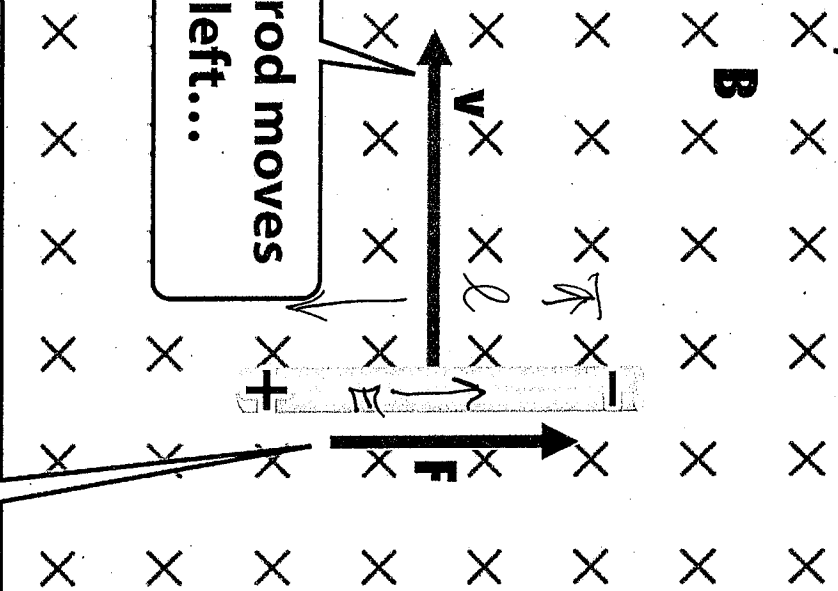


Lect. # 23

Magnetic Induction

Magnetic field B is directed into plane of page.



...magnetic force pushes free electrons upward along rod.

Motional EMF
 Charges in a conductor feel a magnetic force when conductor moves in a magnetic field

$$\vec{F} = -e\vec{v} \times \vec{B}$$

$e > 0$

In equilibrium

$$\vec{F}_{total} = 0 = -e(\vec{v} \times \vec{B} + \vec{E})$$

$$\vec{E} = -\vec{v} \times \vec{B}$$

$\vec{E} \equiv \vec{E}_{ind}$

When rod moving to left is in contact with this conducting path...

Motional EMF produces currents that resist change in enclosed magnetic flux

current in resistor $\times B \times$
 Motional EMF = IR
 EMF = vBL
 Thus $I = vBL/R$

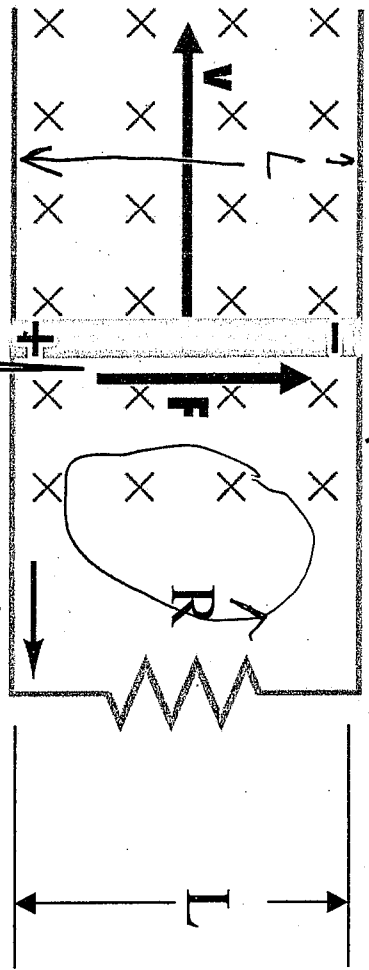
Faraday's View
 Change of B-flux
 In loop in time t

$\Delta\Phi_m = vBLt$
 EMF = $d\Delta\Phi_m / dt$
 = vBL

same EMF as motional EMF

...electrons flow clockwise around path...

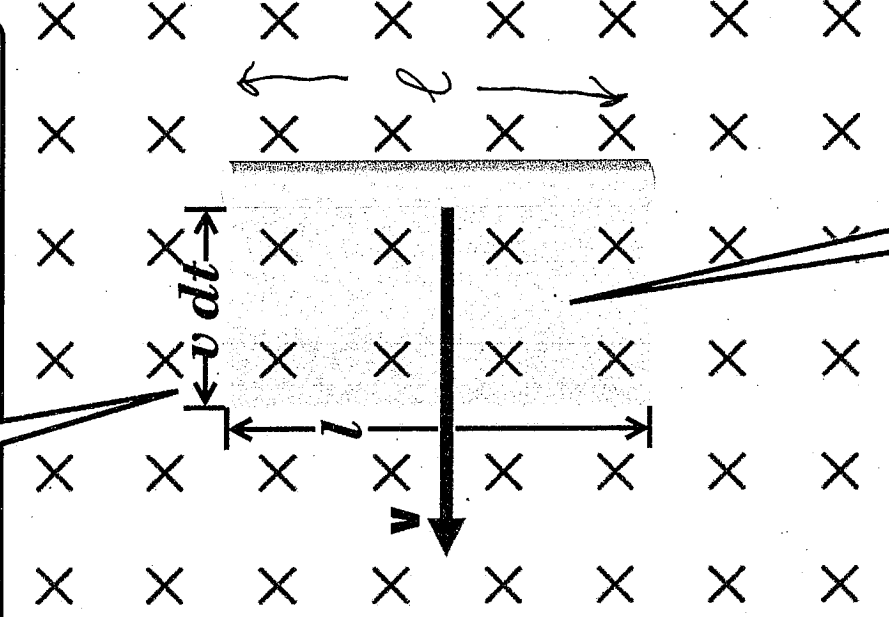
...and conventional current flows counterclockwise.



Note flow of current tries to resist change (Lenz's Law)

Figure 31-2 Physics for Engineers and Scientists 3/e © 2007 W. W. Norton & Company, Inc.

In a time dt , a rod moving perpendicular to its length...



$$\Delta A = l v dt$$

$$\frac{\Delta A}{\Delta t} = l v = \frac{dA}{dt}$$

$$\vec{E}_{in} = -\vec{v} \times \vec{B}$$

$$\mathcal{E}_{MF} = \vec{E}_{in} l = -l v B \frac{d}{dt}$$

$$\mathcal{E}_{MF} = -B \frac{dA}{dt}$$

Faraday's Law
even more generally

...sweeps through this area $l \times v dt$.

$$\mathcal{E}_{MF} = - \frac{d}{dt} (BA)$$

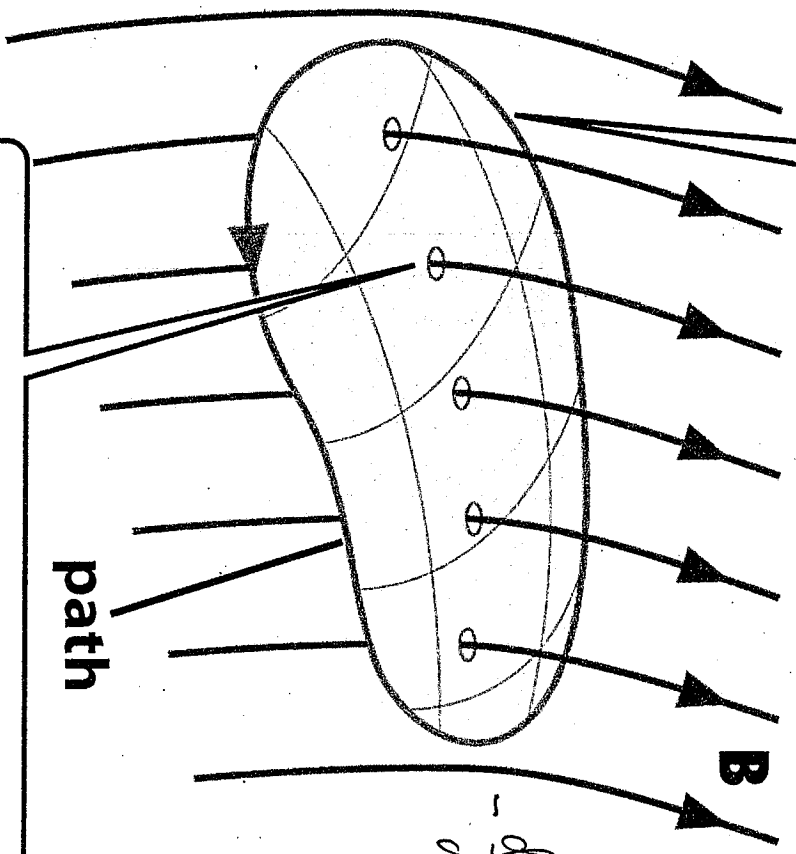
$$= - \frac{d}{dt} \Phi_M$$

Figure 31-7 Physics for Engineers and Scientists 3/e
© 2007 W. W. Norton & Company, Inc.

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

Faraday's Law gives the induced emf along a path...

$$\Phi_M = \int \mathbf{B} \cdot d\mathbf{A}$$



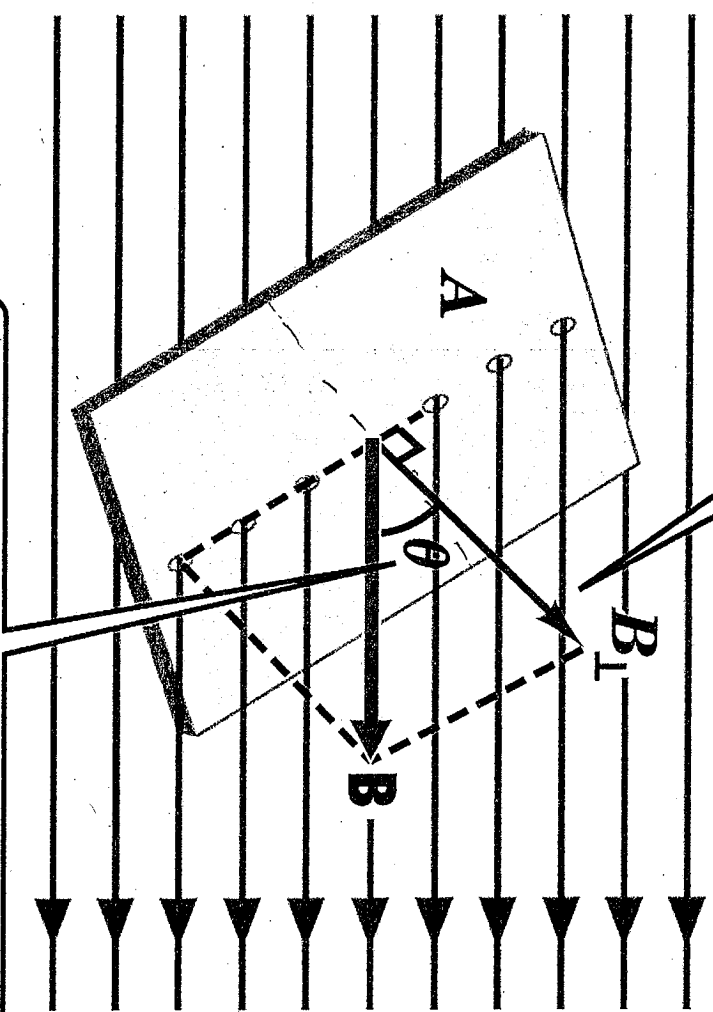
$$-\frac{d\Phi_M}{dt} = \mathcal{E}_{MF}$$

...in terms of the magnetic flux intercepted by any surface within that path.

Figure 31-9 Physics for Engineers and Scientists 3/e
© 2007 W. W. Norton & Company, Inc.

One can change magnetic flux through a surface by rotating surface

Component of magnetic field perpendicular to surface is $B_{\perp} = B \cos \theta$.



θ is angle between magnetic field and perpendicular to surface.

$$\Phi_M = B_{\perp} A = B A \cos \theta$$

$$\theta = \theta(t)$$

$$\frac{d\Phi_M}{dt} = -B A \sin \theta \frac{d\theta}{dt}$$

if $B(t)$

$$\Phi_M = B(t) A \cos \theta$$

$$\frac{d\Phi_M}{dt} = \frac{dB}{dt} A \cos \theta$$

$$= -\mathcal{E}_{MF}$$

Figure 31-6 Physics for Engineers and Scientists 3/e © 2007 W.W. Norton & Company, Inc.

Motional EMF and Stationary Loop EMF

combine together in one compact Law

Faraday's Law

$$\oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_m}{dt}$$

which way is current flow?

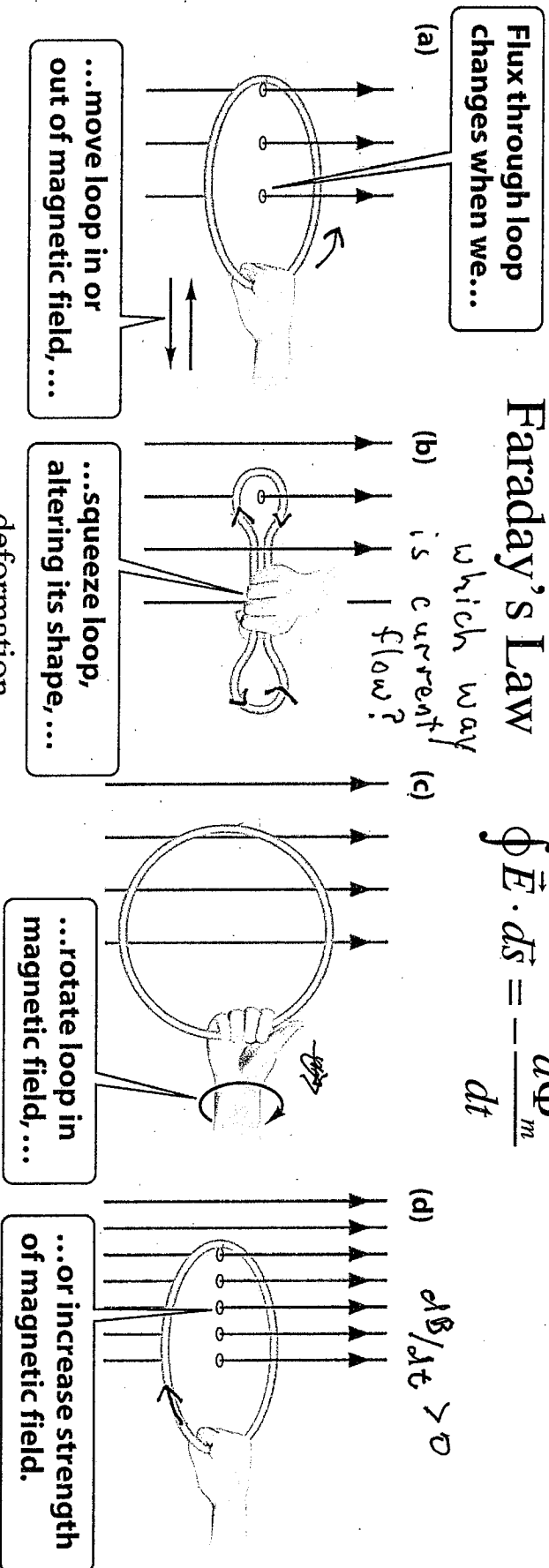


Figure 31-10 Physics for Engineers and Scientists 3/e
© 2007 W.W. Norton & Company, Inc.

Translation through non-uniform field
This Law is true whether the loop moves through a non-uniform magnetic field, deforms, rotates, and B-field changes in time.

In (a), Does the current flow is the clockwise or anti-clockwise direction?
(1) clockwise (2) counter-clockwise

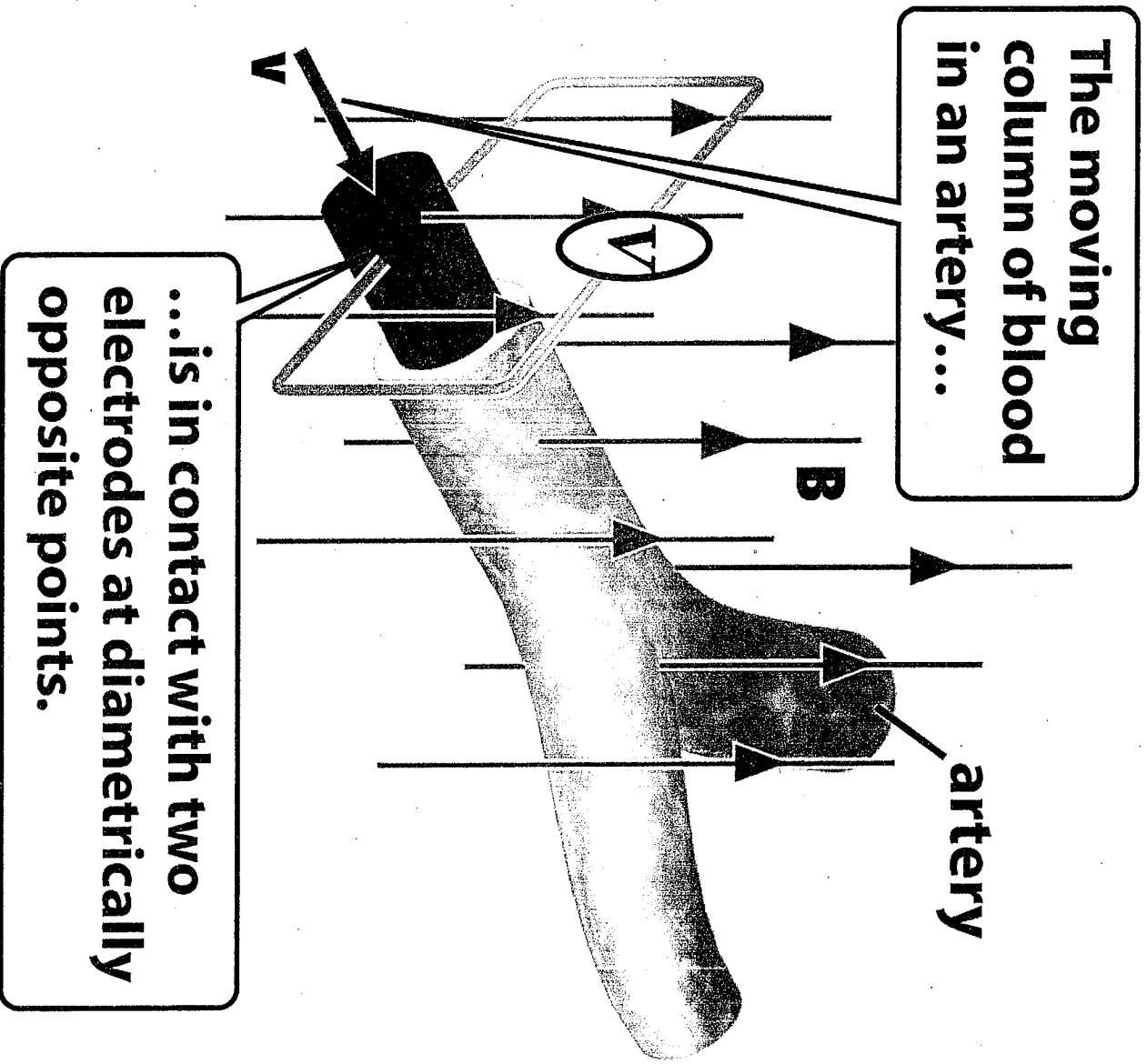


Figure 31-4 Physics for Engineers and Scientists 3/e
 © 2007 W. W. Norton & Company, Inc.

Dynamo is used to generate electrical currents from mechanical input power

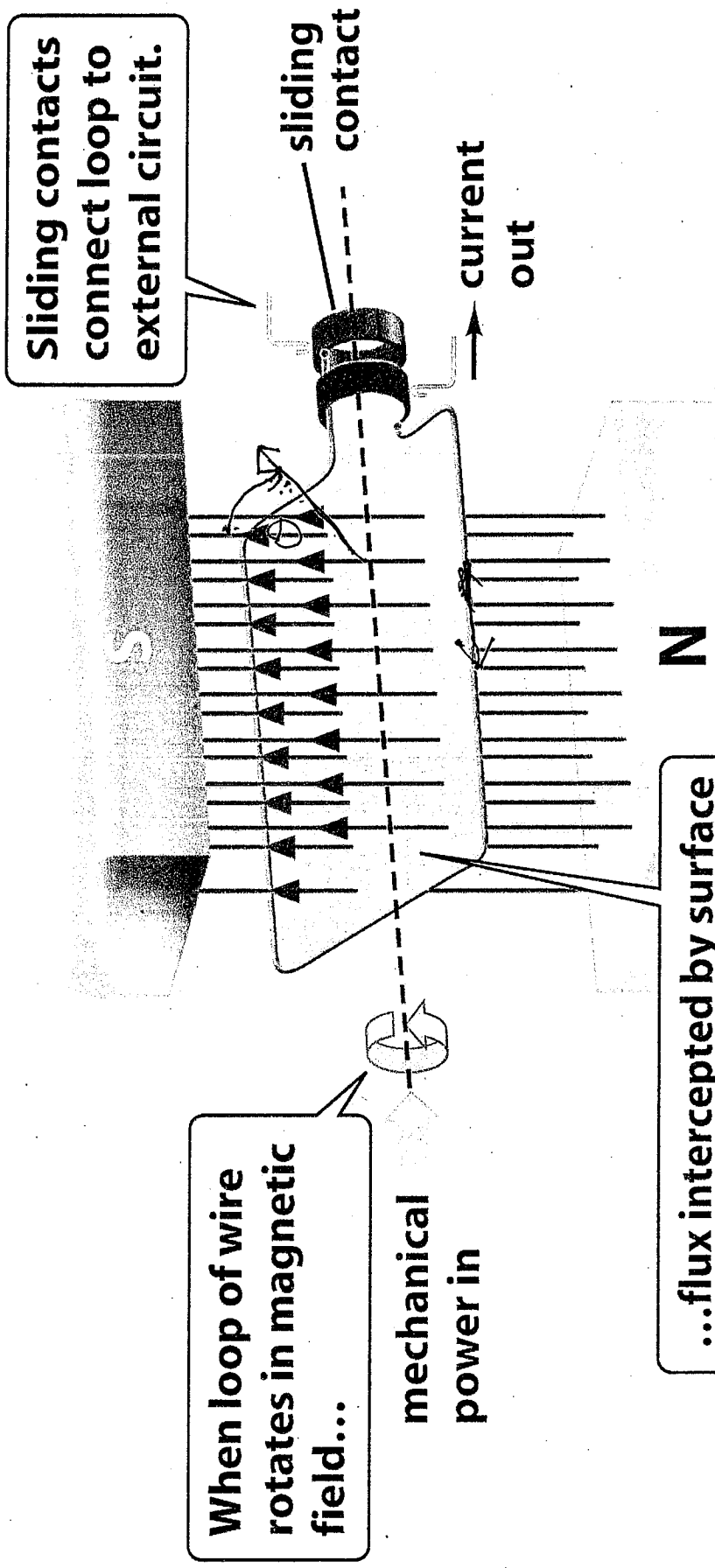


Figure 31-11 Physics for Engineers and Scientists 3/e © 2007 W. W. Norton & Company, Inc.

$$\Phi_M = A B_0 \cos \theta, \quad \theta = \omega t + \theta_0$$

Induced electromagnetic torque is opposite applied torque (Lenz's law).

$$\mathcal{E} = \omega A B_0 \sin(\theta_0 - \omega t) \quad \mathcal{E} = \dot{\Phi}_M = AB \frac{d}{dt} \cos(\theta_0 - \omega t) = \omega A B_0 \sin(\theta)$$

Generator's alternating emf oscillates sinusoidally between positive and negative values.

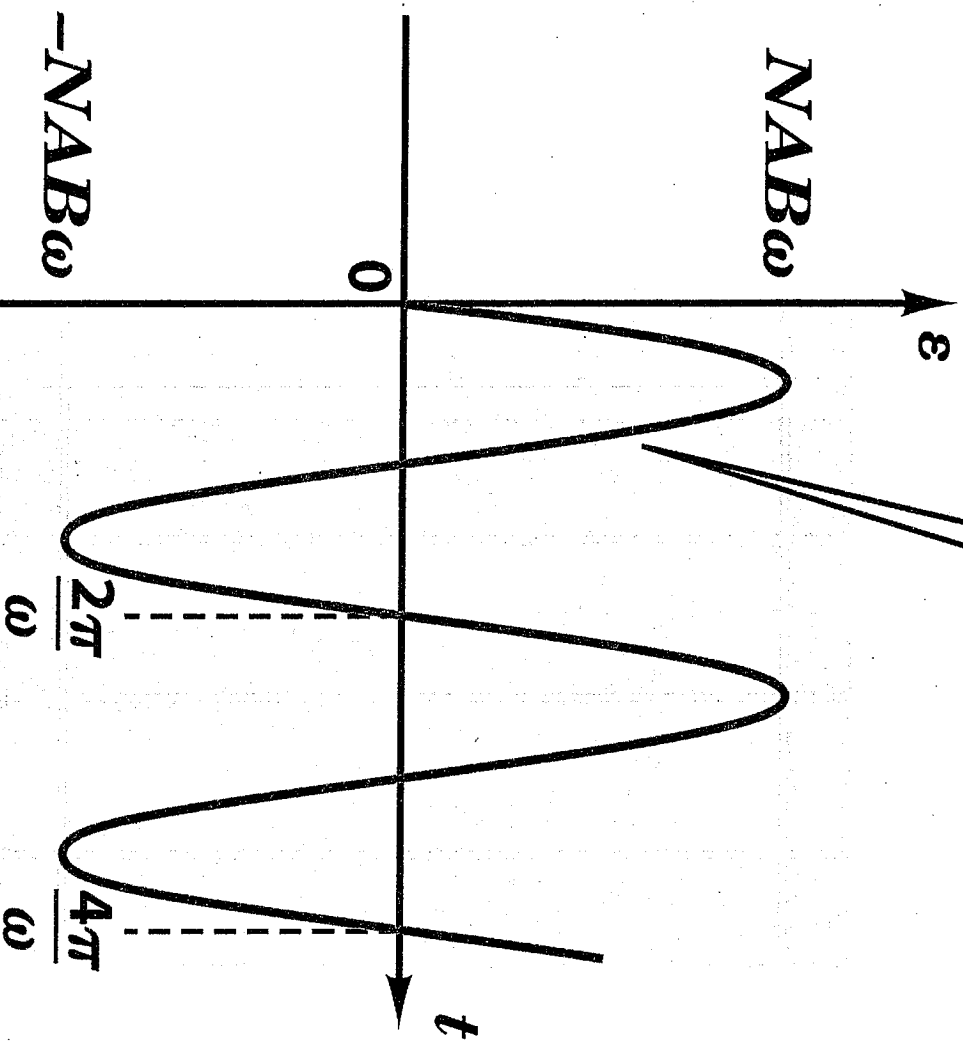
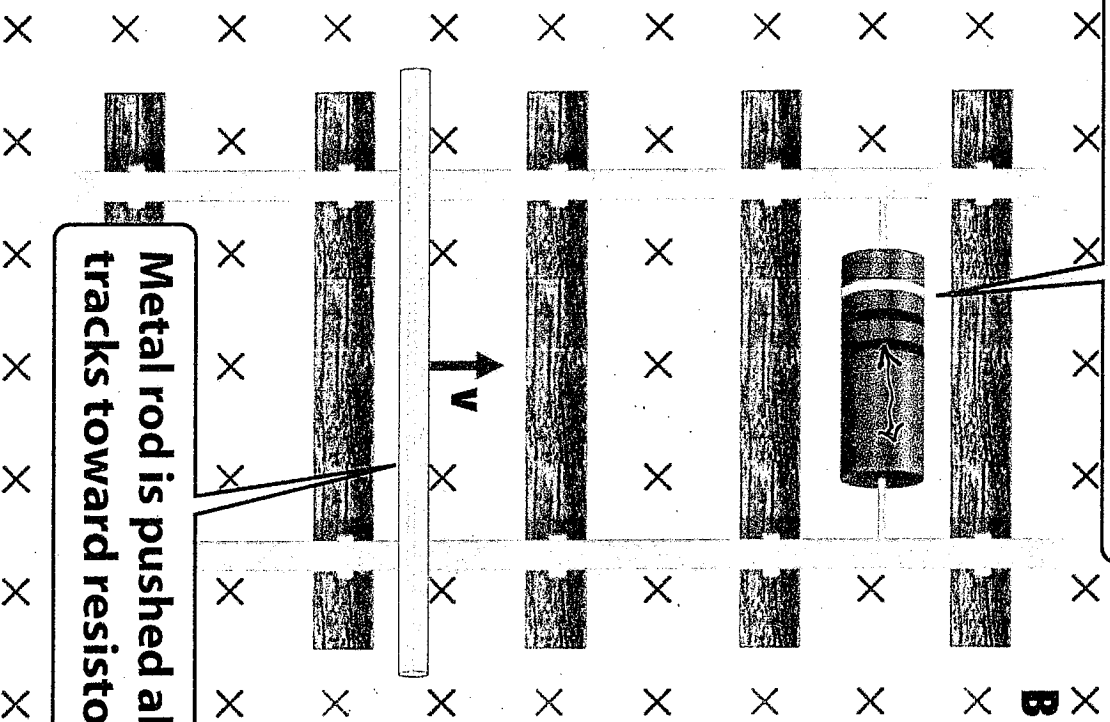


Figure 31-17 Physics for Engineers and Scientists 3/e
© 2007 W. W. Norton & Company, Inc.

Does current flow in resistor? If so, which way?



- a. Left to right ✓
- b. Right to left ✓
- c. Does not flow ✓

Figure 31-20 Physics for Engineers and Scientists 3/e
© 2007 W.W. Norton & Company, Inc.