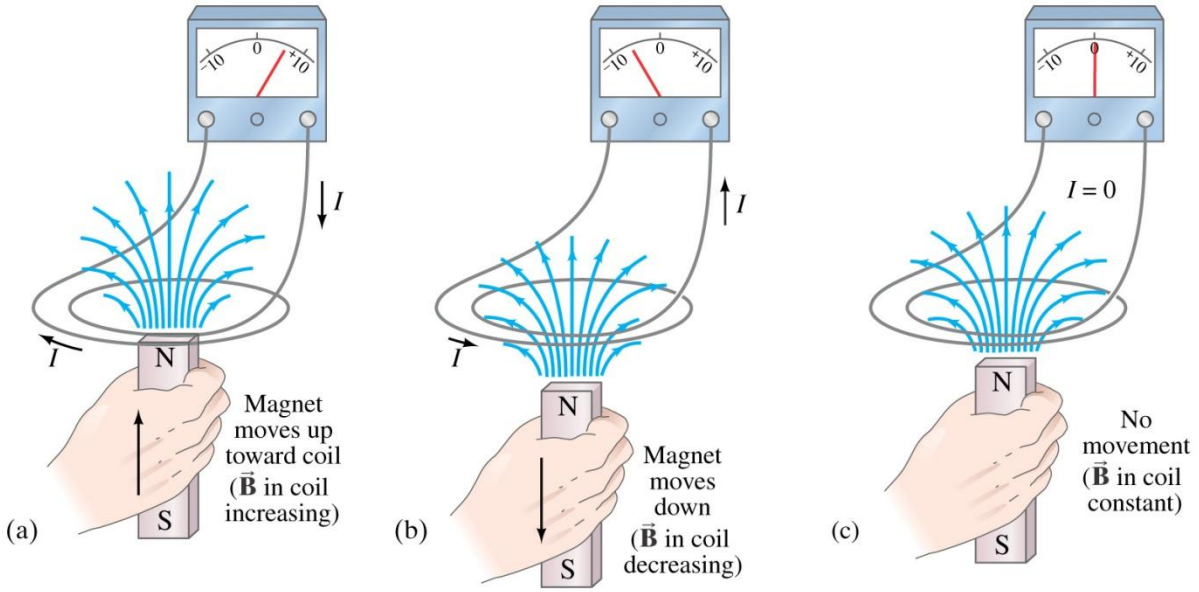
Chapter 21
Electromagnetic Induction

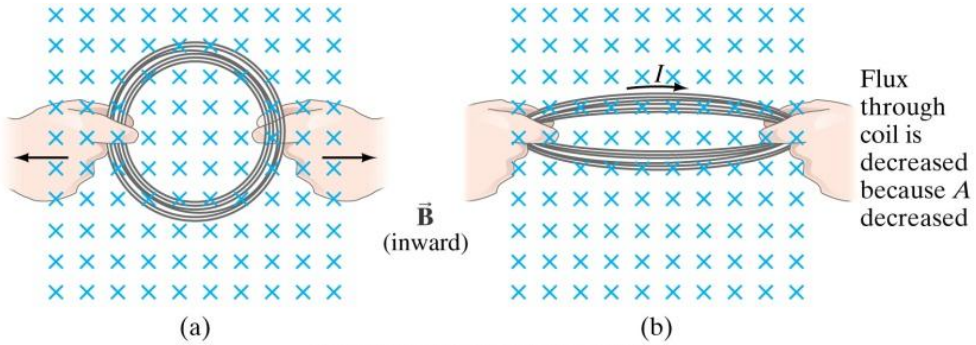
Electromagnetic Induction

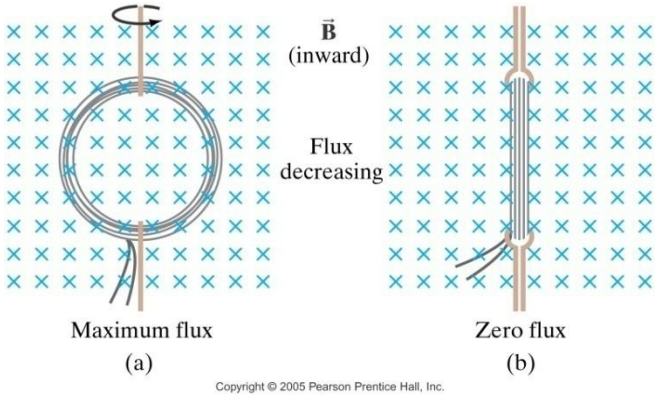
- When the magnetic field passing through a conducting loop is changing with respect to time an emf ($\mathcal{E}$= potential difference), is induced in the loop causing induced current to flow through the loop.



2 ways to change B field through loop

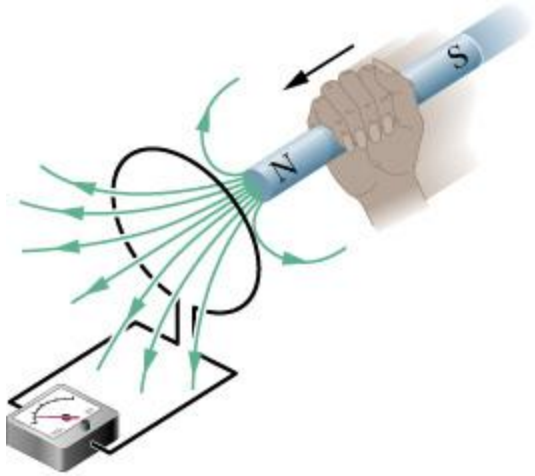
1) change the size of the area that the B field is penetrating

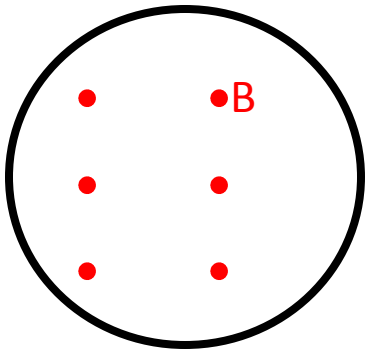




2 ways to change B field through loop

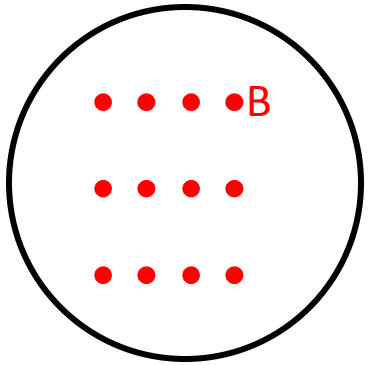
2) change the number of field lines or the intensity of the B field





t = 0

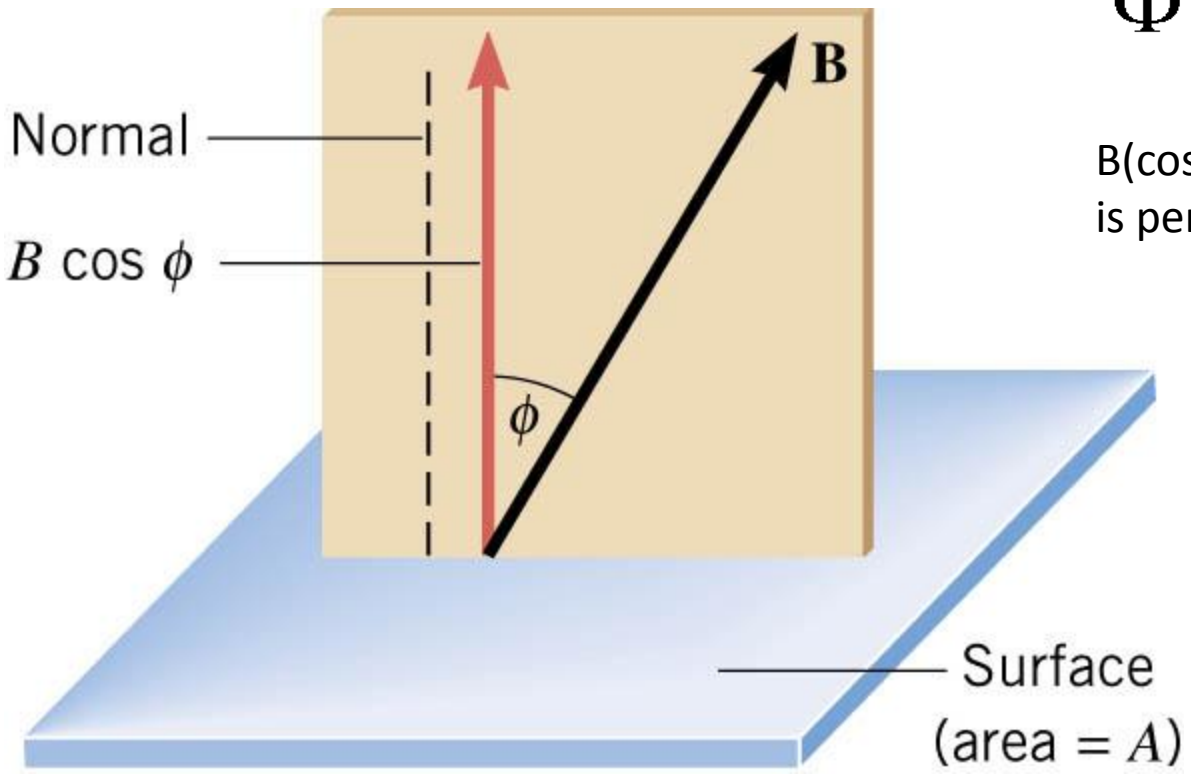
B field is increasing out of the page



t = 2 s

Magnetic Flux Φ_B

- product of B field and area
- measure of how much field is passing through the loop perpendicular to surface area

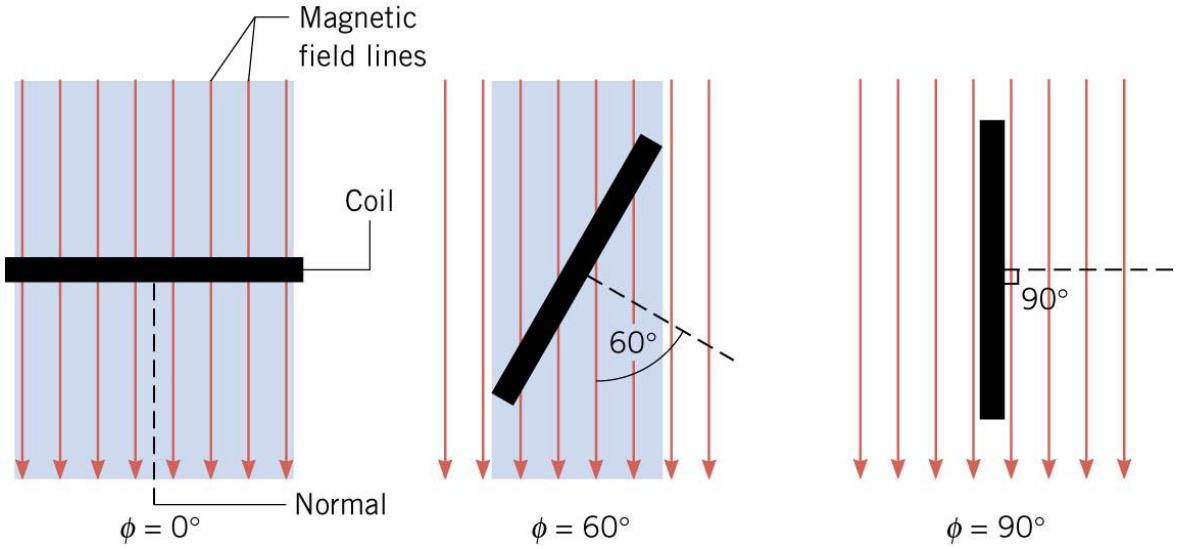


$$\Phi_B = (B\cos\phi) \bullet A$$

B(cosϕ) is component of field that is perpendicular to area A

Units are Webers (Wb)

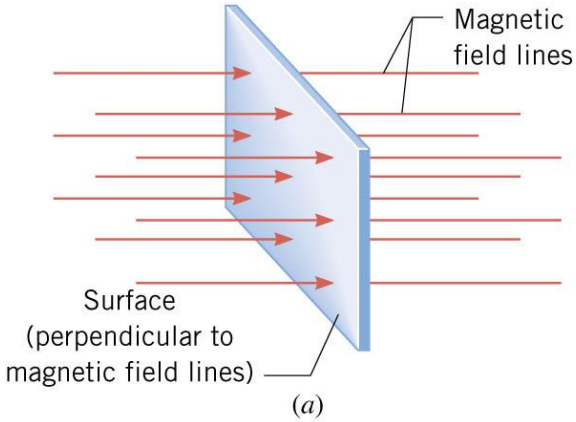
Magnetic Flux Φ_B

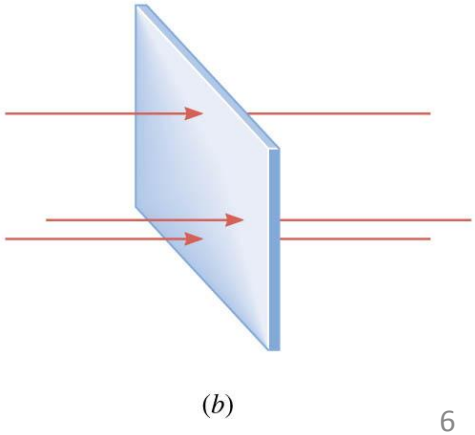


max flux

reduced flux

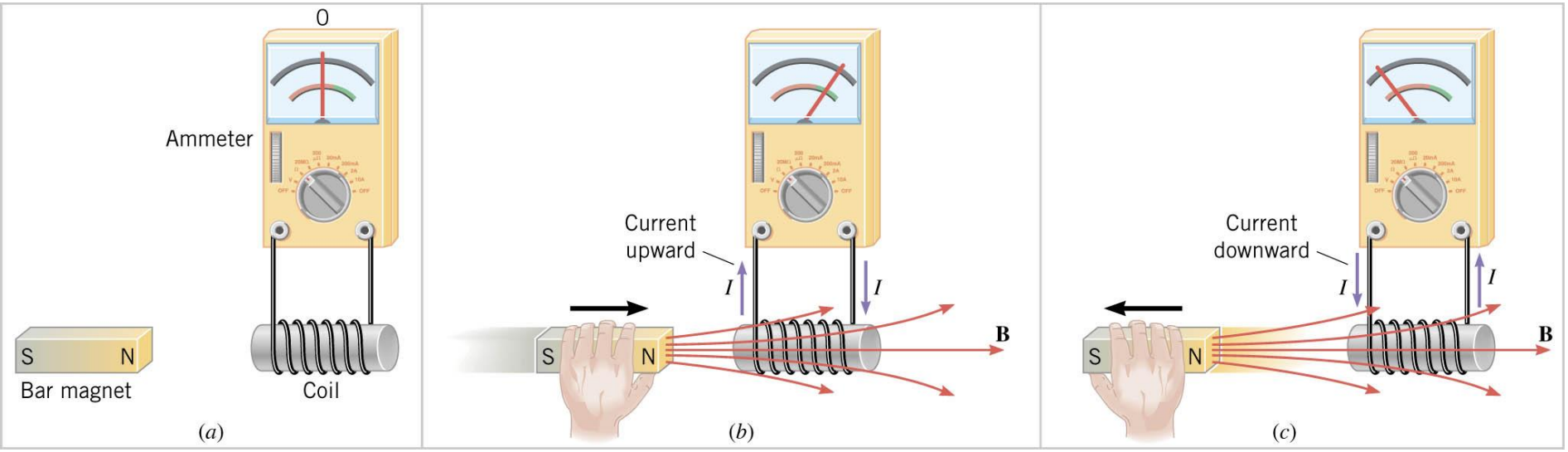
zero flux





Flux is proportional to how many field lines pass in a perpendicular direction through an area

Flux Change Induces emf $\mathcal{E}$



constant flux

$\mathcal{E} = 0$

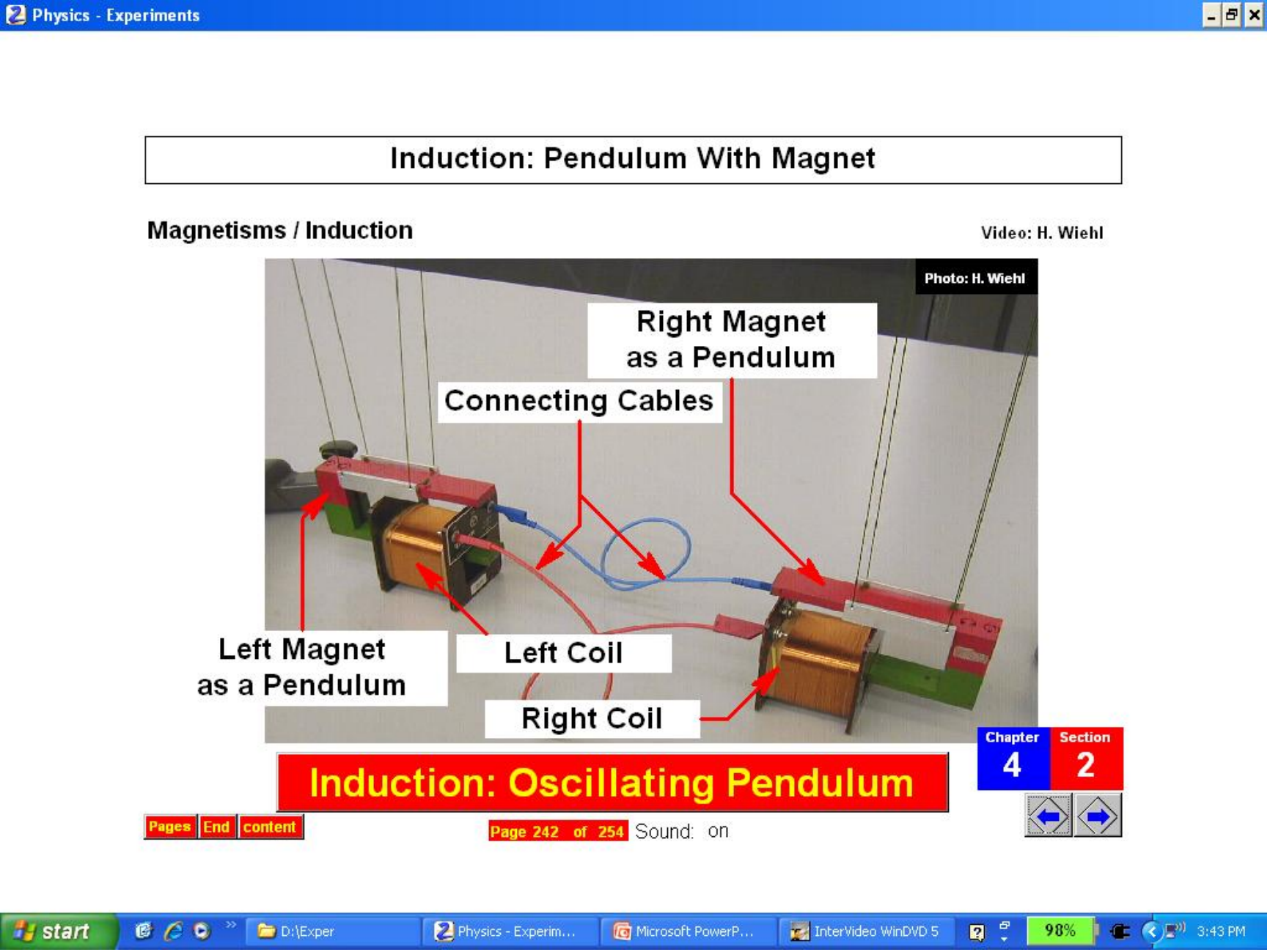
flux increasing

induced current flows one way

flux decreasing

induced current flows opposite direction

solenoid, magnet demo


Physics - Experiments
Induction: Pendulum With Magnet
Magnetisms / Induction
Video: H. Wiehl
Photo: H. Wiehl
Right Magnet as a Pendulum
Connecting Cables
Left Magnet as a Pendulum
Left Coil
Right Coil
Chapter 4
Section 2
Induction: Oscillating Pendulum
Pages
End
content
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Sound: on
start
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Physics - Experim...
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InterVideo WinDVD 5
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demo

Faraday's Law of Electromagnetic Induction

$$\mathcal{E} = -N\frac{\Delta\Phi_B}{\Delta t}$$

emf induced

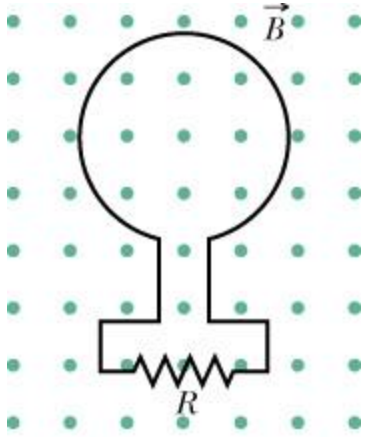
potential difference in Volts

number of loops

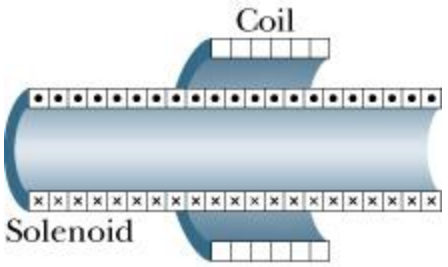
rate of change of magnetic flux with time (Wb/s)

(–)sign indicates that induced current opposes the change in flux = Lenz's Law

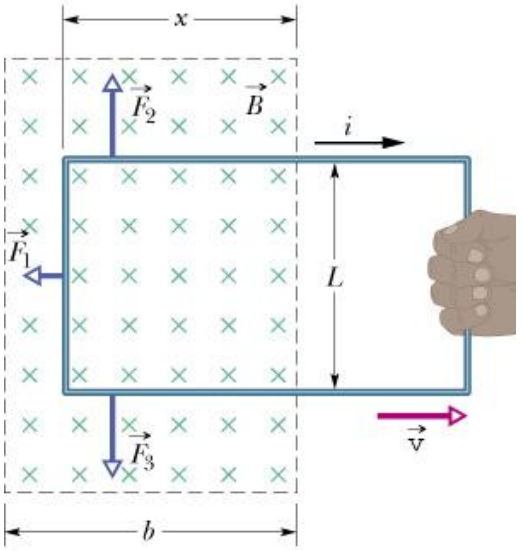
Many ways to change flux through a loop



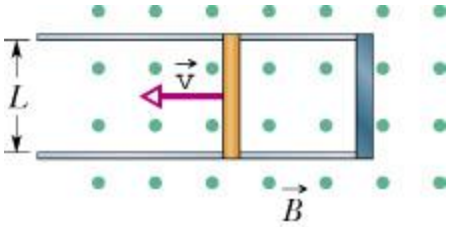
change B intensity



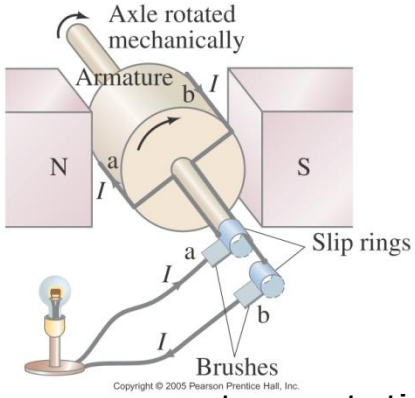
change current in solenoid



pull loop into/out of B



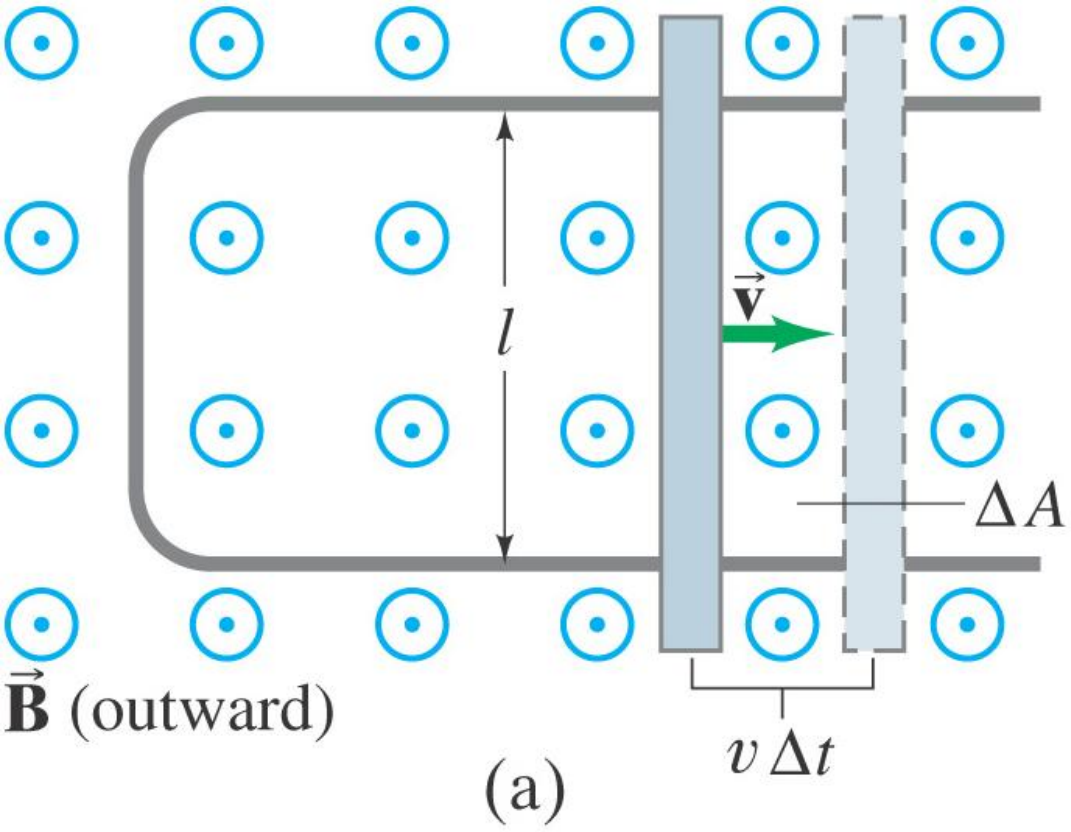
slide a bar across a rail system causing loop to increase in size



generator: rotating coil in fixed B field

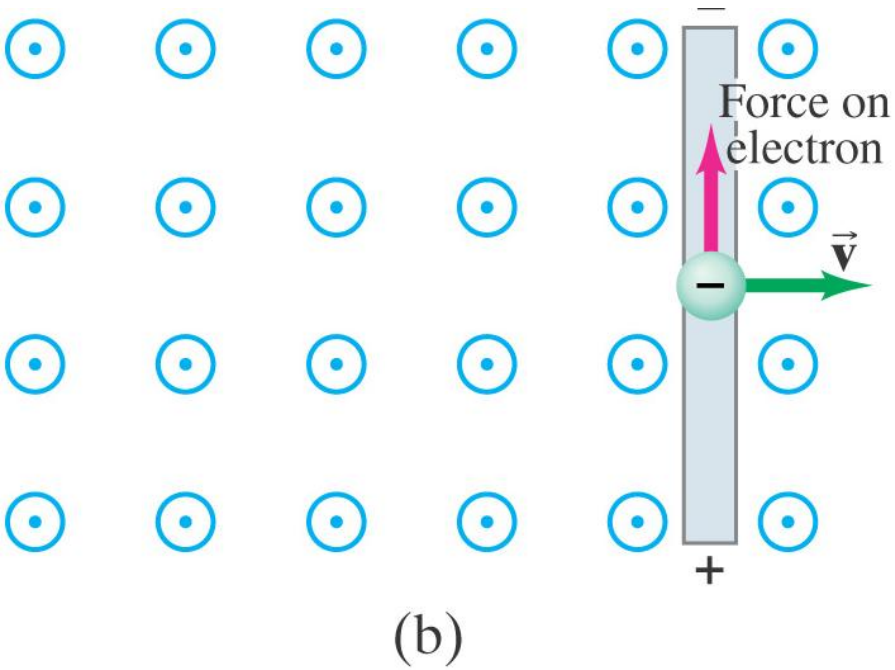
21.3 EMF Induced in a Moving Conductor

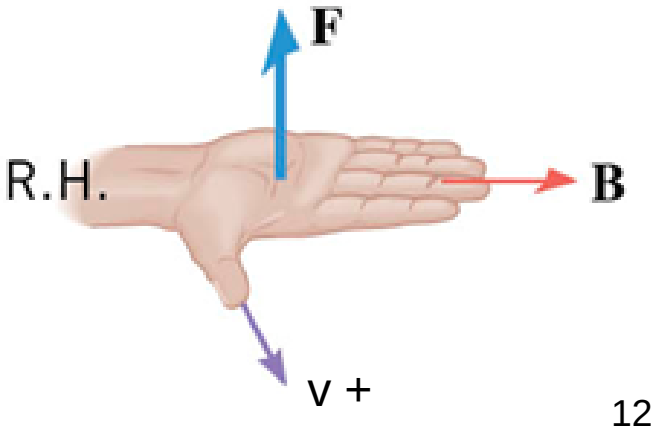
This image shows another way the magnetic flux can change:



21.3 EMF Induced in a Moving Conductor

The induced current is in a direction that tends to slow the moving bar – it will take an external force to keep it moving.

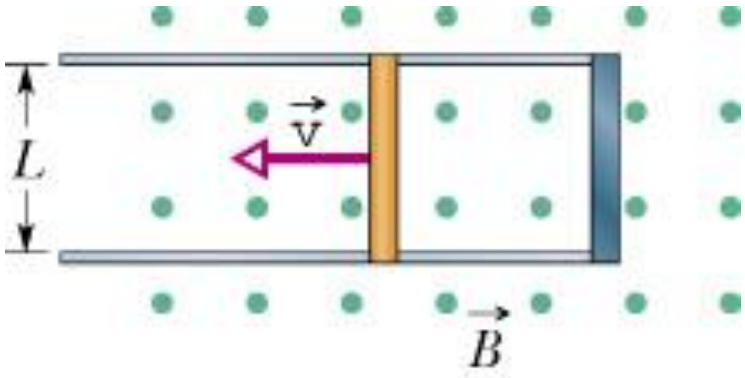




21.3 EMF Induced in a Moving Conductor

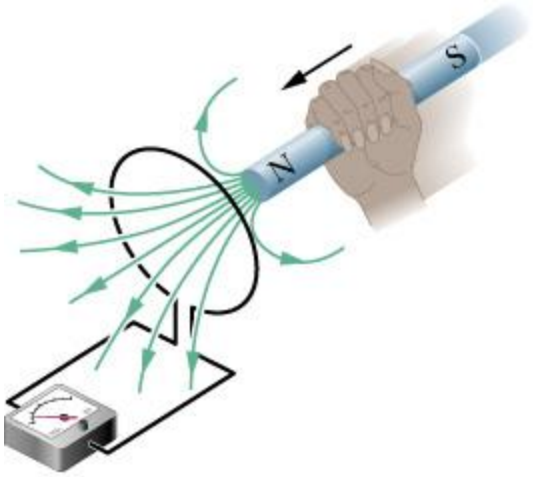
The induced emf has magnitude

$$\mathscr{E} = \frac{\Delta\Phi_B}{\Delta t} = \frac{B\,\Delta A}{\Delta t} = \frac{Blv\,\Delta t}{\Delta t} = Blv \qquad \textbf{(21-3)}$$

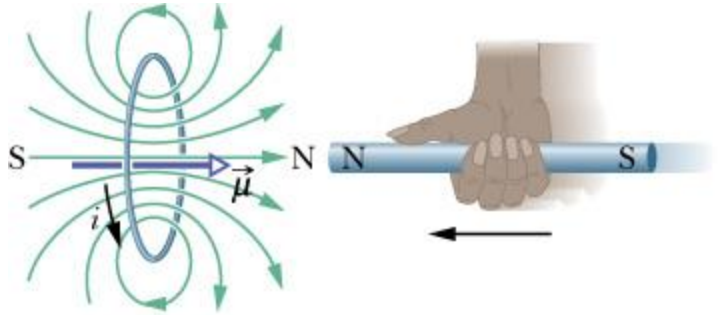


Lenz's Law

- Current induced by changing flux flows in such a direction to oppose the change that caused it



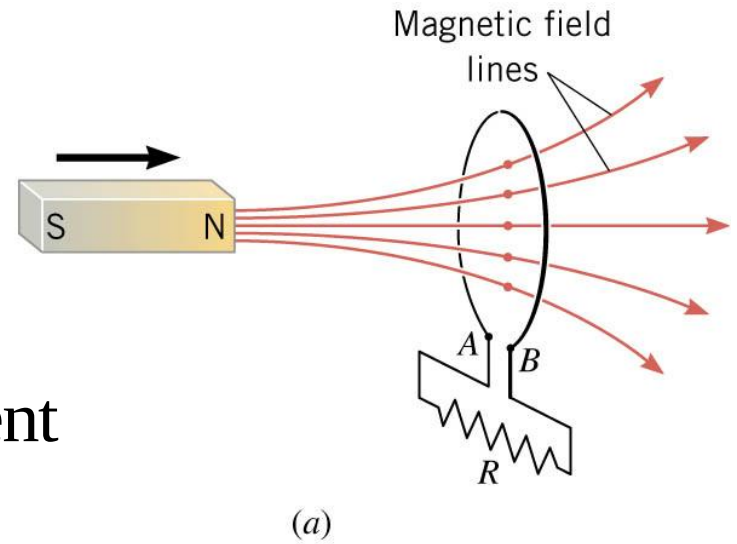
Faraday's Law states that changing flux induces current



Lenz's Law states the principle that allows you to determine the induced current direction

Lenz's Law

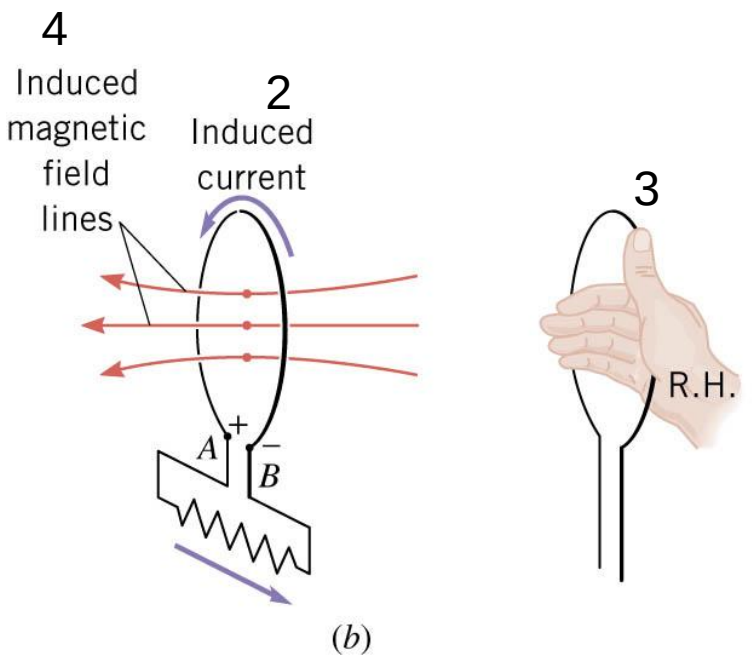
1) $\frac{\Delta\Phi}{\Delta t} \Rightarrow$ *induced* emf in coil



2) induced emf $\Rightarrow$ induced current

3) induced current $\Rightarrow$ induced B field

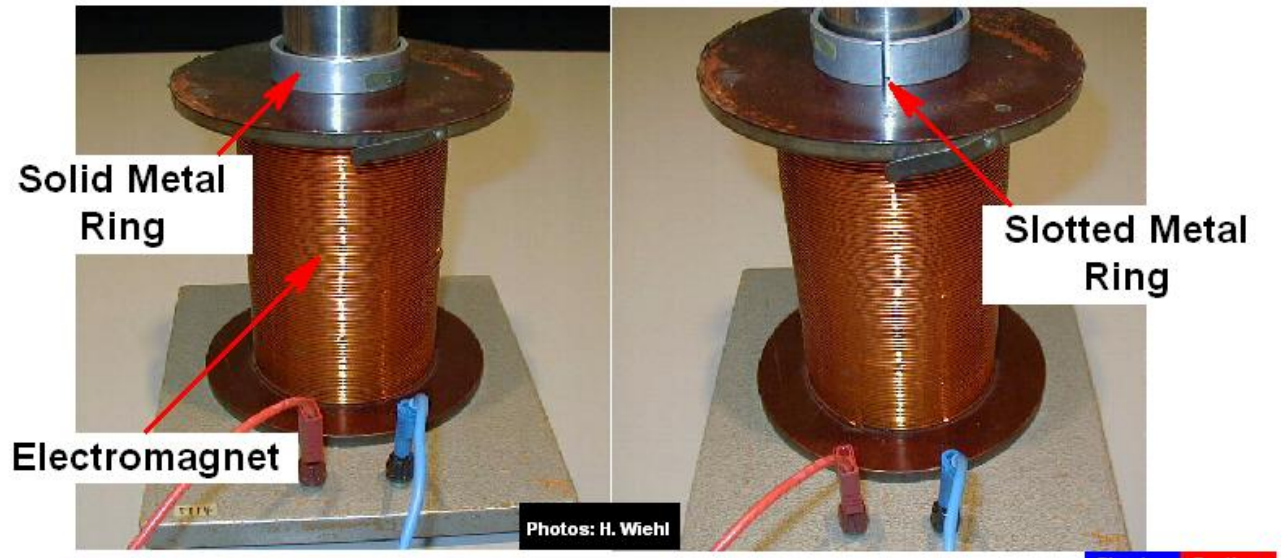
4) induced B field opposes the incoming North pole



Lenz's Rule: Solid and Slotted Metal Ring

Magnetism / Induction

Video: H. Wiehl



Lenz's Rule: Metal Rings in a B-Field

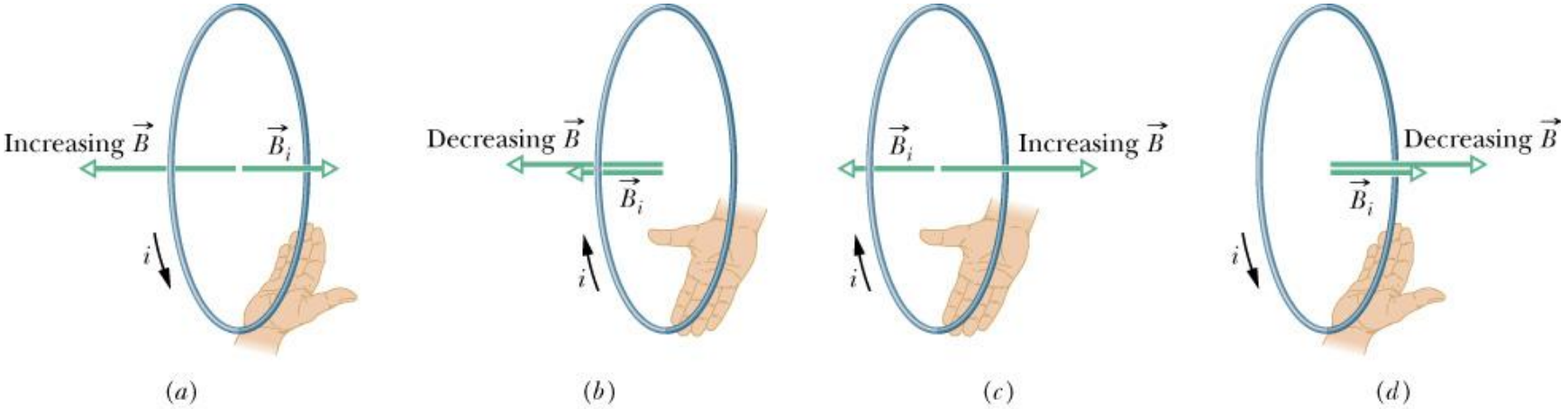
Chapter 4 Section 2

demo

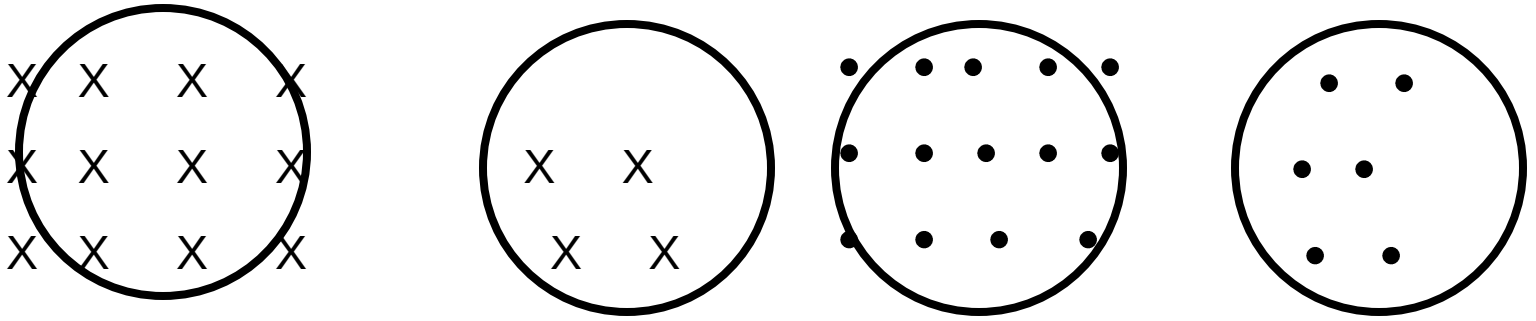
Applying Lenz's Law

1. Determine direction of changing B field and whether it is increasing or decreasing
2. Draw direction of induced B field to oppose this change
3. Use RHR to predict the induced current direction that will yield this induced B field

Lenz's Law



identify direction of changing B, $B_{induced}$ points opposite



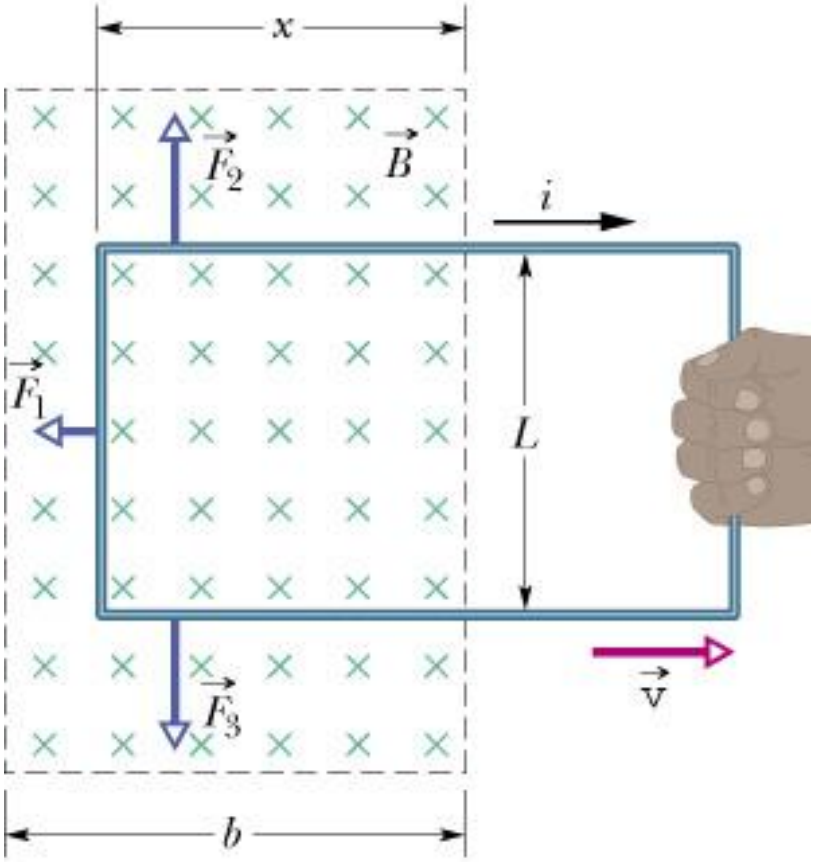
B increasing into page

B decreasing into page

B increasing out of page

B decreasing out of page

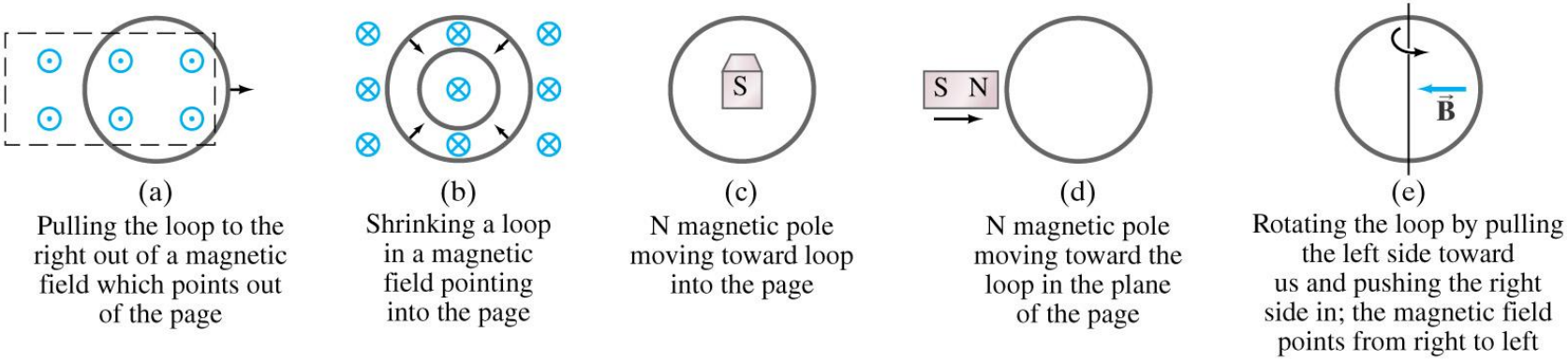
Lenz's Law



flux is decreasing into the page

induced current flows clockwise to create induced B field into page to offset that change

Lenz's Law Practice – Example 4



(a) Pulling the loop to the right out of a magnetic field which points out of the page

(b) Shrinking a loop in a magnetic field pointing into the page

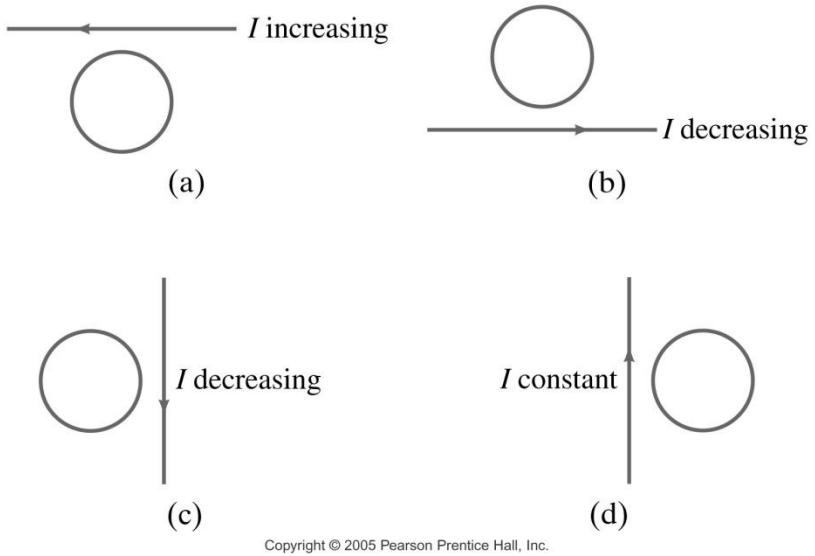
(c) N magnetic pole moving toward loop into the page

(d) N magnetic pole moving toward the loop in the plane of the page

(e) Rotating the loop by pulling the left side toward us and pushing the right side in; the magnetic field points from right to left

Lenz's Law Practice

Predict direction of induced current in the loop – page 589



Lenz's Law Practice

Predict direction of induced current in loop and through the resistor R