} \times \vec{B}$

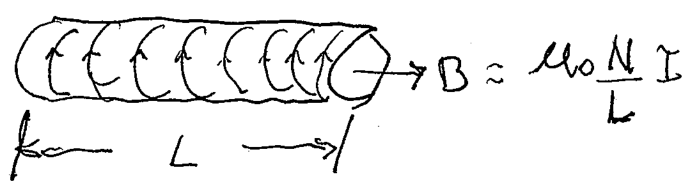


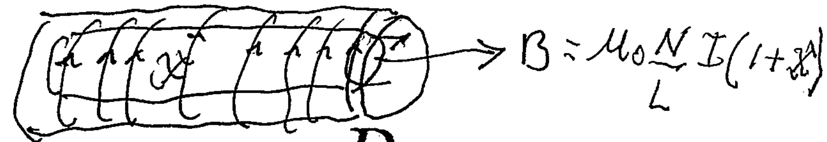

Dynamo: converts mechanical energy to electrical energy

Figure 30-16 Physics for Engineers and Scientists 3/e

Magnetic Materials

# MAGNETIC SUSCEPTIBILITY




$$\chi = \frac{B_{\text{matter}}}{B_{\text{external}}}$$

$\chi$ positive and $\chi \ll 1$: paramagnetic

$\chi$ positive and $\chi \gg 1$: ferromagnetic
and more complicated

$\chi$ negative: diamagnetic

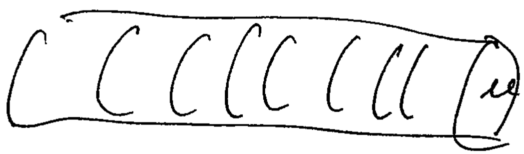
In solenoid

$B = \mu B_0 = \mu_0 (1+\chi) B_0$

$B = \mu_0 \chi B_0$ from material currents // from external currents only

# MAGNETIC PERMEABILITY

$$\mu = \mu_0(1 + \chi)$$



$$B_v = \frac{\mu_0 I N}{L}$$

$$B_{in} = \frac{\mu_0 I N}{L} = \frac{\mu I N}{L}$$

Equation 30-25 Physics for Engineers and Scientists 3/e

# Hall Effect

## Measurement of sign of charge current carriers -

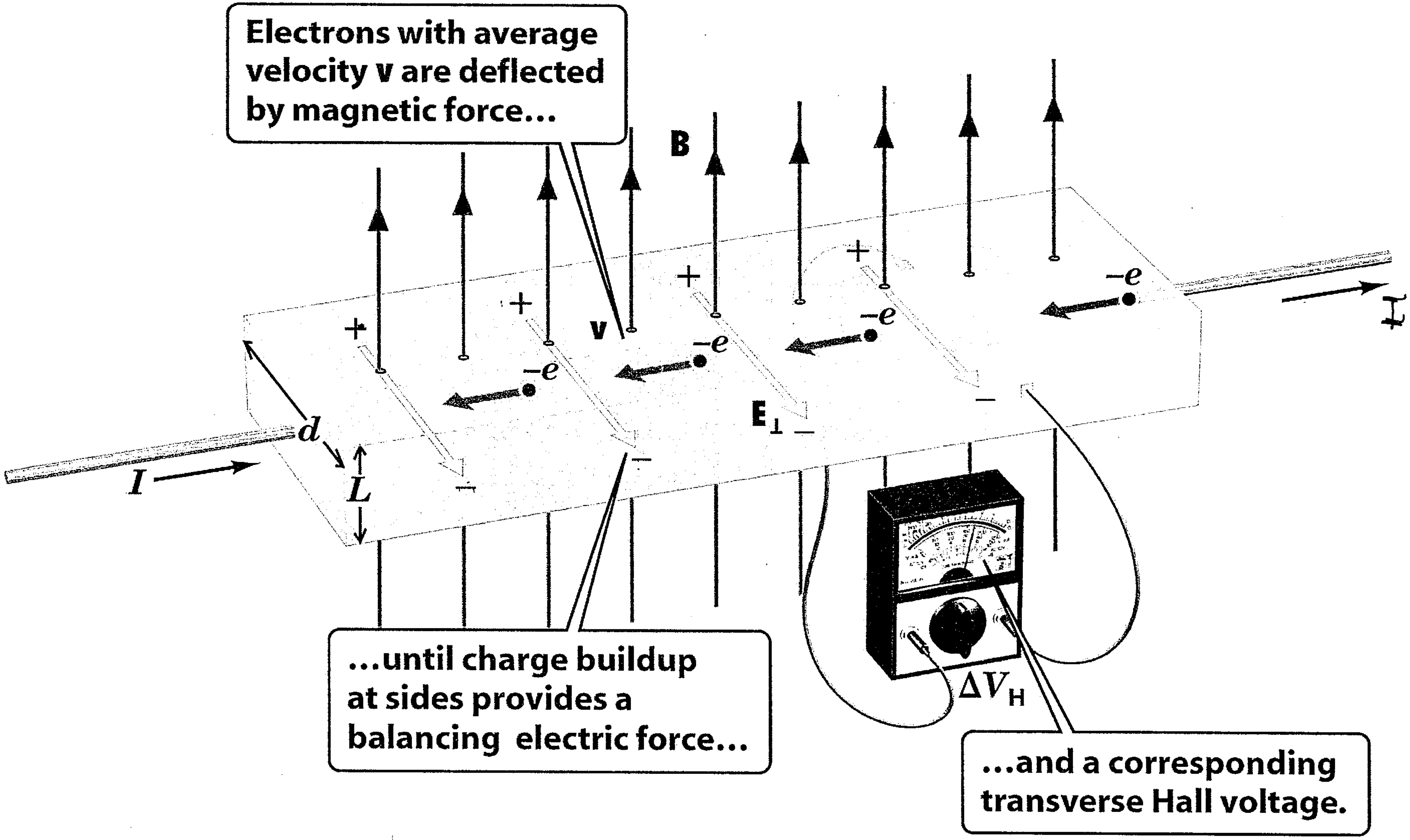



Figure 30-23 Physics for Engineers and Scientists 3/e

# Measurement of sign of charge current carriers

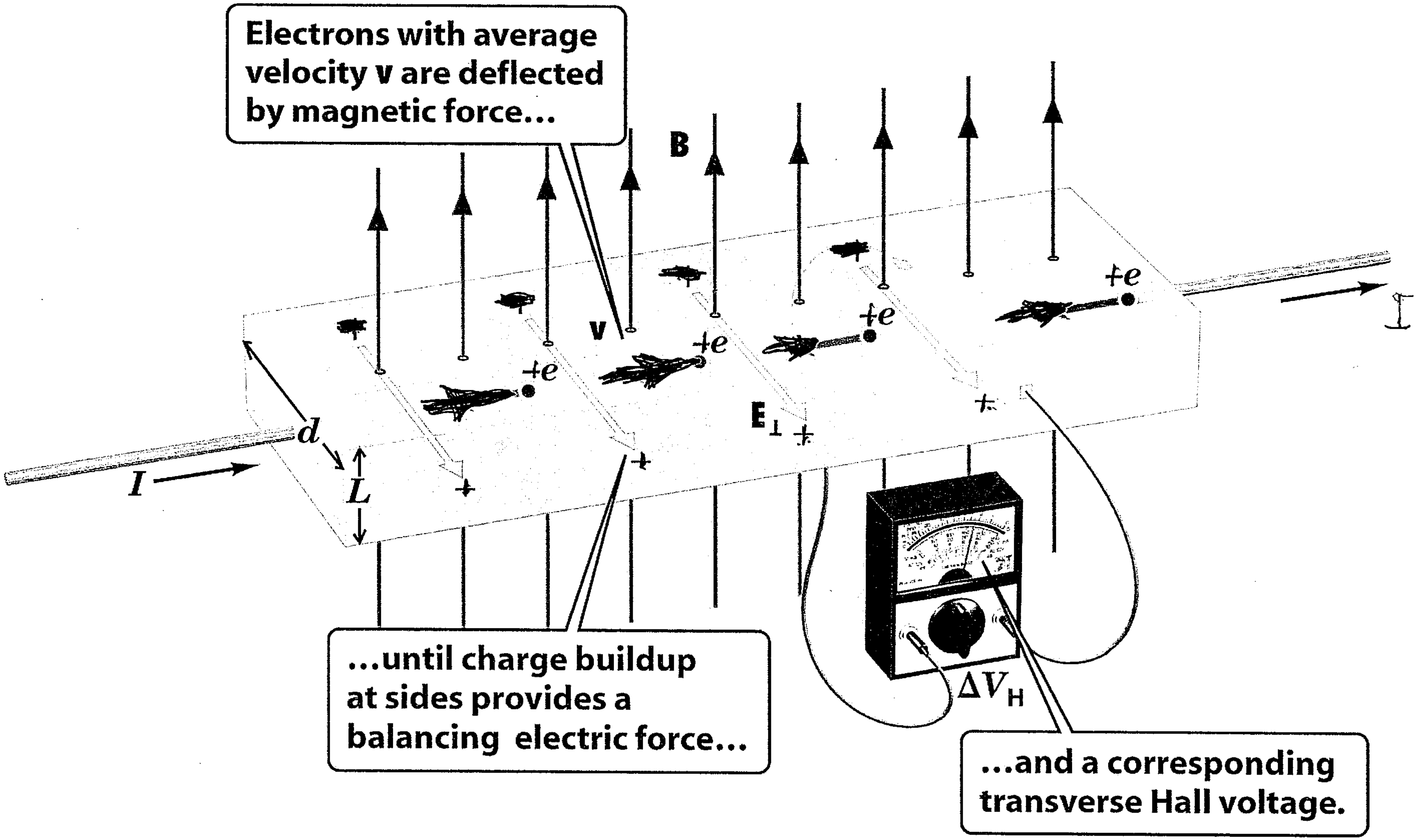
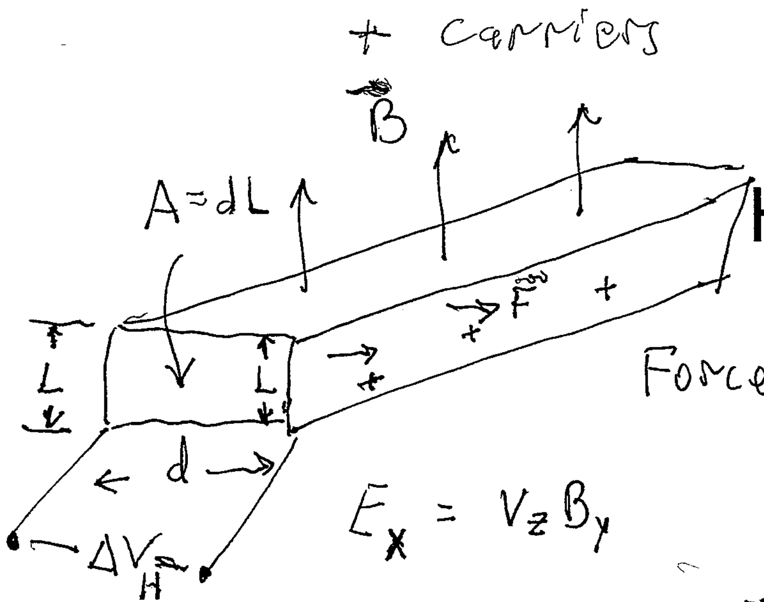
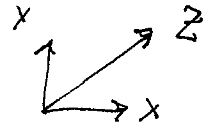



Figure 30-23 Physics for Engineers and Scientists 3/e




# HALL VOLTAGE

Force balance after polarization: $qvB = qE$

$(I = n_c e v)$

$E_x = V_z B_y$

$\Delta V = E_x d = V_z d B_y = \frac{V_z A}{L} B_y = \frac{I B_y}{e L n_c} = IR$

$$\Delta V_H = vBd = \frac{IB}{neL} = I R_H$$

$R_H \equiv$ Hall Resistance $\equiv \frac{B}{neL}$

Fundamental unit of resistance $\equiv \frac{h}{e^2} = 25{,}816.802\ \Omega$