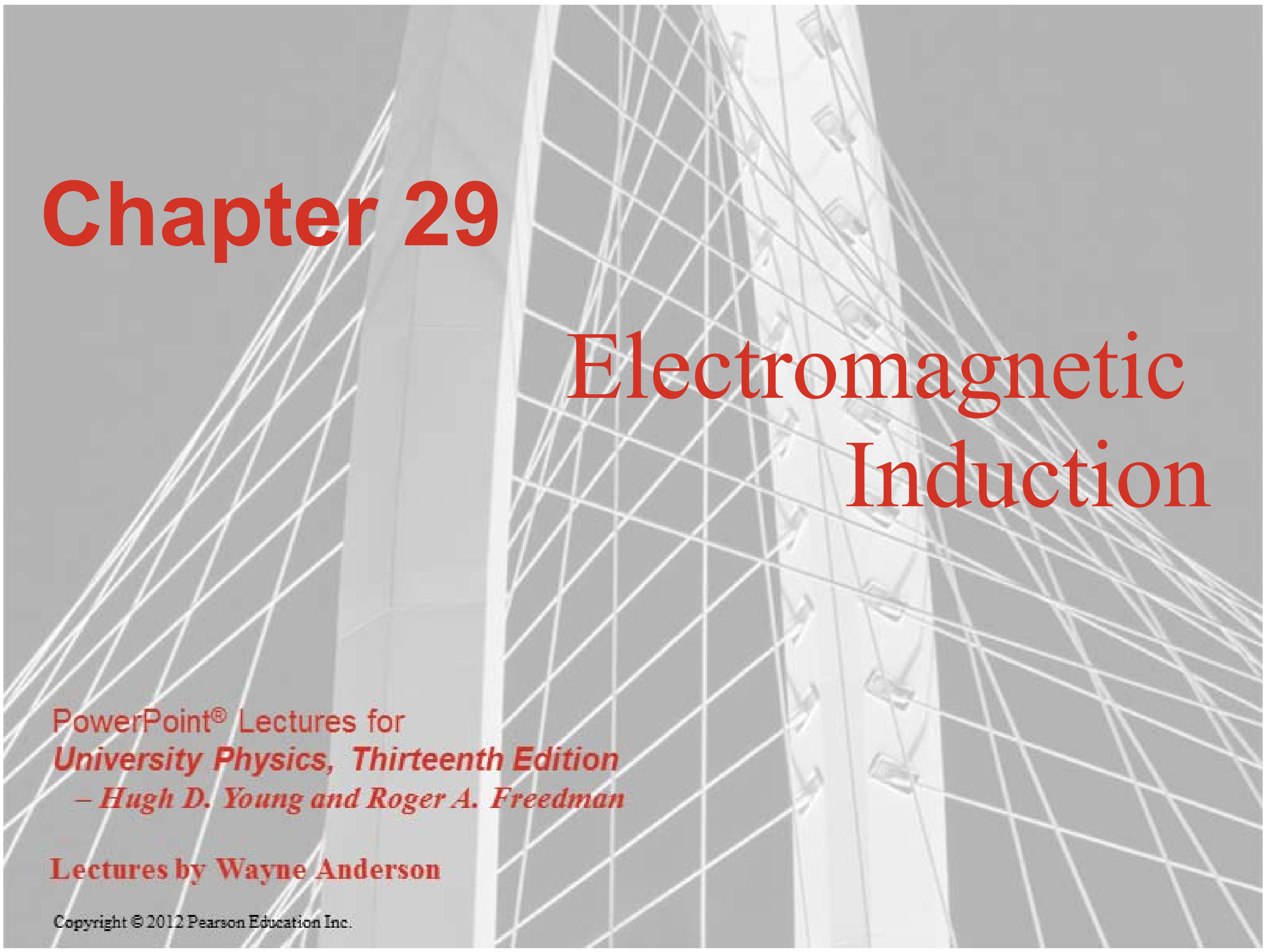
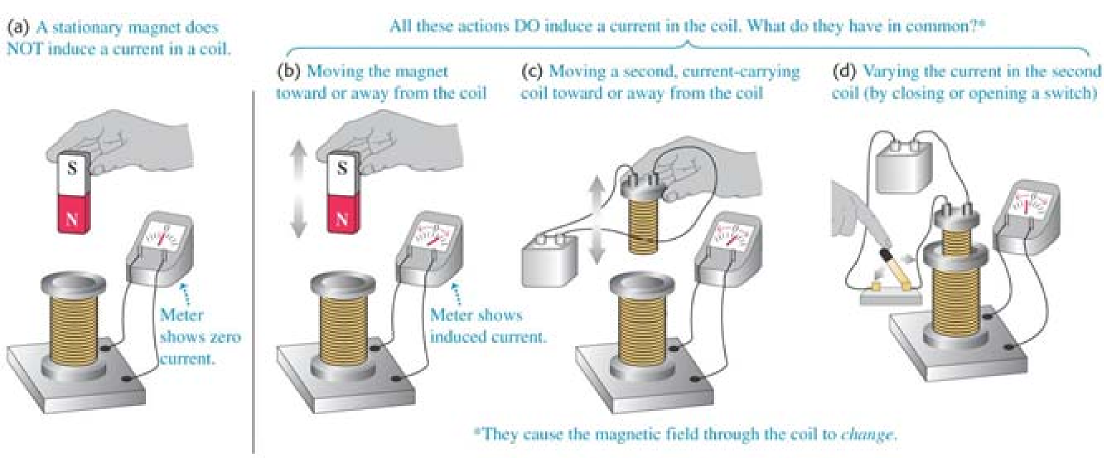
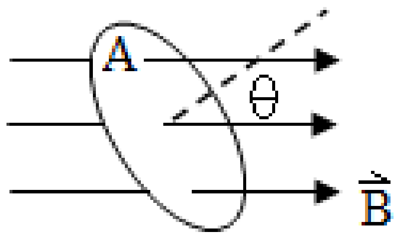

Chapter 29
Electromagnetic Induction
PowerPoint® Lectures for
University Physics, Thirteenth Edition
– Hugh D. Young and Roger A. Freedman
Lectures by Wayne Anderson
Copyright © 2012 Pearson Education Inc.

Induced current

- Moving charges and currents create magnetic fields
- Changing magnetic fields can create or *induce* a current



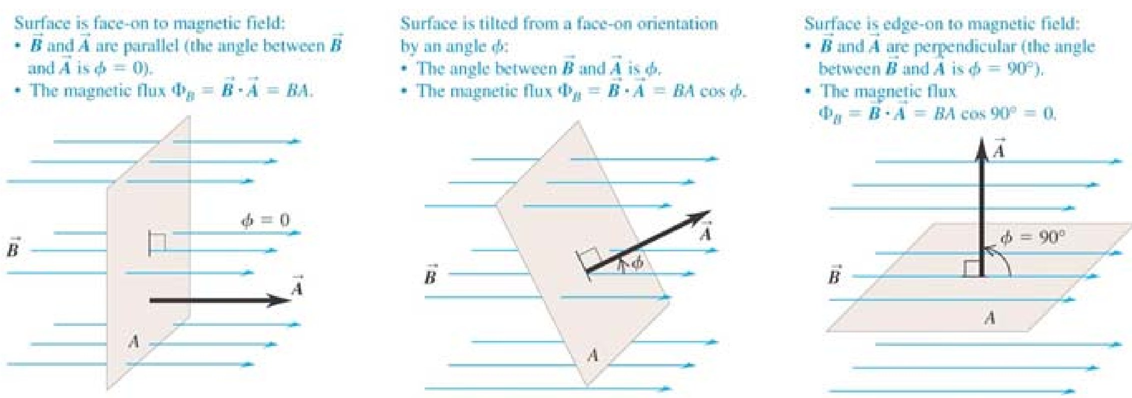
Magnetic flux

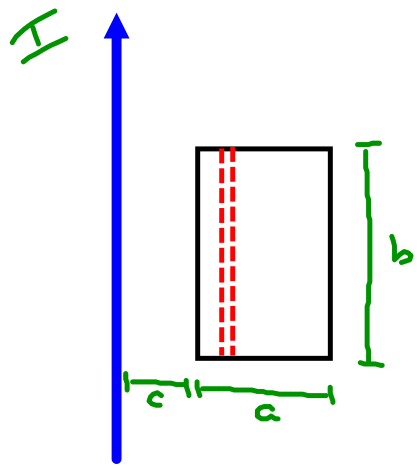


$\Phi_B = \int B \cdot dA$

unit of magnetic flux : $T \cdot m^2$ = Weber (Wb)

- Magnetic flux depends on 3 things
    - Magnetic field strength
    - Loop area
    - Orientation of the loop with respect to the field





A rectangular loop with width *a* and length *b* is located near a wire carrying a current *I*. The distance from the wire to the closest side of the loop is *c*. The wire and loop are parallel. Calculate the total magnetic flux through the loop.

$$\Phi_B = \int B \cdot dA$$

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

$$\Phi_B = \int_c^{c+a} \frac{\mu_0 I}{2\pi r} b\, dr$$

$$= \frac{\mu_0 I b}{2\pi} \int_c^{c+a} \frac{1}{r}\, dr$$

$$\Phi_B = \frac{\mu_0 I b}{2\pi} \ln\left(\frac{c+a}{c}\right)$$

Faraday's law

- *Faraday's law*: The induced emf in a closed loop equals the negative of the time rate of change of magnetic flux through the loop

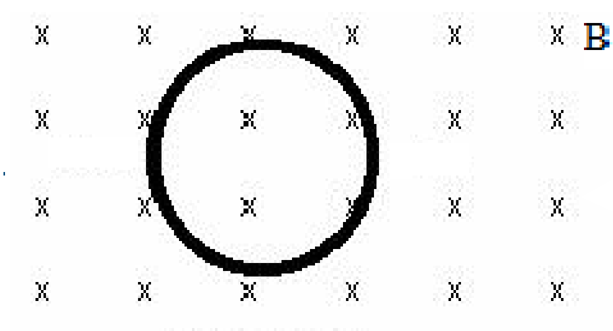
$$\mathcal{E} = -\frac{d\Phi_B}{dt}$$

From Lenz's Law

If the loop has multiple coils

$$\mathcal{E} = -N\frac{d\Phi_B}{dt}$$

Example:
How can an EMF be induced in the loop below?

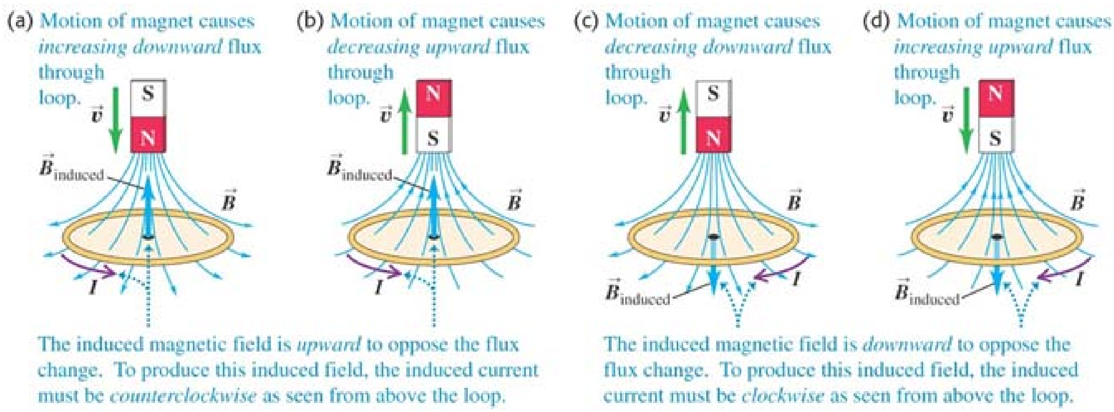


Lenz's law

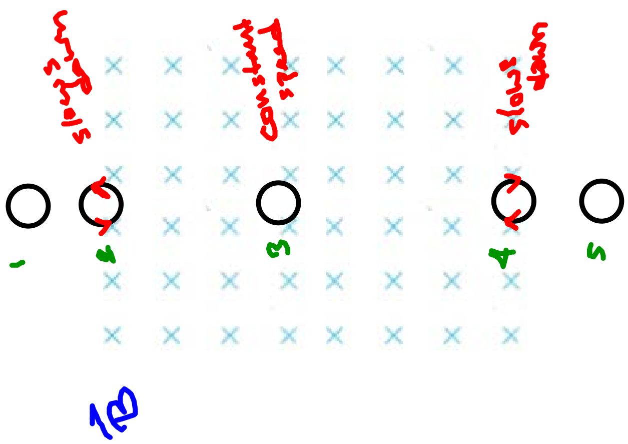
- *Lenz's law*: The magnetic field created by an induced current (due to the induced emf) will always *oppose* the change in magnetic flux through the loop

consequence of conservation of energy

Dropping a bar magnet through a loop



Dropping a loop through a magnetic field



1) No induced current

2) Flux into page increasing
loop creates a field pointing out of page
→ current flows CCW

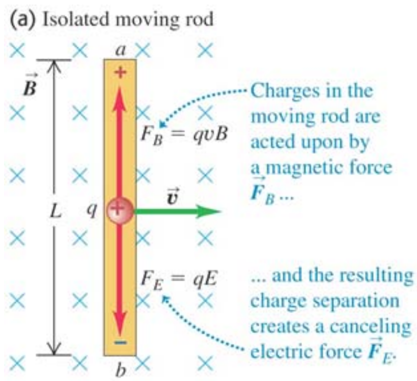
3) No induced current
no change in flux

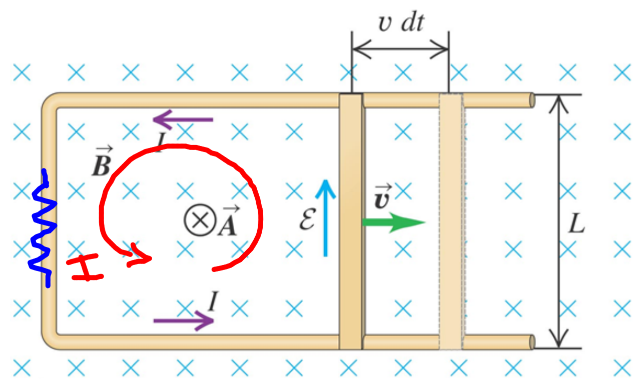
4) flux into page decreasing
loop creates field pointing into page
→ current flows CW

5) no induced current

Motional emf

- Move a conductor of length L through a magnetic field B at a speed v, perpendicular to the field





$$\mathcal{E} = -\frac{d\Phi_B}{dt}$$

$$\Phi_B = BA\cos\theta$$

$$\mathcal{E} = B\frac{dA}{dt}$$

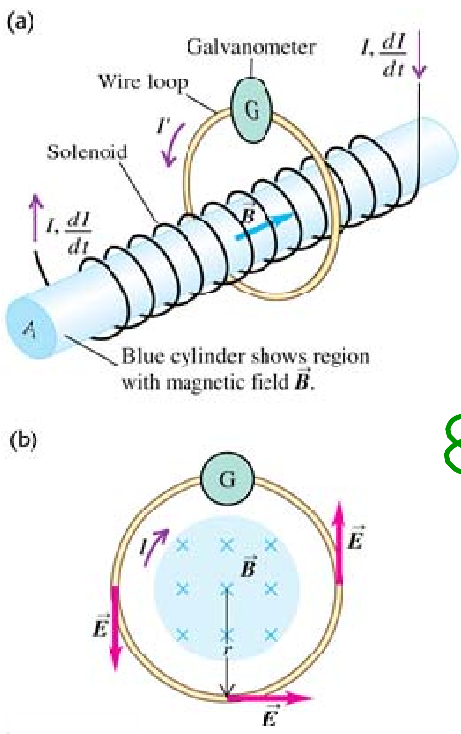
$$dA = Lv\,dt$$

$$\mathcal{E} = B\frac{Lv\cancel{dt}}{\cancel{dt}}$$

$$\boxed{\mathcal{E} = BLv}$$

$$I = \frac{\mathcal{E}}{R}$$

Induced electric fields

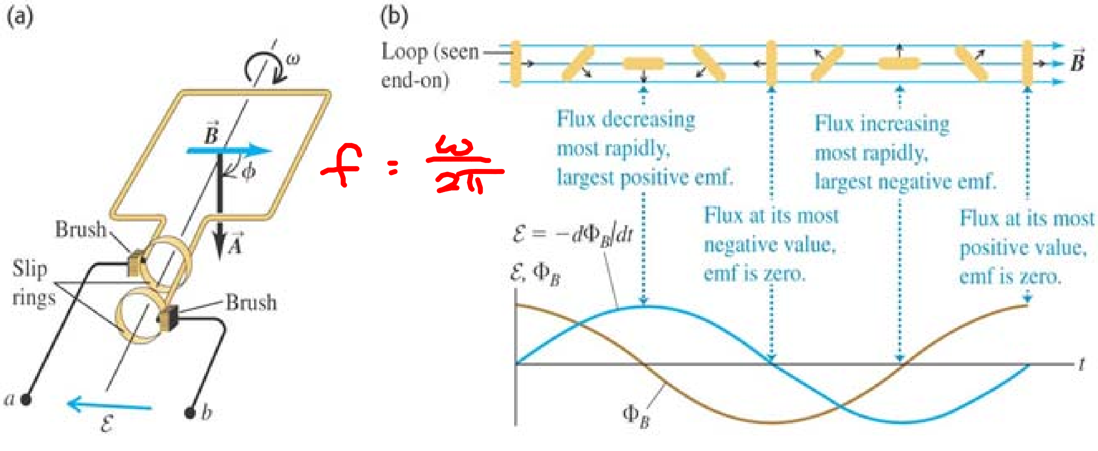


$$\mathcal{E} = \oint E \cdot dl$$

$$\mathcal{E} = -\frac{d\Phi_B}{dt} = \oint E \cdot dl$$

A simple alternator

- Follow Example 29.3 using Figures 29.8 (below) and 29.9 (right).



Maxwell's equations

$$\oint E \cdot dA = \frac{Q_{enc}}{\varepsilon_0}$$ Gauss's Law

$$\oint B \cdot dA = 0$$ Gauss's Law for Magnetism

→ no magnetic monopoles

$$\mathcal{E} = \oint E \cdot dl = -\frac{d\Phi_B}{dt} = -\frac{d}{dt}\int B \cdot dA$$ Faraday's Law

$$\oint B \cdot dl = \mu_0 I_{enc} + \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt}$$ Ampere's Law