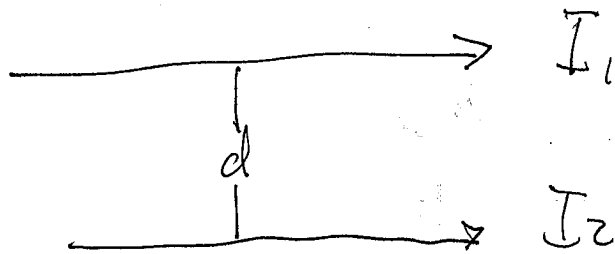


Lecture #19

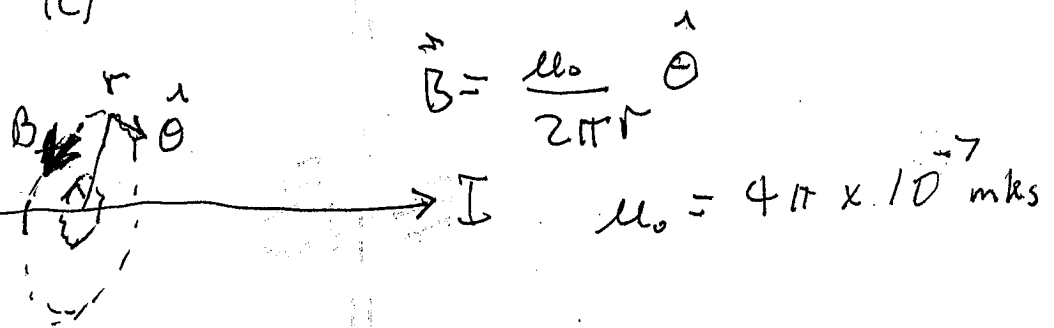
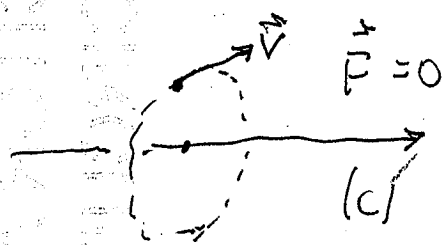
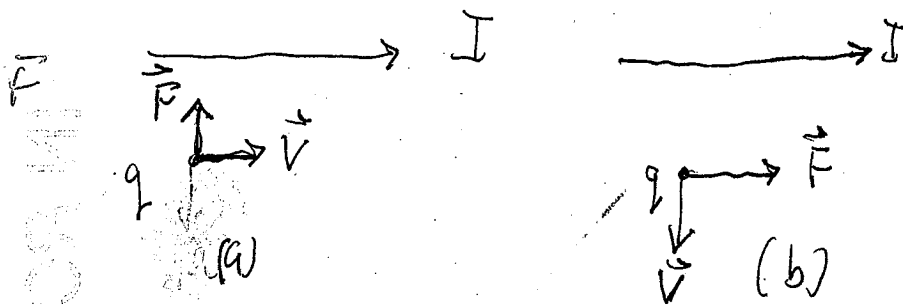
Magnetic Fields

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)



$$\vec{F} = q \vec{v} \times \vec{B}$$

\vec{v} along I , force radial toward current

Force also compatible with
 (b) and (c)

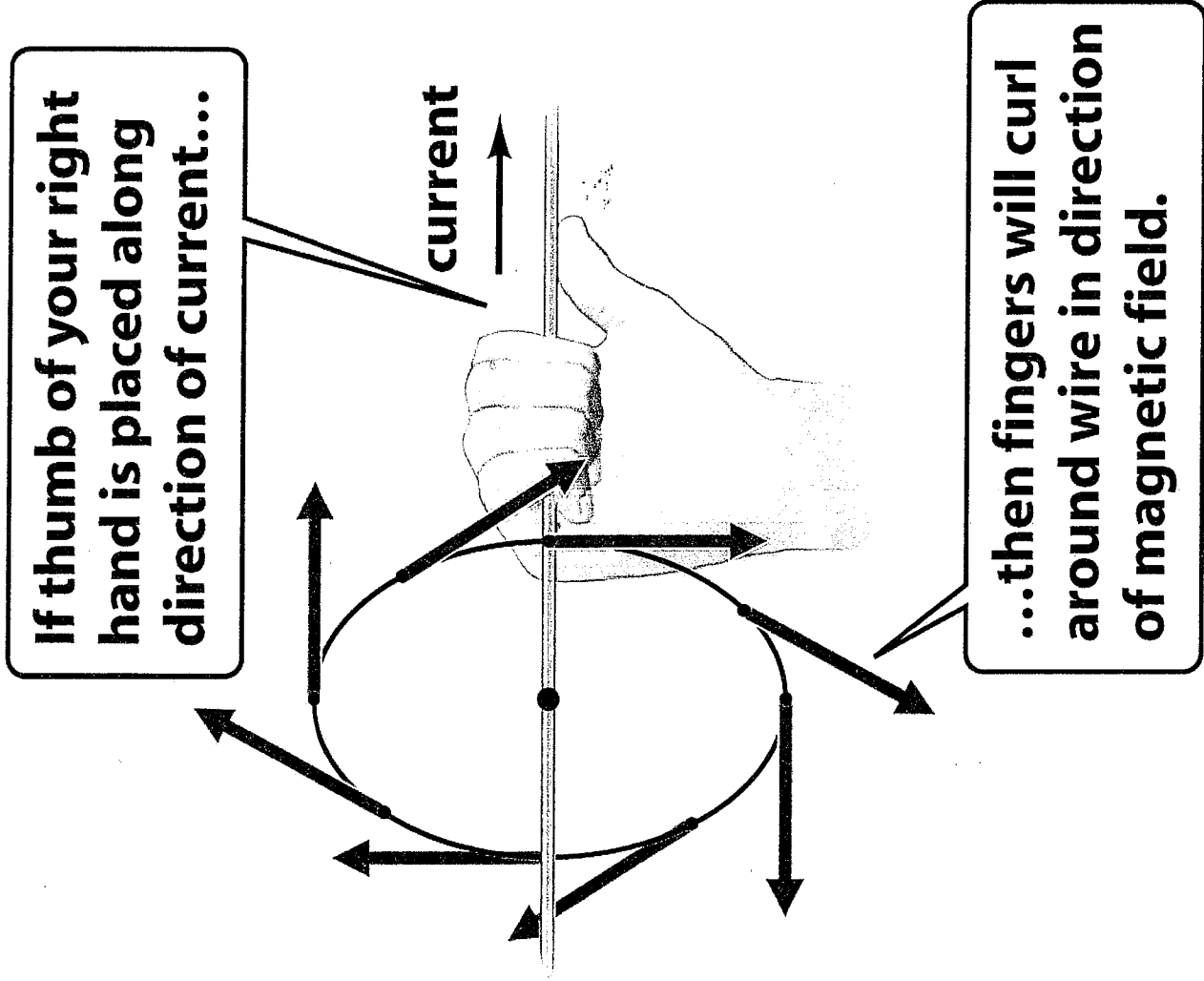


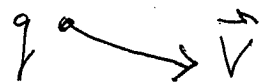
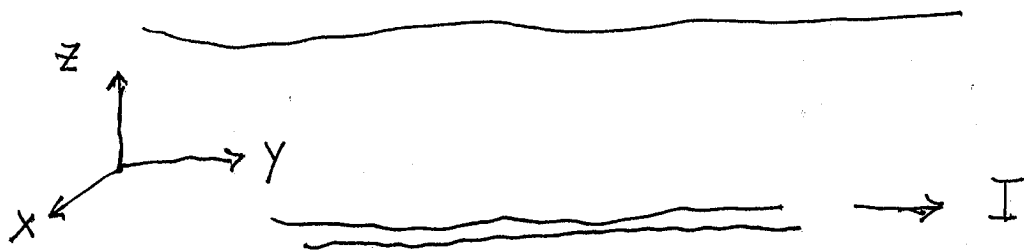
Figure 29-10 Physics for Engineers and Scientists 3/e
 © 2007 W. W. Norton & Company, Inc.

(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

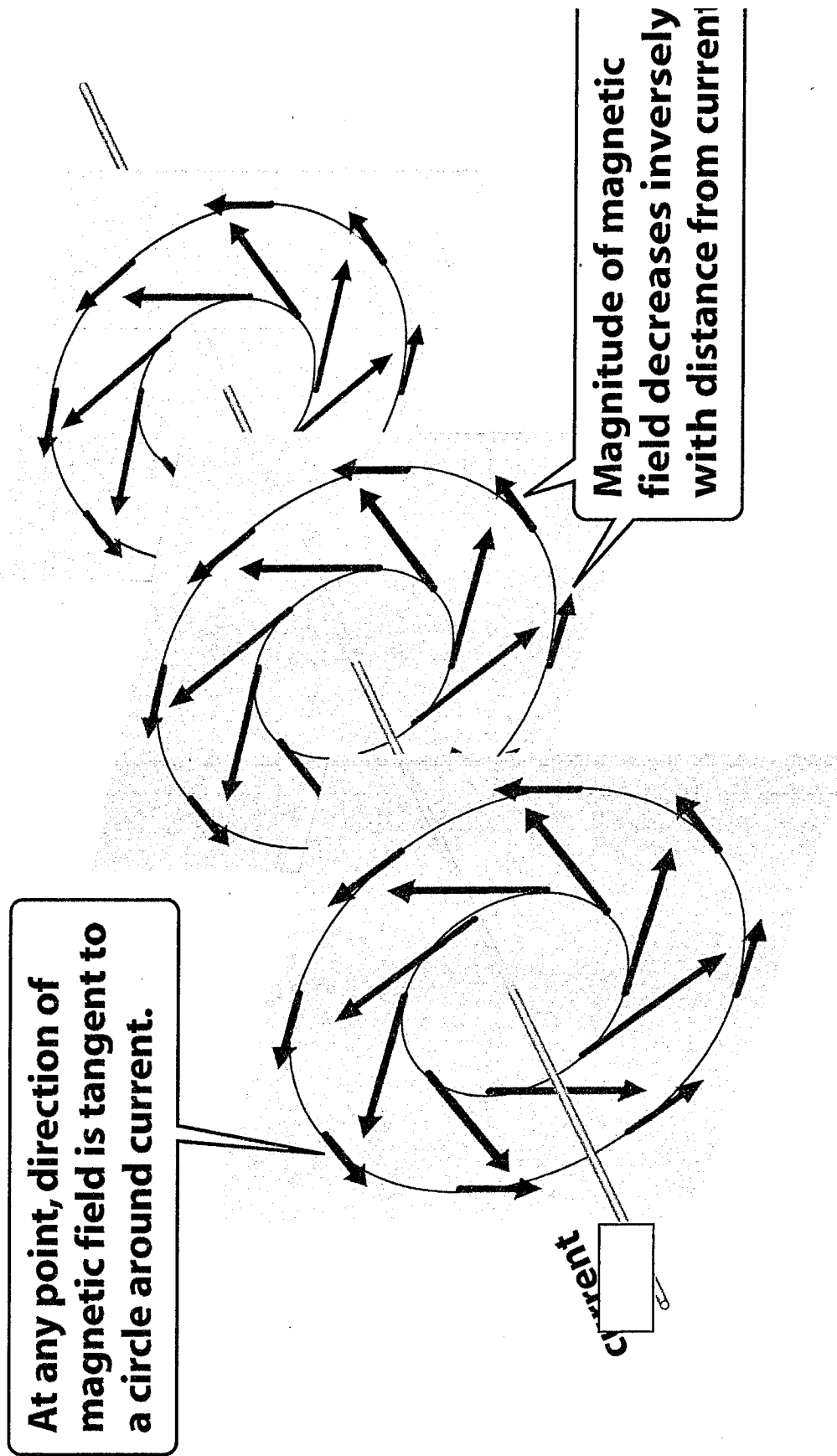
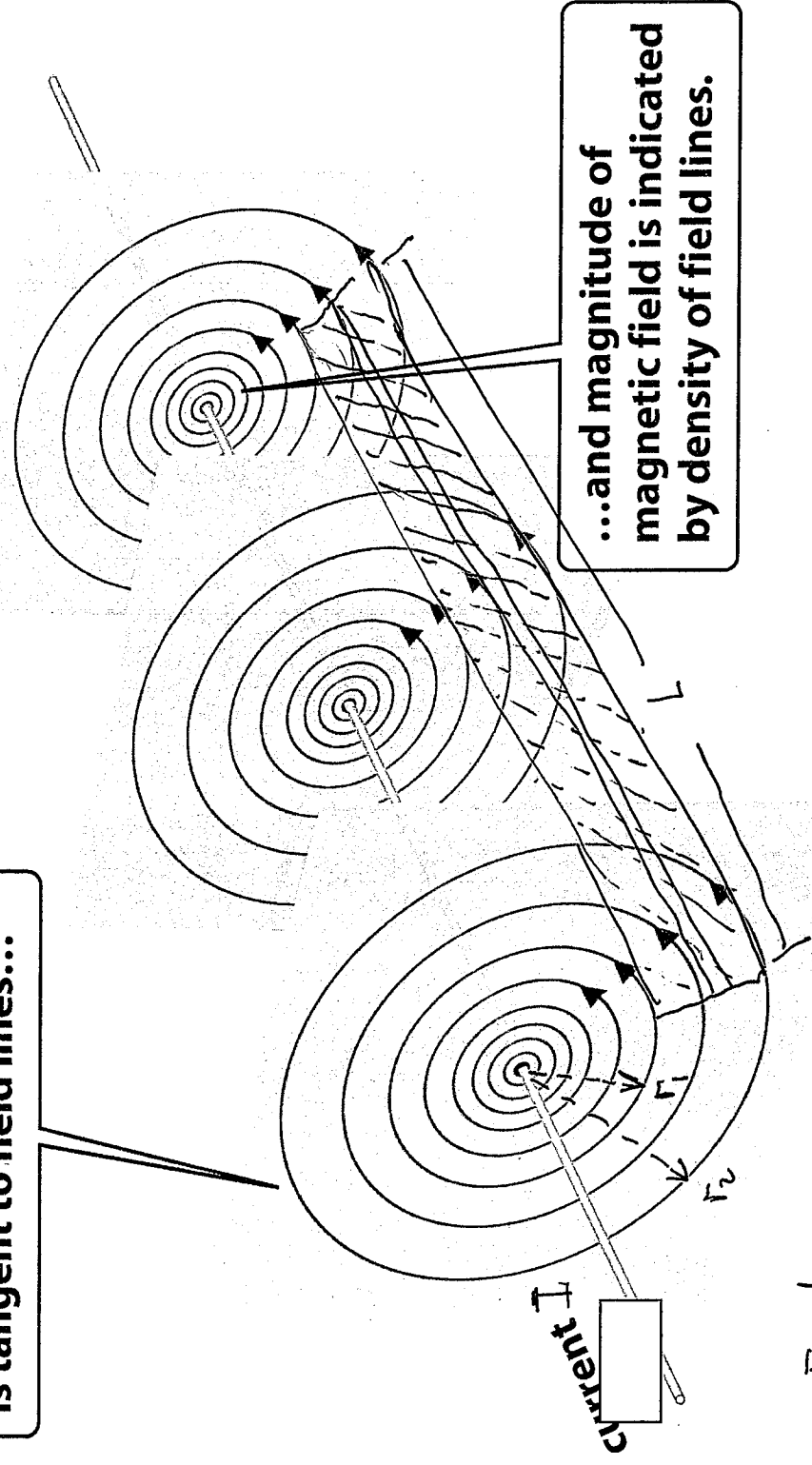


Figure 29-9 Physics for Engineers and Scientists 3/e
© 2007 W. W. Norton & Company, Inc.

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

Direction of magnetic field is tangent to field lines...



Find magnetic flux through strip

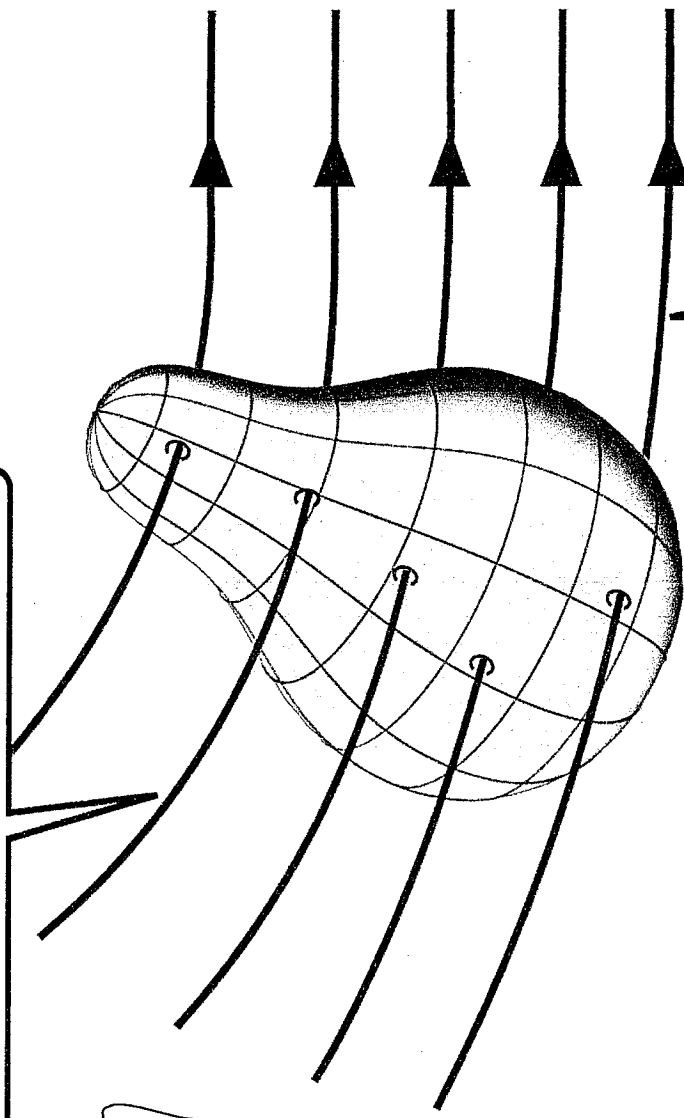
Figure 29-14 Physics for Engineers and Scientists 3/e © 2007 W.W. Norton & Company, Inc.

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

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

"Gauss-less" Law

Number of magnetic field lines entering a closed surface...



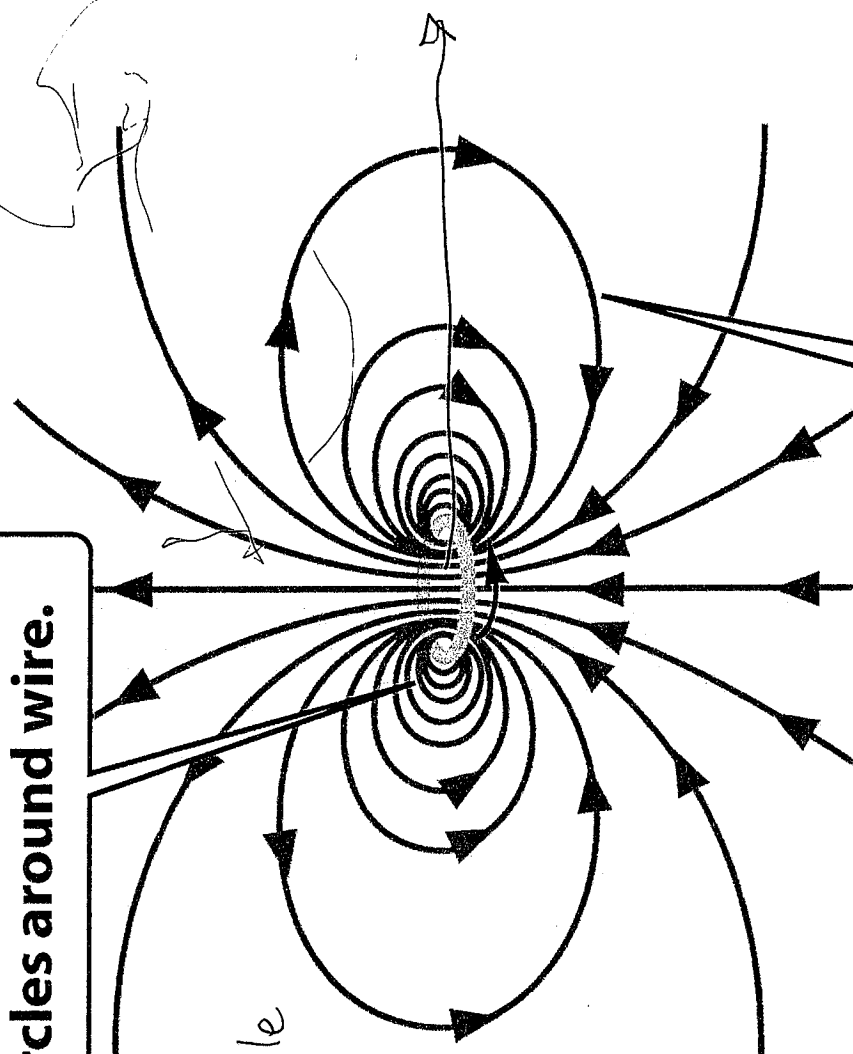
...equals number leaving the surface.

$$\oint_M \vec{B} \cdot d\vec{A} = 0$$

no magnetic mono-poles in this universe ever found

Figure 29-18 Physics for Engineers and Scientists 3/e © 2007 W. W. Norton & Company, Inc.

Near wire, magnetic field lines are almost circles around wire.



Far from any current loop, complex field line pattern is that of "dipole field."

Magnetic Dipole Moment

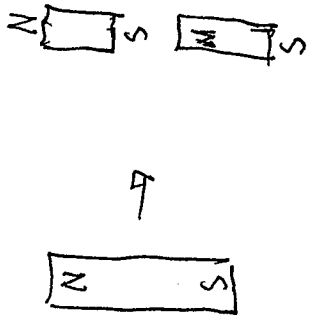
$$\vec{p} = I \vec{A}$$

$\vec{A} \equiv$ area of current loop

Figure 29-23 Physics for Engineers and Scientists 3/e
© 2007 W. W. Norton & Company, Inc.

Magnetic field lines emerge from north pole of a magnet...

What Happens when we cut a magnetic dipole in half

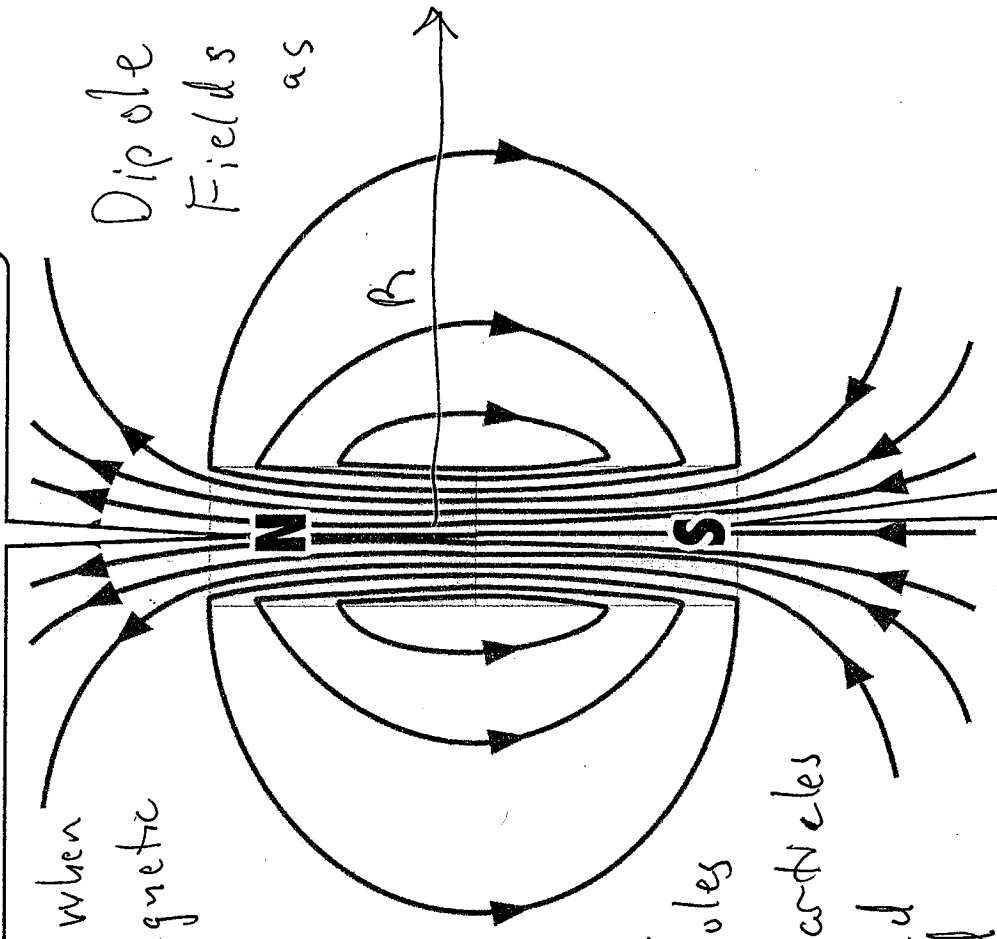


The smallest magnetic dipoles are elementary particles like electrons and even protons and neutrons.

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

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

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



...and enter at south pole.

Figure 29-16 Physics for Engineers and Scientists 3/e © 2007 W. W. Norton & Company, Inc.

Superposition of fields

Find magnetic field on midline between the wires

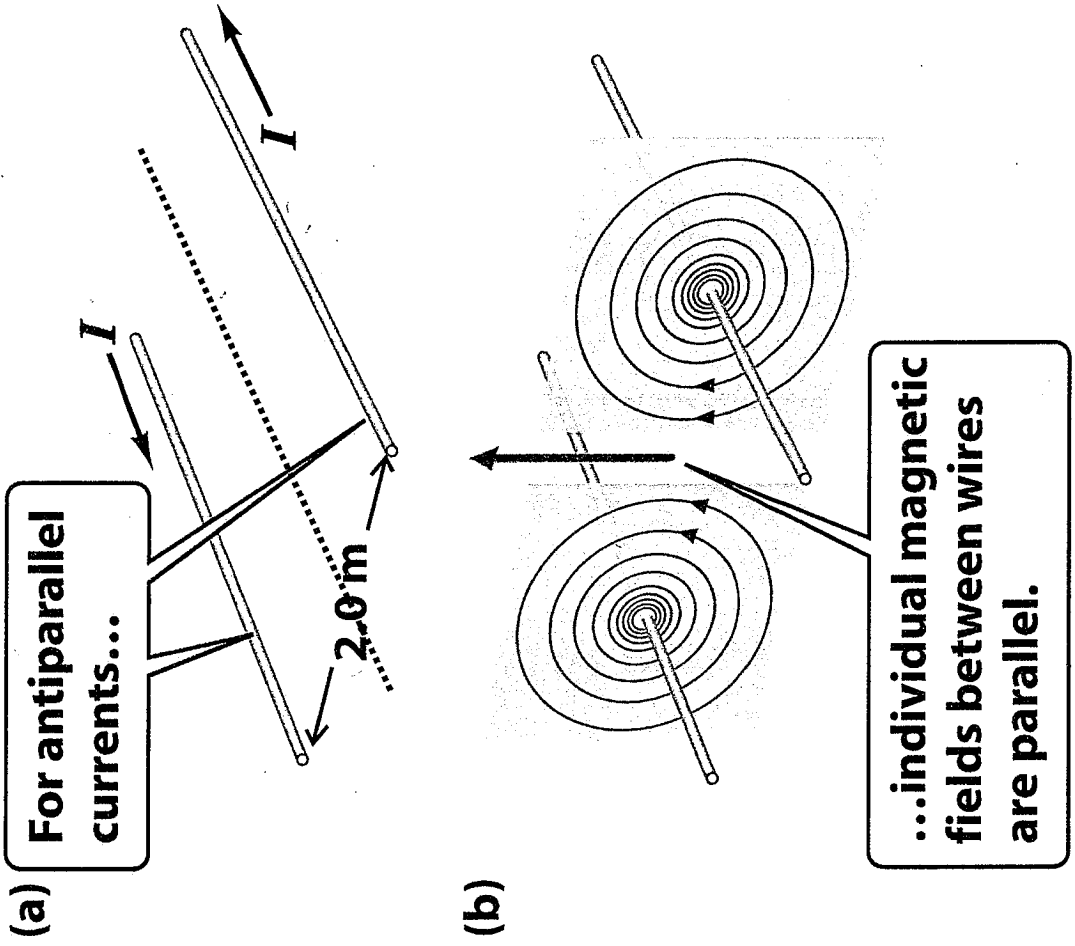


Figure 29-19 Physics for Engineers and Scientists 3/e
© 2007 W. W. Norton & Company, Inc.

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

Consider a circular path of radius r around current, along which magnetic field is everywhere tangent.

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

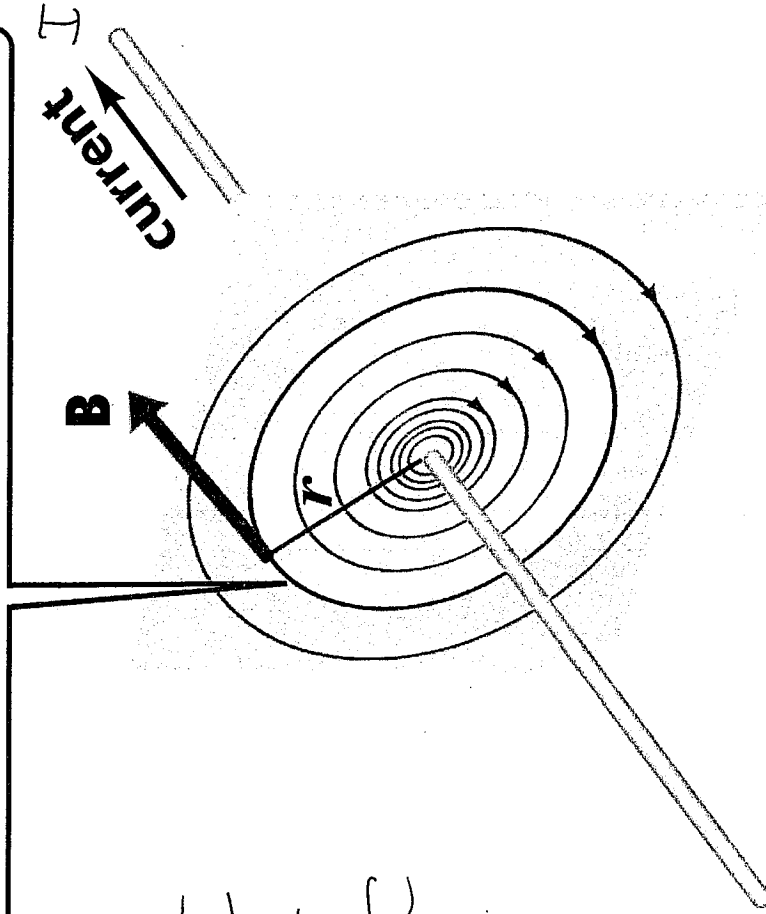


Figure 29-20 Physics for Engineers and Scientists 3/e
© 2007 W. W. Norton & Company, Inc.

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

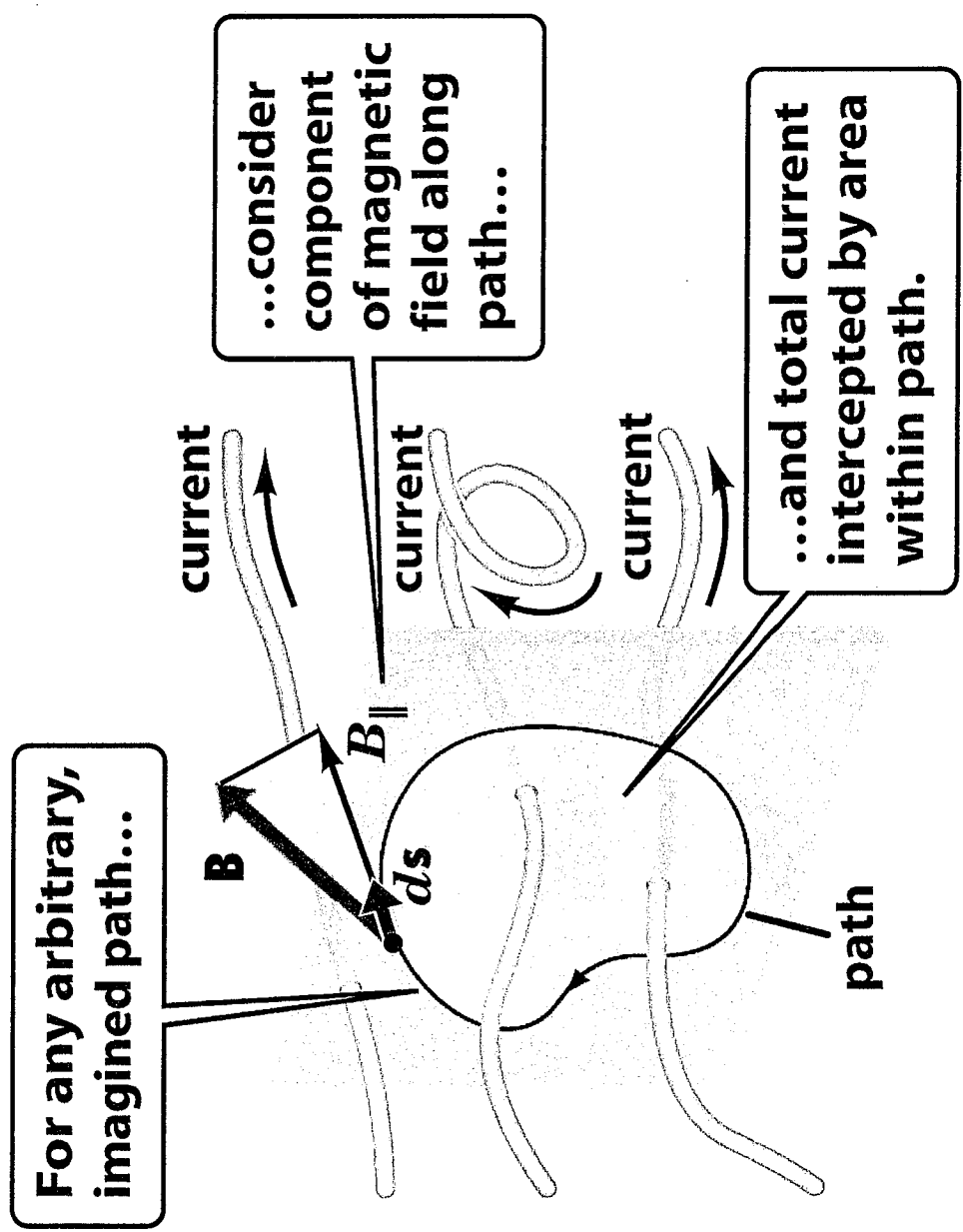
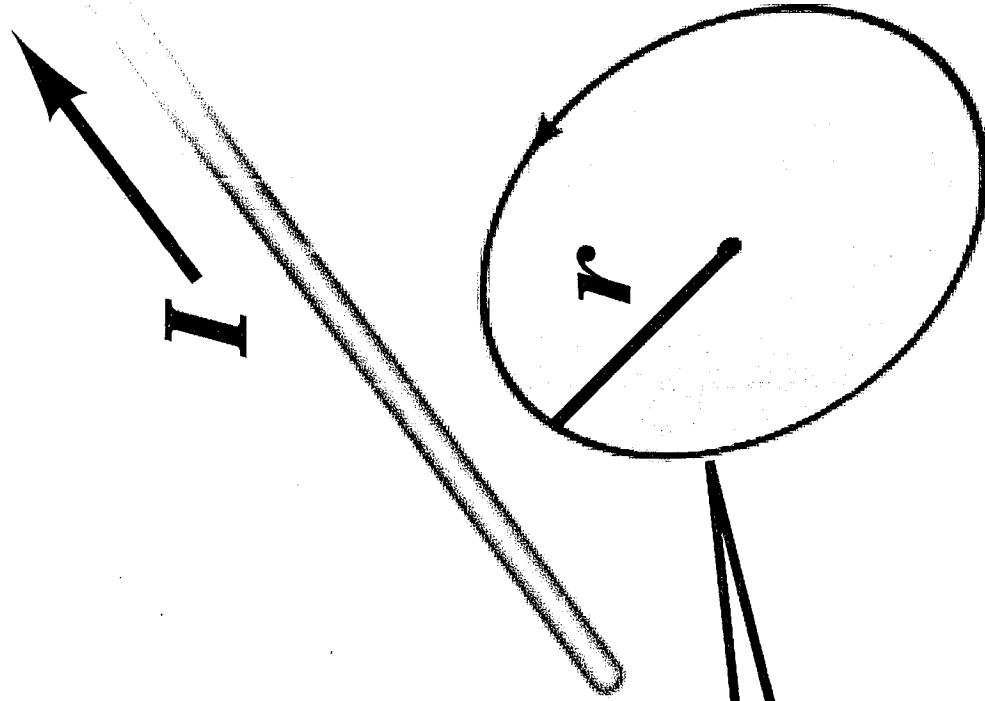


Figure 29-21 Physics for Engineers and Scientists 3/e
© 2007 W. W. Norton & Company, Inc.

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

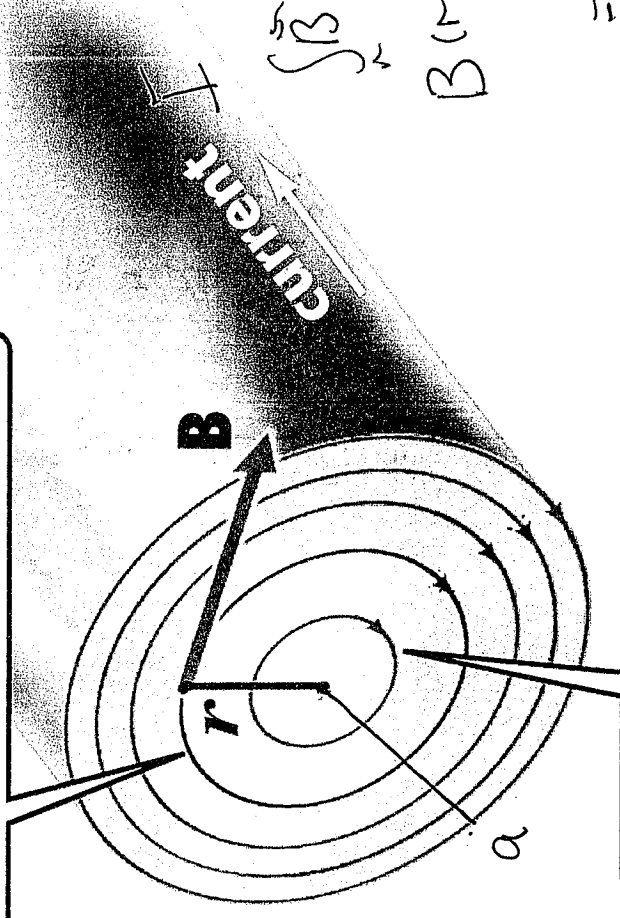


**What is $\oint B_{\parallel} ds$
for this path?**

Figure 29-27 Physics for Engineers and Scientists 3/e
© 2007 W. W. Norton & Company, Inc.

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

First, imagine a path at radius r where we want to find B ...



...and then determine amount of current crossing area *inside* that path.

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

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

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

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

Figure 29-22 Physics for Engineers and Scientists 3/e © 2007 W. W. Norton & Company, Inc.