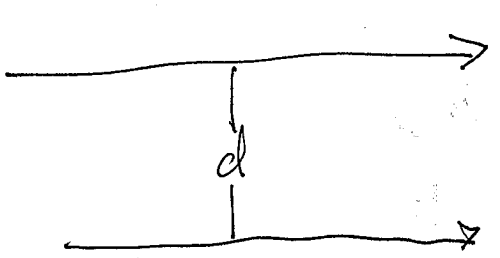
Lecture #19

Magnetic Fields

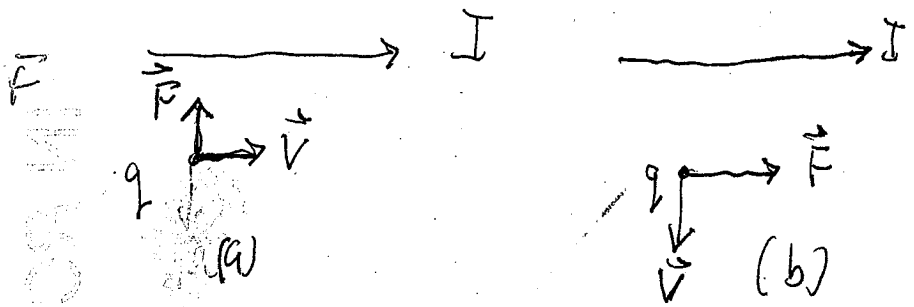
Summary

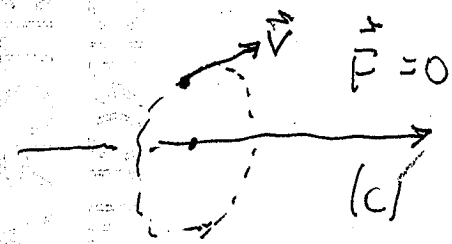
current I_1 and I_2

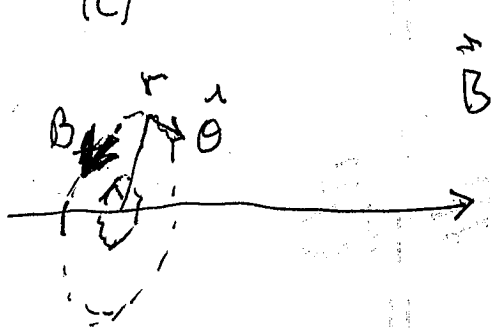


attract with force $\propto \frac{I_1 I_2}{d}$

(repel if I_1, I_2 opposite directions)







$$\vec{B} = \frac{\mu_0}{2\pi r}\hat{\theta}$$

$\mu_0 = 4\pi \times 10^{-7}$ mks

$$\vec{F} = q\,\vec{V} \times \vec{B}$$

$\vec{V}$ along I. Force radial toward current

Force also compatible with (b) and (c)

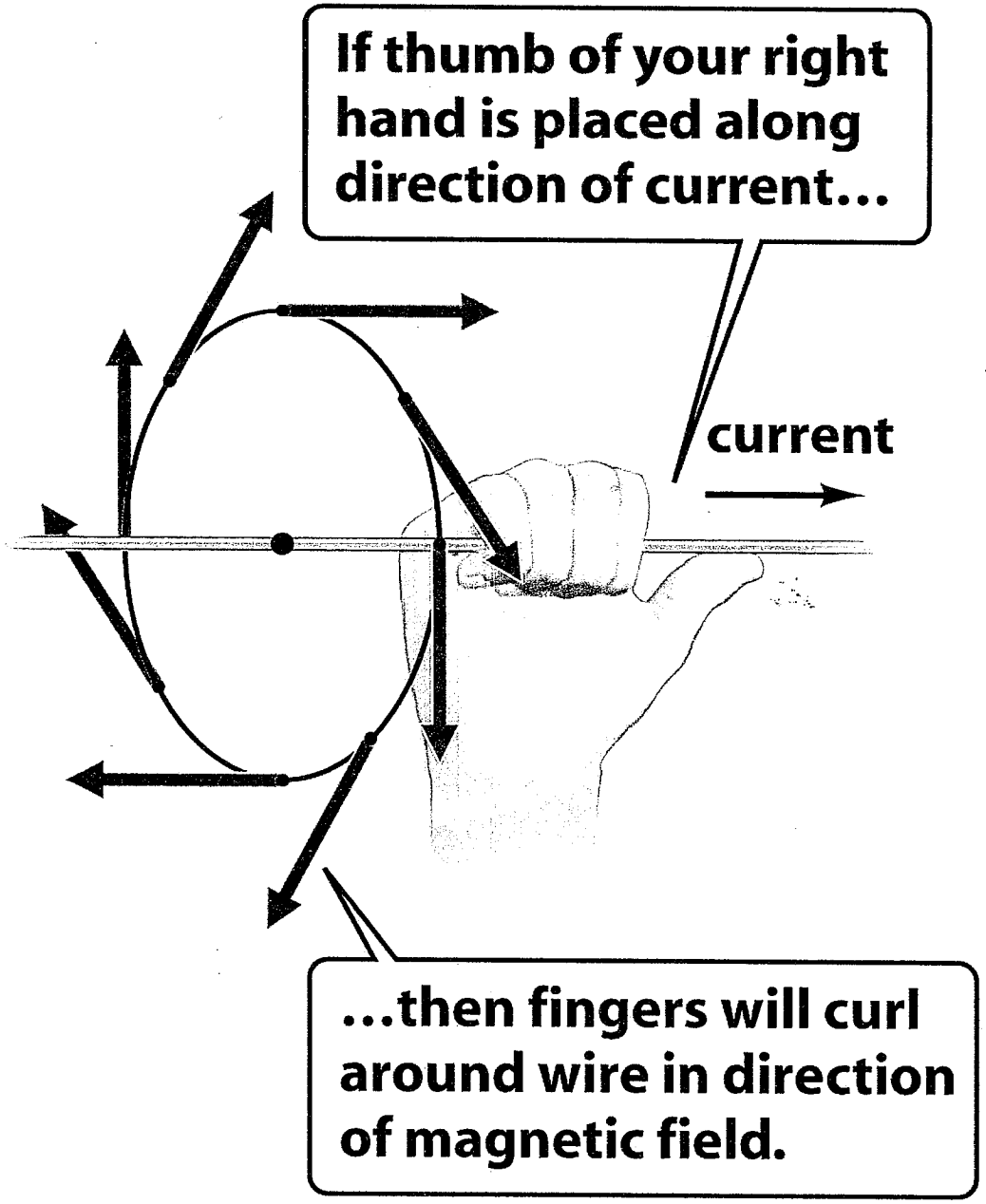


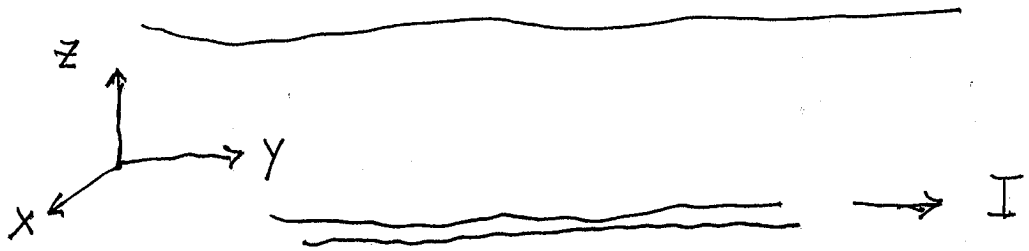
Figure 29-10 Physics for Engineers and Scientists 3/e

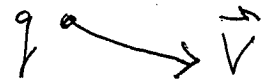
(1) The cross product of

$2\hat{x} \times (3\hat{x} + \hat{y} + 2\hat{z}) =$ $\hat{x} \times \hat{z} = -\hat{y}$

(1) $6\hat{y} + 4\hat{z}$ (2) $4\hat{y} + 2\hat{z}$

(3) $-4\hat{y} + 2\hat{z}$ ✓ (4) $-6\hat{y} + 4\hat{z}$





A current +I is in the $\hat{y}$ direction. The charge q at the position shown is guaranteed to have a zero magnetic force component along

(a) $\hat{y}$ (b) along $\vec{v}$ (c) along $\hat{z}$

In what direction is current in wire?
(a) to the left (b) to the right

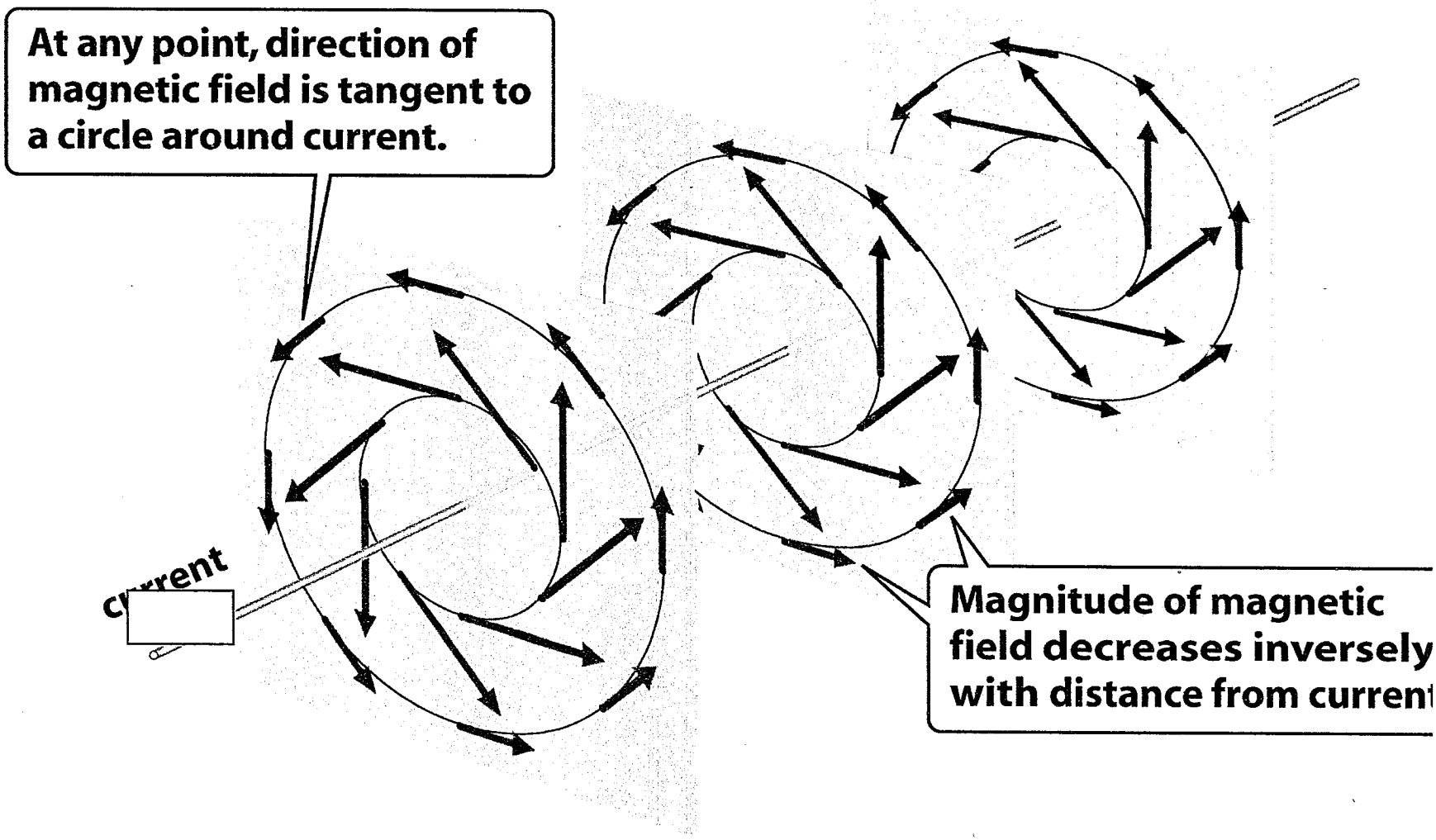
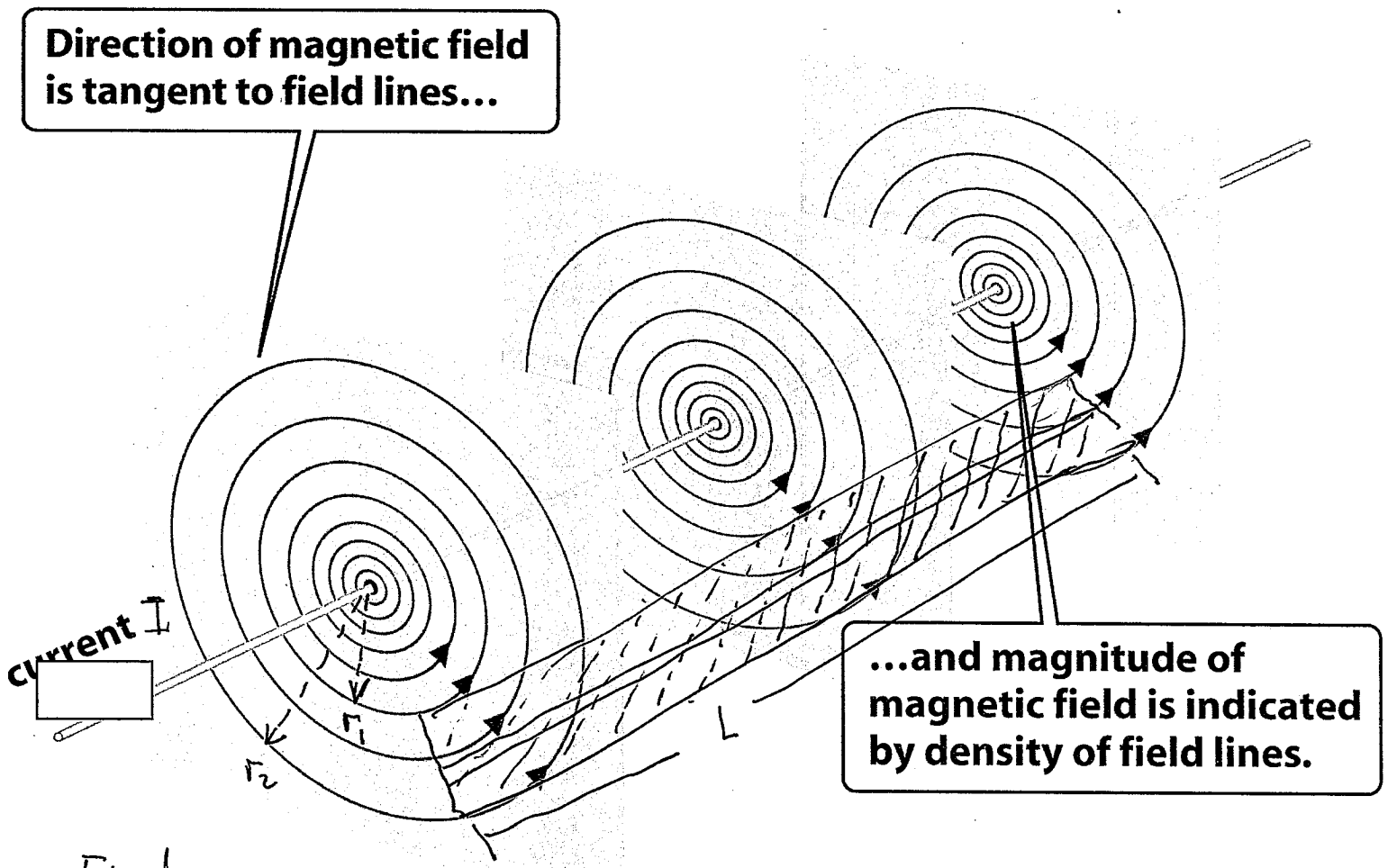


Figure 29-9 Physics for Engineers and Scientists 3/e

Magnetic Flux $d\Phi_M = \vec{B} \cdot d\vec{A}$



Find magnetic flux through strip

Figure 29-14 Physics for Engineers and Scientists 3/e

$$\Phi_B = \frac{\mu_0 L I}{2\pi} \ln\left(\frac{r_2}{r_1}\right)$$

Direction of current is to the:
(a) Right (b) Left

"Guass-less" Law

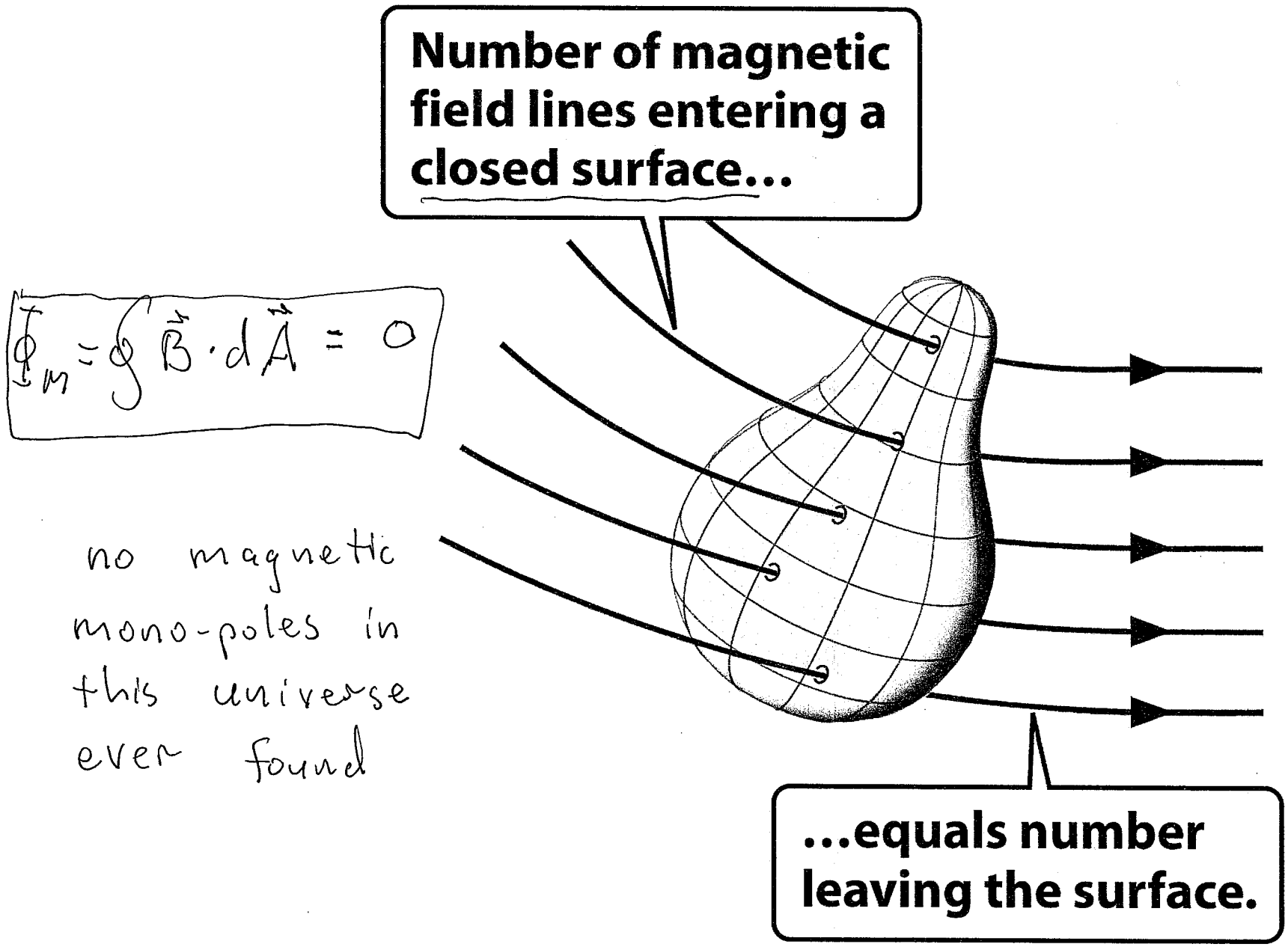
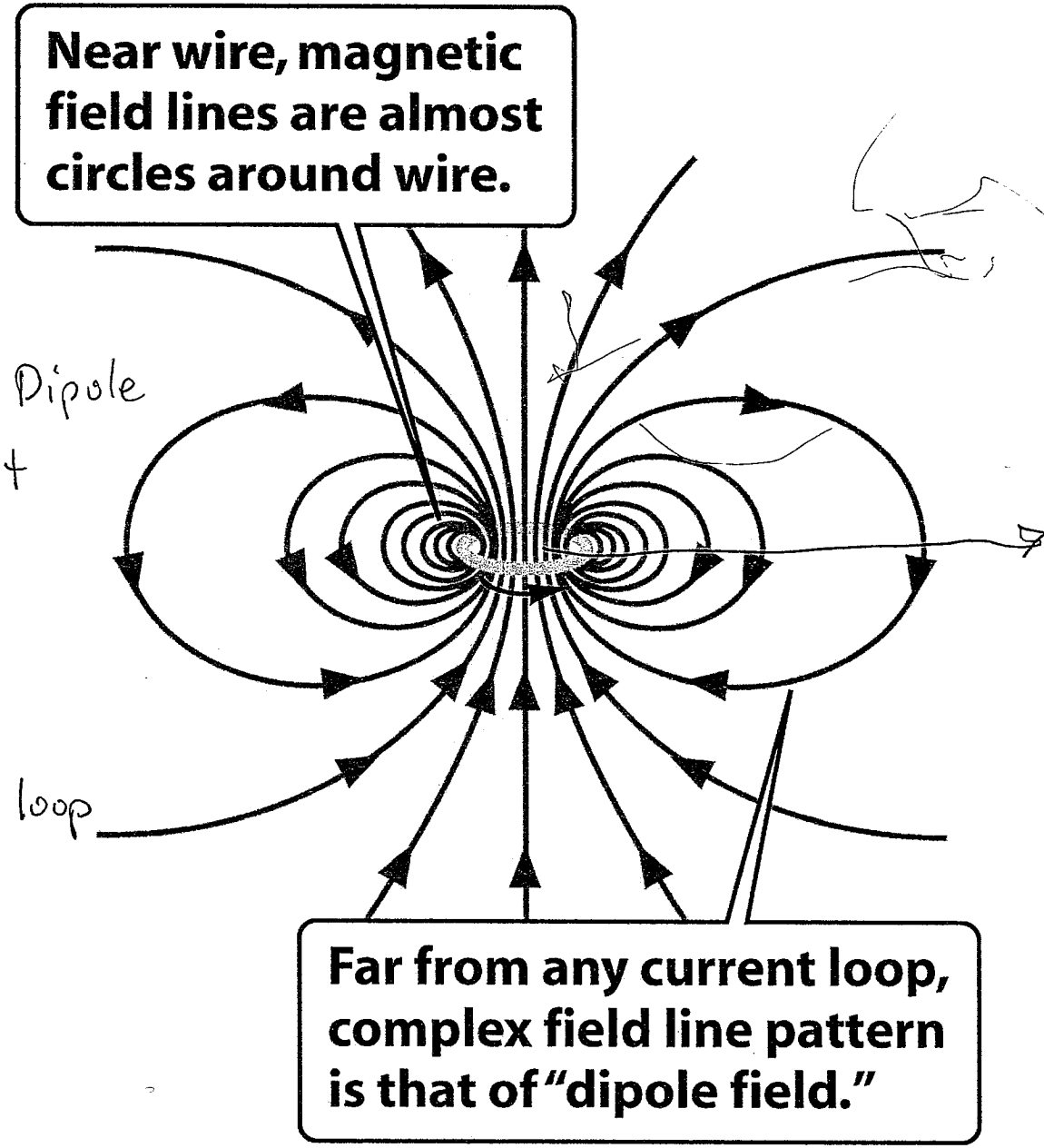


Figure 29-18 Physics for Engineers and Scientists 3/e



Magnetic Dipole Moment

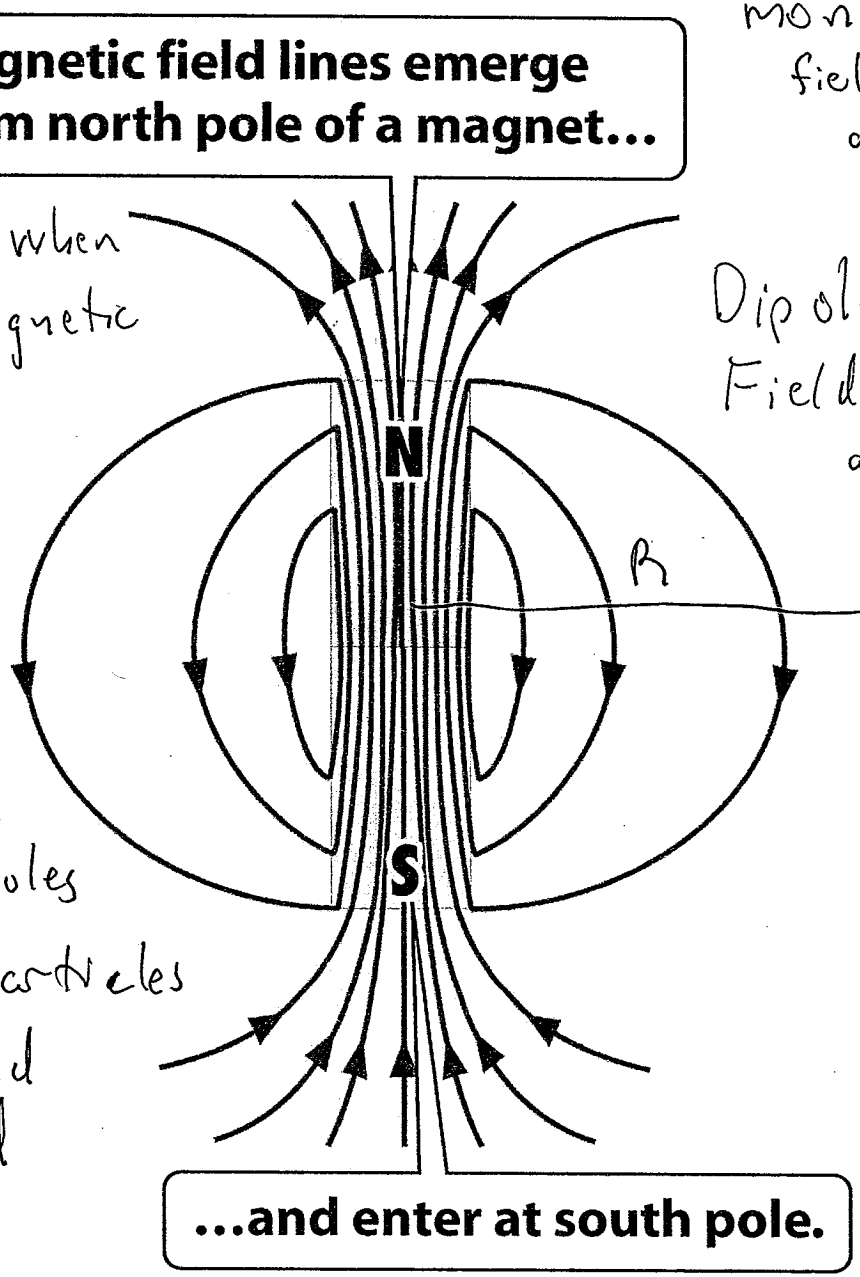
$\vec{p} = I\vec{A}$

$\vec{A}$ ≡ area of current loop

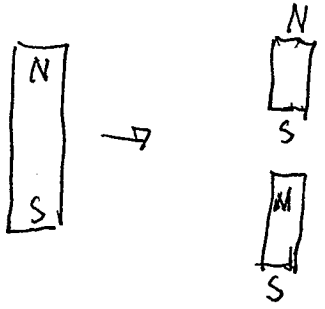
$B \propto \frac{1}{r^3}$

Figure 29-23 Physics for Engineers and Scientists 3/e

monopole magnetic field falls off as $B \propto 1/R^2$



What Happens when we cut a magnetic dipole in half



Dipole magnetic Fields fall off as $1/R^3$

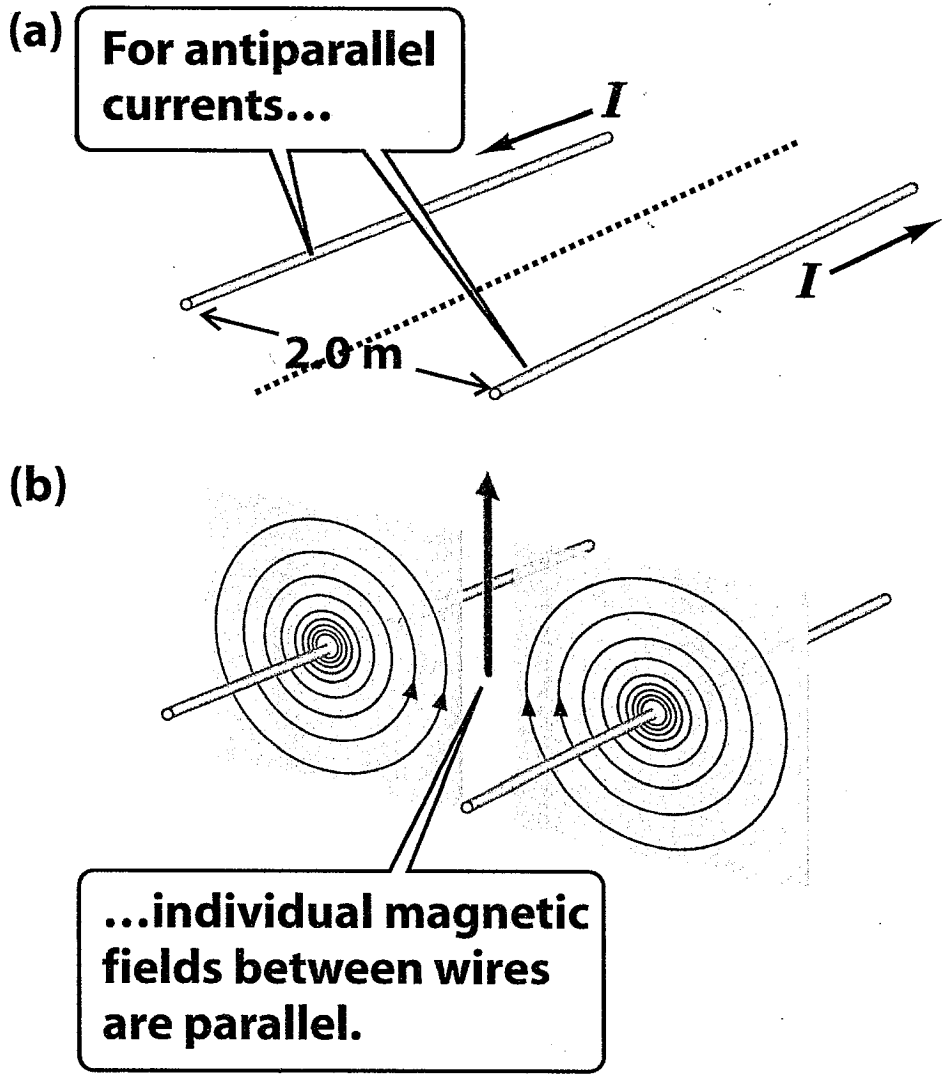
$\vec{B} \propto \frac{1}{R^3}$

The smallest magnetic dipoles are elementary particles like electrons and even protons and neutrons.

Figure 29-16 Physics for Engineers and Scientists 3/e

Superposition of fields

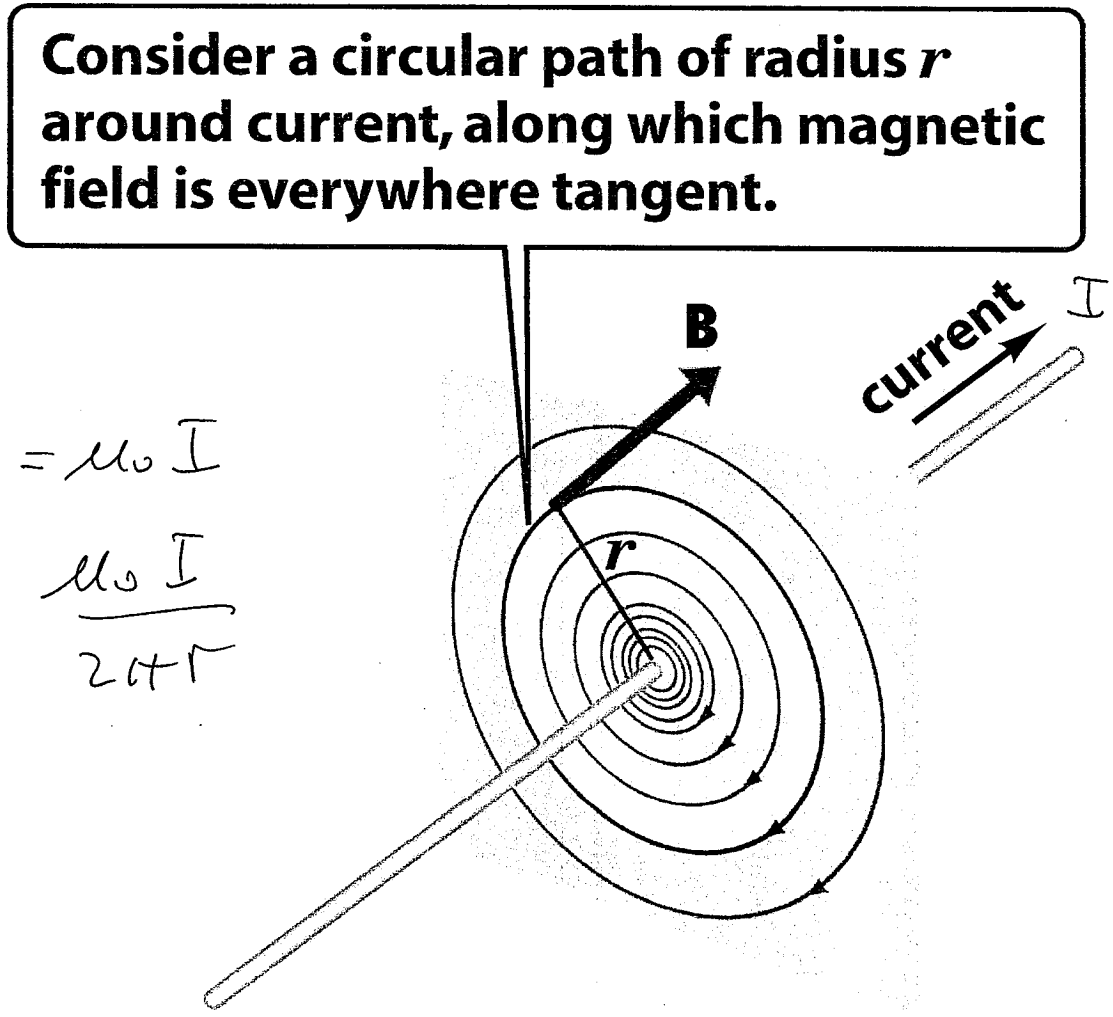
Find magnetic field on midline between the wires



$$B_1 = \frac{\mu_0}{2\pi}\frac{I}{1m} + \frac{\mu_0}{2\pi}\frac{I}{1m}$$

Figure 29-19 Physics for Engineers and Scientists 3/e

Ampere's Law: $\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{total}$ or $\oint B_{\parallel} ds = \mu_0 I_{total}$



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

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

Figure 29-20 Physics for Engineers and Scientists 3/e

Ampere's Law: $\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{total}$ or $\oint B_{\parallel} ds = \mu_0 I_{total}$

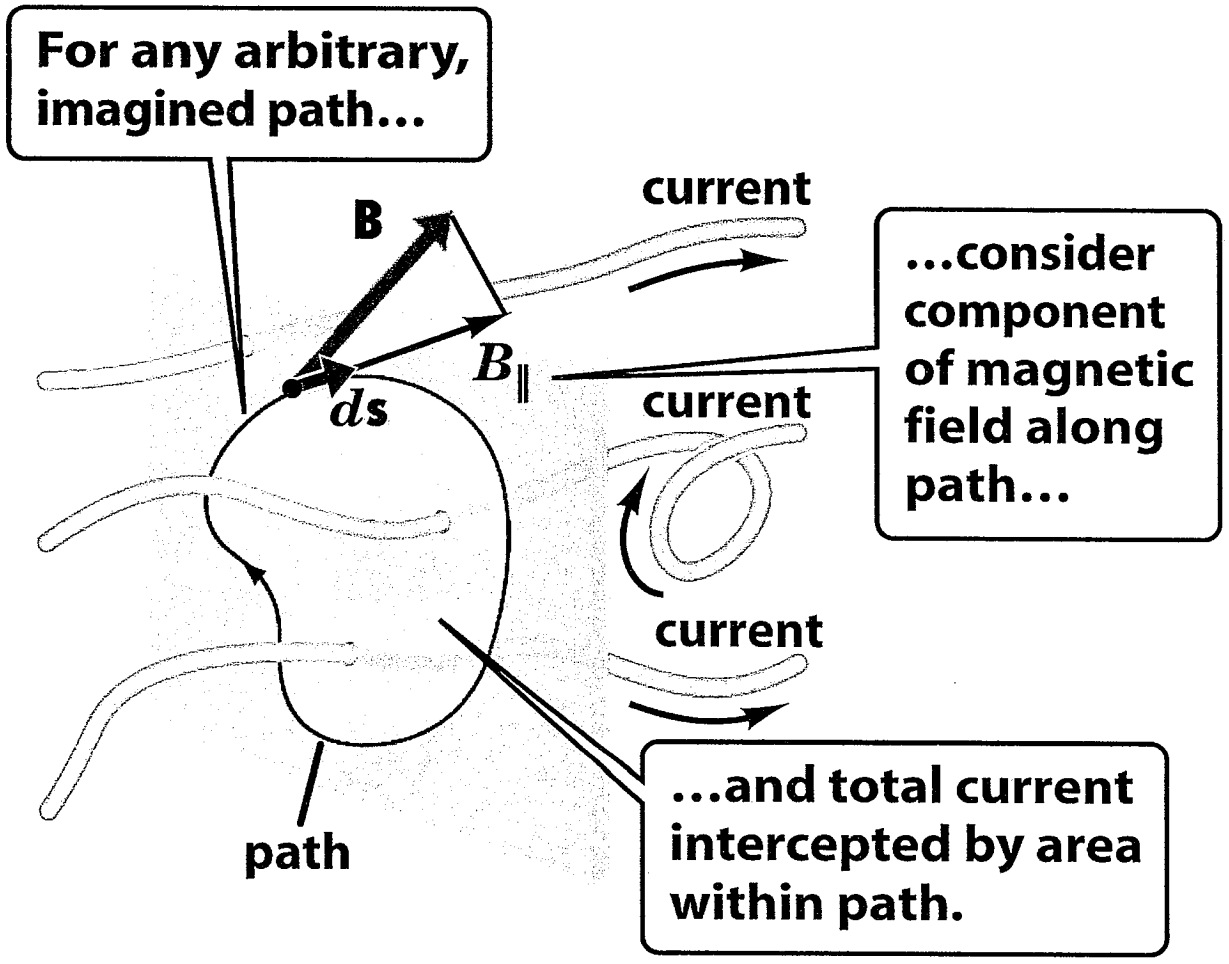
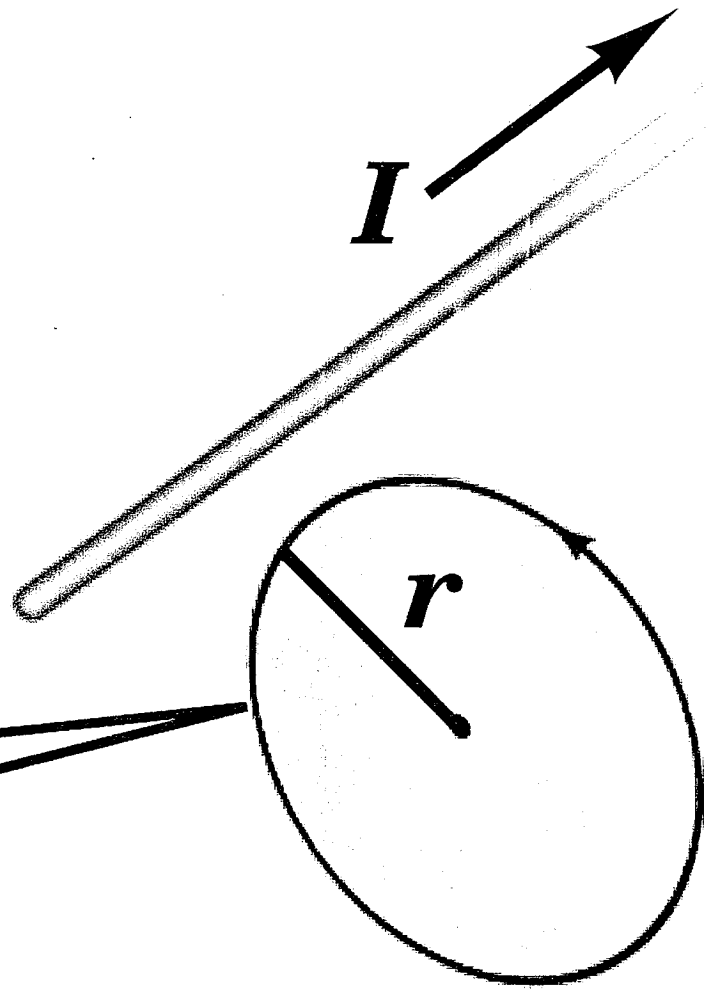


Figure 29-21 Physics for Engineers and Scientists 3/e

(a) 0; (b) $\frac{\mu_0 I}{2\pi r}$



What is $\oint B_{\parallel} ds$ for this path?

Figure 29-27 Physics for Engineers and Scientists 3/e

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Suppose we have uniform current density $\vec{J} = \frac{I}{\pi a^2}$. Find B for $r < a$

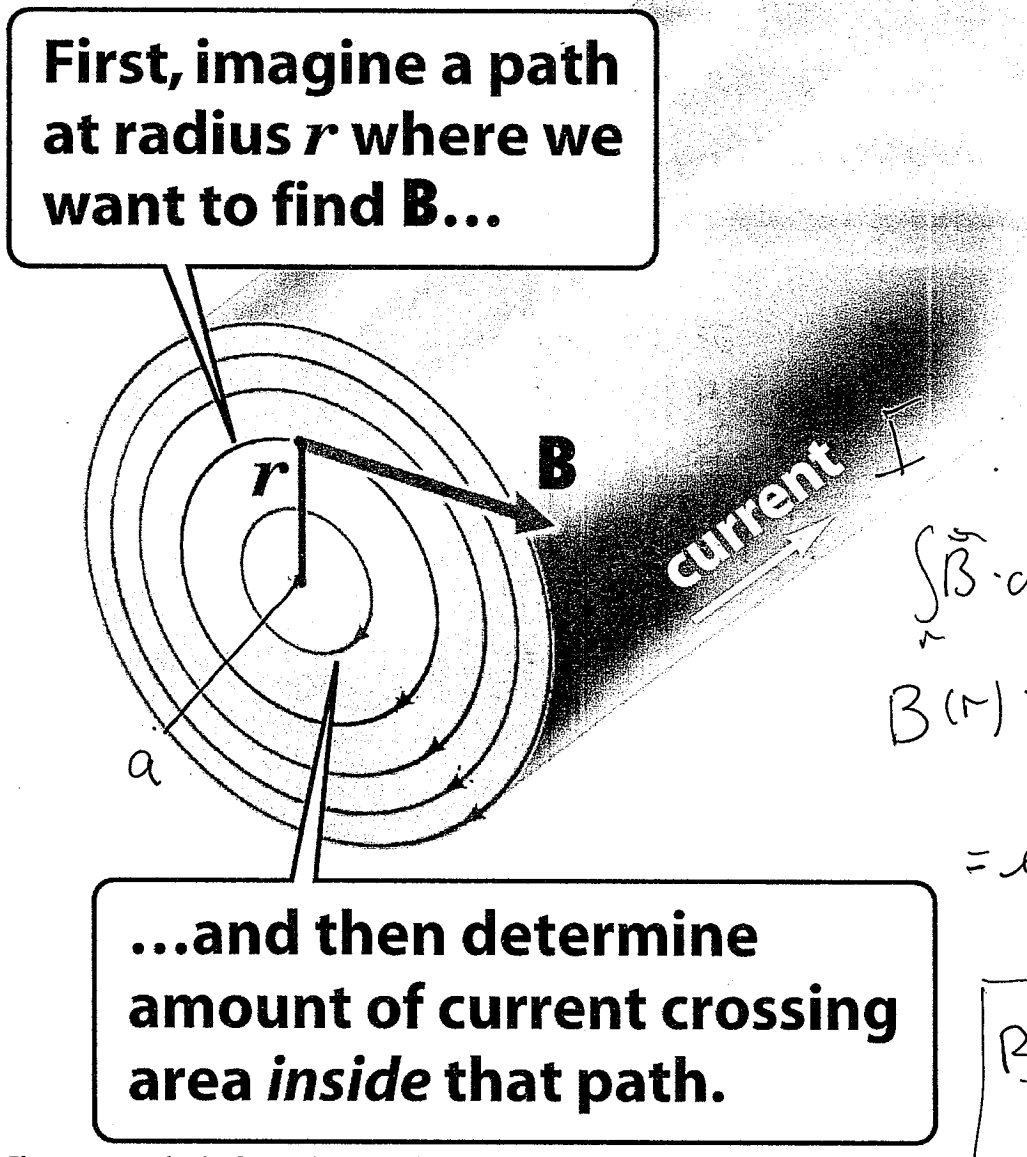

Figure 29-22 Physics for Engineers and Scientists 3/e

$$\oint_r \vec{B} \cdot d\vec{s} = I(r)\mu_0$$

$$B(r)\,2\pi r = \mu_0 j (\pi r^2)$$

$$= \mu_0 \pi r^2 \frac{I}{\pi a^2}$$

$$B(r) = \mu_0 \frac{r I}{2\pi a^2}$$