PHYSICS 571 – Master's of Science Teaching

"Electromagnetism and Light"
Lecture 5 – Magnetic Induction and Flux
Instructor – Richard Sonnenfeld

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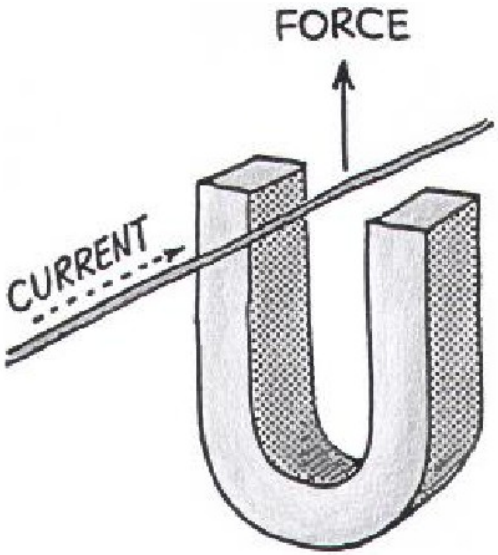
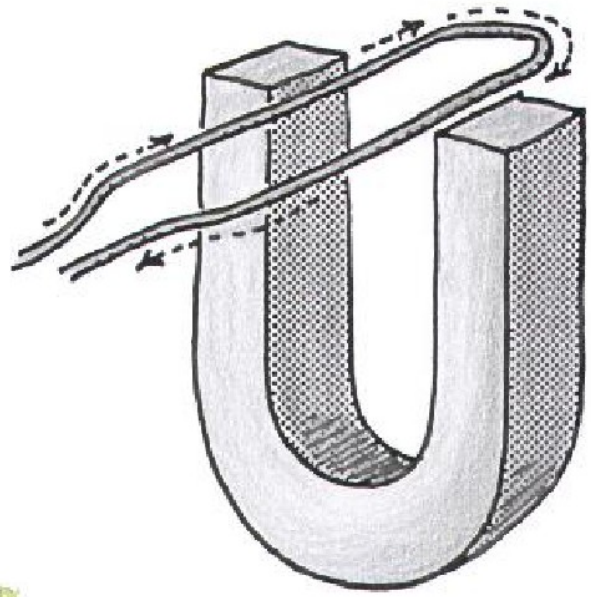
NEXT-TIME QUESTION

CONCEPTUAL Physics

When current flows in the wire that is placed in the magnetic field shown, the wire is forced upward. If the wire is made to form a loop as shown below, the loop will tend to





a) rotate clockwise.

b) rotate counterclockwise.

c) remain at rest.

ARBOR SCIENTIFIC
TOOLS THAT TEACH.

Hewitt Drew-it!

Ways to change flux

Let $\vec{B}$ be uniform over the loop. Then

$$\Phi_B = \vec{B} \cdot \vec{A}$$

$$\frac{d\Phi_B}{dt} = \frac{d\vec{B}}{dt} \cdot \vec{A} + \frac{d\vec{A}}{dt} \cdot \vec{B}$$

- Can move loop into stronger or weaker B.
- Can increase/decrease B.
- Can rotate B.
- Can increase/decrease size of loop.
- Can rotate loop.

Faraday's law, electromagnets, generators etc.

http://phet.colorado.edu/en/simulation/faraday

Electromagnetic Induction
CHECK YOUR NEIGHBOR

More voltage is induced when a magnet is thrust into a coil

A. more quickly.
B. more slowly.
C. both A and B
D. neither A nor B

Electromagnetic Induction
CHECK YOUR NEIGHBOR

Not only is voltage induced when a magnet is thrust into a coil of wire, but _____ is also induced.

A. current
B. energy
C. power
D. none of the above

Electromagnetic Induction
CHECK YOUR NEIGHBOR

The resistance you feel when pushing a piece of iron into a coil involves

A. repulsion by the magnetic field you produce.
B. energy transfer between the iron and coil.
C. Newton's third law.
D. resistance to domain alignment in the iron.

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Outline

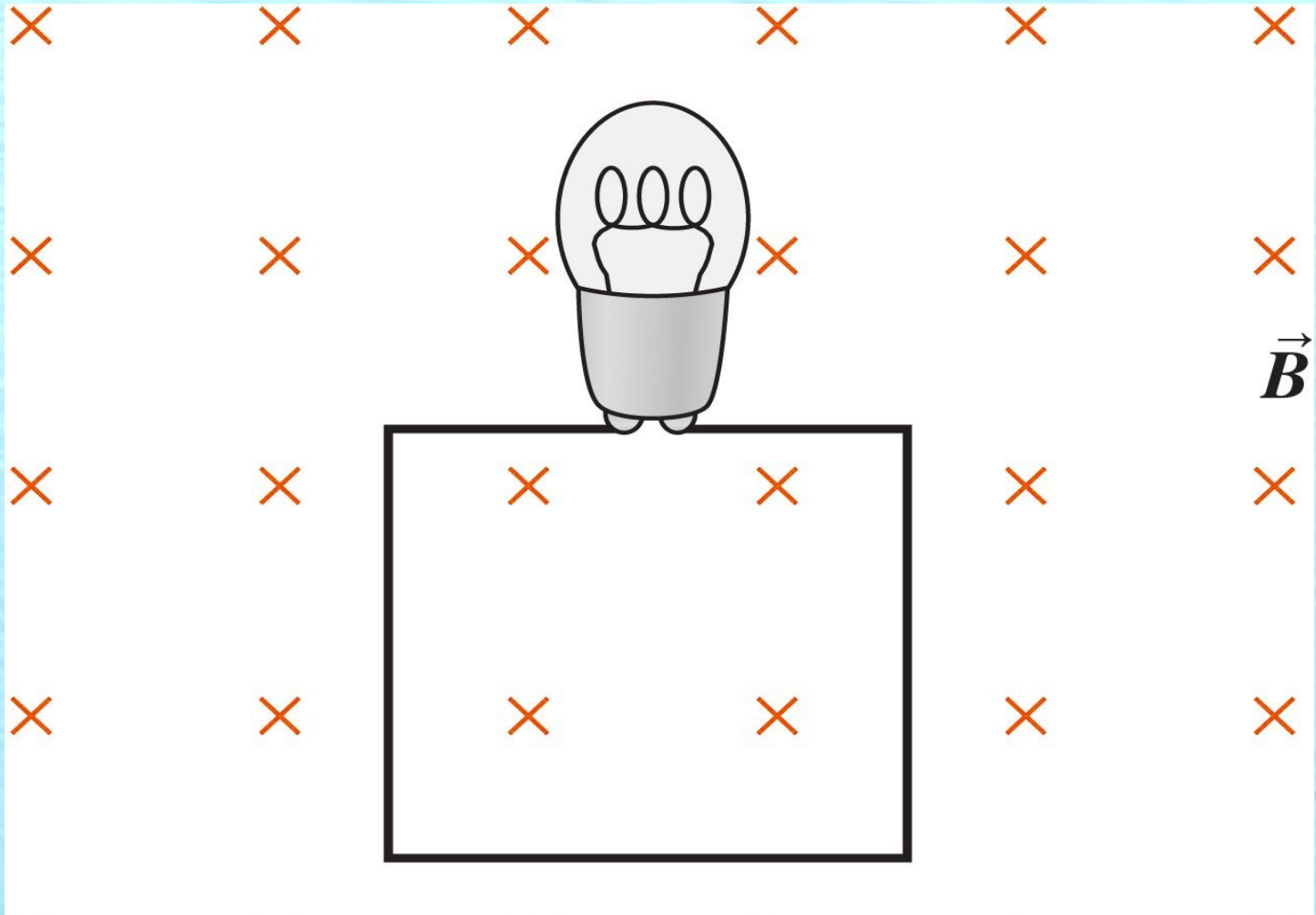
Review of magnetic forces and cross products.
Magnetic forces do no Work.
Magnetic Induction
Faradays Law
Examples
- Changing B, constant A
- Changing A, constant B

Generators
- Constant B, rotating A

Rigorous definition of Flux

Changing Flux by Changing B-field

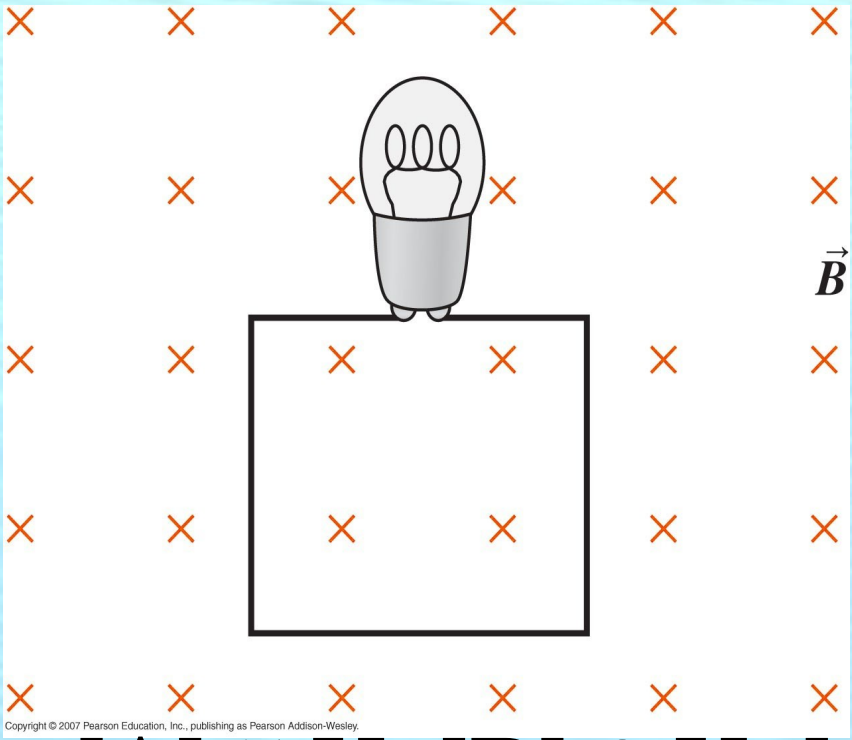
$$\frac{d\Phi_B}{dt} = \frac{d\vec{B}}{dt}\cdot\vec{A} + \frac{d\vec{A}}{dt}\cdot\vec{B} \rightarrow \frac{d\Phi_B}{dt} = \frac{d\vec{B}}{dt}\cdot\vec{A}$$



Changing B-field parallel to A.

$$\varepsilon = \frac{-d\Phi_B}{dt} = -A\frac{dB}{dt}$$

In the sketch below $B(t) = 2t^2 + 3$



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The loop is square with side 3 m.
At 1 second,
What voltage is applied to the bulb?

[A] 5 V, [B] 9 V, [C] 18 V, [D] 36 V, [E] 45 V

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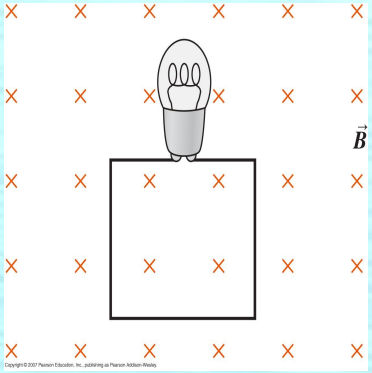

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Changing Flux by Changing size Of Loop

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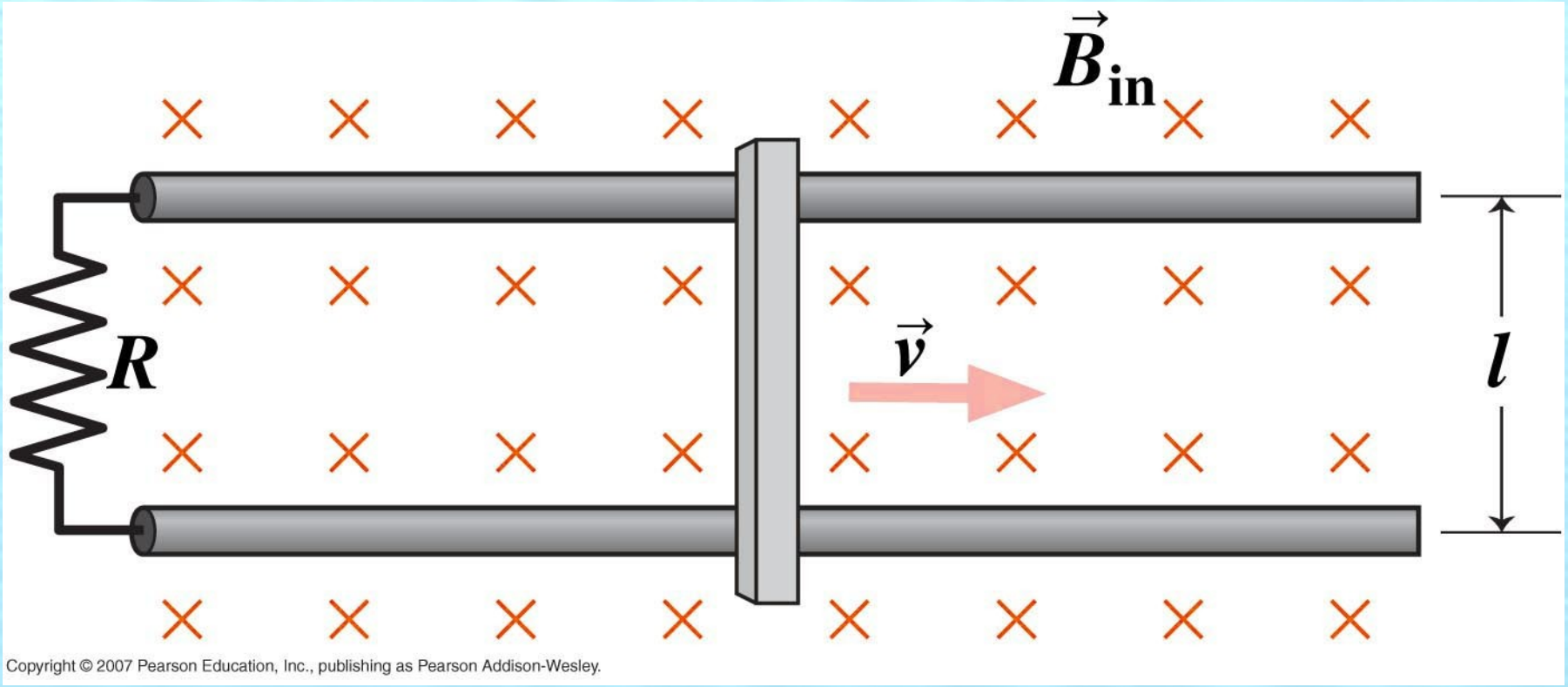

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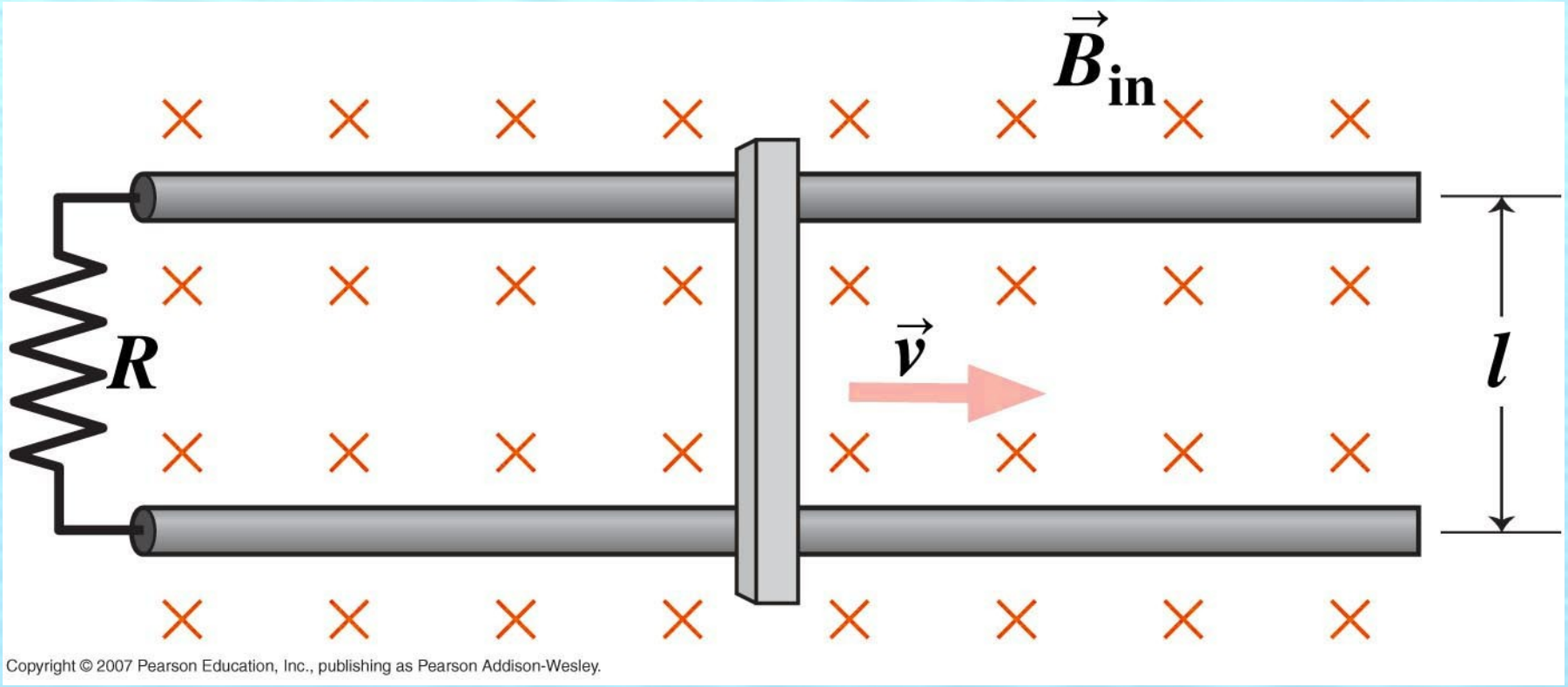
Changing Flux by Changing size Of Loop

Given B=0.1 T, “l”=0.1 m, v=20 m/s, R=30 Ohms, What are V, I, and P?



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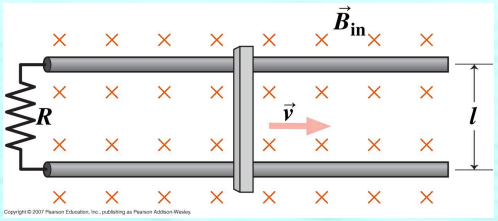

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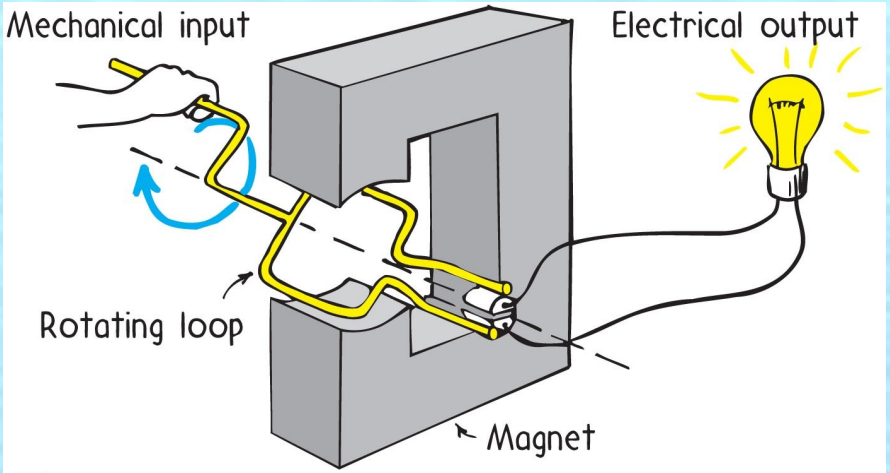
Rigorous definition of Flux

Generators and Alternating Current

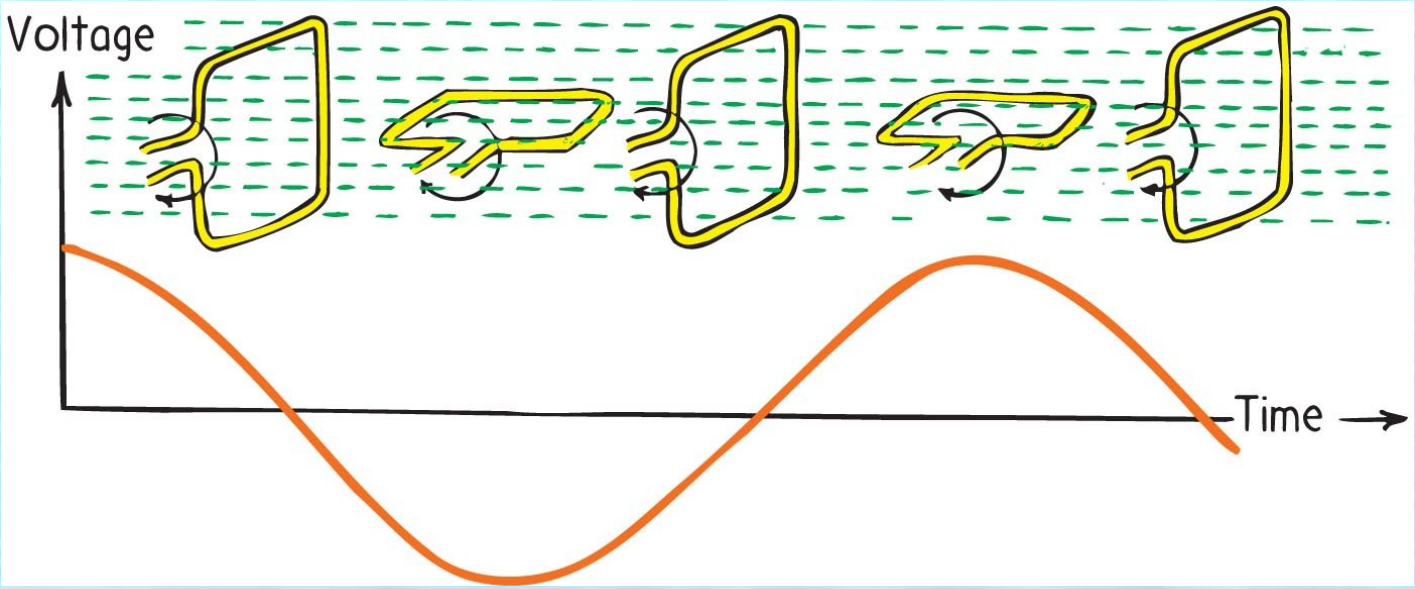
Generator

- opposite of a motor
- converts mechanical energy into electrical energy via coil motion
- produces alternating voltage and current



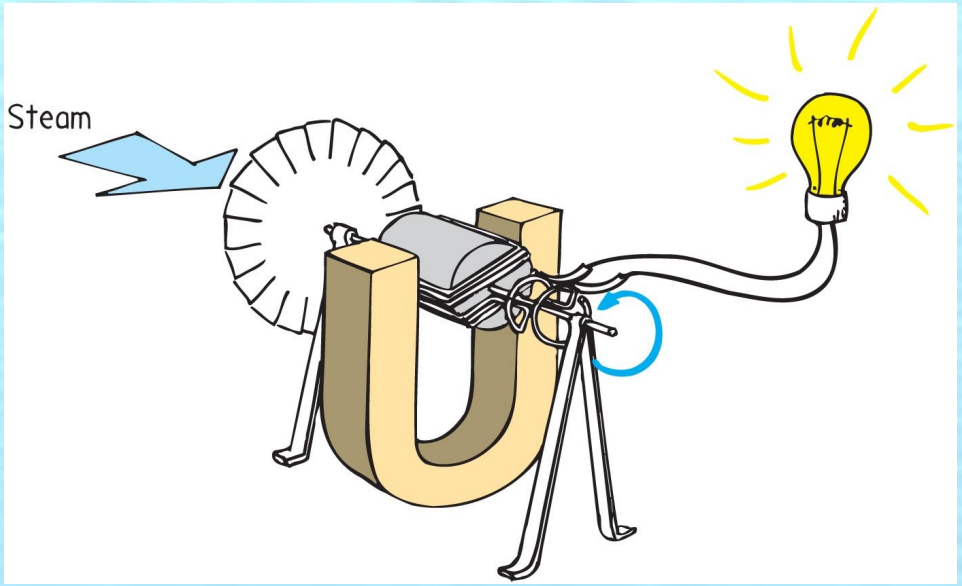
Generators and Alternating Current

The frequency of alternating voltage induced in a loop is equal to the frequency of the changing magnetic field within the loop.

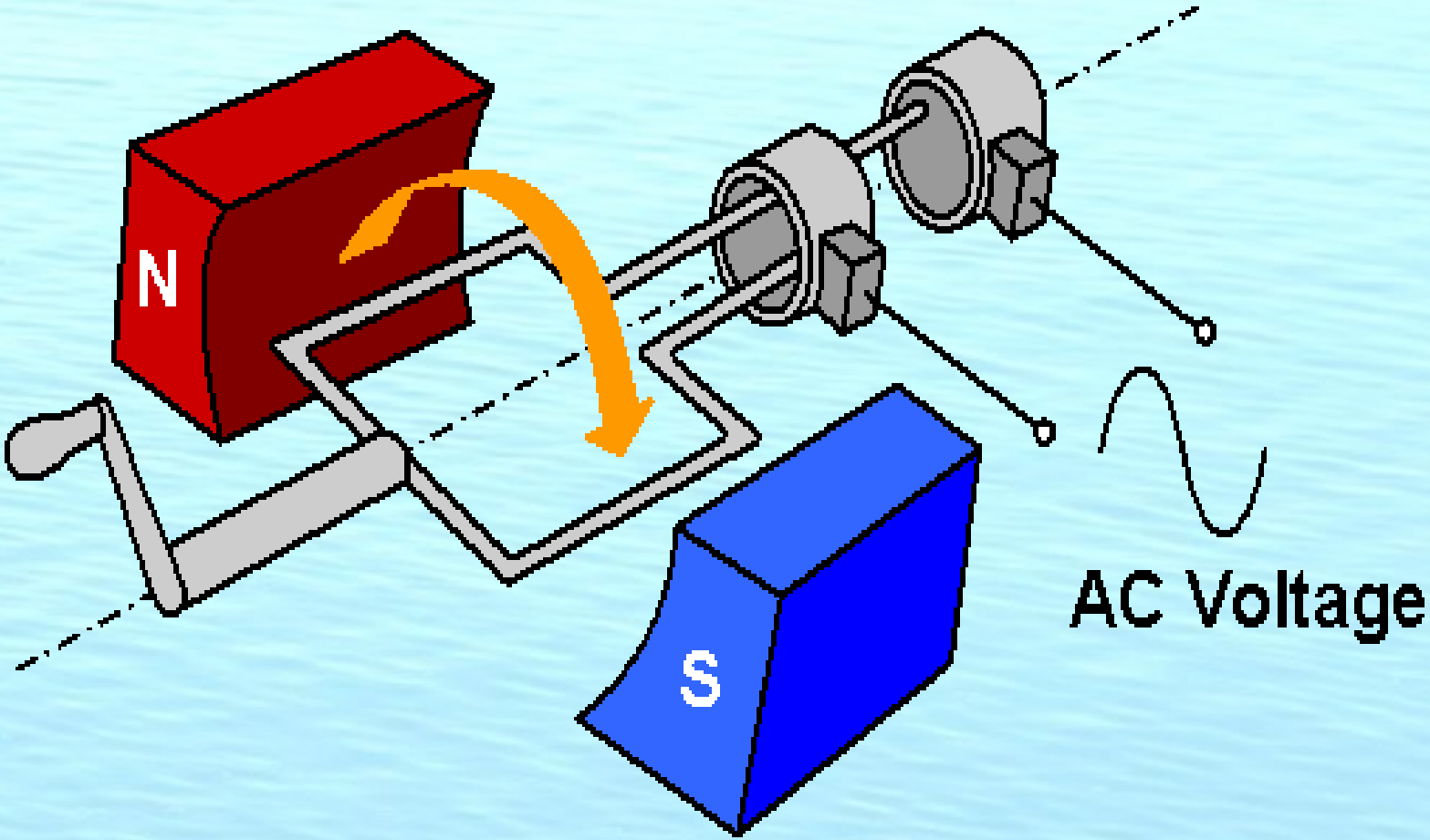


Power Production

Using Faraday and Henry's discovery of electromagnetic induction, Nikola Tesla and George Westinghouse showed that electricity could be generated in sufficient quantities to light cities.



Changing flux by rotating loop



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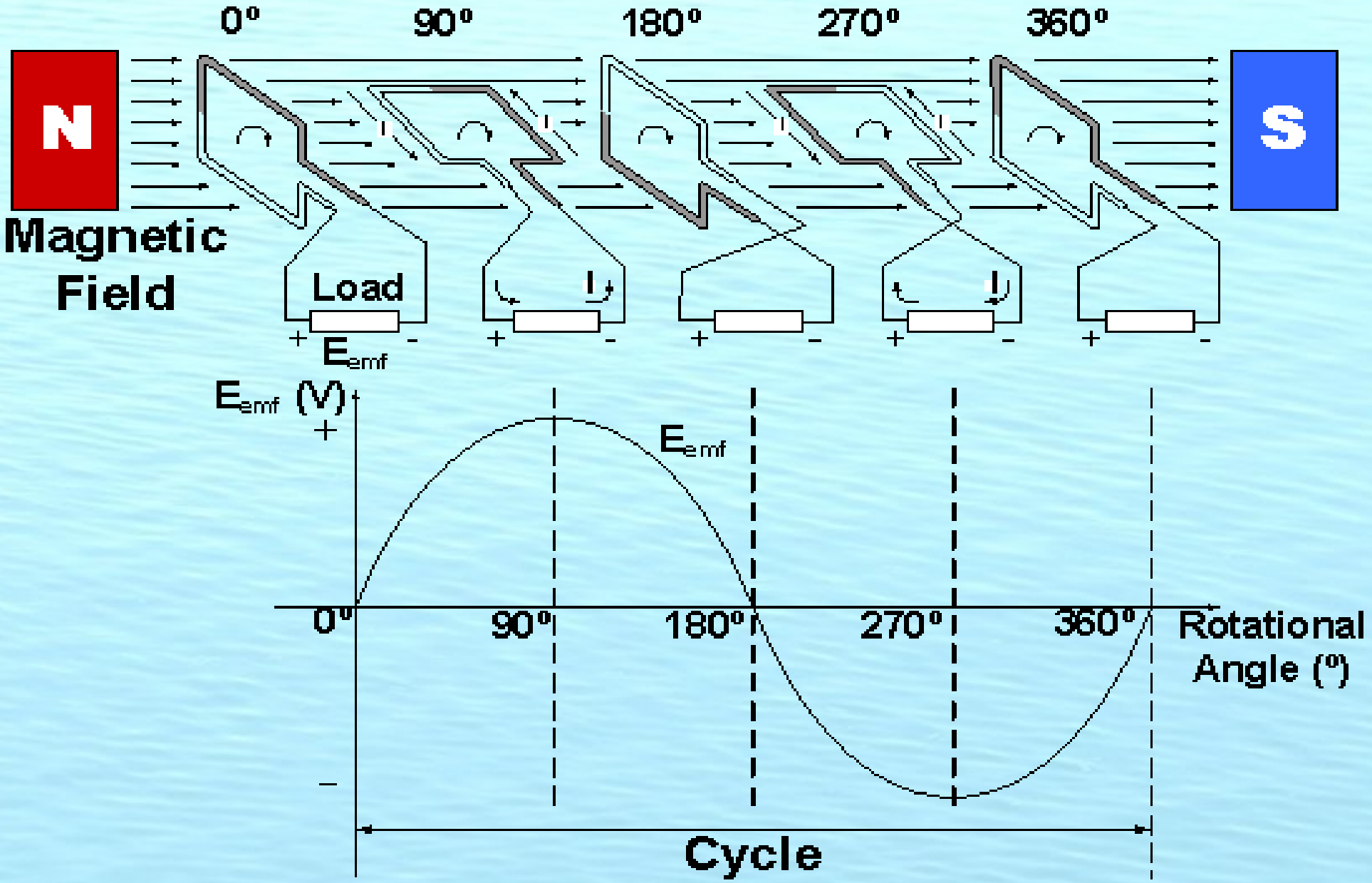

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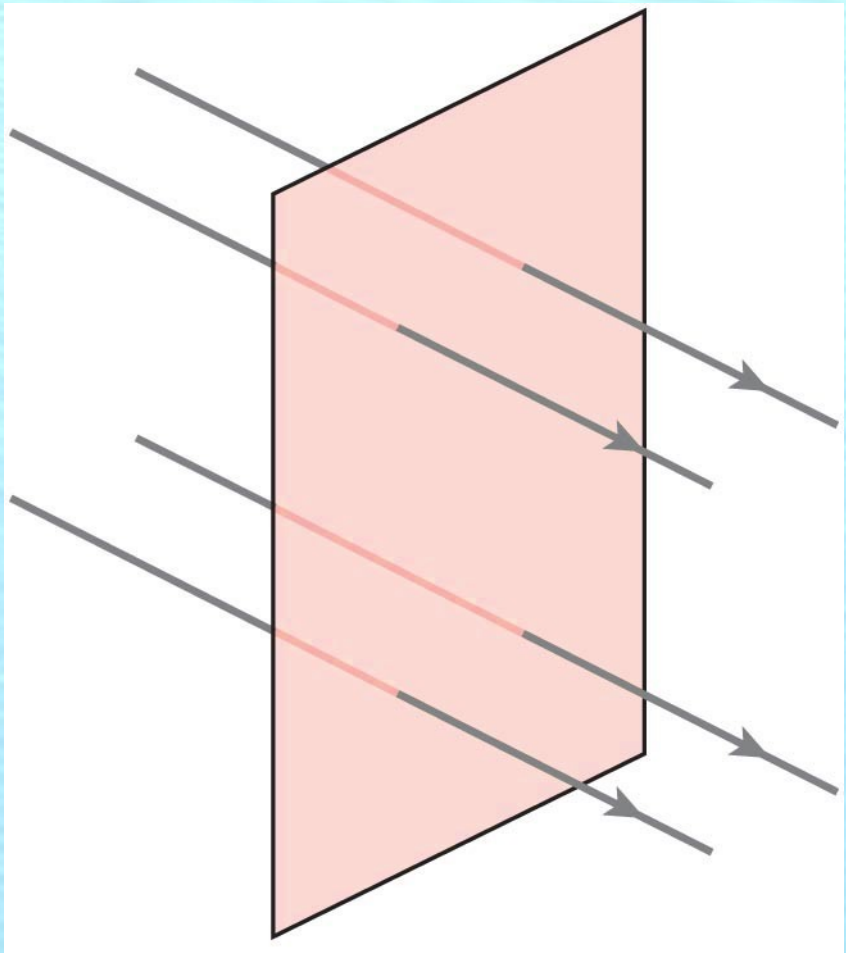
What is magnetic flux?

Flux – flow – like water through a river,
or magnetic field lines through a surface.



$$\Phi_E = \int \vec{E} \cdot d\vec{A}$$

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

For B uniform
over area A:

$$\Phi_B = \vec{B} \cdot \vec{A}$$

Flux in science and engineering

The word flux comes from Latin: fluxus means "flow",

Electric flux, Magnetic flux amount of E or B-field crossing a unit of area ← **Physics, EE**

Momentum flux, the rate of transfer of momentum across a unit area – Viscosity ← **Mech. E, Chem E.**

Heat flux – Rate of heat flow across a unit area
--Heat conduction – (Fourier's law) ← **Mech. E.**

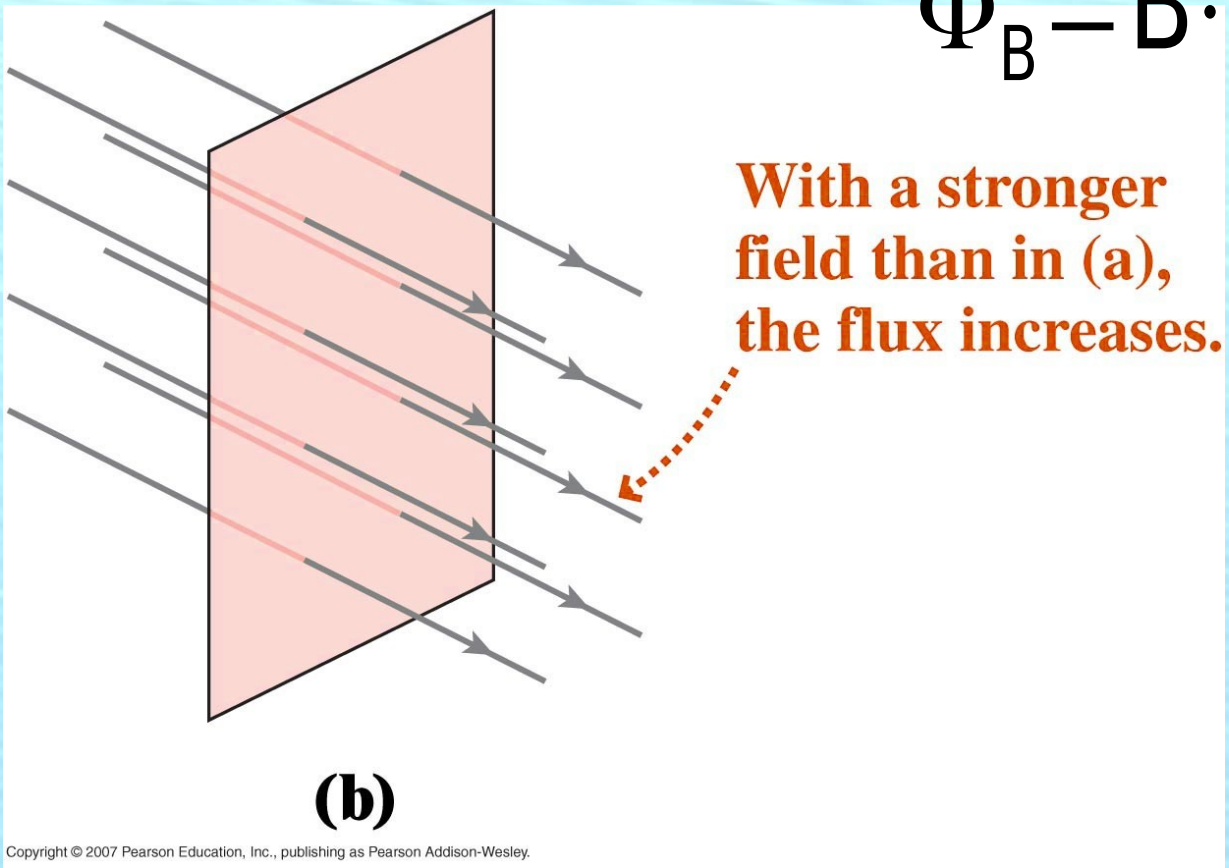
Diffusion flux, the # of molecules across a unit area per second – (Fick's law of diffusion) ← **Chem, Bio.**

Volumetric flux, the # of kilograms of water crossing a unit area per second (Darcy's law, groundwater flow) **Hydrology**

What is flux?

Flux – flow – like water through a river, or electric field lines through a surface.

$$\Phi_B = \vec{B} \cdot \vec{A}$$



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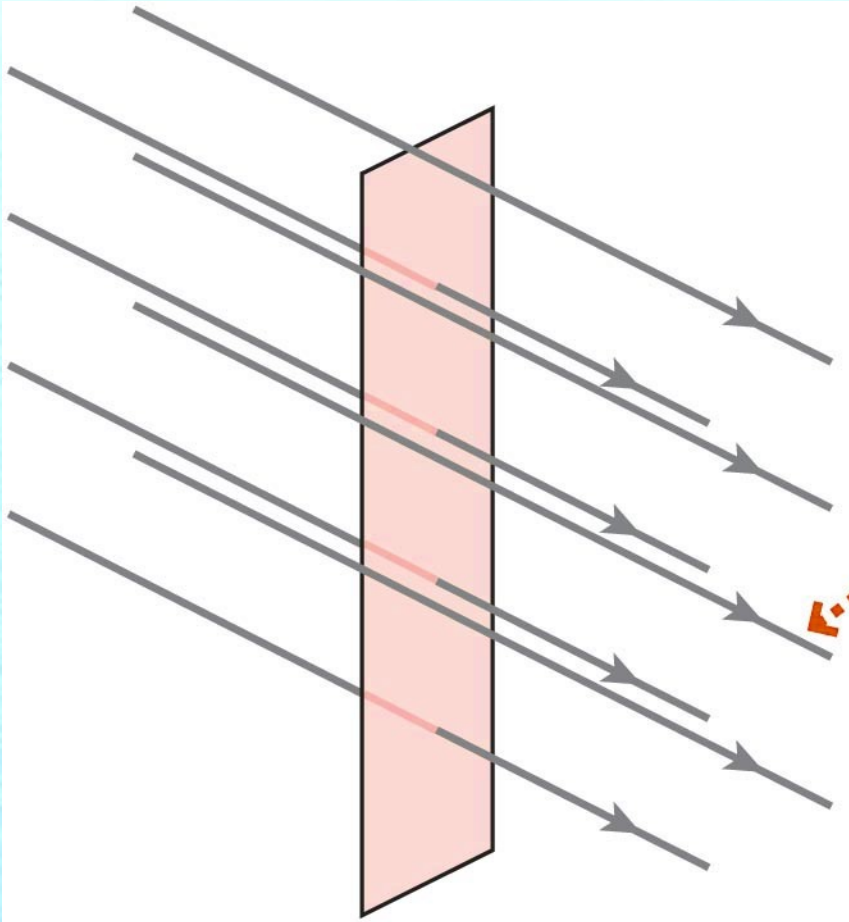

A smaller surface area than in (b) reduces the flux.

(c)

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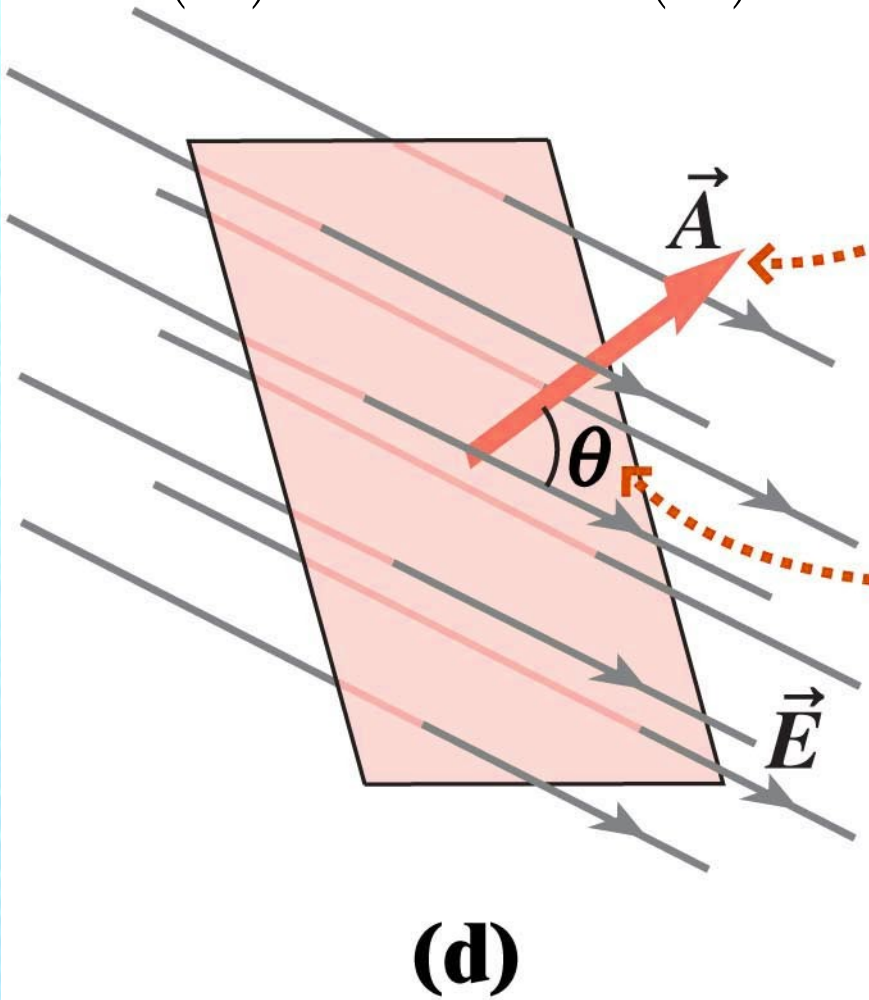
$$\Phi = \vec{B} \cdot \vec{A}$$

$$\Phi = |\vec{B}||\vec{A}|\cos(\theta) = BA\cos(\theta)$$



(d)

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The vector $\vec{A}$ is perpendicular to the surface and has a magnitude equal to the surface area.

The electric flux Φ depends on the angle θ between $\vec{A}$ and $\vec{E}$.

Flux videos

www.youtube.com/user/pelletierphysics

Electric Flux

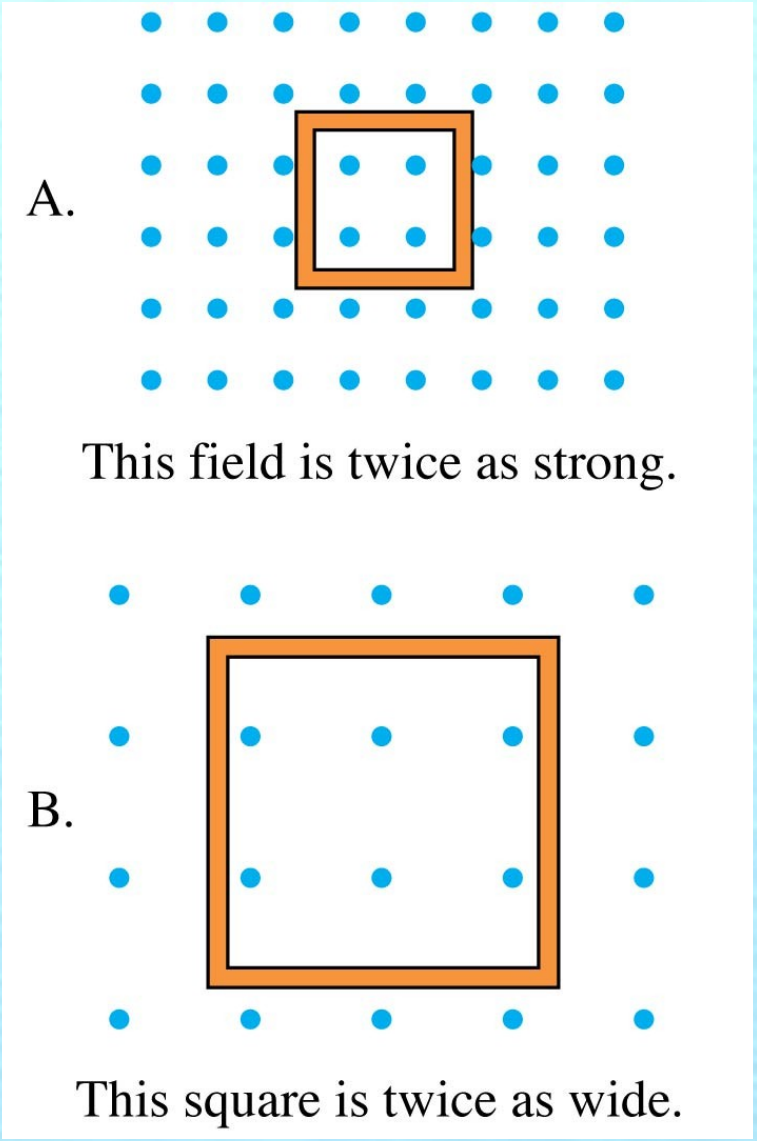
Which loop has the larger magnetic flux through it?

A. Loop A.

B. Loop B.

C. The fluxes are the same.

D. Not enough information to tell.



Clicker

Find the flux through a square loop 10 cm on a side with the loop normal at 60 degrees to a uniform 0.08 T magnetic field

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

$(A) 8 \times 10^{0}\ \mathrm{T \cdot m^2}$

$(B) 8 \times 10^{-2}\ \mathrm{T \cdot m^2}$

$(C) 8 \times 10^{-4}\ \mathrm{T \cdot m^2}$

$(D) 6.9 \times 10^{-4}\ \mathrm{T \cdot m^2}$

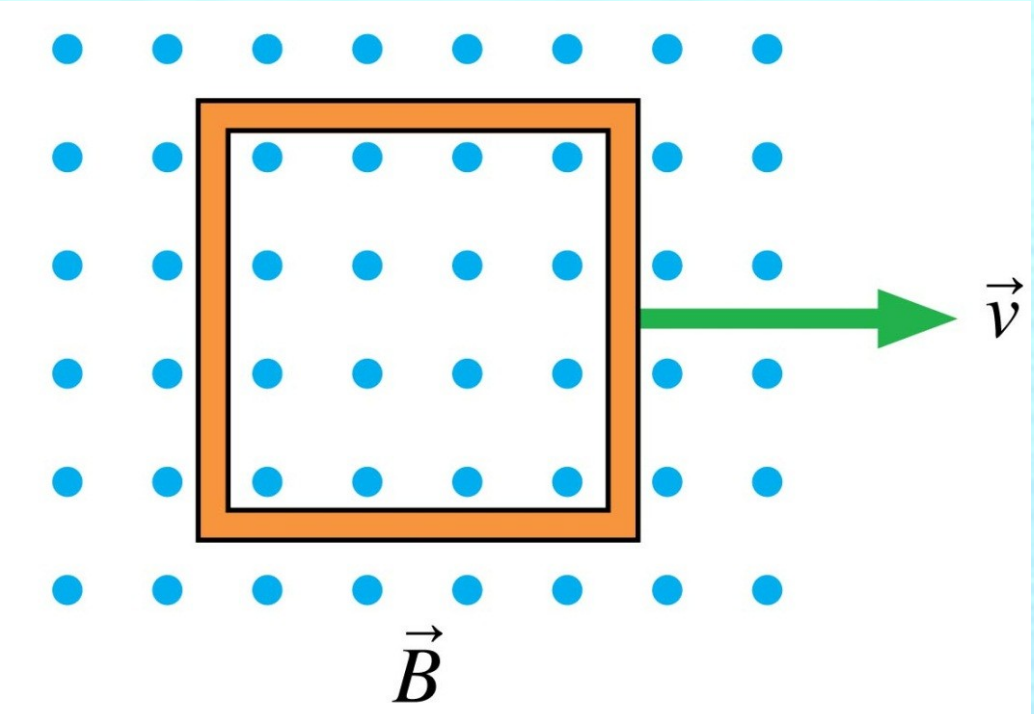
$(E) 4 \times 10^{-4}\ \mathrm{T \cdot m^2}$

Clicker

The metal loop is being pulled through a uniform magnetic field. Is the magnetic flux through the loop changing?

A. Yes.

B. No.

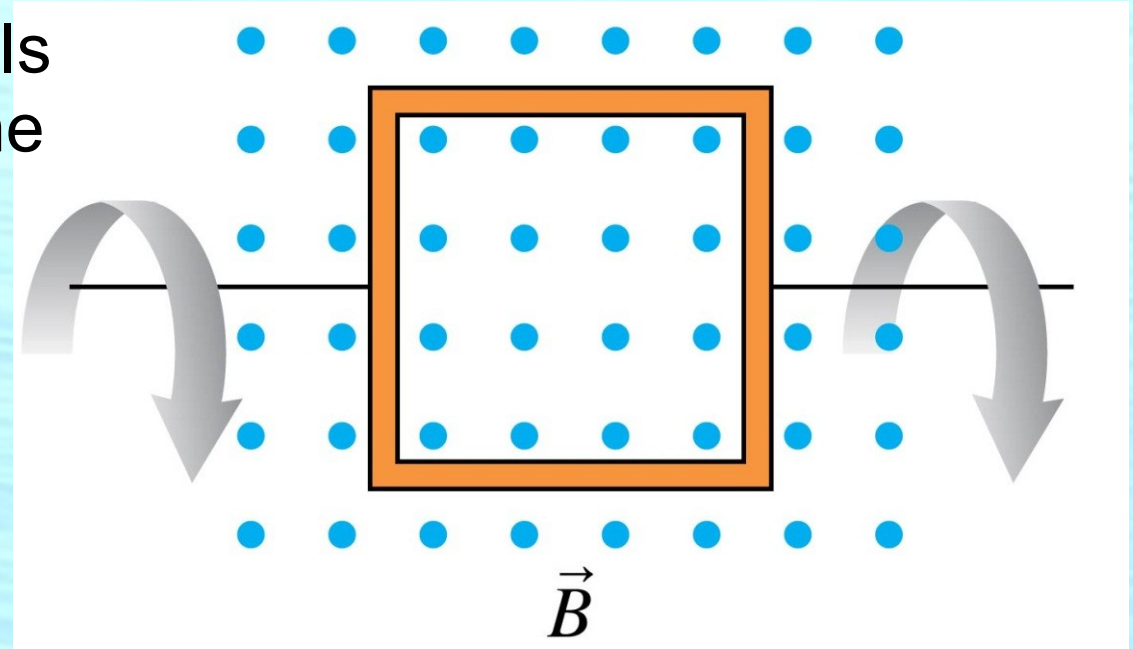


Clicker

The metal loop is rotating in a uniform magnetic field. Is the magnetic flux through the loop changing?

A. Yes.

B. No.



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Next Time

Transformers
Connection between Electromagnetism and waves