

Lecture 12
Magnetism

Each magnet has two distinct ends.

Magnetic forces push like ends apart...

...and pull unlike ends together.

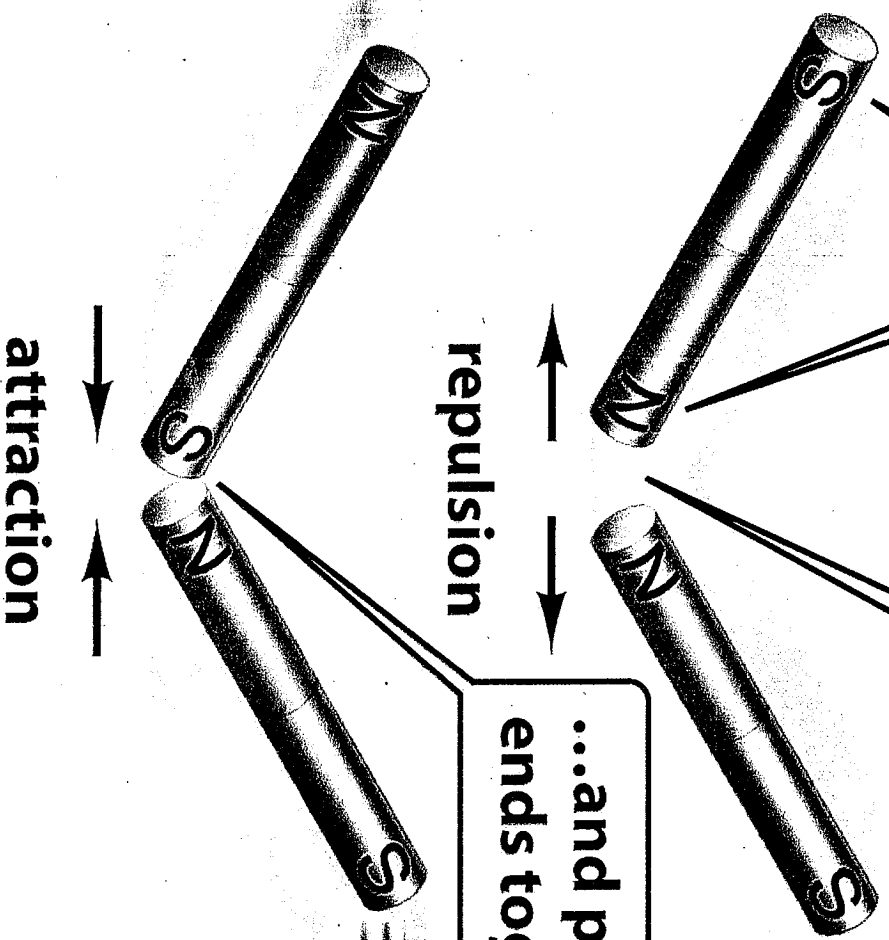
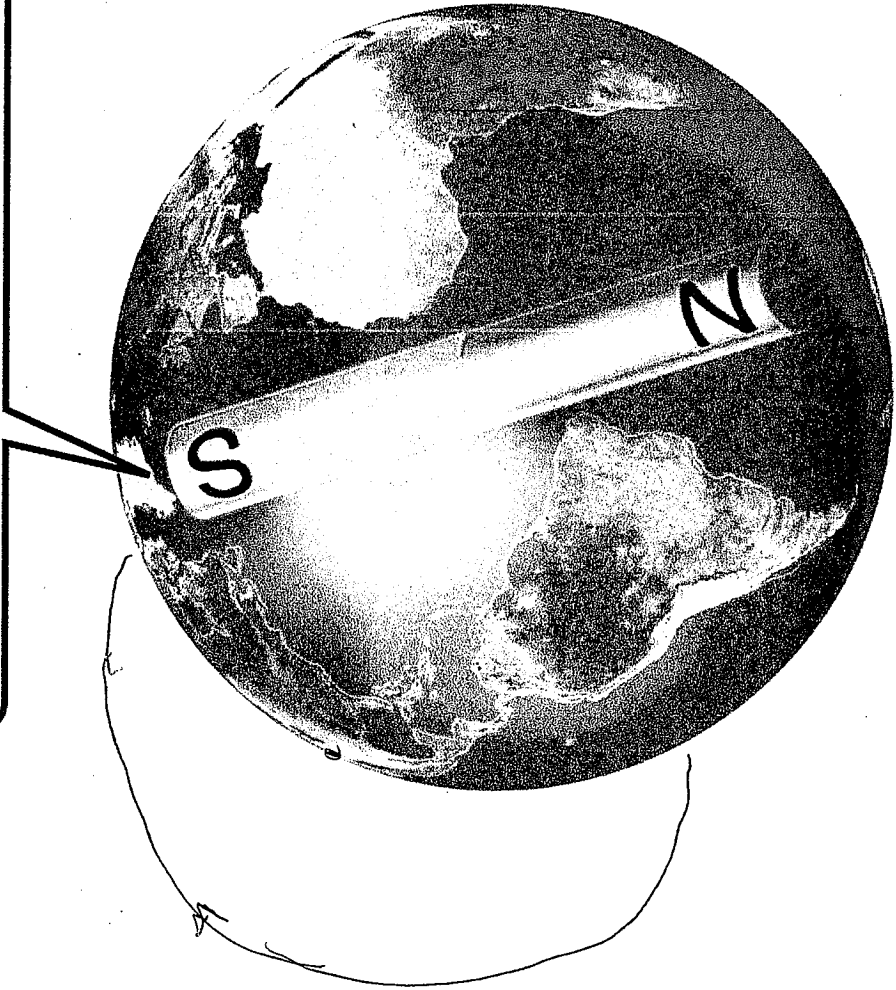


Figure 29-1 Physics for Engineers and Scientists 3/e
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**Magnetic south pole
of Earth is near our
geographic north pole.**



- Which is the smallest magnet
1. an iron atom
 2. an electron
 3. the smallest iron crystal that can we fabricated

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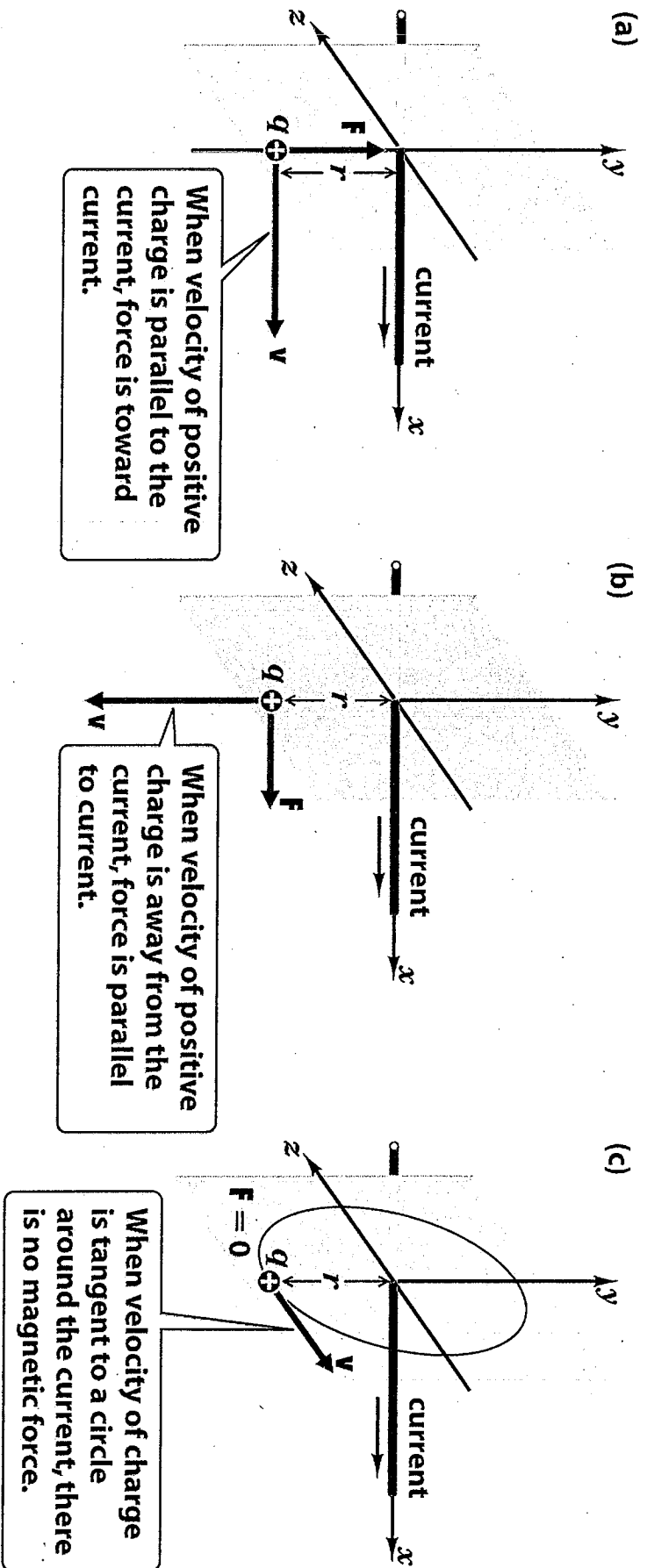
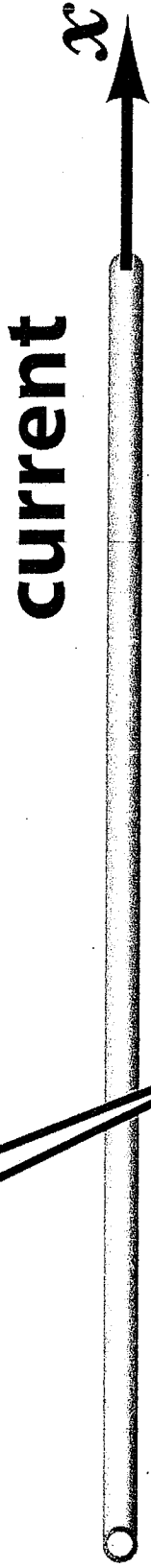


Figure 29-6 Physics for Engineers and Scientists 3/e
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**Motion is parallel
to current...**



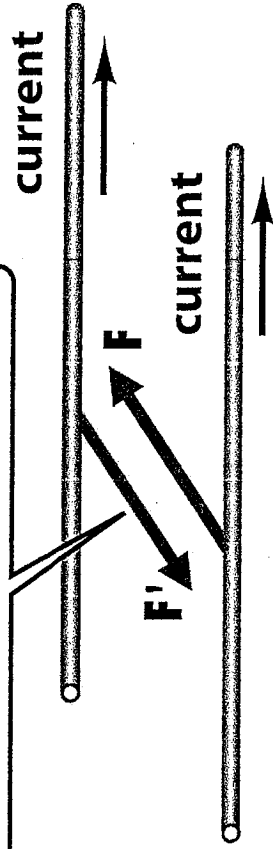
electron

**...but electron charge
is negative, so force is
radially outward.**

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(a)

Magnetic forces between parallel currents are attractive...



(b)

...and between antiparallel currents are repulsive.

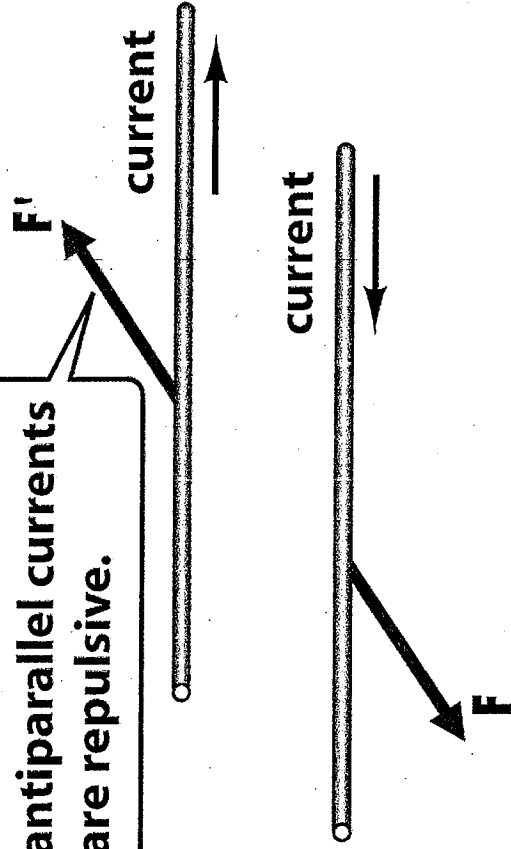


Figure 29-8 Physics for Engineers and Scientists 3/e
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Electro-magnetic force on a charge q

$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$$

We need to review cross product relations

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

$$= -q \vec{B} \times \vec{V}$$

$$|q \vec{V} \times \vec{B}| = q |\vec{V}| |\vec{B}| \sin \alpha$$

Begin with fingers of your right hand pointing along \vec{v} ...

...then rotate your arm...

...until you can curl your fingers through the smallest angle from \vec{v} toward \vec{B} .

Your thumb then points in direction of \vec{F} for a positive charge.

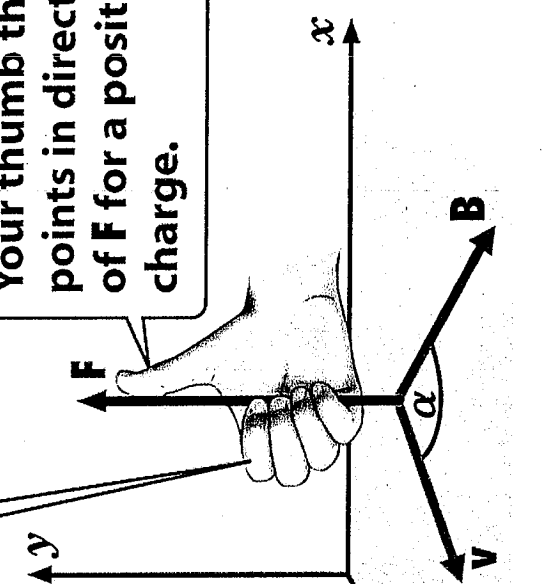
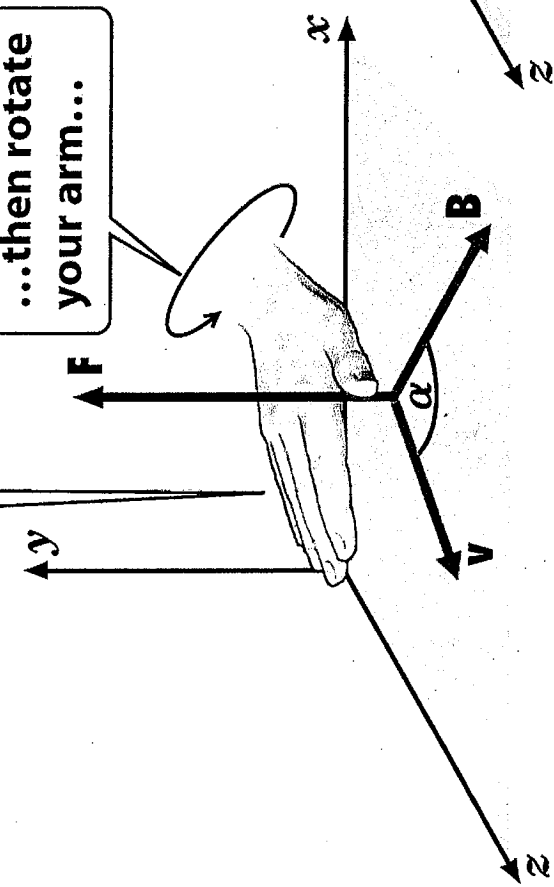


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$$\hat{x} \times \hat{y} = \hat{z}$$

$$\hat{y} \times \hat{x} = -\hat{z}$$

$$\hat{y} \times \hat{z} = \hat{x}$$

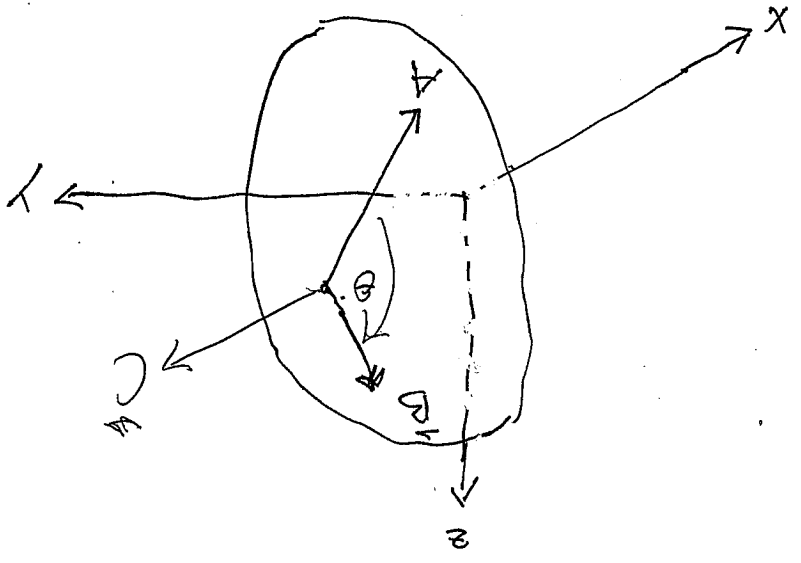
$$\hat{z} \times \hat{y} = -\hat{x}$$

$$\hat{z} \times \hat{x} = \hat{y}$$

$$\hat{x} \times \hat{z} = -\hat{y}$$

$$\vec{B} = b_x \hat{x} + b_y \hat{y} + b_z \hat{z}$$

$$\vec{A} = a_x \hat{x} + a_y \hat{y} + a_z \hat{z}$$



$$|C| = |A| |B| \sin \theta$$

$$(1) \quad b^x a^z - b^z a^x$$

$$(2) \quad b^z a^y - b^y a^z$$

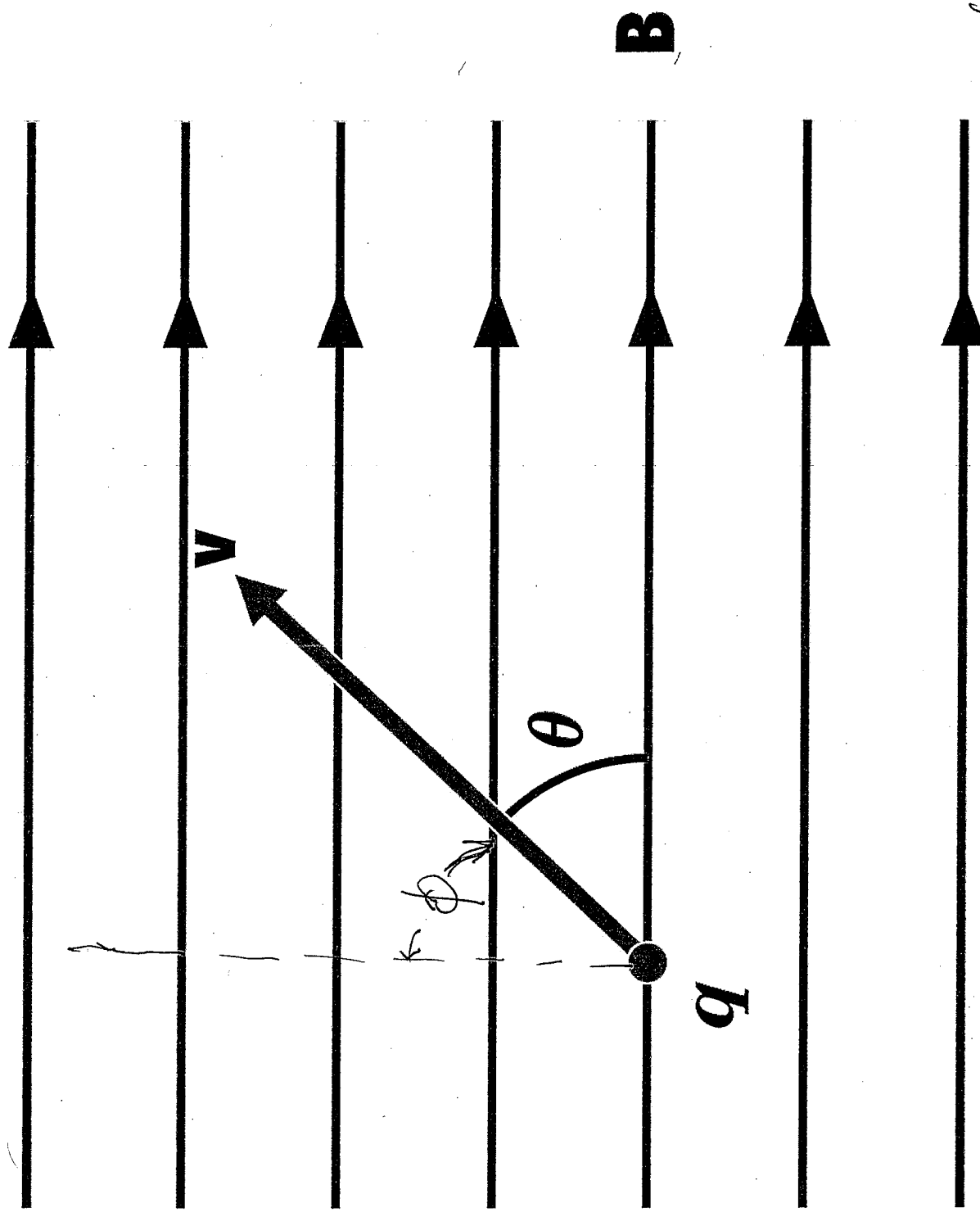
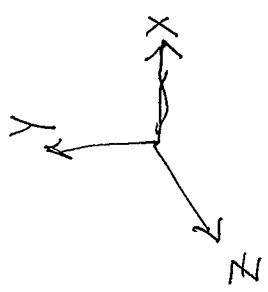
$$(3) \quad b^y a^x - b^x a^y$$

What is y-component of \vec{C} ?

$$\vec{C} = \vec{B} \times \vec{A}$$

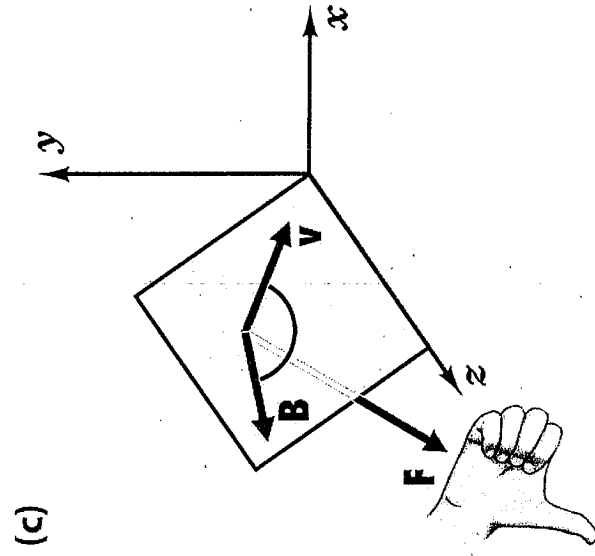
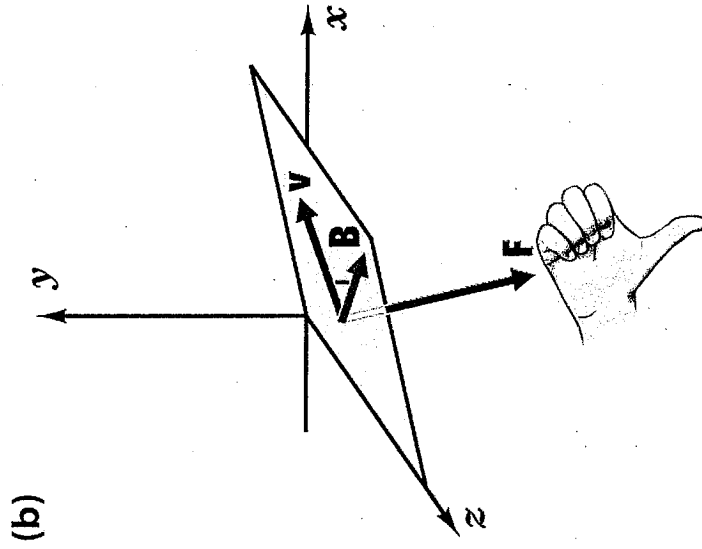
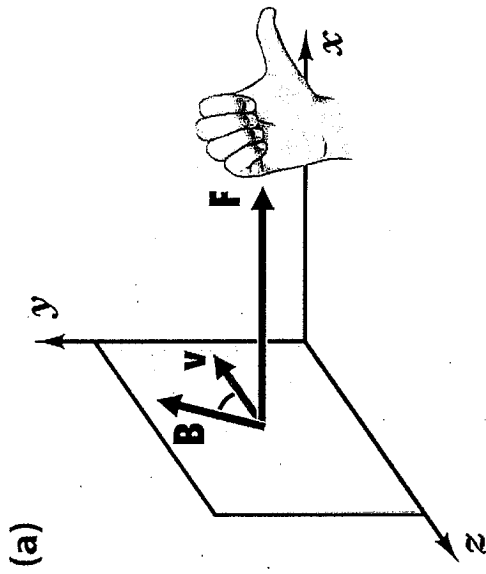
If $\vec{A} = a^x \hat{x} + a^y \hat{y} + a^z \hat{z}$; $\vec{B} = b^x \hat{x} + b^y \hat{y} + b^z \hat{z}$

Where is direction of force
 (a) \hat{z} , (b) $-\hat{z}$ (c) \hat{y} (d) $-\hat{y}$



What is magnitude of force?
 (a) $qvB \sin \theta$, (b) qvB (c) $qvB \cos \theta$

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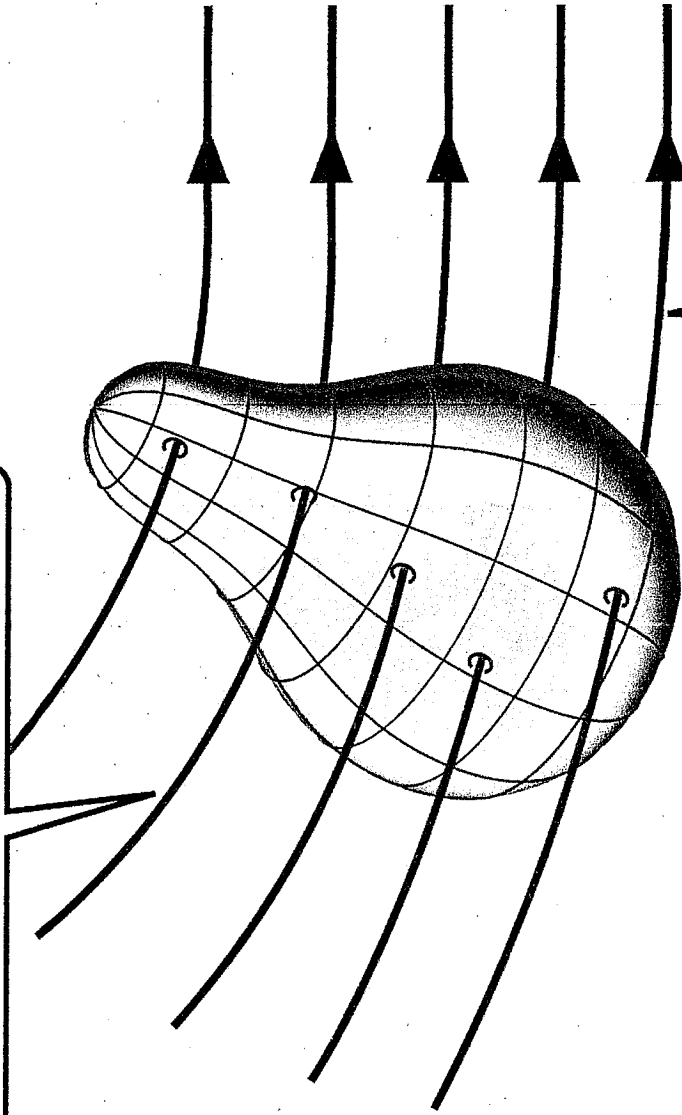


Magnetic Flux

$$\Phi_B = \int_{\text{Surface}} \vec{B} \cdot d\vec{A}$$



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



...equals number leaving the surface.

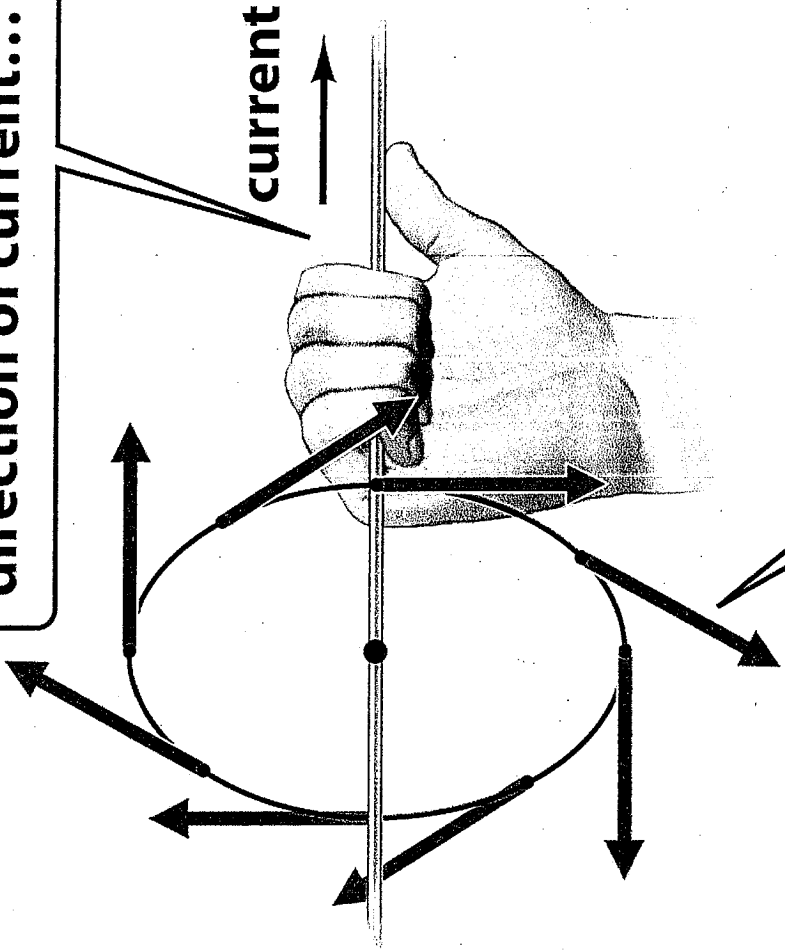
Are there magnetic charges on Earth?

(1) yes

(2) no ✓

Figure 29-18 Physics for Engineers and Scientists 3/e
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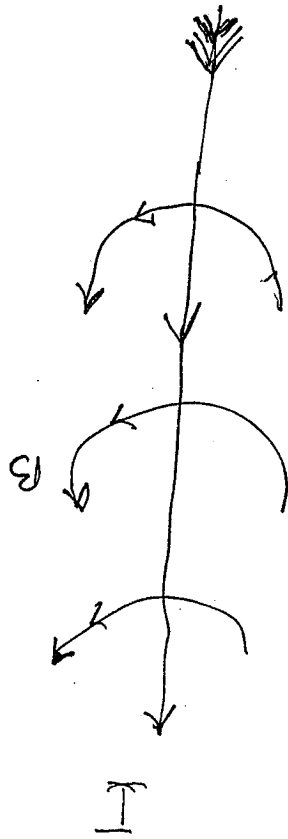
If thumb of your right hand is placed along direction of current...

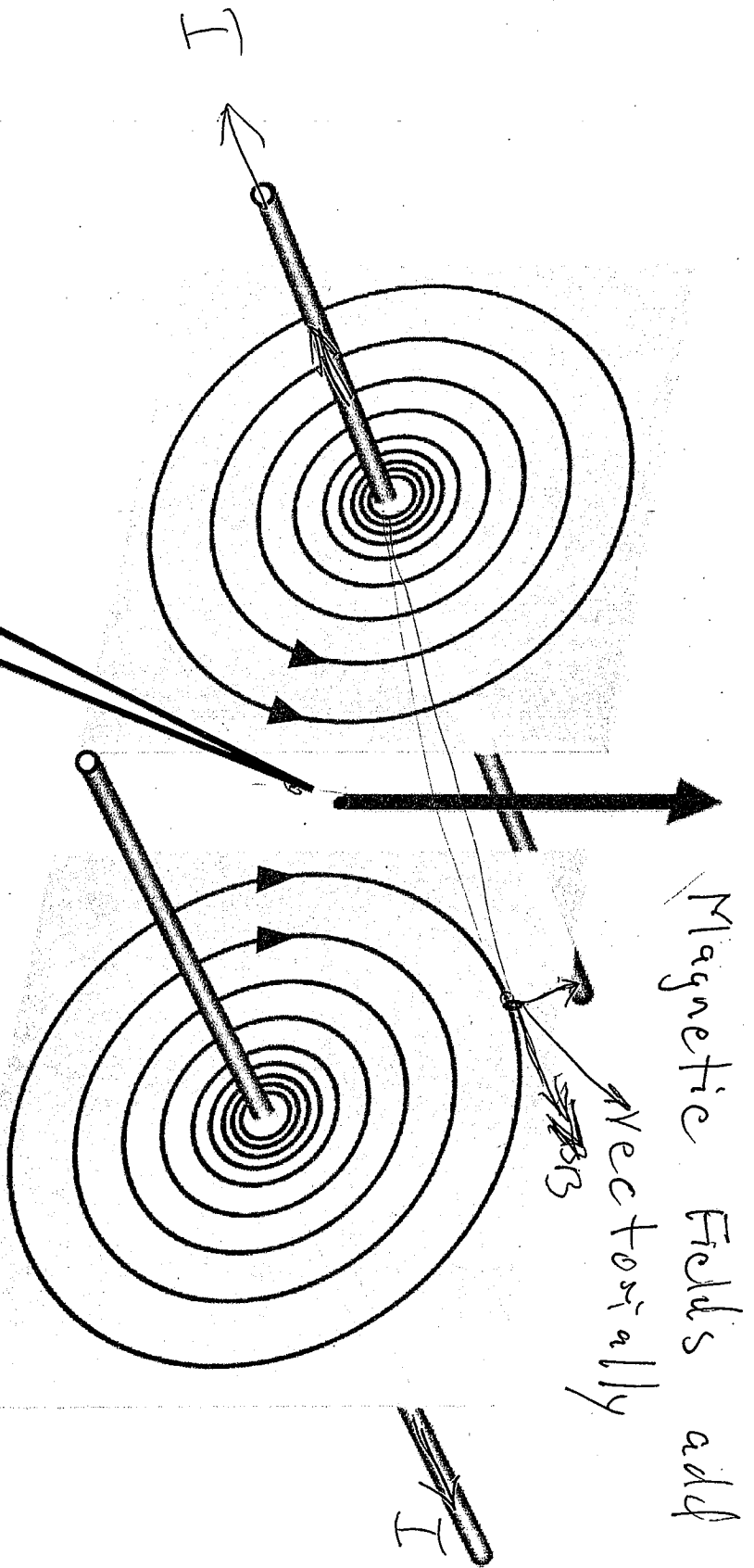


...then fingers will curl around wire in direction of magnetic field.

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Magnetic Field of a straight current





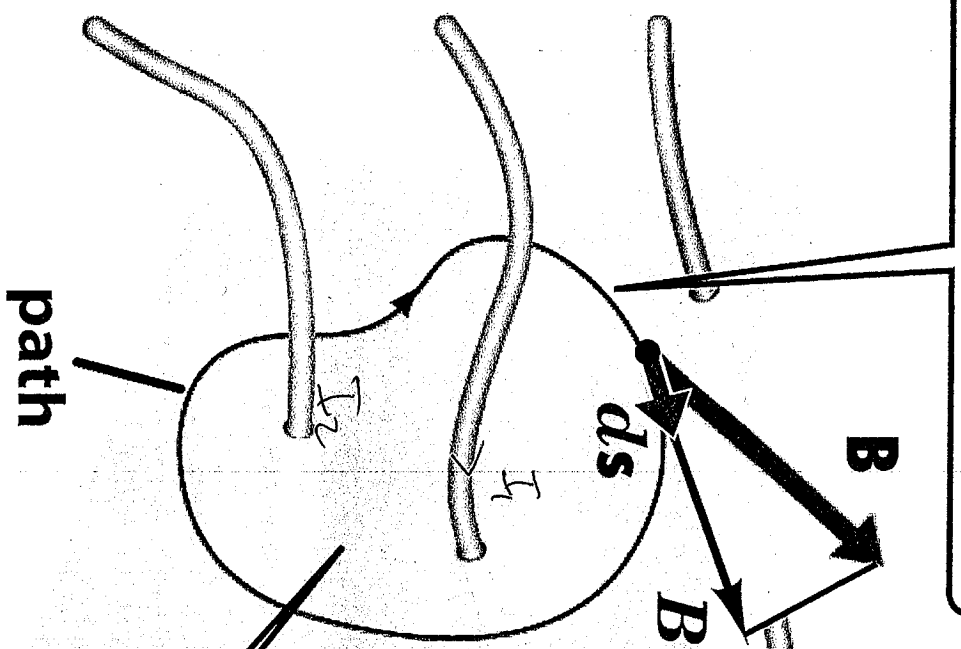
...individual magnetic fields between wires that are parallel.

Figure 29-19b Physics for Engineers and Scientists 3/e
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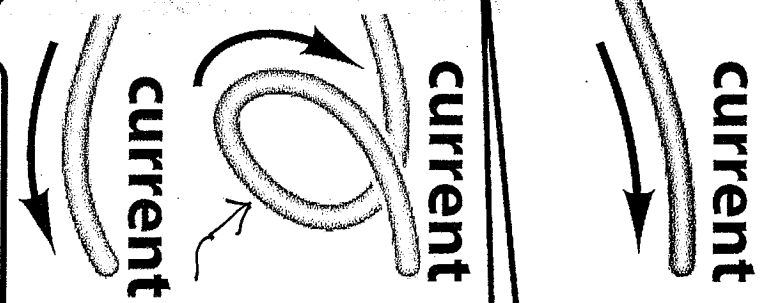
Ampere's Law

For any arbitrary, imagined path...

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{total}$$



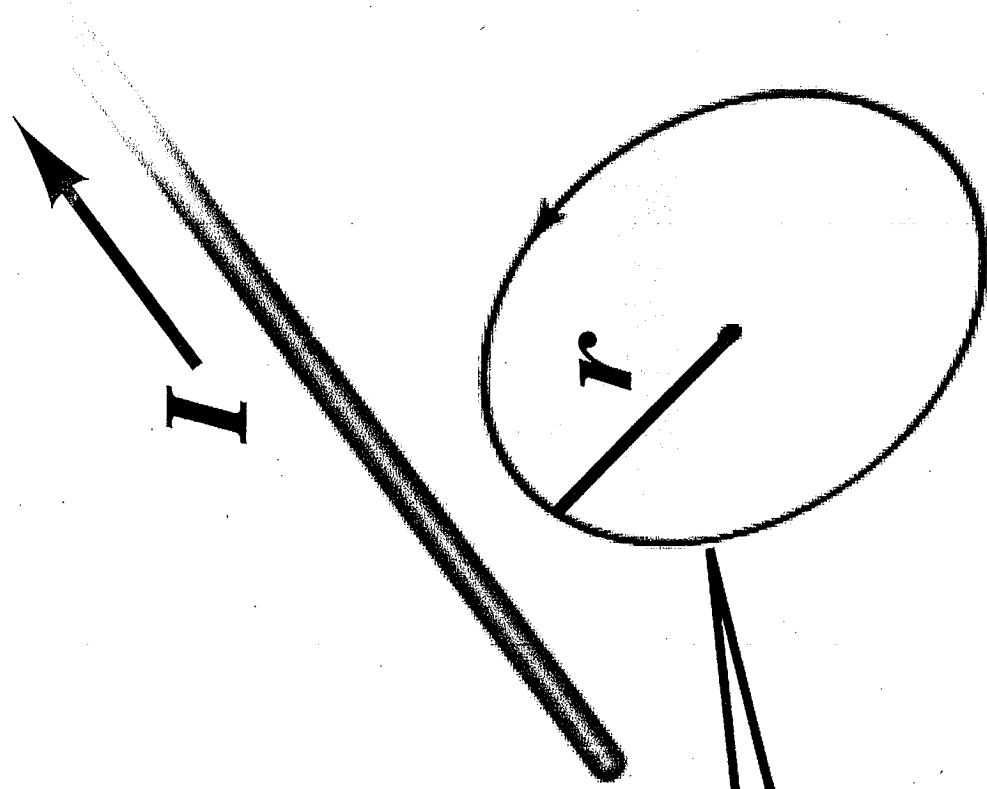
...consider component of magnetic field along path...



...and total current intercepted by area within path.

(a) yes (b) no ✓

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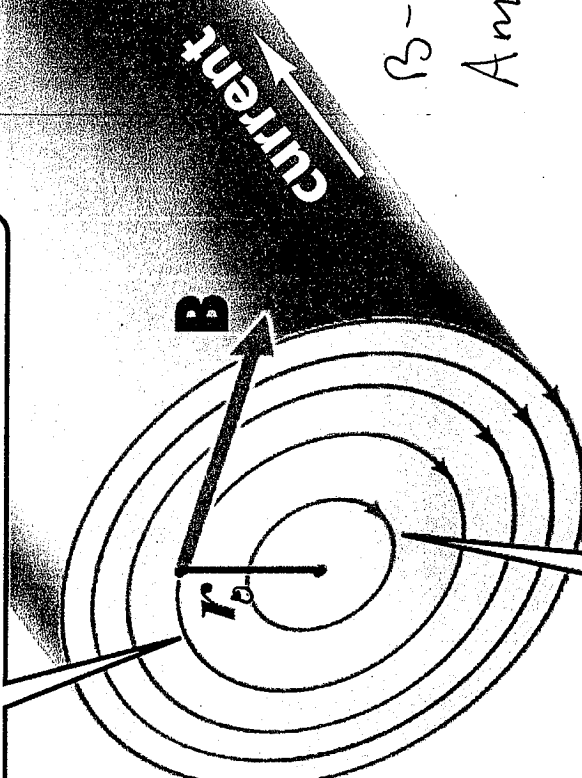
**What is $\oint B_{\parallel} ds$
for this path?**

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

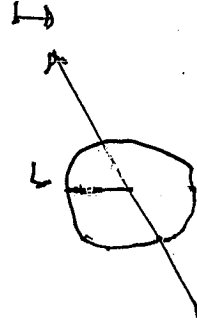
Constant current density within r_0 .

What is magnetic field at radius r ?



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

Calculating B -fields with Ampere's Law.



What is magnetic field at radius r ?