
PH 220
Lance Nelson

Outline

- Understand Motional EMF
  - What causes it?
  - Why can it drive a current?
- Understand Eddy currents.
- Lenz's Law

Flow of discussion:

1) Remind them of what we have learned in Ch 32. Currents create B fields, Currents experience magnetic forces. There are lots of cross products and we need to keep them all straight.
2) Motional EMFs. Discuss the bar moving through a magnetic field. Take about how the charge carriers experience magnetic forces because they are moving. Moving charges is current.
3) Check their understanding with two concept quizzes.
4) Do a demo illustrating eddy currents. Talk about how this is the exact same situation as the bar touching the conducting rails while moving.
5)

$$F = q\vec{v} \times \vec{B}$$

$$\vec{B} = \frac{\mu_0 I}{4\pi} \frac{\Delta\vec{s} \times \hat{r}}{r^2}$$

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I$$

$$\vec{B} = \frac{\mu_0 q}{4\pi} \frac{\vec{v} \times \hat{r}}{r^2}$$

$$F = I\vec{l} \times \vec{B}$$

$$\vec{\tau} = \vec{\mu} \times \vec{B}$$

6

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4

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I$$

2

3

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1

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5

6

moving charges **feel** magnetic forces.

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4

$$\vec{B} = \frac{\mu_0 I}{4\pi} \frac{\Delta\vec{s} \times \hat{r}}{r^2}$$

currents **create** magnetic fields.

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1

3

$$F = I\vec{l} \times \vec{B}$$

current-carrying wires **feel** magnetic forces

$$\vec{\tau} = \vec{\mu} \times \vec{B}$$

current loops **feel** magnetic torque.

5

What's ahead

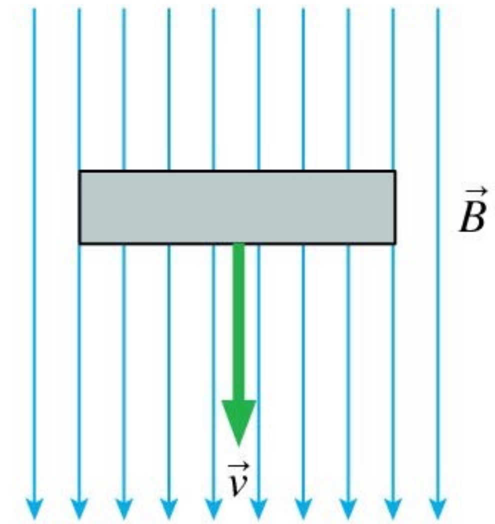
$$\vec{E} = \frac{kq}{r^2}\hat{r}$$

How electric fields are created…. right?

<u>There is a totally different way to create an electric field!!</u>

Question #22A

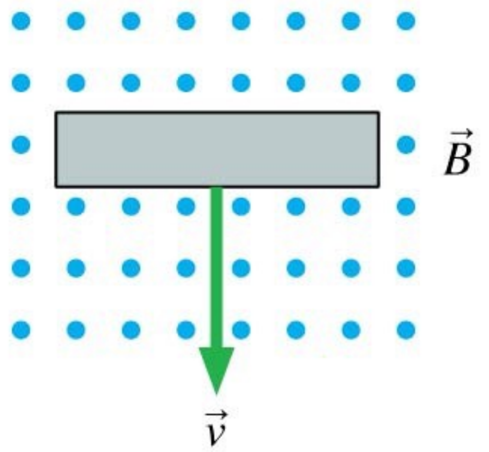
A metal bar moves through a magnetic field. The induced charges on the bar are

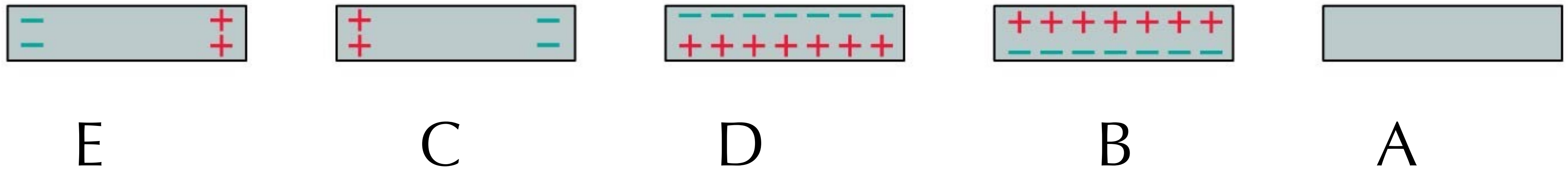


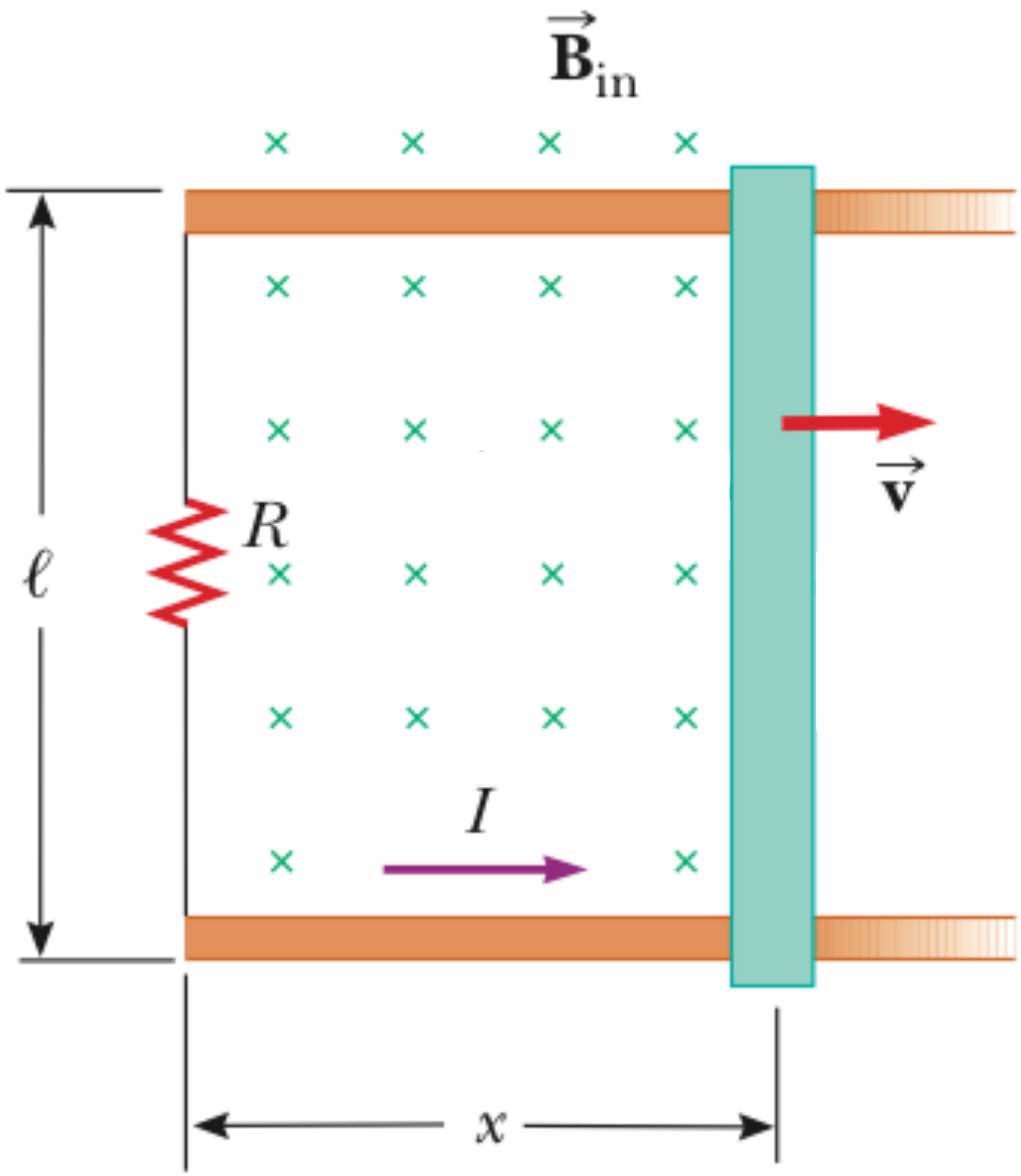
E B A C D

Question #23

A metal bar moves through a magnetic field. The induced charges on the bar are







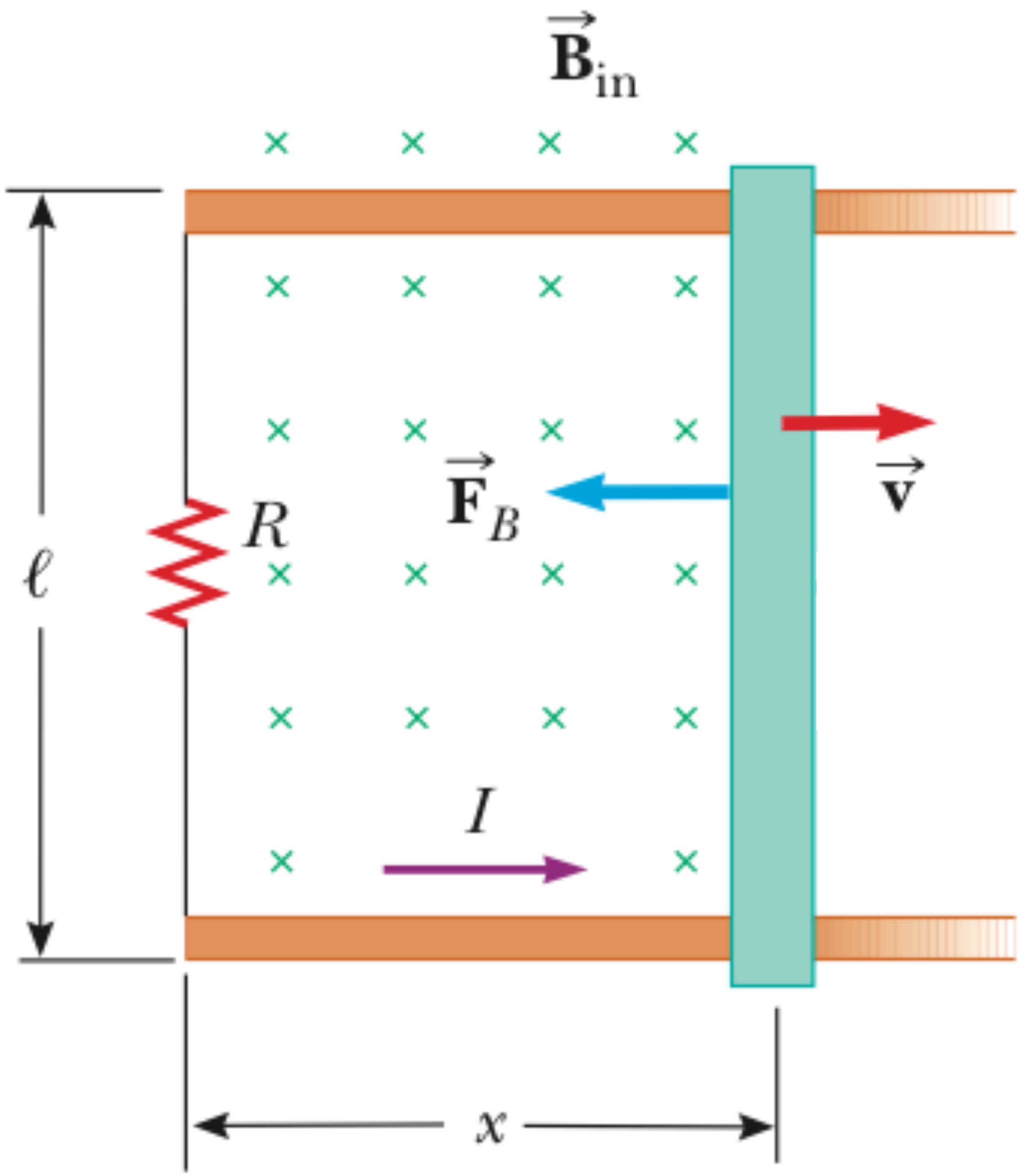
What we know:

$$F = q\vec{v} \times \vec{B}$$

$$F = I\vec{l} \times \vec{B}$$

Explain to your neighbor why a current flows in this situation.

How many forces will the bar experience?



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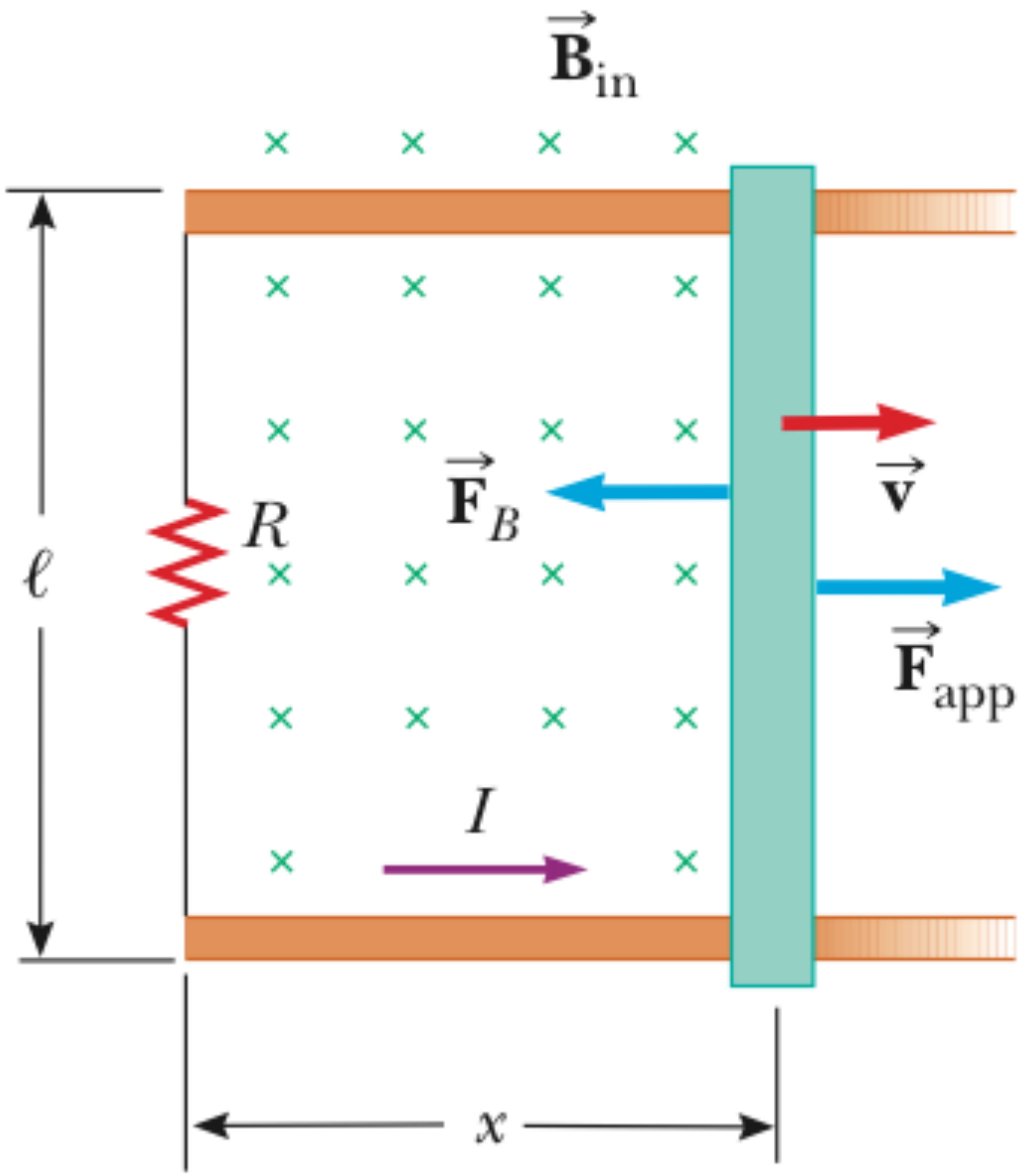

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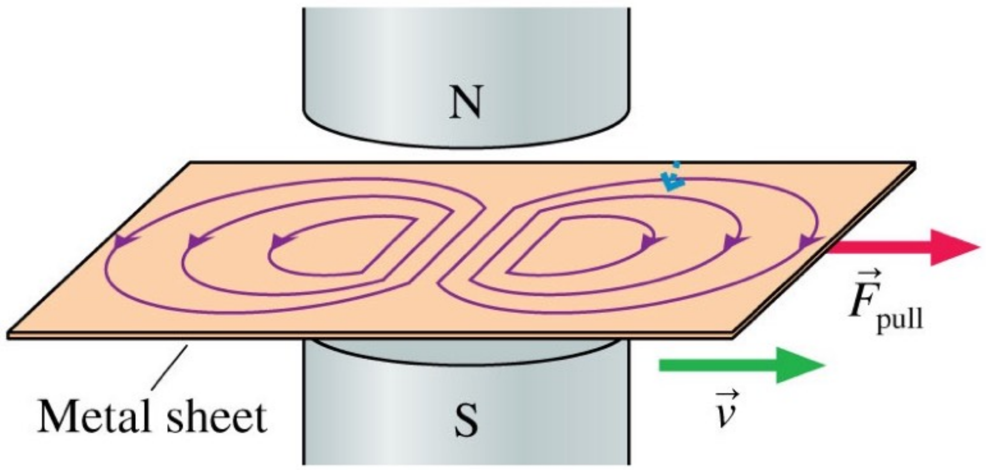
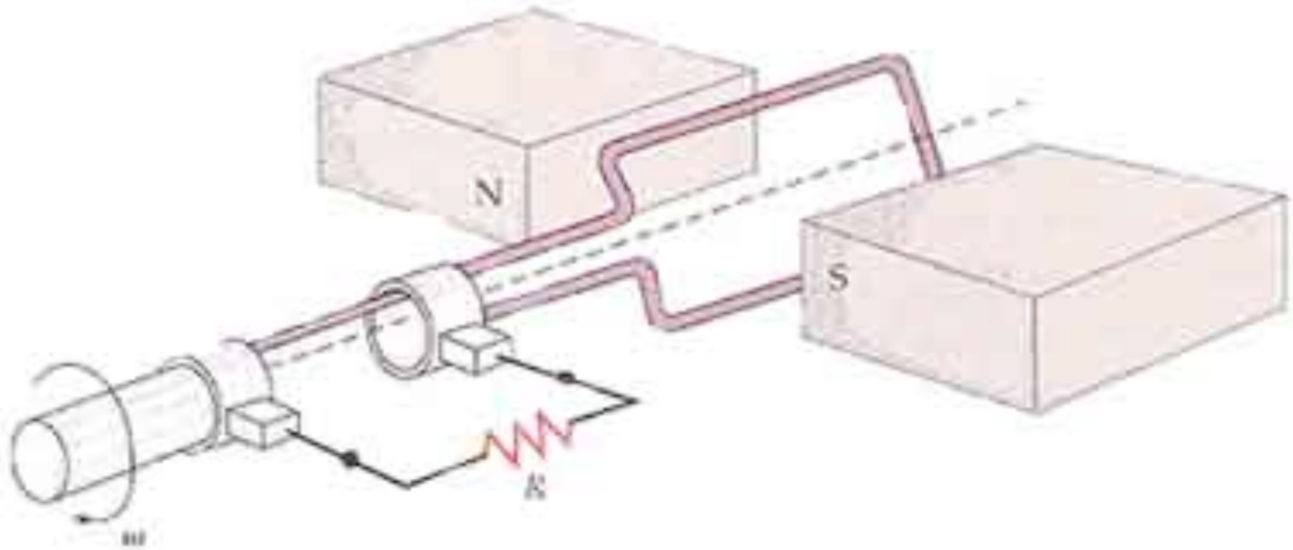
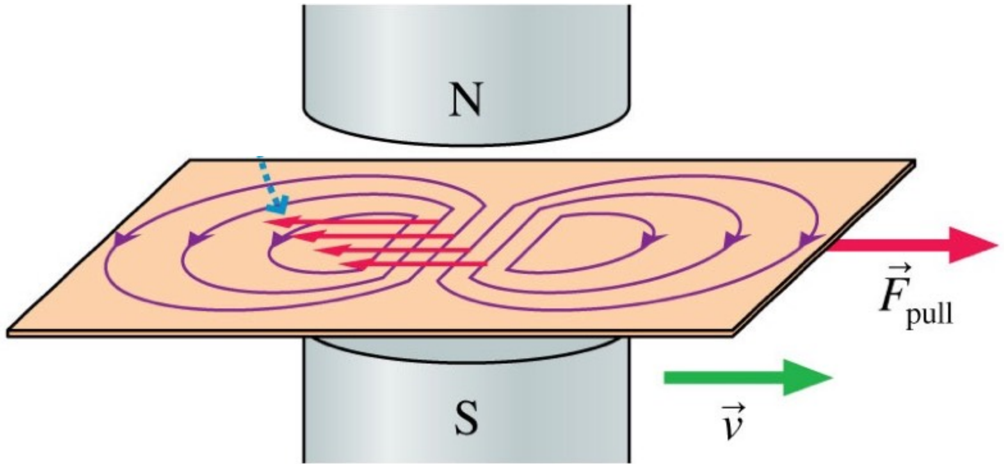
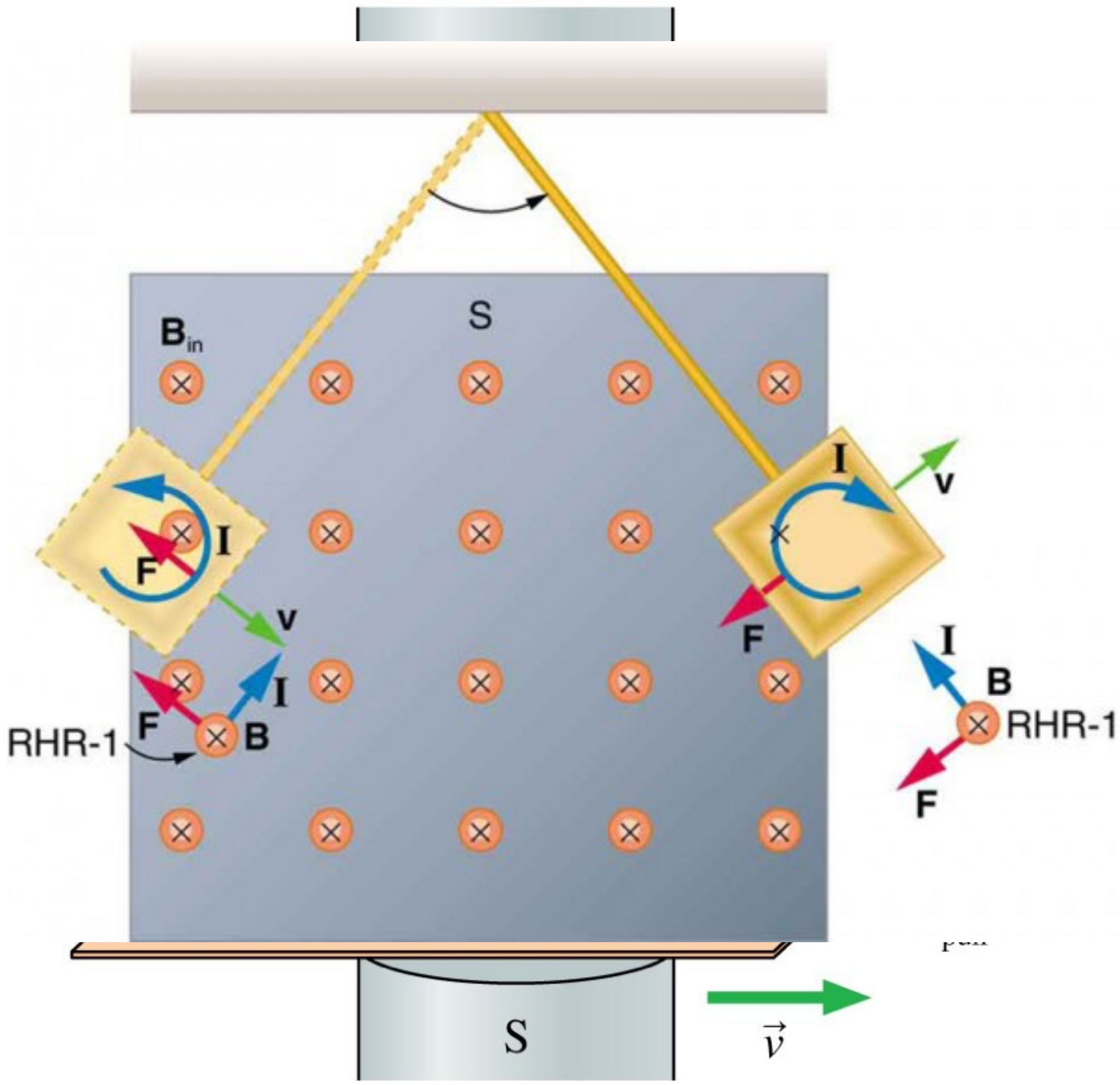
Eddy currents, magnetic braking, generators

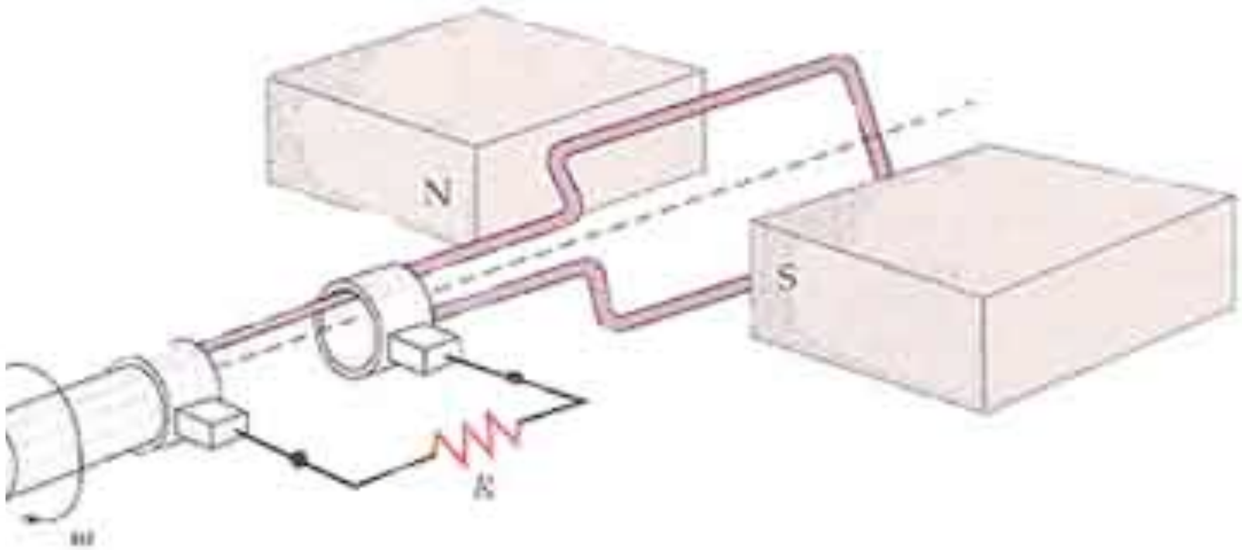






Eddy currents, magnetic braking, generators





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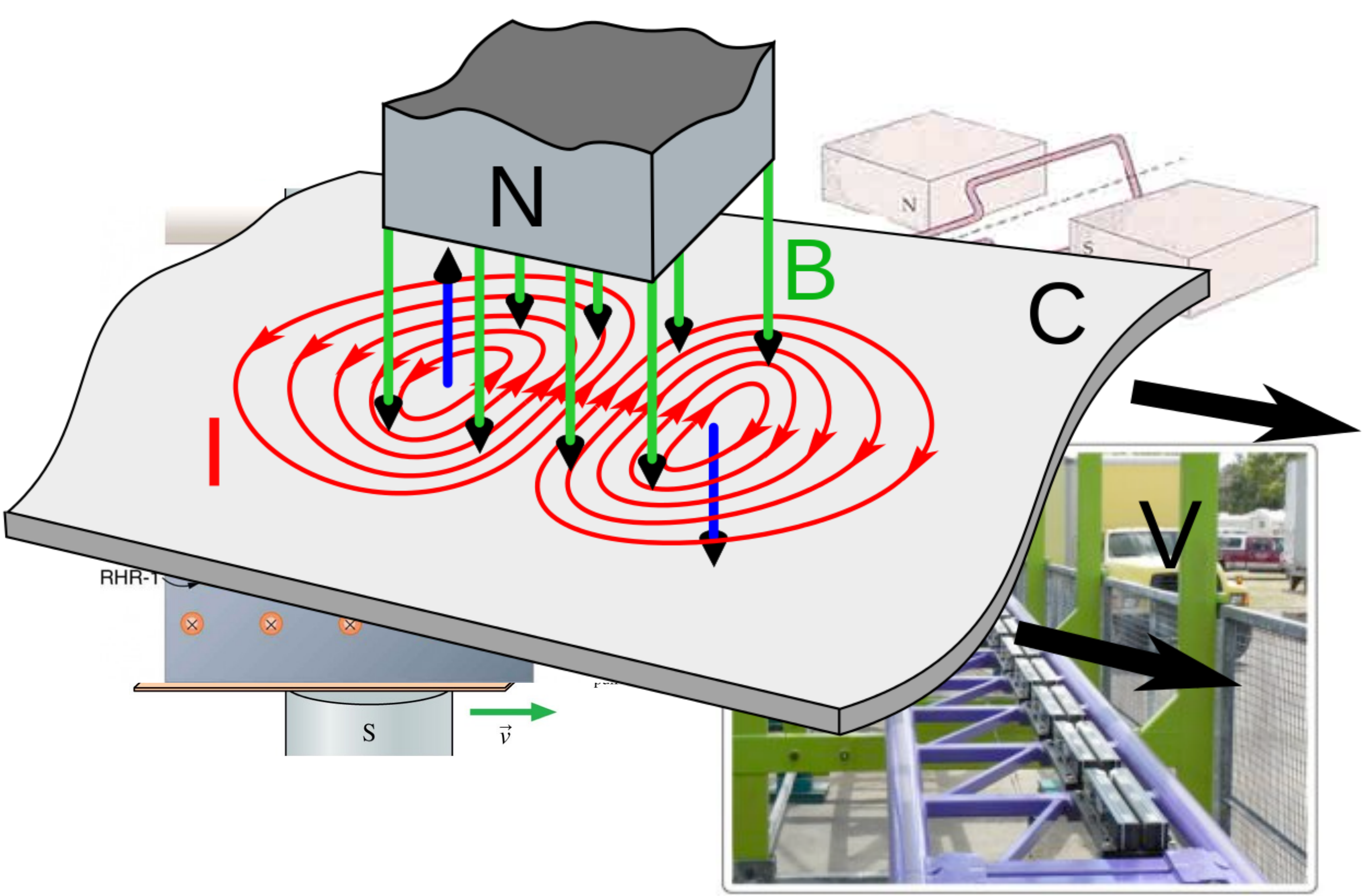

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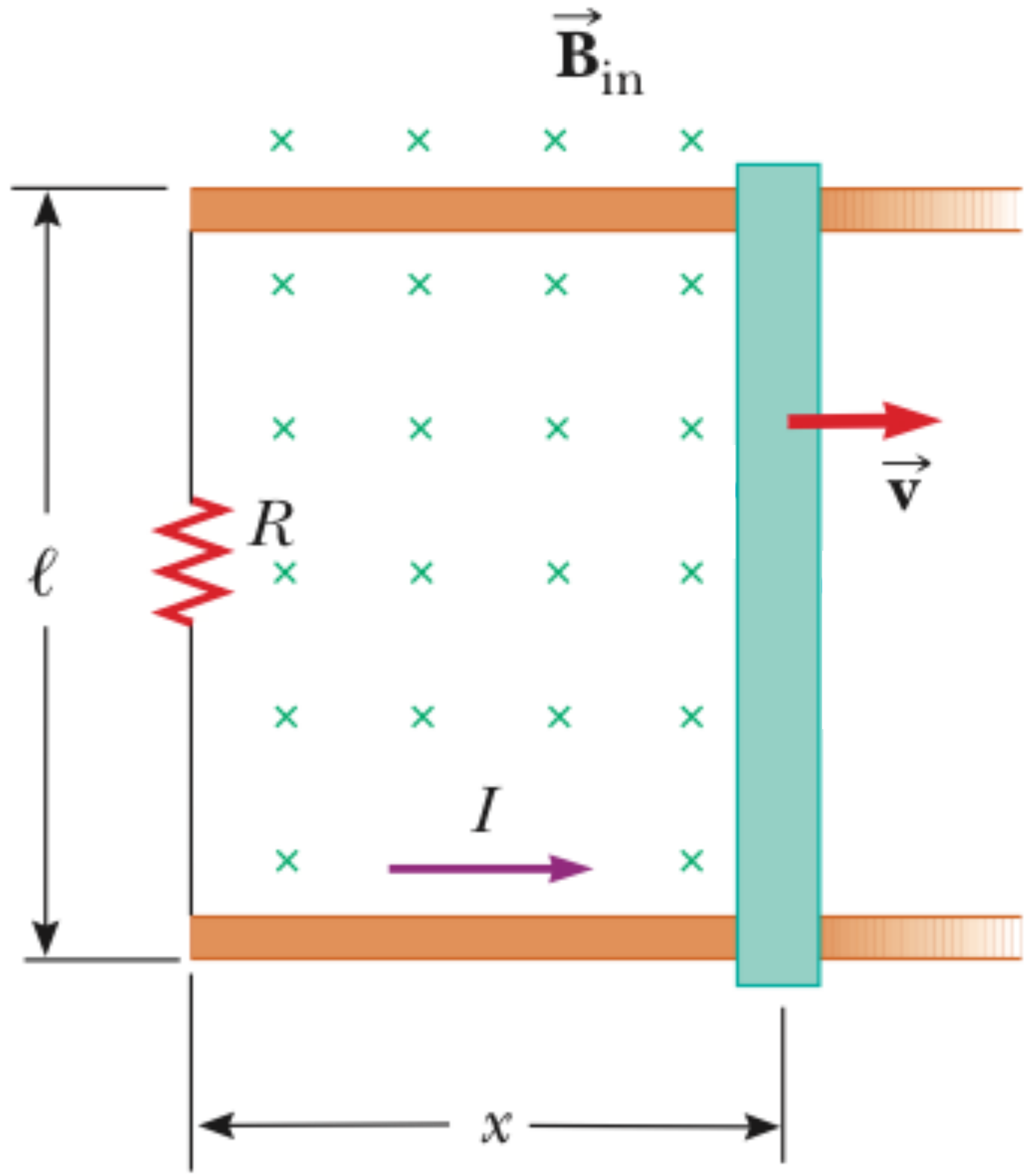
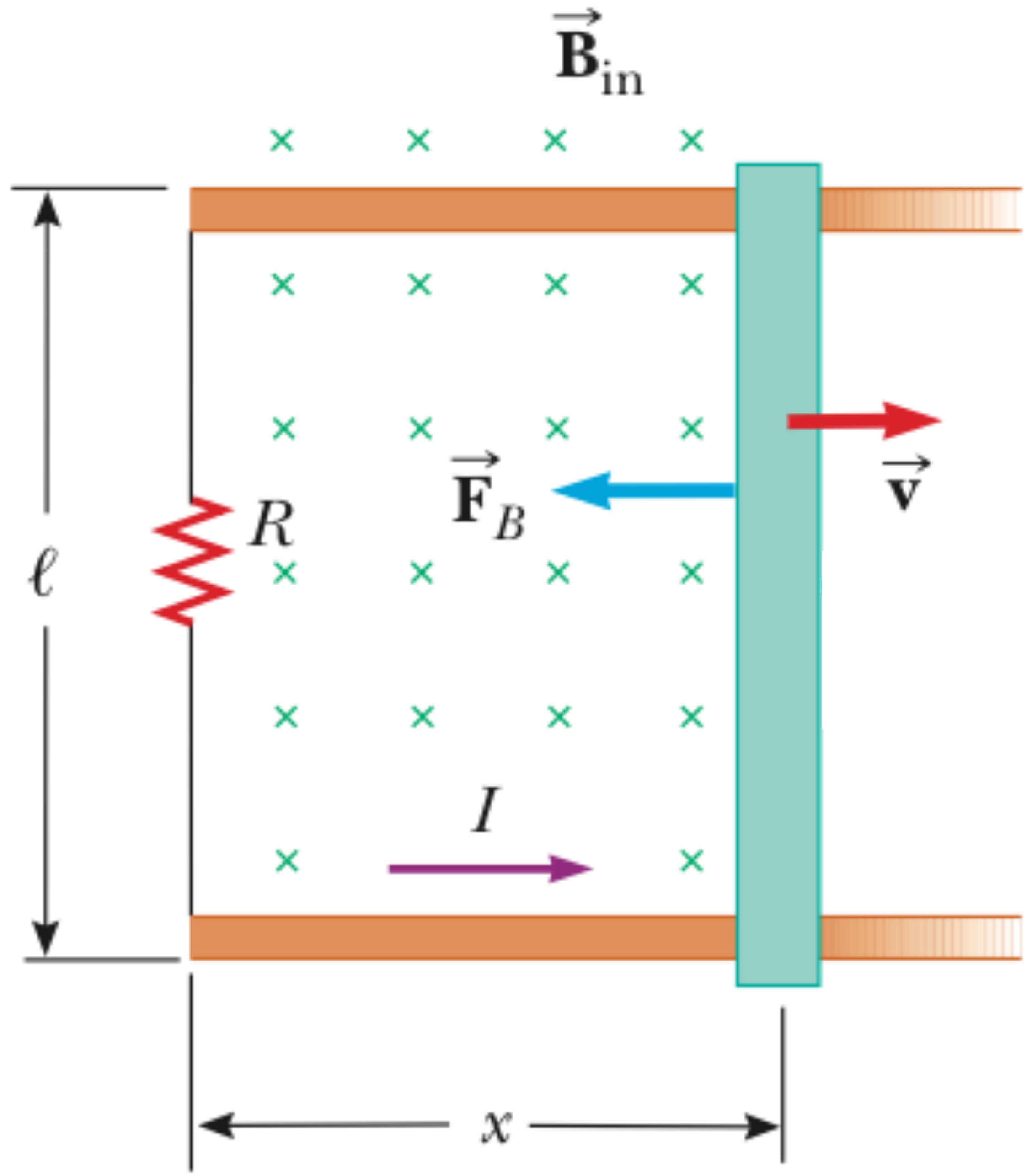


$\vec{B}_{in}$
R
ℓ
I
$\vec{v}$
x



$\vec{B}_{in}$
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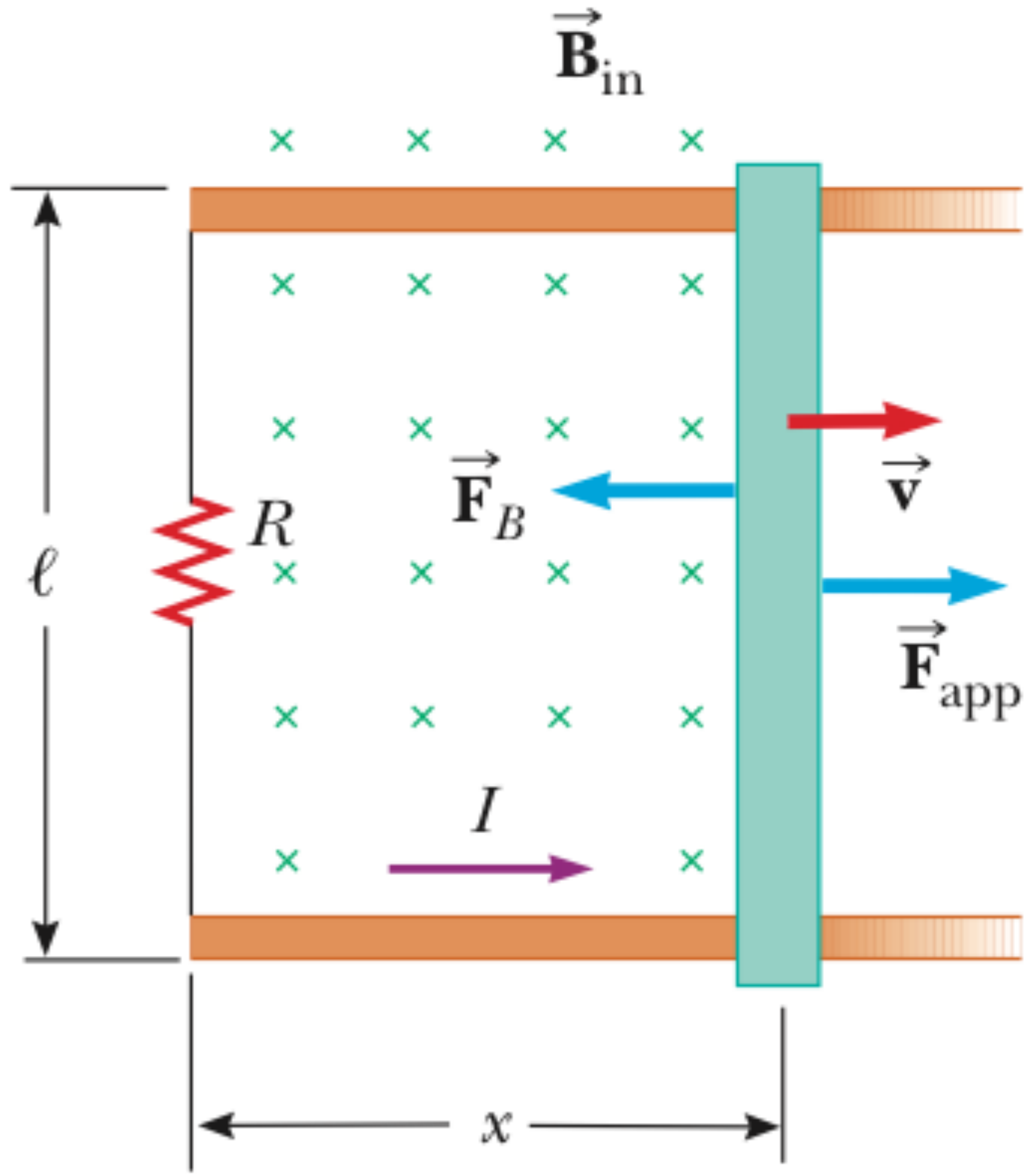
$\vec{B}_{in}$
R
$\vec{F}_B$
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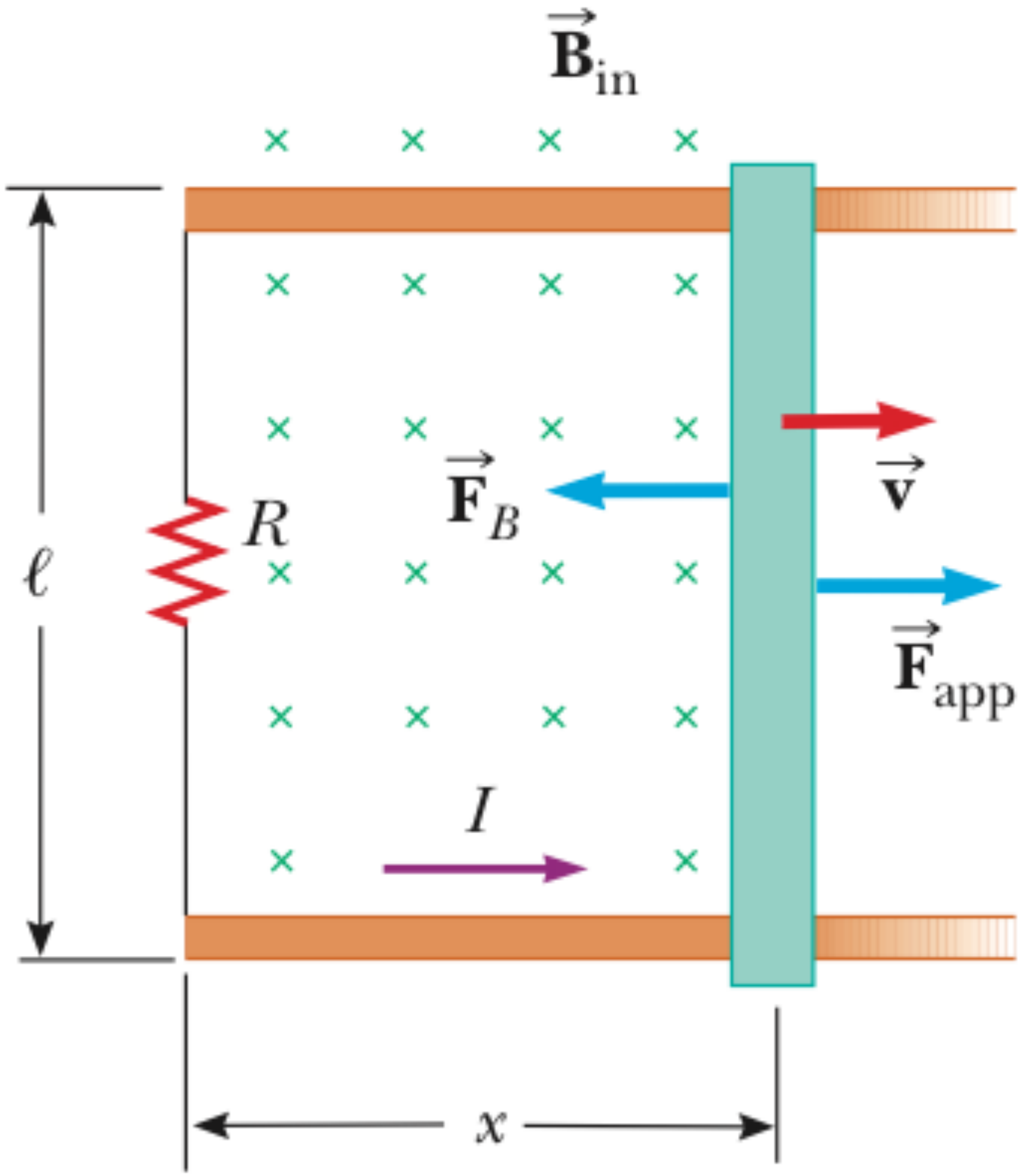
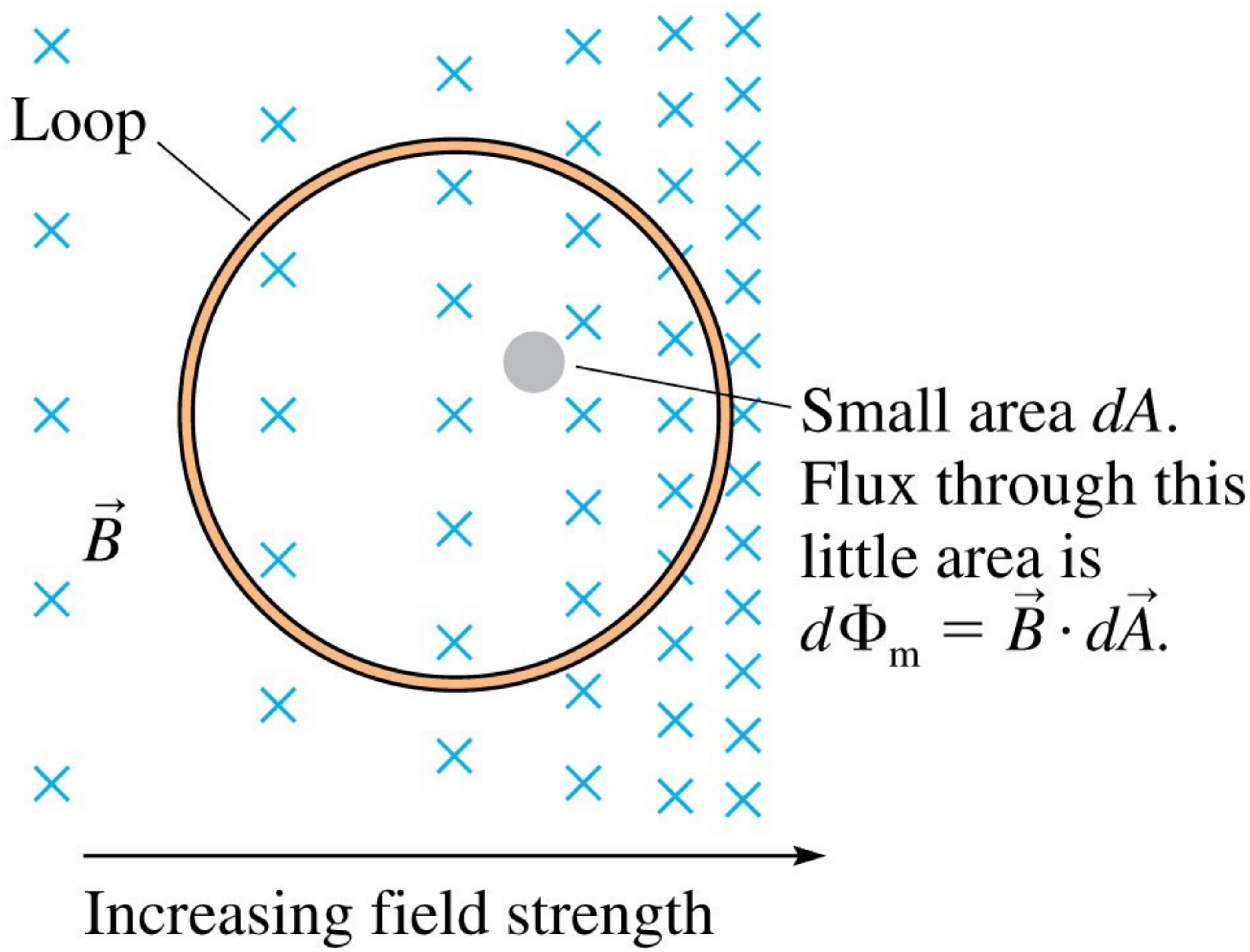
x

$$\Phi_m = \int_{\text{area of loop}} \vec{B} \cdot d\vec{A}$$



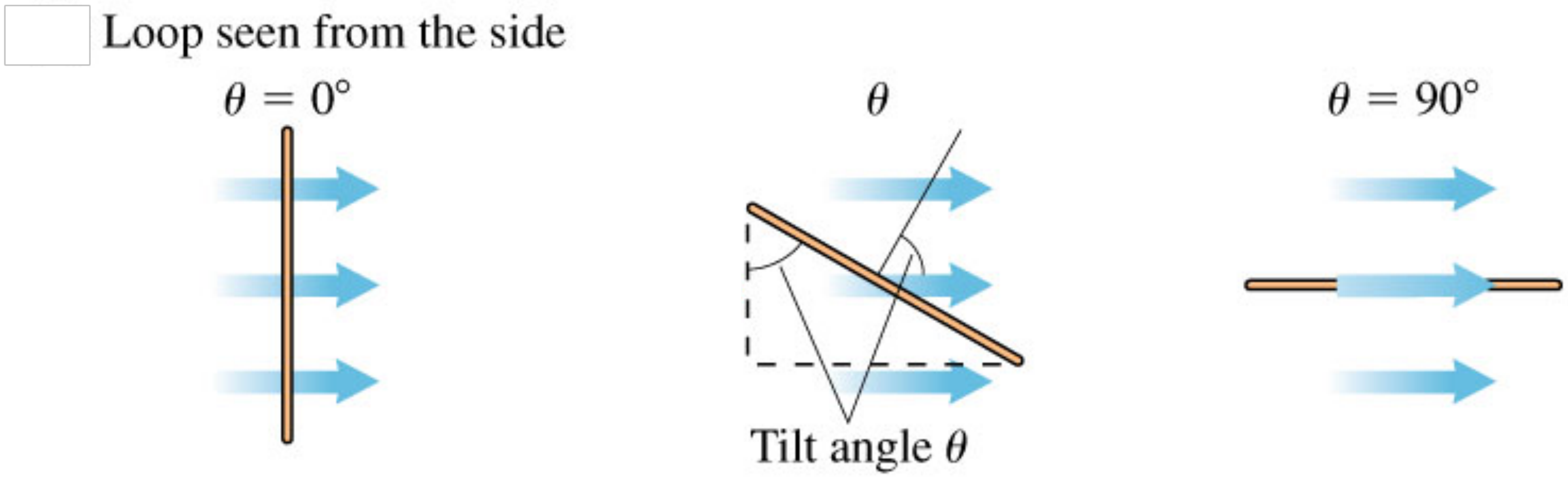
Magnetic Flux



$$\Phi_m = \int_{\text{area of loop}} \vec{B} \cdot d\vec{A}$$

Flux again

Draw the loop and field from the perspective of a person standing to the right of the loop looking left.



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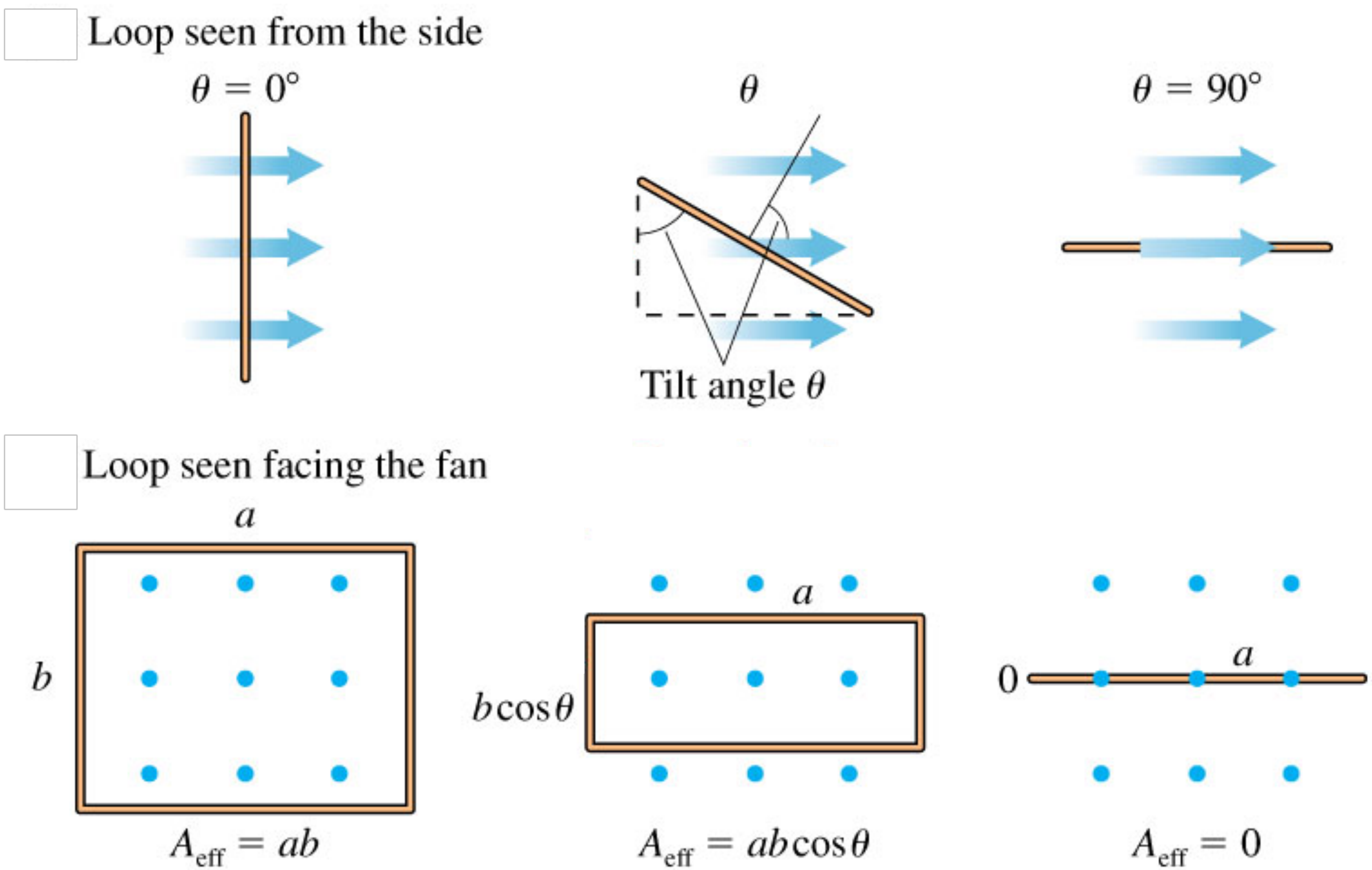
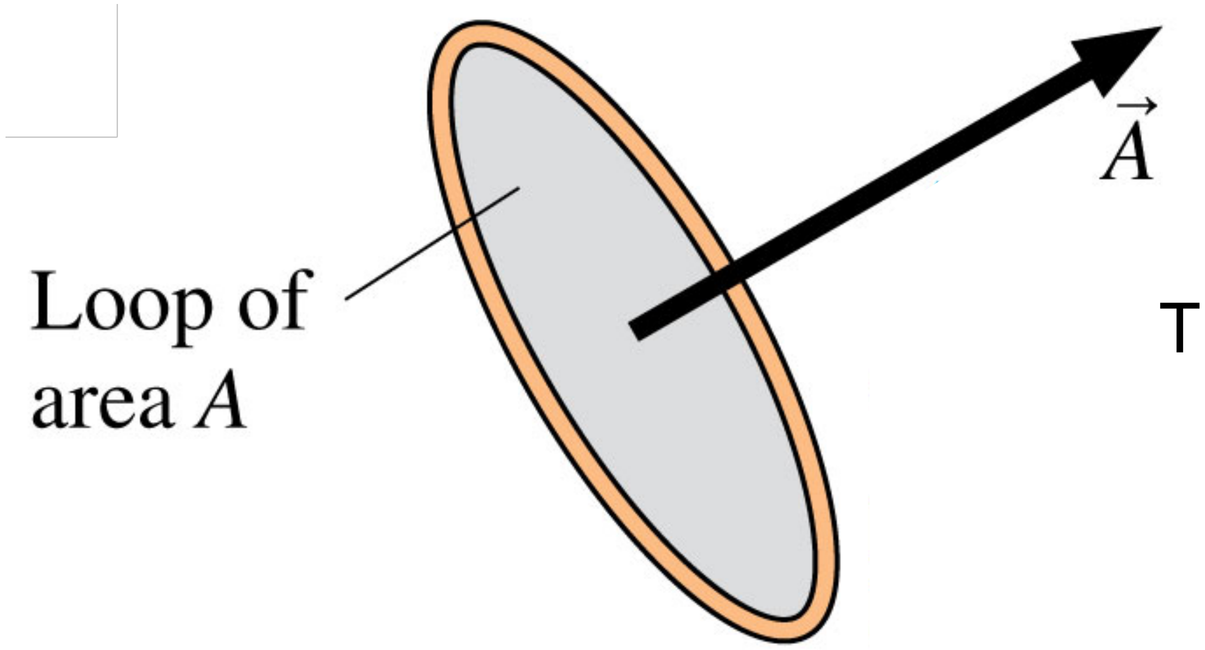


Area Vector

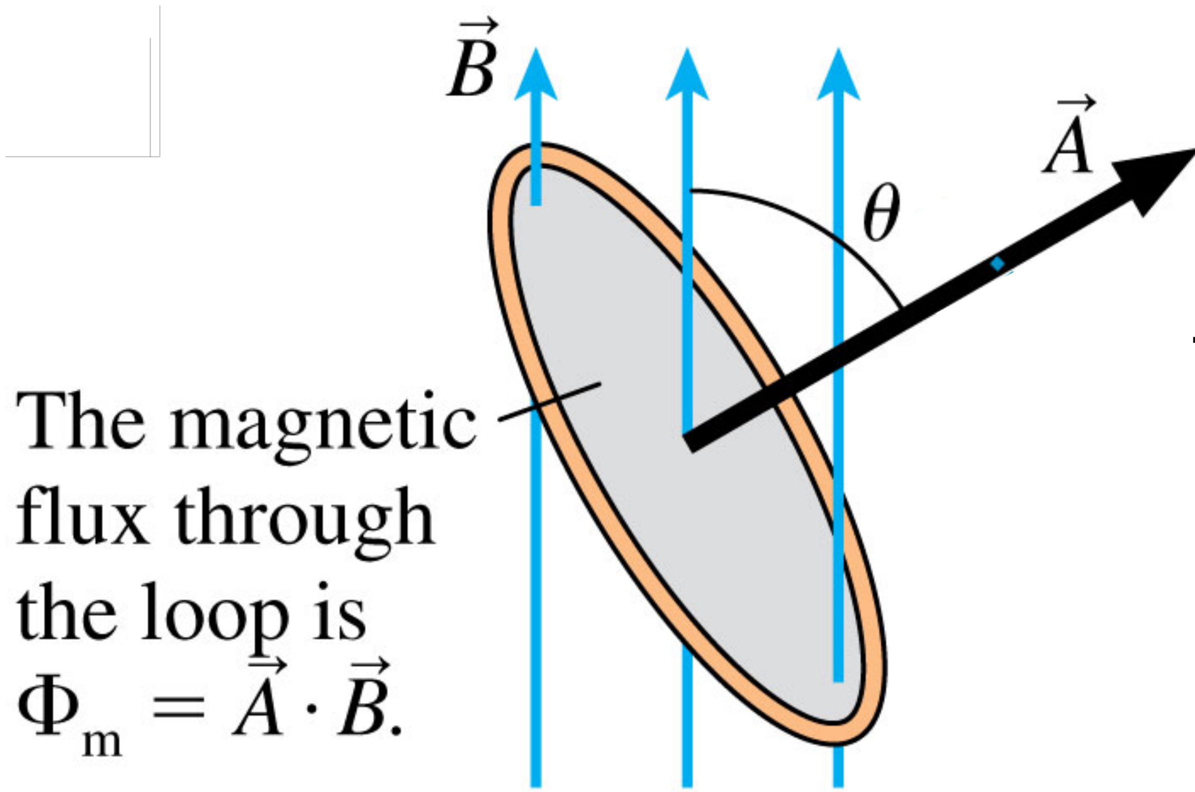


$$\Phi_m = A_{eff}B = AB\cos\theta$$

The SI unit of magnetic flux is the **weber**:

1 weber = 1 Wb = 1 T m^2

Area Vector



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The SI unit of magnetic flux is the **weber**:

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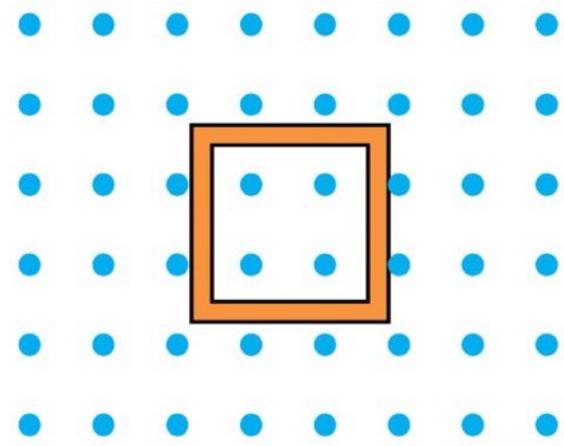
Question #24

Which loop has the larger magnetic flux through it?

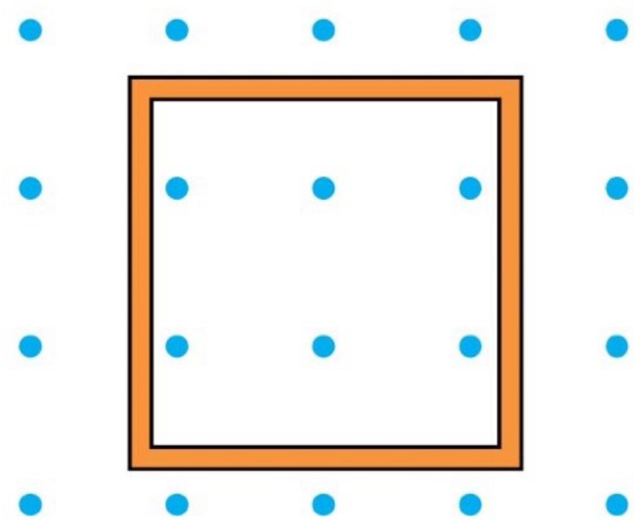
A. Loop A.
B. Loop B.
C. The fluxes are the same.
D. Not enough information to tell.

A.



This field is twice as strong.

B.



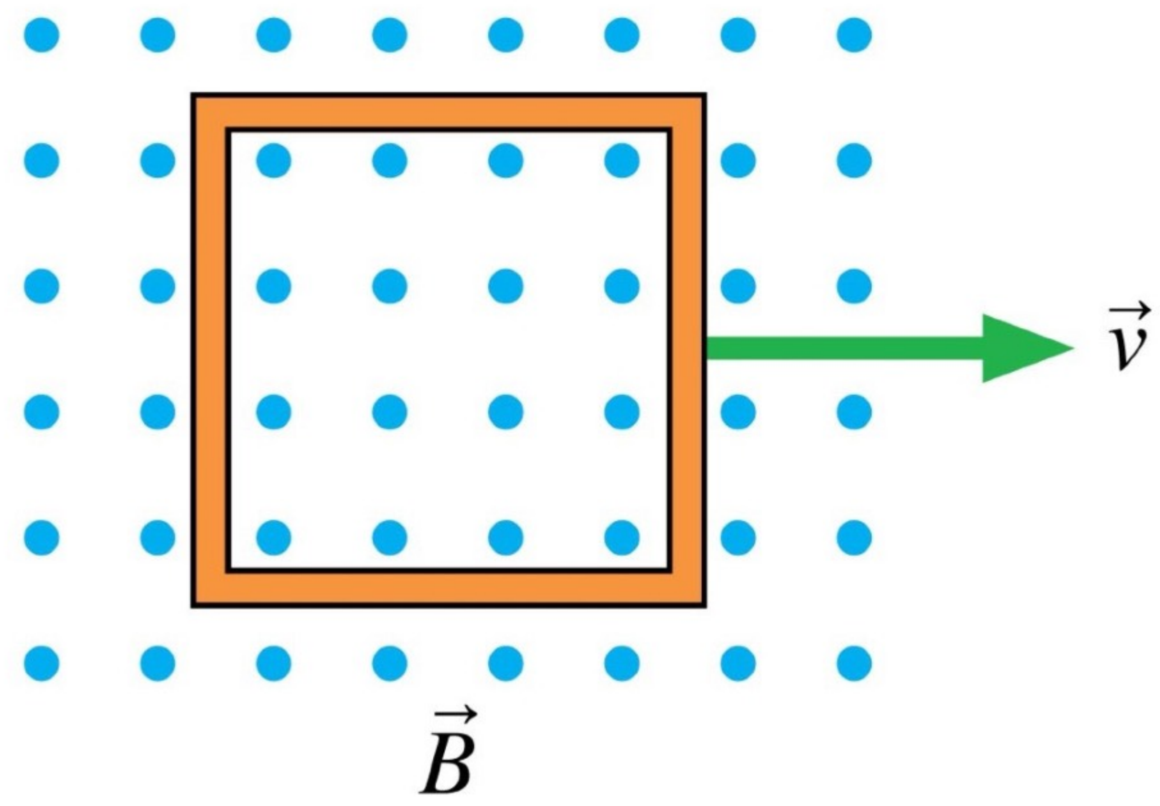
This square is twice as wide.

Question #25

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

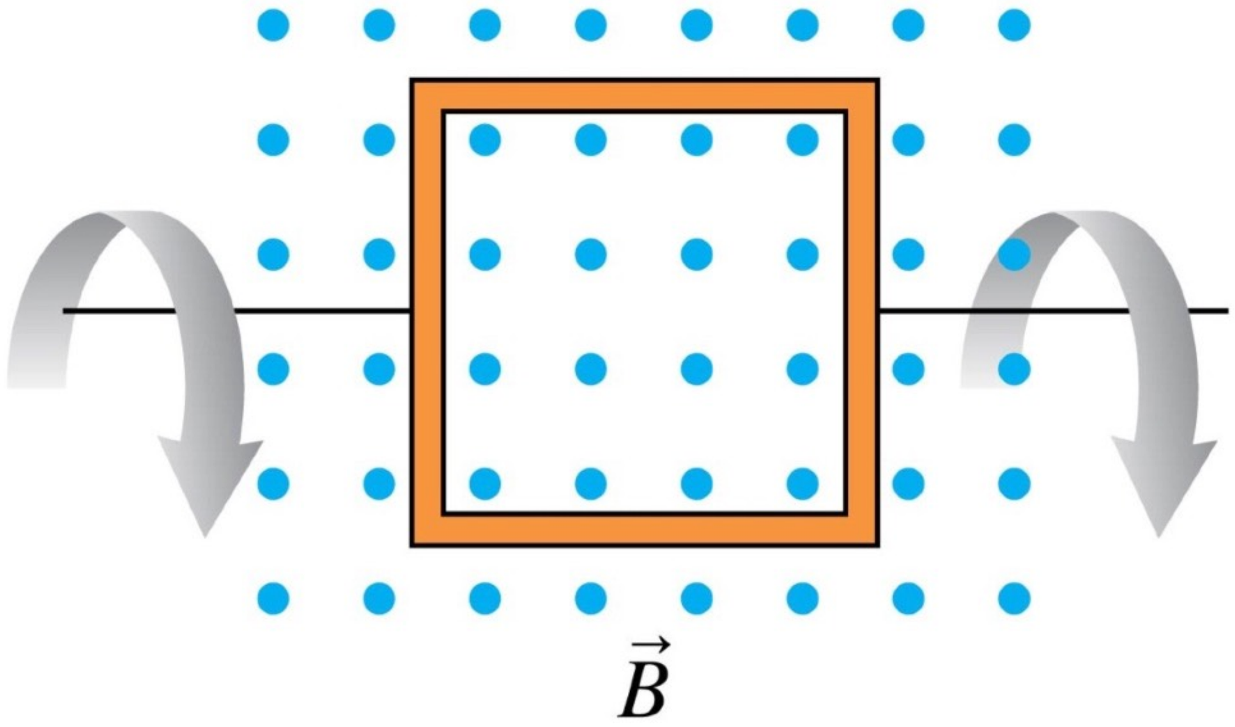
A. No.

B. Yes.



Question #26

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



C. Yes.

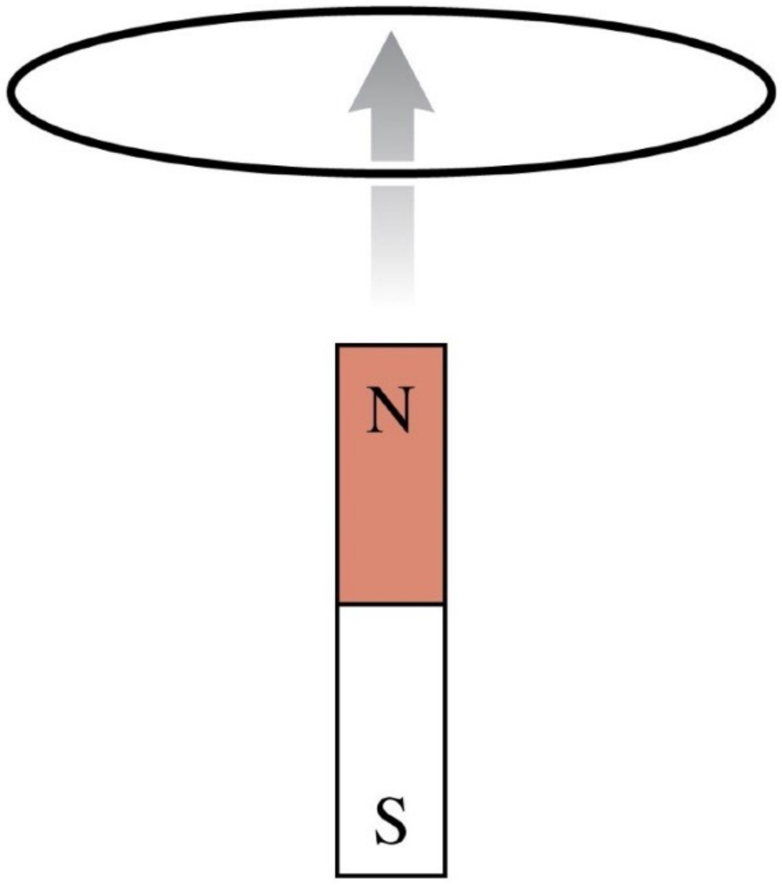
D. No.

Lenz's Law

There is an induced current in a closed, conducting loop *if and only if the magnetic flux through the loop is changing*. The direction of the induced current *is such that the induced magnetic field opposes the change in flux*.

Question #27

The bar magnet is pushed toward the center of a wire loop. Which is true?



A. There is no induced current in the loop.
B. There is a counterclockwise induced current in the loop.
C. There is a clockwise induced current in the loop.

Question #28

The current in the straight wire is decreasing. Which is true?

B. There is a counterclockwise induced current in the loop.
C. There is no induced current in the loop.
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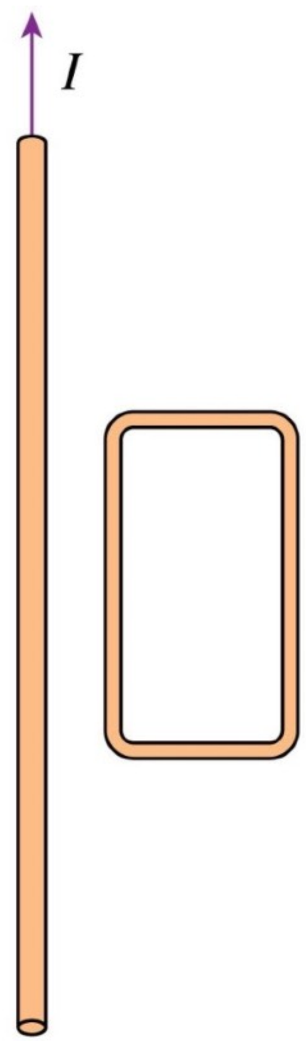

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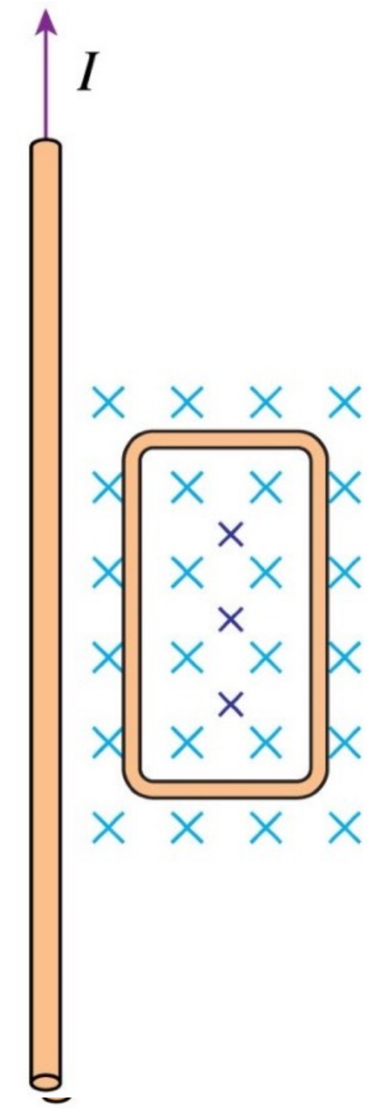
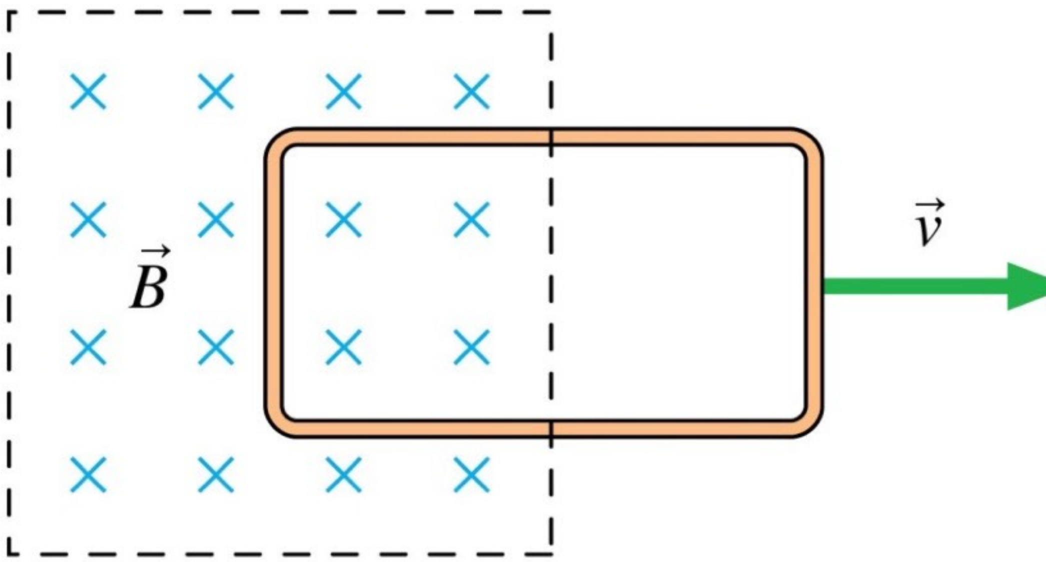


Question #29

The magnetic field is confined to the region inside the dashed lines; it is zero outside. The metal loop is being pulled out of the magnetic field. Which is true?



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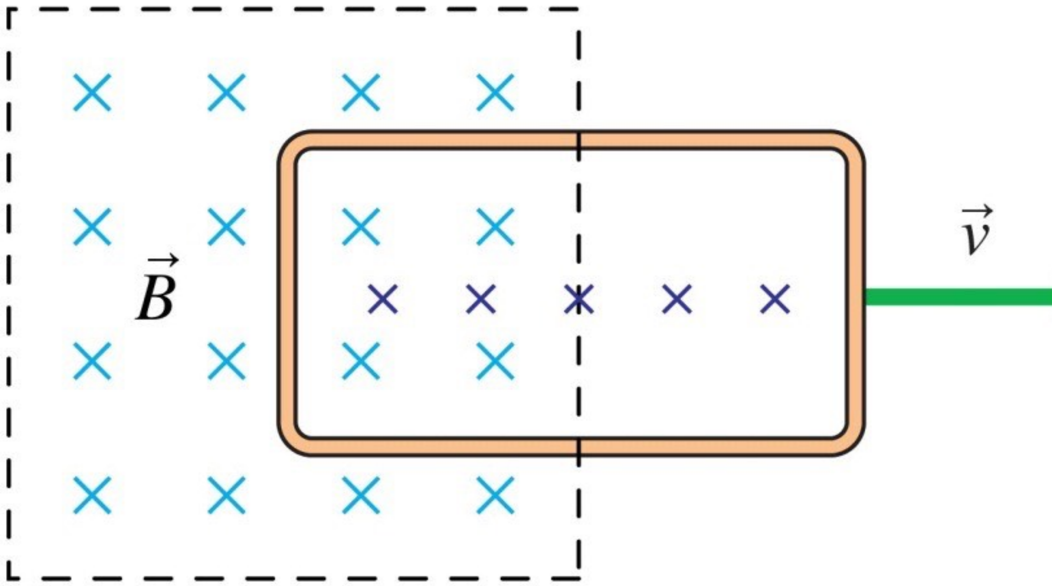
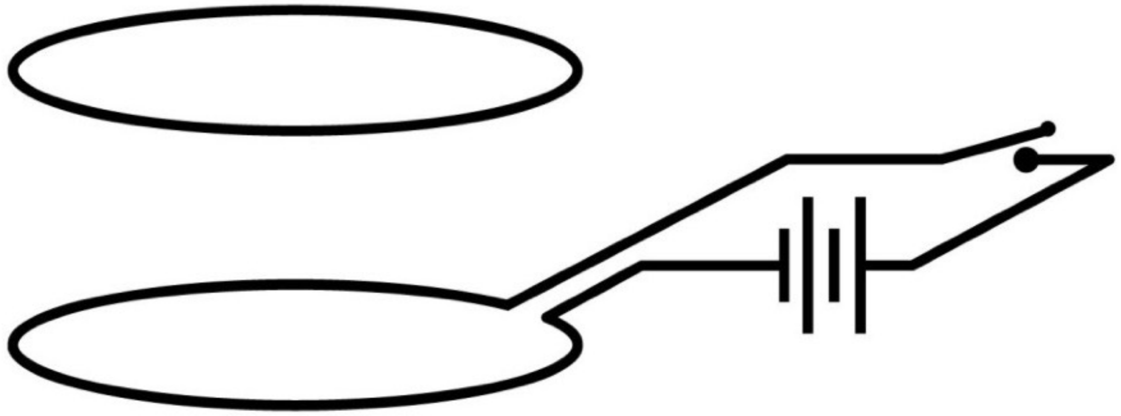


C. There is a counterclockwise induced current in the loop.
D. There is no induced current in the loop.
E. There is a clockwise induced current in the loop.

Question #30

Immediately after the switch is closed, the lower loop exerts ____ on the upper loop.

A. a torque
B. an upward force
C. a downward force
D. no force or torque



Faraday's Law

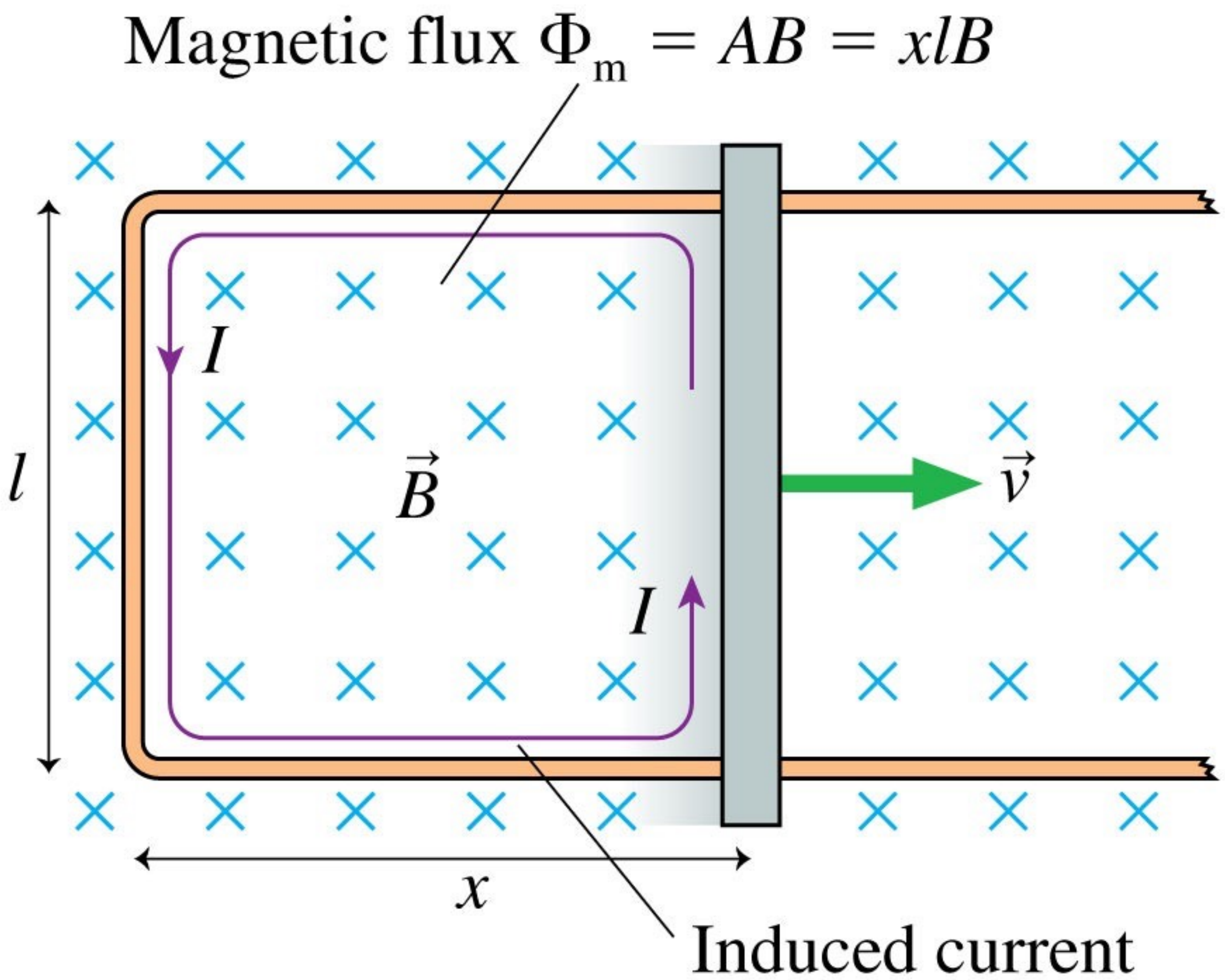
The magnitude of the potential difference is given by Faraday's law…..

$$\mathcal{E} = |\frac{d\Phi}{dt}|$$

The direction is given by Lenz's law…

Let's try it out

$$\mathcal{E} = |\frac{d\Phi}{dt}|$$



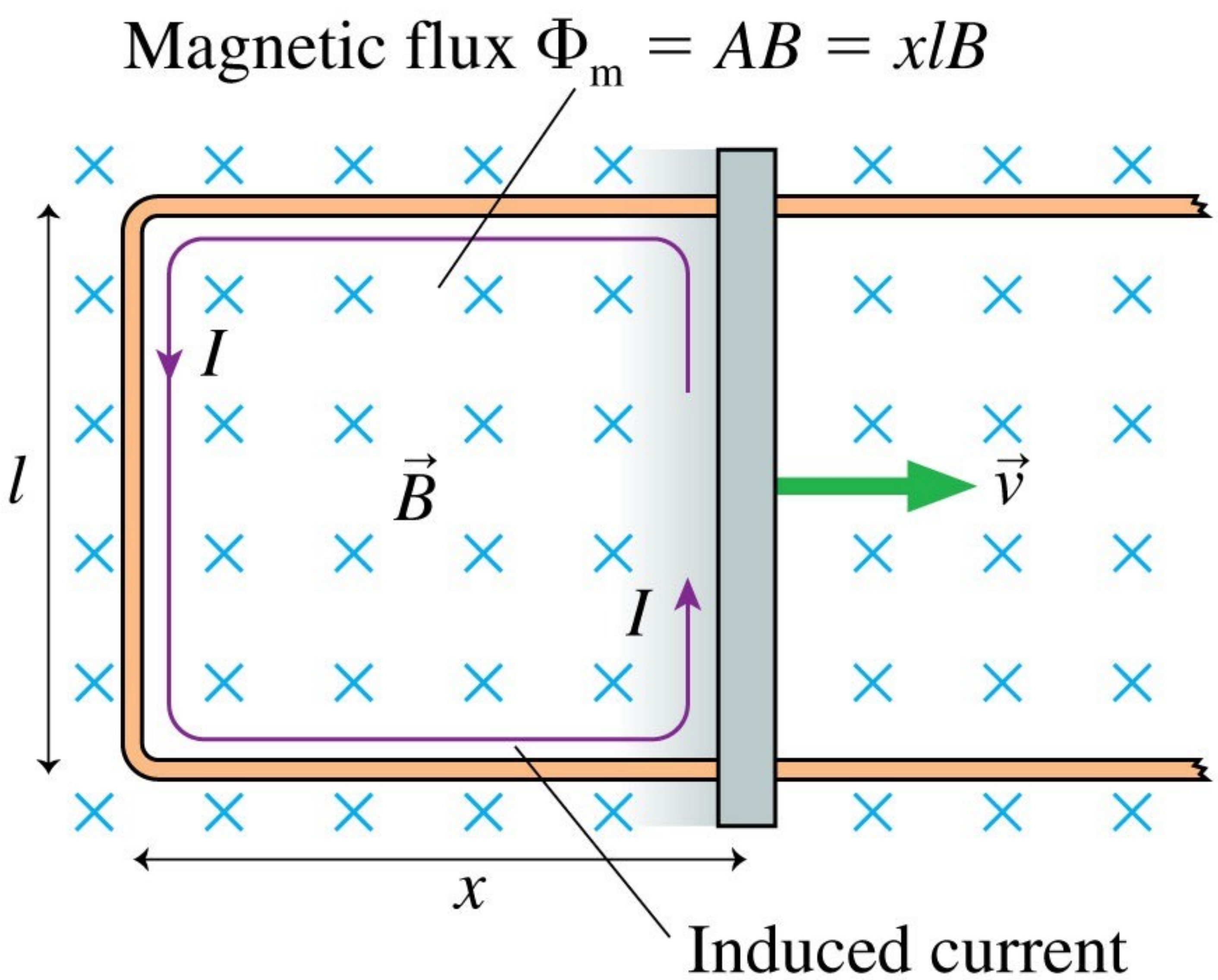
You and your neighbor use different methods for finding the induced emf.

1) Use the idea of magnetic forces.
2) Use Faraday's law.

Compare your answers.

Let's try it out

$$\mathcal{E} = |\frac{d\Phi}{dt}|$$



$$\mathcal{E} = \left|\frac{d\Phi_m}{dt}\right| = \frac{d}{dt}(xlB) = \frac{dx}{dt}lB = vlB$$

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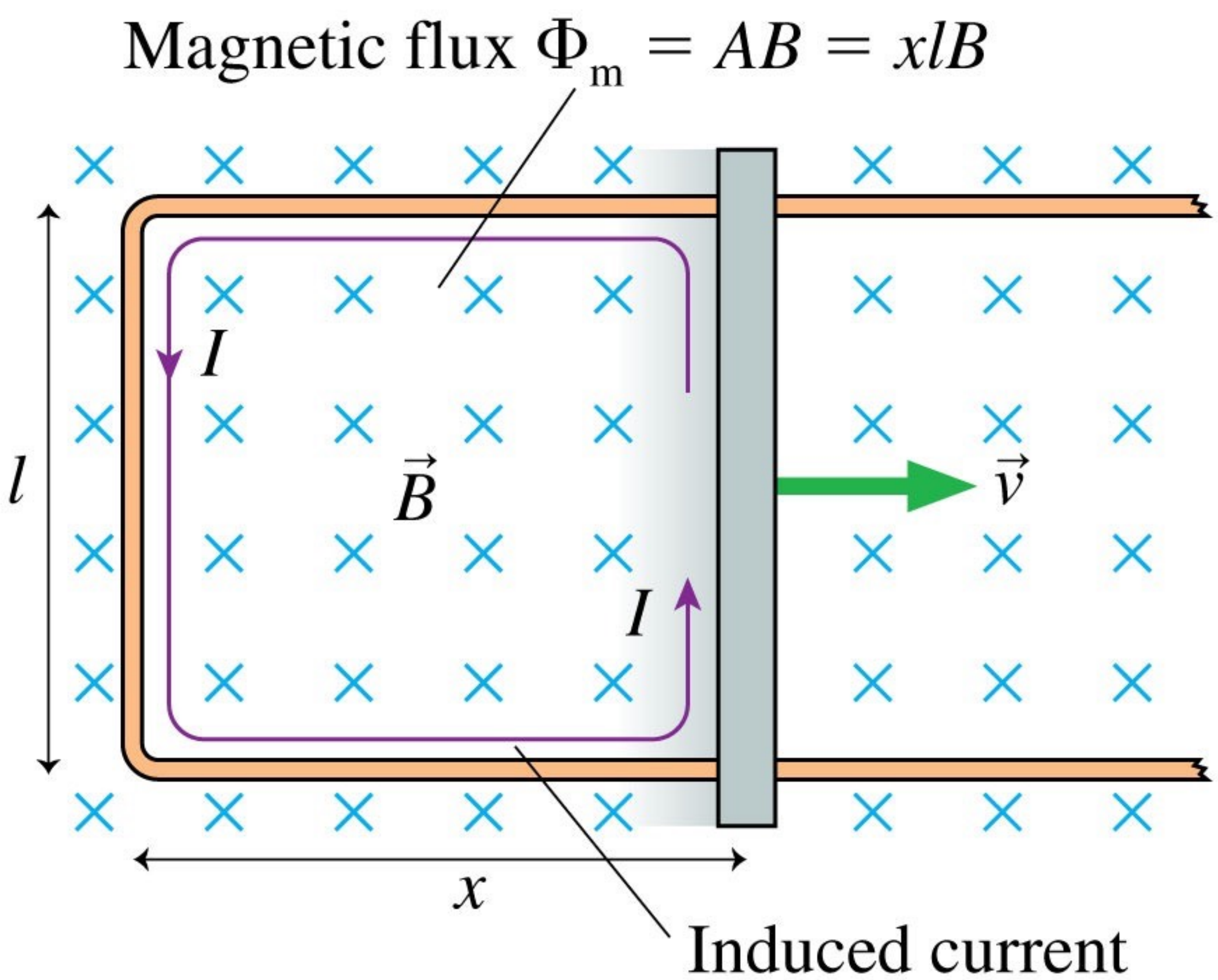

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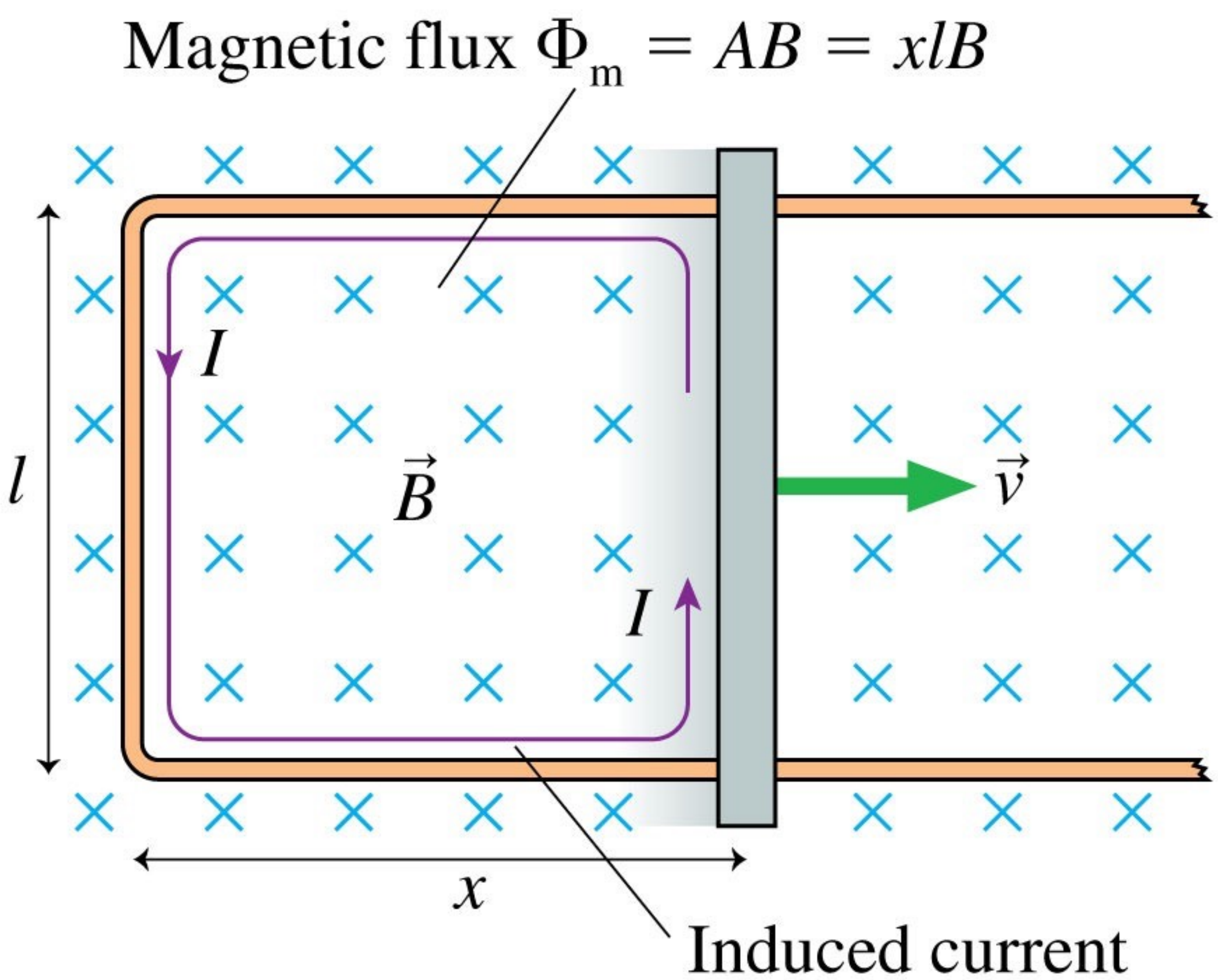

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$$E = vB$$

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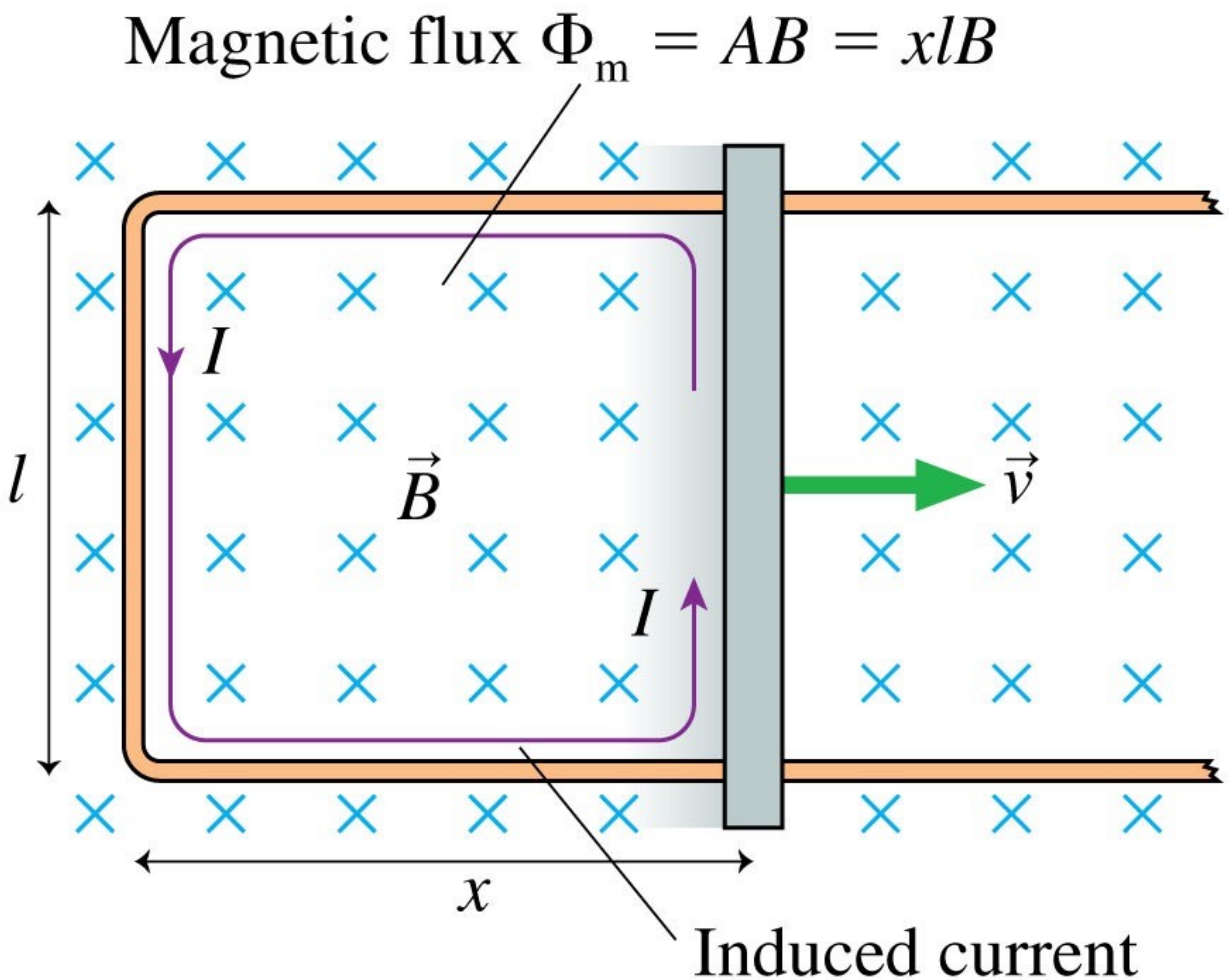
$$\mathcal{E} = |\frac{d\Phi}{dt}|$$



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1) Use the idea of magnetic forces.
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Compare your answers.

$$qE = qvB$$

$$E = vB$$

$$V = vBl$$

The induced emf around this loop is

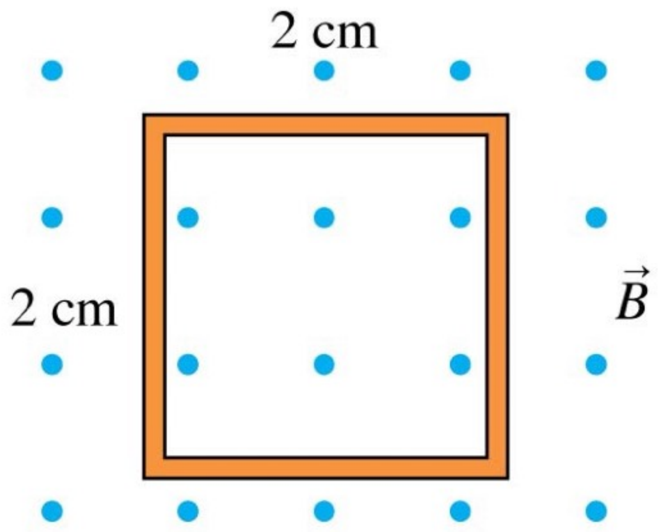
A. 200 V.

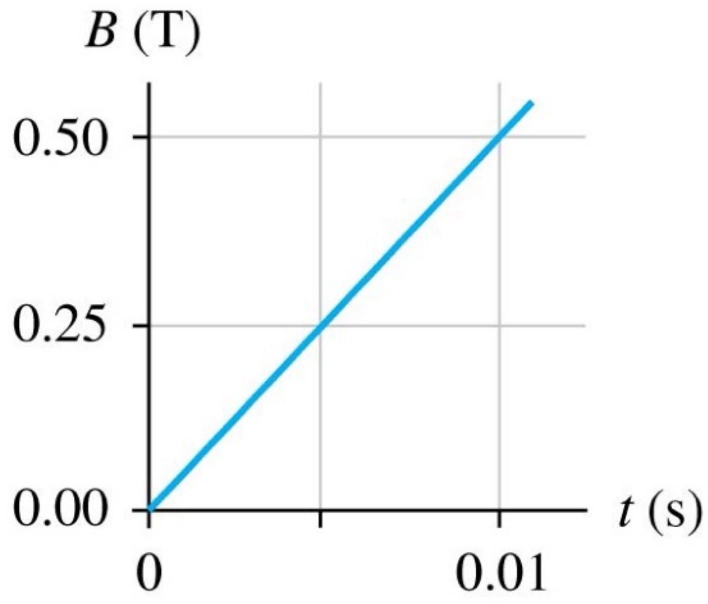
B. 50 V.

C. 2 V.

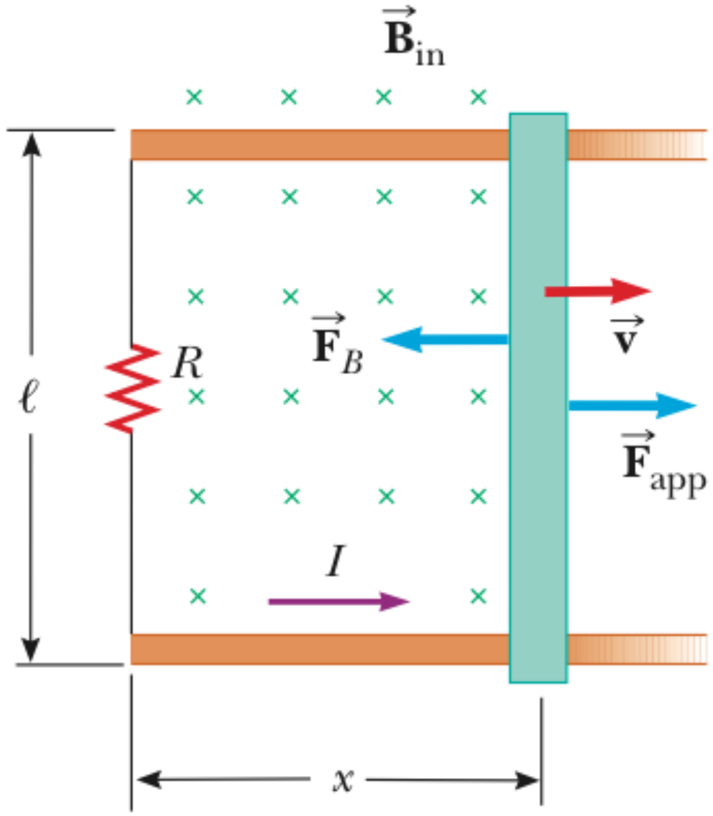
D. 0.5 V.

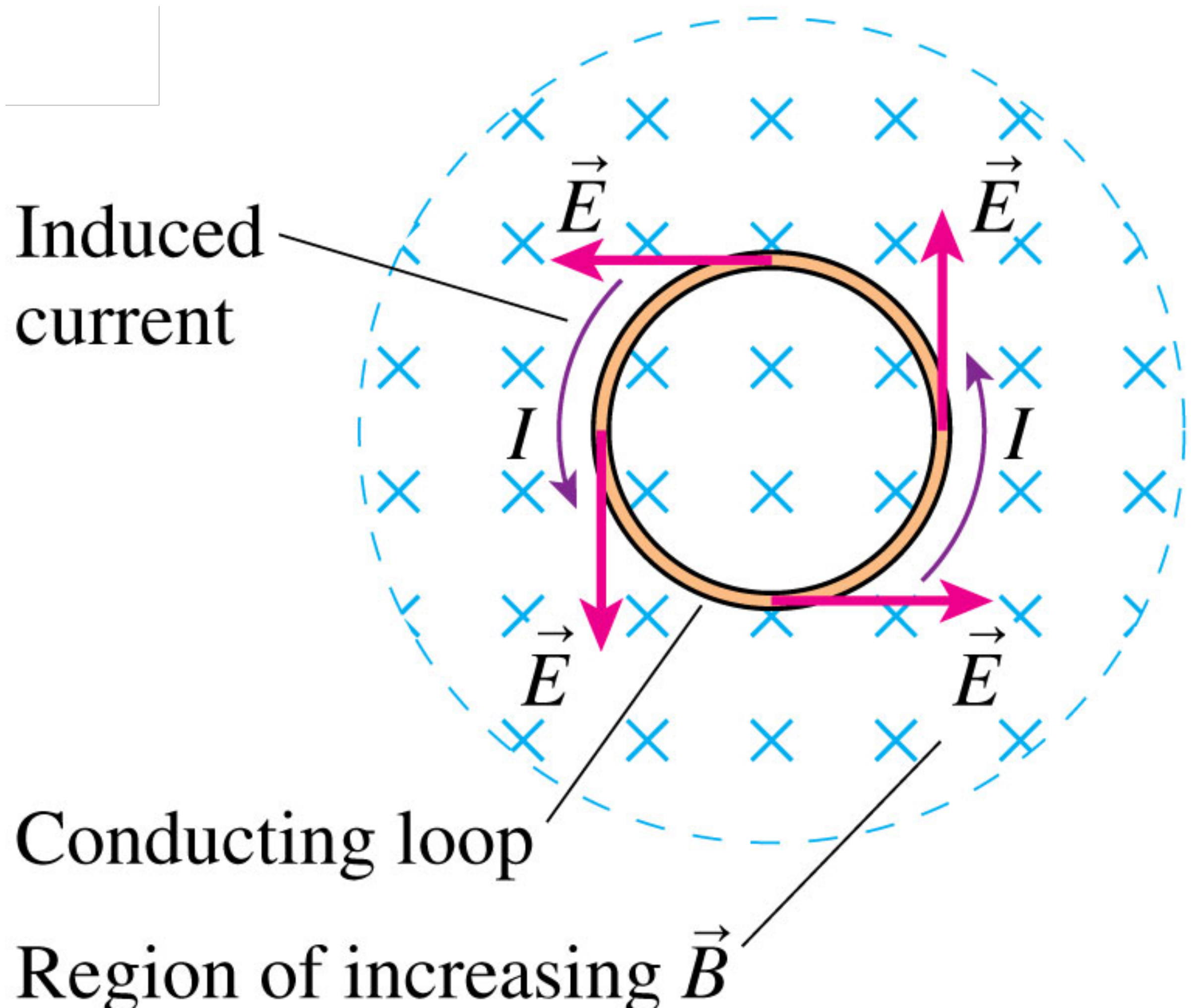
E. 0.02 V.





Induced Field





This is not the electric field that we are used to. It's a new kind of field called an "induced" electric field

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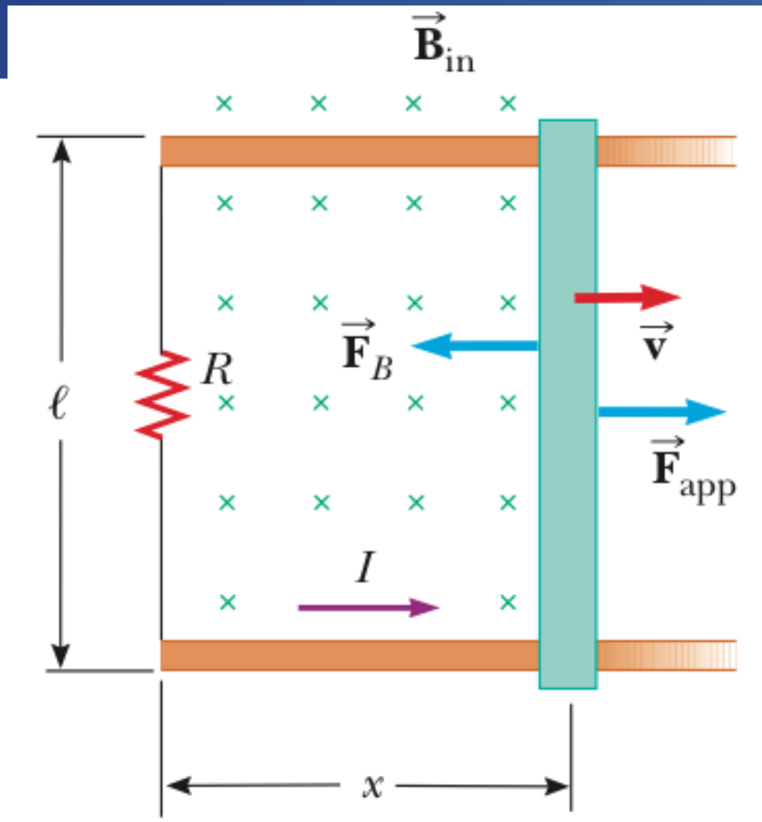
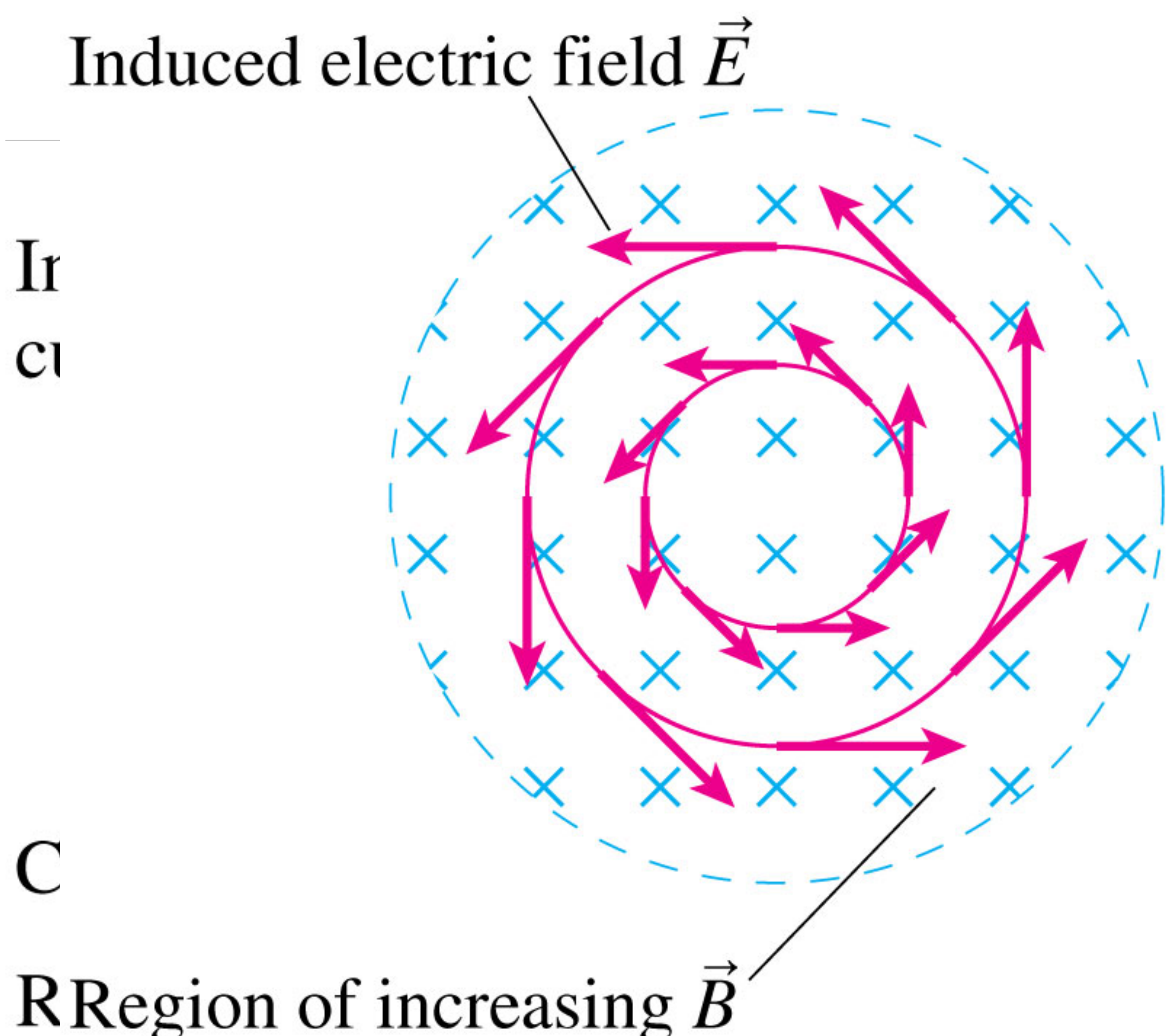
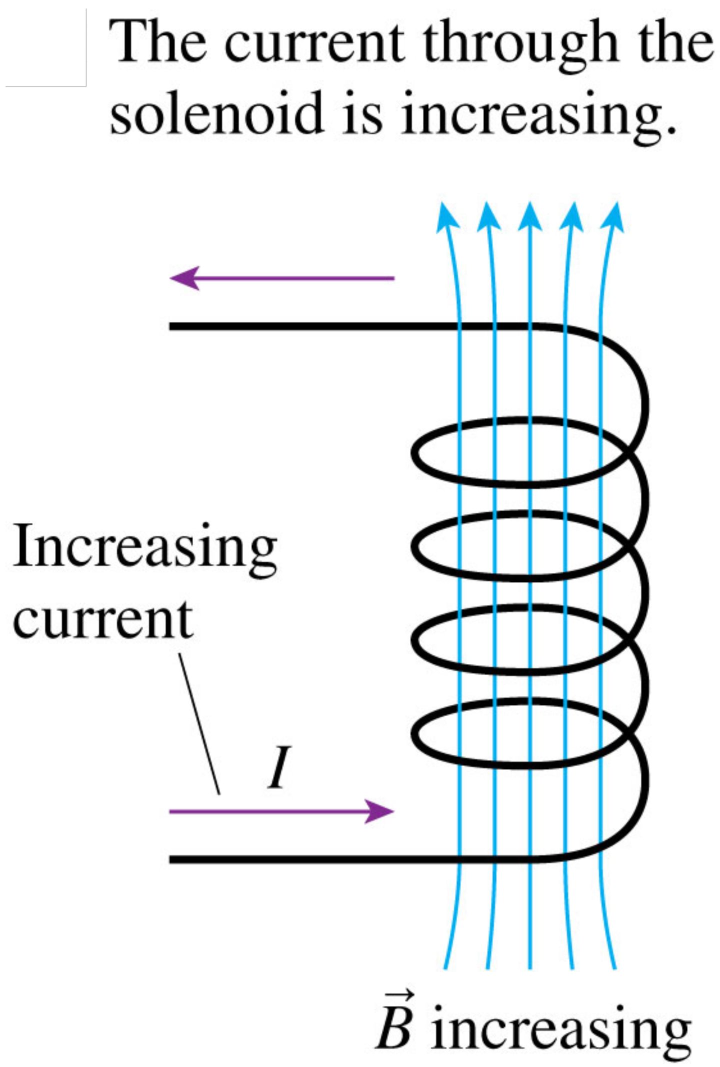




This is not the electric field that we are used to. It's a new kind of field called an "induced" electric field

The field is there whether there is a conductive loop present or not.



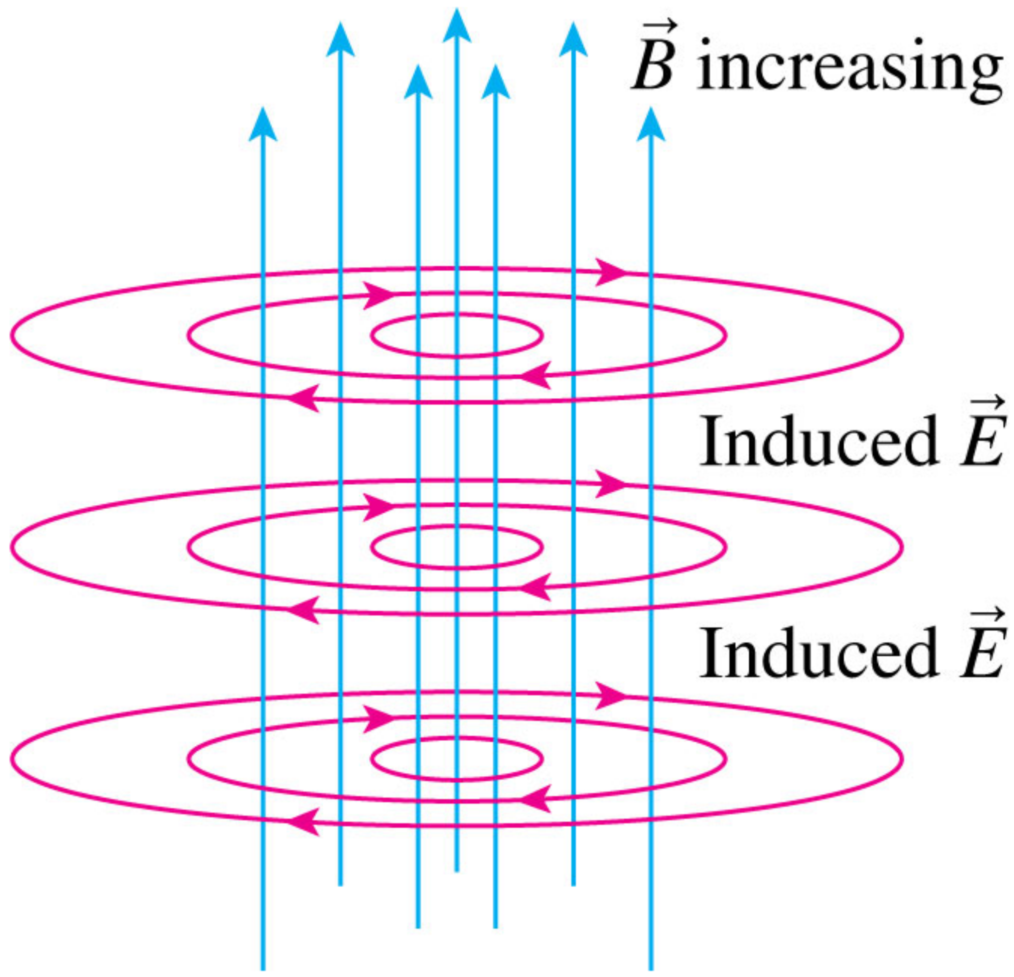
$$\mathcal{E} = \left|\frac{d\Phi}{dt}\right|$$

Convince yourself that the expression below is the same as the expression above for this situation. Then convince your neighbor.

$$\oint \vec{E} \cdot d\vec{s} = A\left|\frac{dB}{dt}\right|$$

Once again: The induced field is there whether the solenoid is present or not.

The induced electric field circulates around the magnetic field lines.



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Top view into the solenoid.
$\vec{B}$ is coming out of the page.

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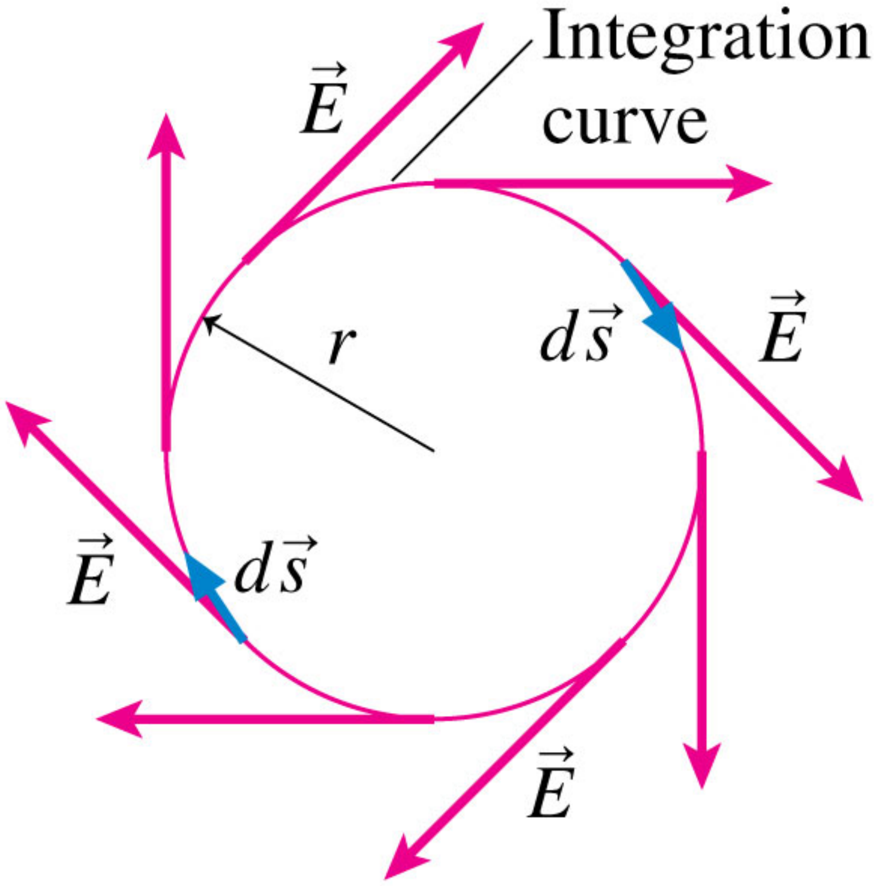

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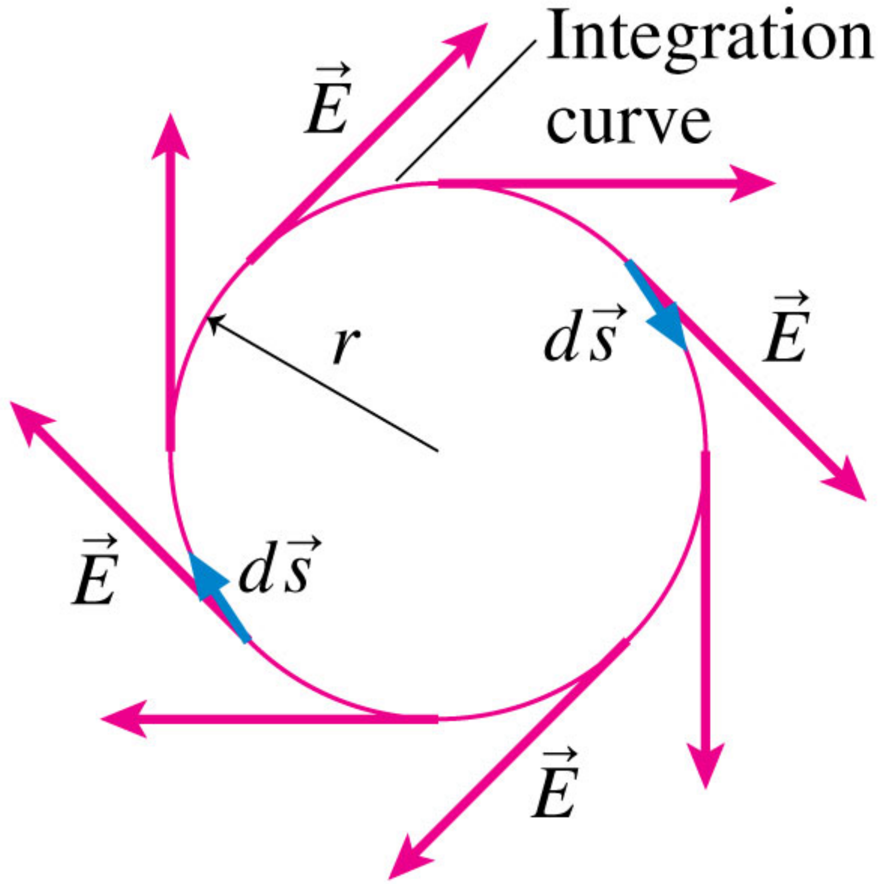
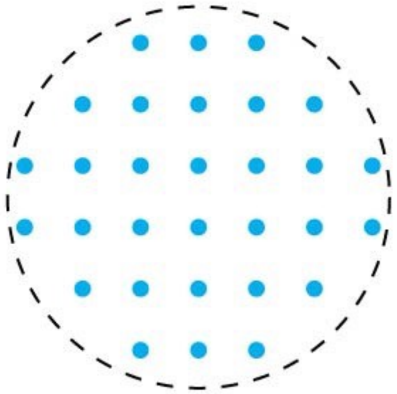
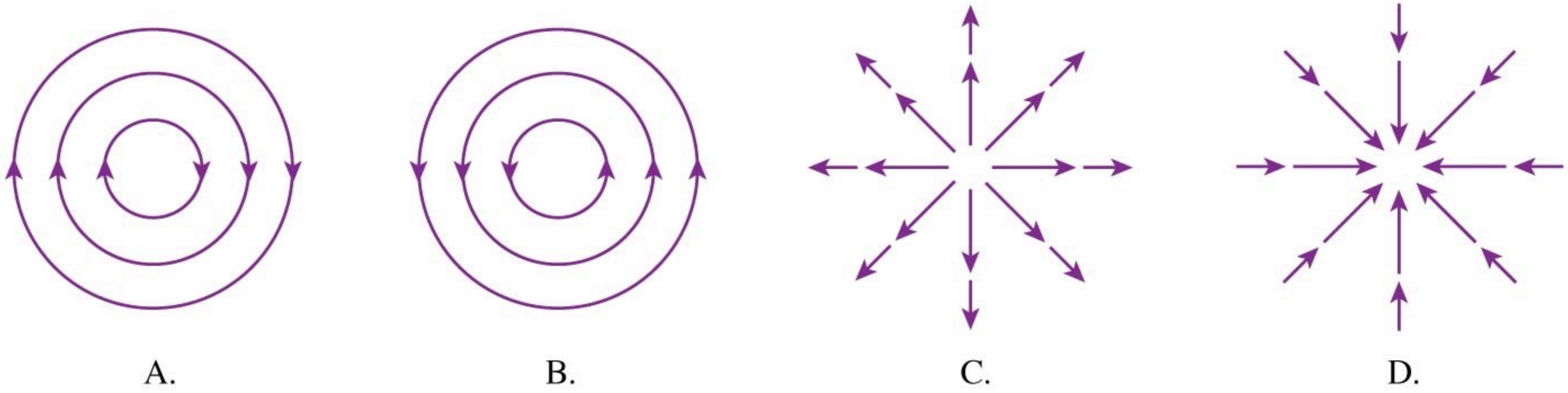


Assemble this equation for this situation and solve for the induced electric field

$$E_{\text{inside}} = \frac{r}{2}\left|\frac{dB}{dt}\right|$$

The magnetic field is decreasing.
Which is the induced electric field?





E. There's no induced field in this case.