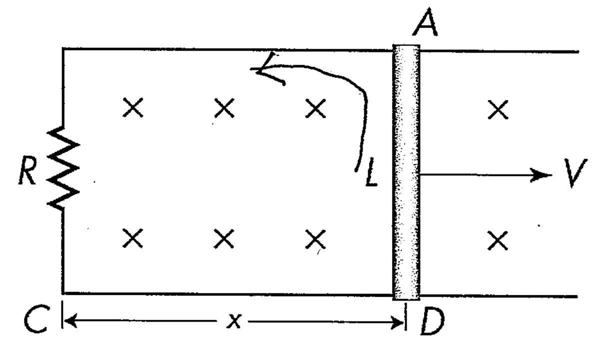
Lect 24

Magnetic Induction

Inductive Electric field

# PhysiQuiz 31-1



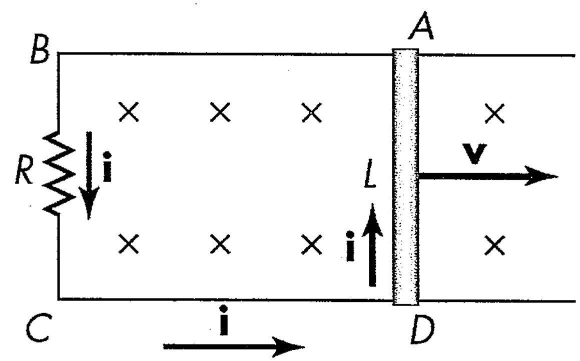

A metal rod *AD* is sliding to the right along the parallel metal railings shown. The resistance connecting the railings is *R*. Also, there is a magnetic field **B** directed into the paper. $L = AD$. Determine the direction of the induced current:

| | A | B | C |
|---|---|---|---|
| Direction of $\mathbf{i}_{ind}$ | Clockwise | 0 | Counterclockwise |

**Hint:** Lenz's Law states that $B_{ind}$ tends to maintain the original flux.

**Extra**: Based on $\varepsilon_{ind} = -\frac{d\phi}{dt} = -\frac{d}{dt}(BLx)$, $i_{ind} = \frac{\varepsilon_{ind}}{R}$.
Show that $i_{ind} = BvL/R$.

# PhysiQuiz 31-2




A metal rod *AD* is sliding to the right along the parallel railings shown. The resistance of the loop is *R*. The direction of the magnetic field **B** is into the paper. The direction of the induced current **i** is shown. What is the direction of $\mathbf{F}_{ext}$, the external force that keeps *AD* moving with constant **v** to the right?

| | A | B | C | D |
|---|---|---|---|---|
| Direction of $\mathbf{F}_{ext}$ | $\rightarrow$ | $\uparrow$ | $\leftarrow$ | $\downarrow$ |

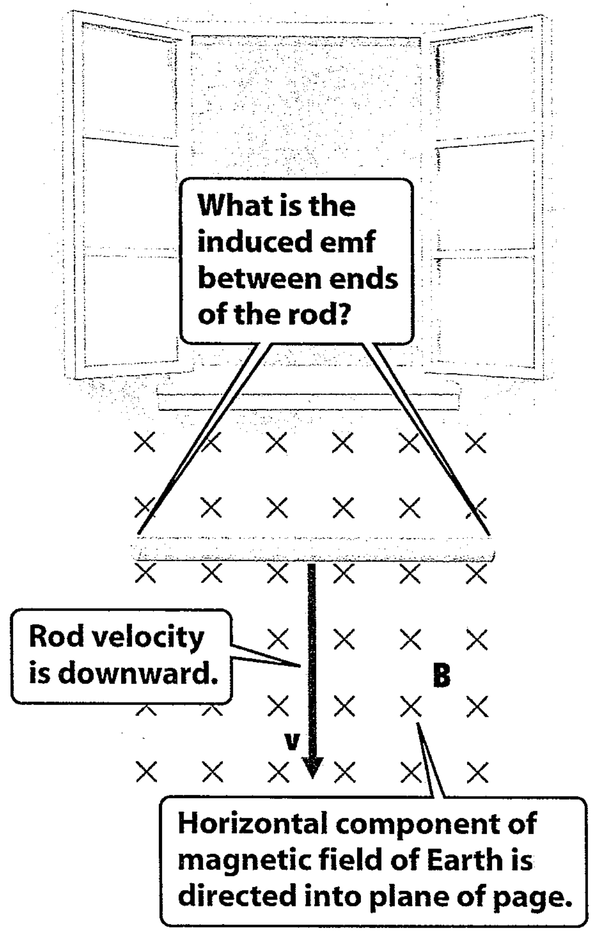
**Hint:** Let the magnetic force on *AD* be $\mathbf{F}_B = i\mathbf{L} \times \mathbf{B}$. To keep **v** constant, we must have $\mathbf{F}_{ext} + \mathbf{F}_B = 0$.

**Extra:** Show that the mechanical power applied to the rod is given by $P_{mech} = \mathbf{F}_{ext} \cdot \mathbf{v} = i^2R$. (Recall that $\varepsilon_{ind} = BvL$.)

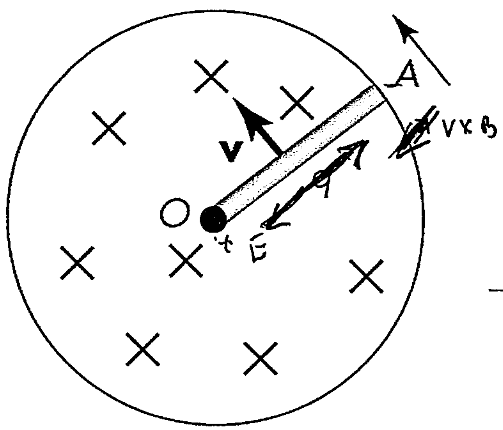
# Checkup 31.1

What is the direction of the induced electric field in the reference frame of the rod shown in the figure?

a. Up
b. Into page
c. Out of page
d. To left
e. To right



# PhysiQuiz 31-4




Consider a metal bar *OA*, shown rotating in a plane perpendicular to a magnetic field **B**, directed into the page. Which end of the bar has a higher potential?

| | A | B | C |
|---|---|---|---|
| $V_O$ versus $V_A$ | $V_O < V_A$ | $V_O = V_A$ | $V_O > V_A$ |

**Hint:** The magnetic force due to **B** asserted on $q$, a positive charge on the rod, is given by $\mathbf{F} = q\mathbf{v} \times \mathbf{B}$. This force "pushes" $q$ from a low-potential point to a higher-potential point.

**Extra:** Show that $|V_O - V_A|$ the magnitude of the potential difference is $\omega BR^2/2$, where $R = OA$ and $\omega$ is the angular frequency of rotation.

***Hint:*** When $q$ is pushed by a displacement $\Delta r$, the corresponding potential difference is given by $\Delta V = F\Delta r/q = qvB\Delta r/q = \omega Br\Delta r$.

Magnetic field is B, rod's length is L, angular velocity is ω, and resistance is R. What is current through resistor?

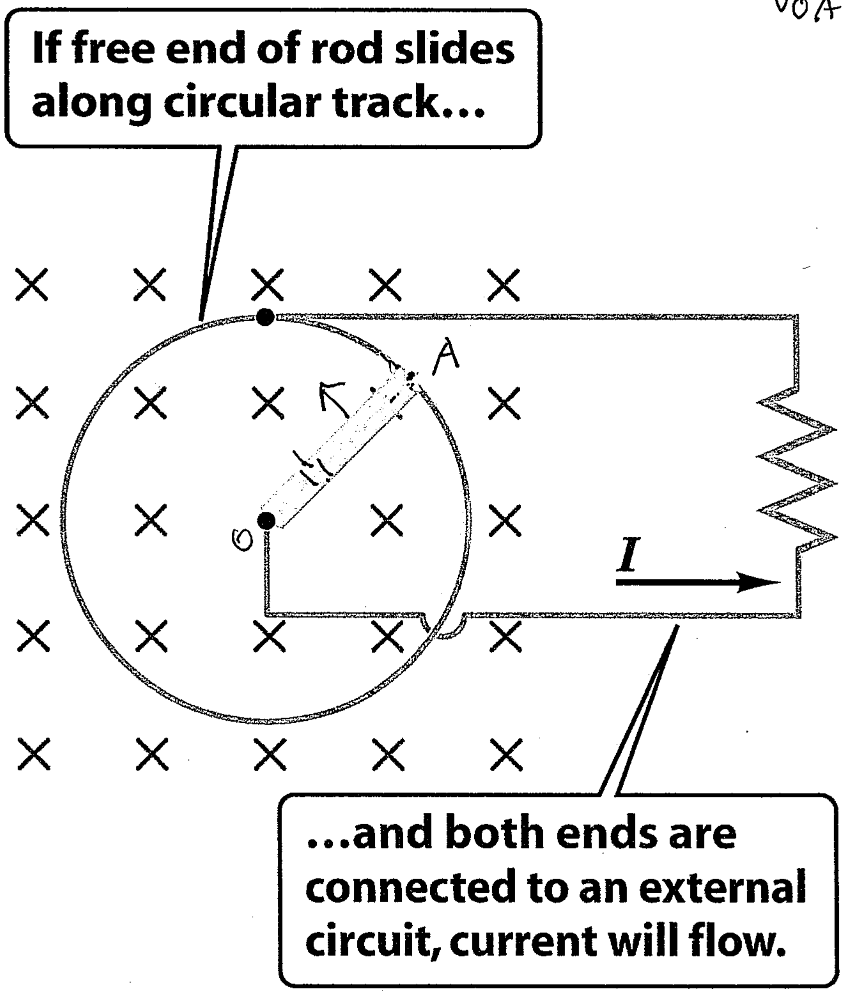



Figure 31-18b Physics for Engineers and Scientists 3/e



$T = \frac{2\pi}{\omega}$

$\mathcal{E} = \frac{(\pi R^2)B}{T}$

$\mathcal{E} = \frac{\omega R^2 B}{2}$ ✓

$\mathcal{E} = \dot{\Phi}_M = \frac{B(R^2\pi)}{T}$

$V_{OA} = \frac{1}{2}\omega \frac{R^2}{2} B$

$\omega r = v$

$vB = E = \omega r B$

$V_{OA} = \int_0^R E\,dr = \omega B \int_0^R r\,dr = \omega B \frac{r^2}{2}\Big|_0^R = \omega B \frac{R^2}{2}$

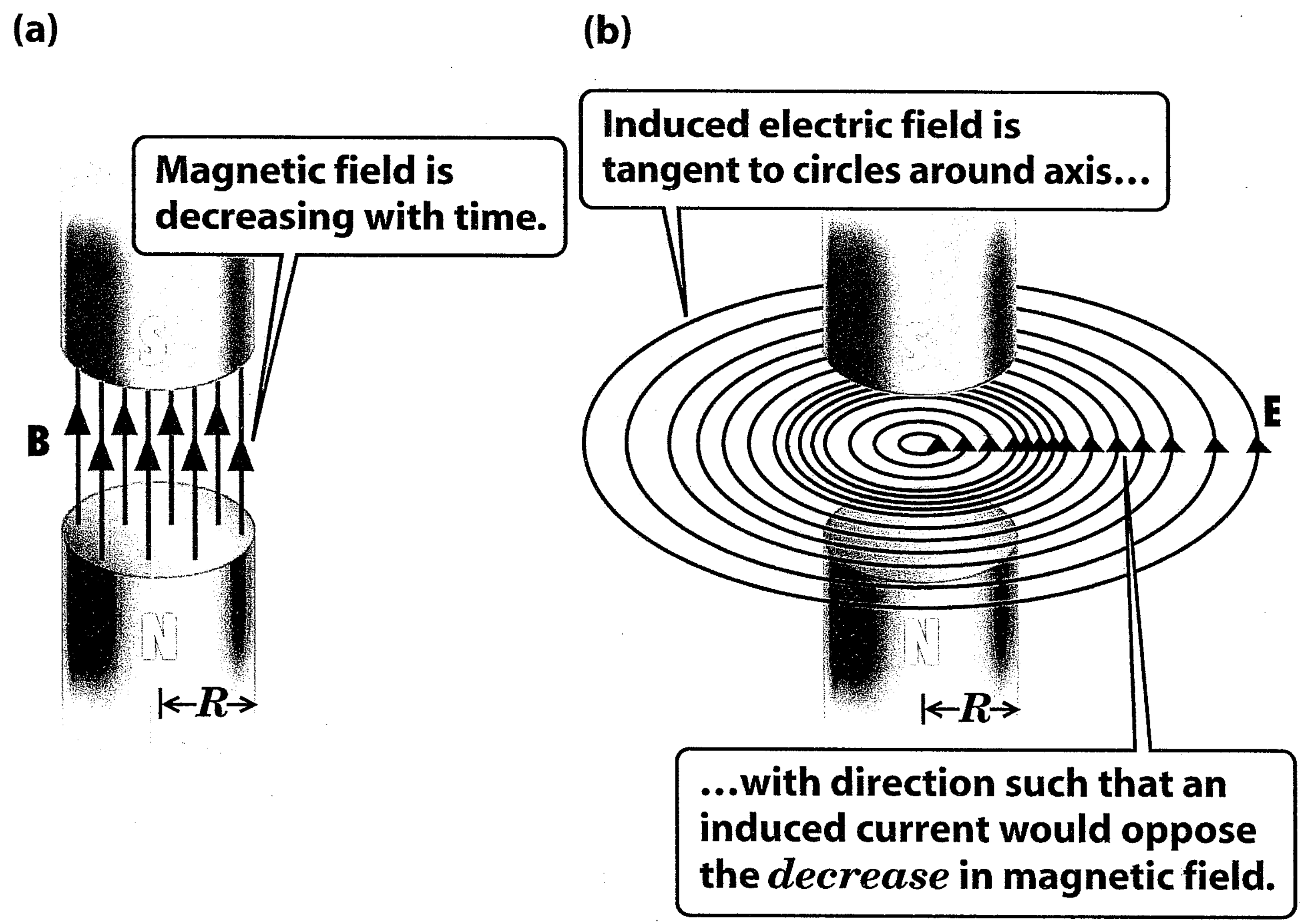
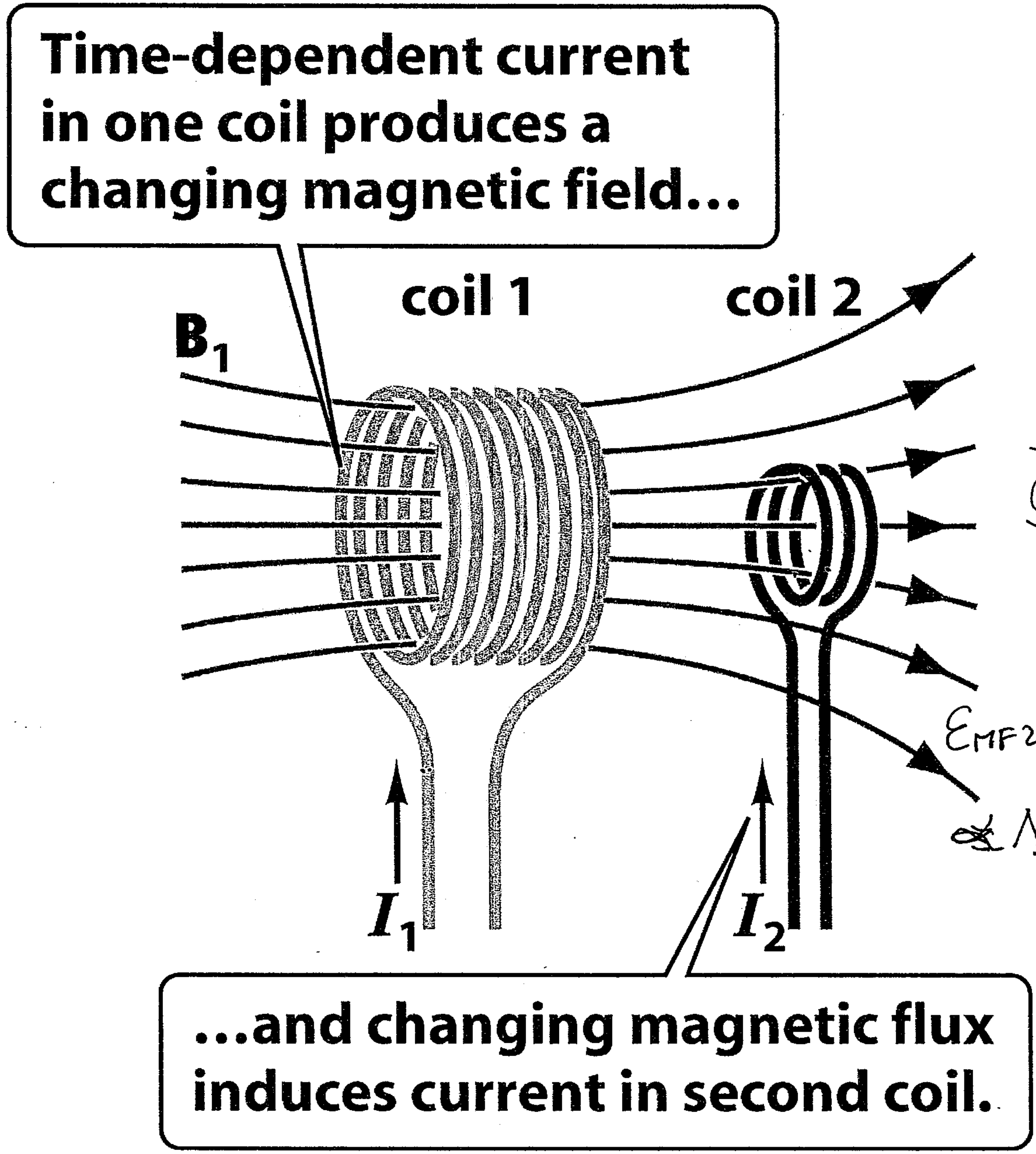



Figure 31-19 Physics for Engineers and Scientists 3/e

# Mutual induction




$$\Phi_{M2} \propto N_2 A_2 B_2$$
$$\propto N_2 A_2 I_1 N_1$$

$$\mathcal{E}_{MF2} = \dot{\Phi}_{M2}$$
$$\propto N_2 N_1 A_2 \frac{dI_1}{dt}$$