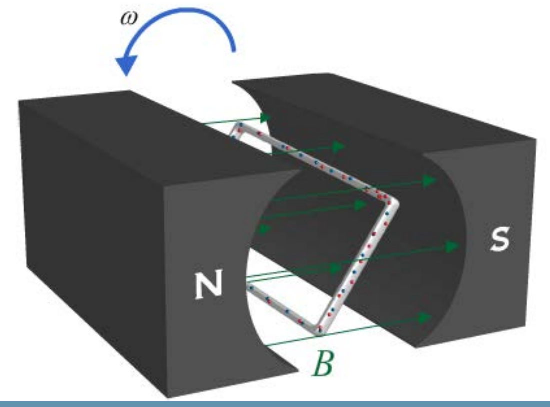
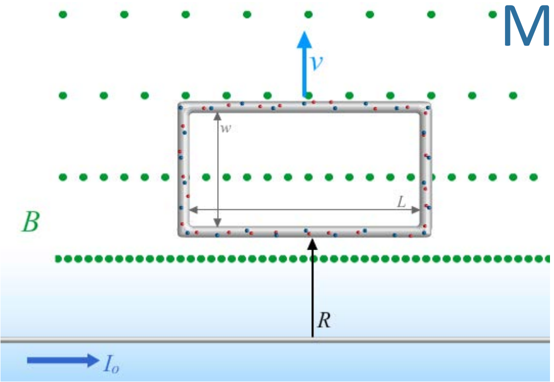
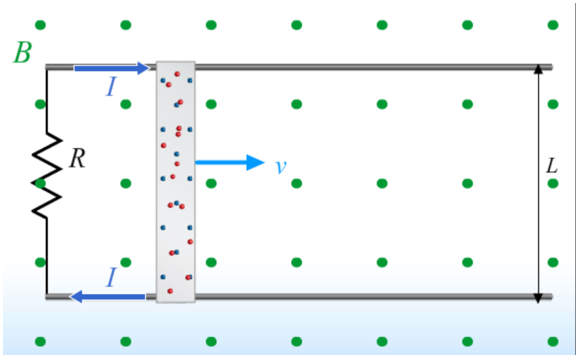


Physics 212
Lecture 16

Today's Concept:

Motional EMF





Your Comments

What's the acronym emf stand for   Electro Motive Force (like a battery)

How do you define the direction of a current? The direction of moving protons or electrons? Does the current in the battery has the same direction as that in the loop? Also, it seems that we use right hand rule a lot in this prelecture but I find out that I just know "yes, i have to use RHR" but I don't know the direction of what I'm trying to find!!!

Is it possible to find the direction of the flow of current in a loop using F=qvxB and the right hand rule on a positive charge.

Please go through everything. Please, these stuff will be on the exam. What am I gonna do if they are all very very confusing?

Conductors and E=0. So, how can the moving electrons create an E field in the bar?

Is the "Sorry prof., I didn't think of this" choice like choices "D" or "E" on the i-clicker, or used to see if people are paying attention to their answers?

Can you try to get people to be quieter while you're lecturing? It has been getting overly loud lately.

Would you please explain how we derived the motional emf formula for the loop traveling away from the wire? I'm particularly confused about how the individual voltages add up to the emf of the wire

Some Exam Stuff

Exam 2: Thursday March 19 at 7:00

- Covers material in Lectures 9 – 16 (Today's material)
- Sign up in Gradebook for Conflict Exam at 5:15pm
- Link in Gradebook if you have a double-conflict

Exam Preparation:

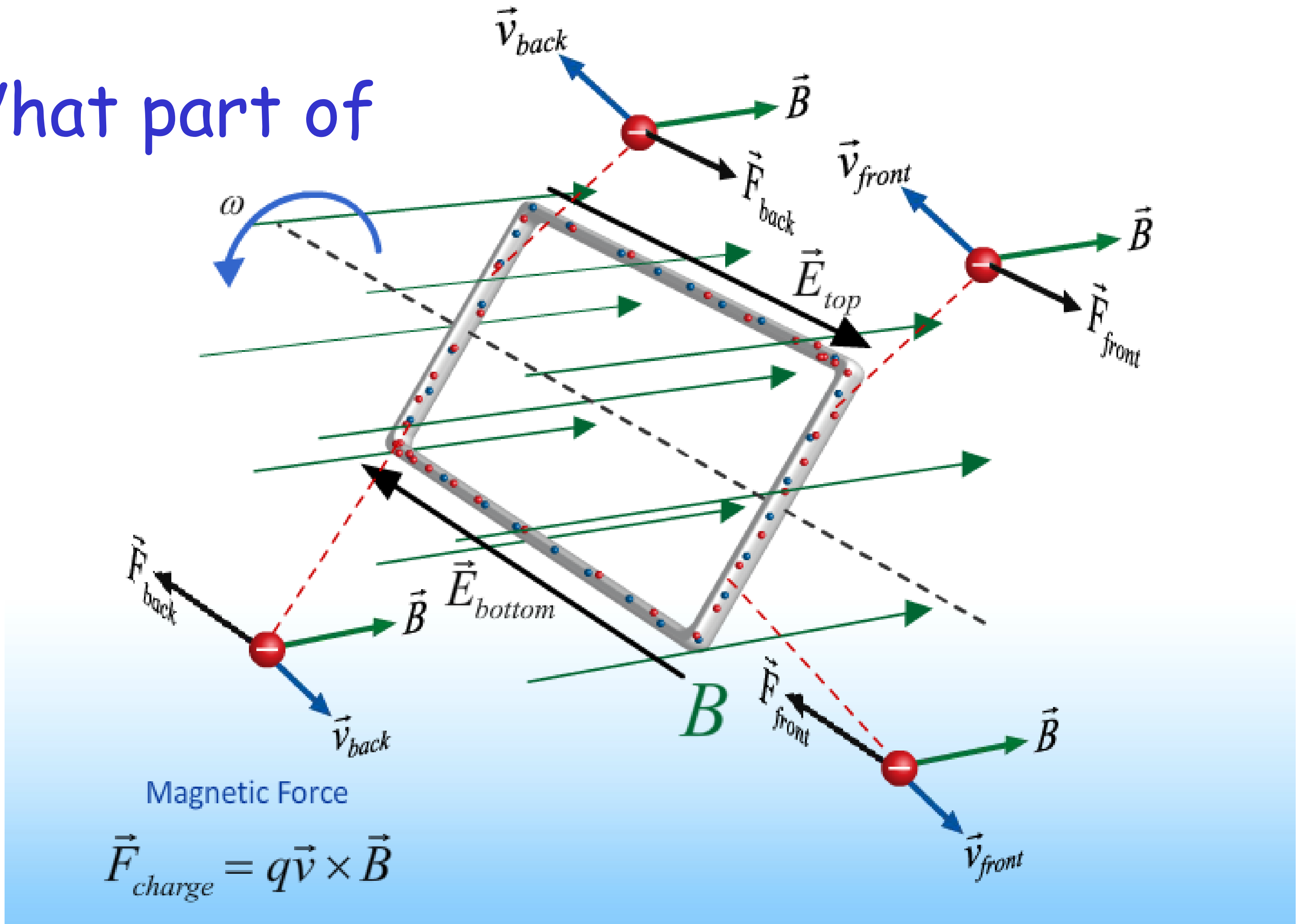
- Old Exams are a good way to assess what you need to know
- Prelecture of Fall 2010 solutions available ("prelecture")
- Video Solutions of Spring 2014 Hour Exam 2 ("optional HW")

No Lab or Quiz on Exam week

Some Confusion?

"i have no idea what's going on on the generators slide"

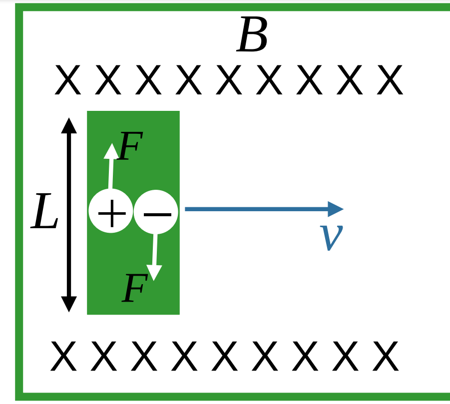
What part of



Don't you understand?

The Big Idea

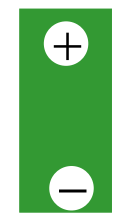
When a conductor moves through a region containing a magnetic field:



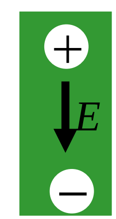
Magnetic forces may be exerted on the charge carriers in the conductor

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

These forces produce a charge separation in the conductor



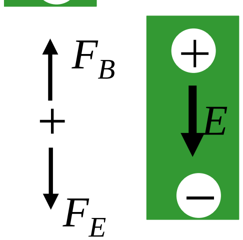
This charge distribution creates an electric field in the conductor



The equilibrium distribution is reached when the forces from the electric and magnetic fields cancel

$$qvB = qE$$

$$E = vB$$

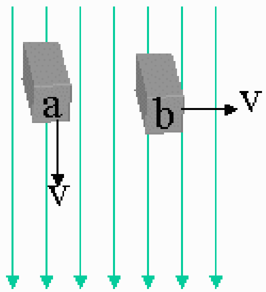


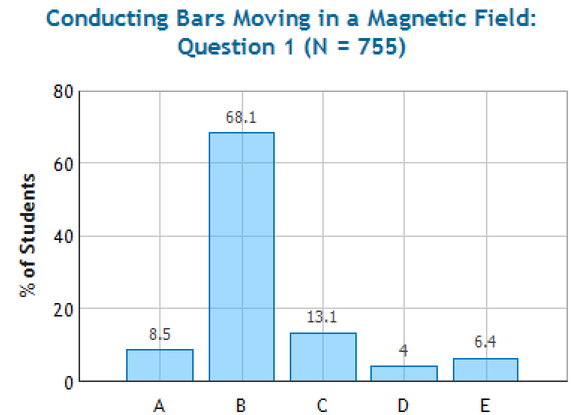
The equilibrium electric field produces a potential difference *(emf)* in the conductor

$$V = EL \rightarrow V = vBL$$

CheckPoint 1

Two identical conducting bars (shown in end view) are moving through a vertical magnetic field. Bar (a) is moving vertically and bar (b) is moving horizontally.





Which of the following is true?

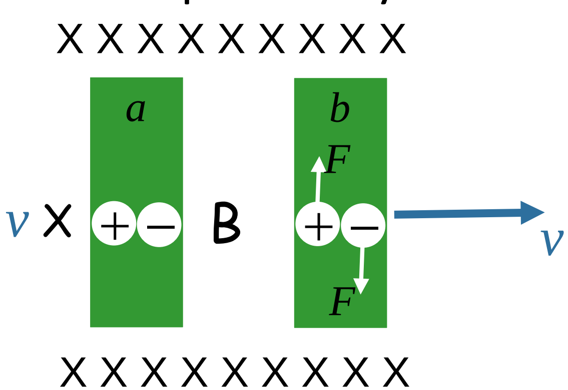
A. A motional emf exists in the bar for case (a), but not (b)

B. A motional emf exists in the bar for case (b), but not (a)

C. A motional emf exists in the bar for both cases (a) and (b)

D. A motional emf exists in the bar for neither case (a) nor case (b)

Rotate picture by 90^o



$F_a = 0$ $\quad F_b = qvB$

Bar a

No force on charges

No charge separation

No E field

No emf

Bar b

Opposite forces on charges

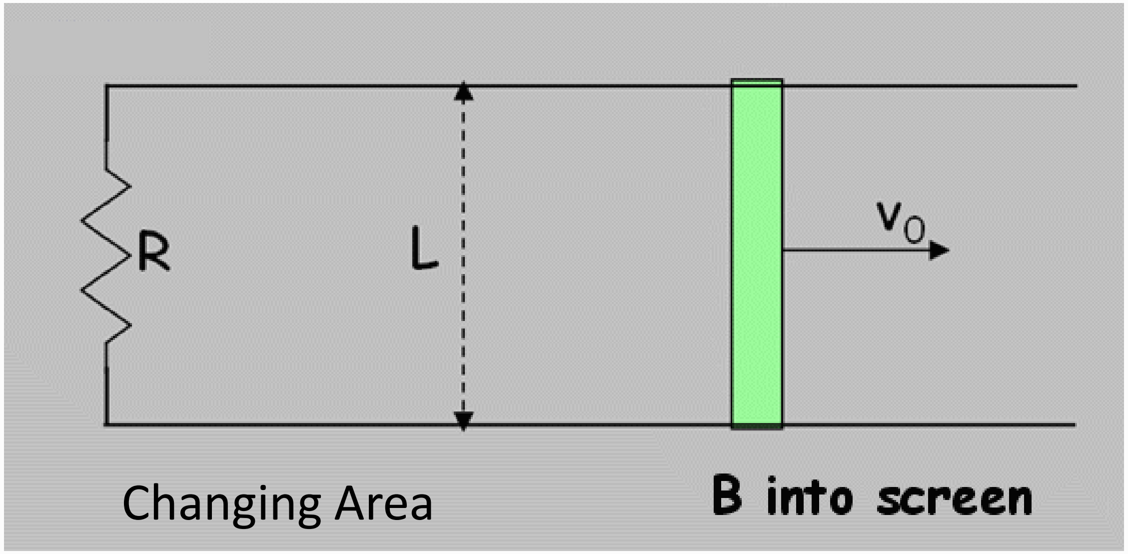
Charge separation

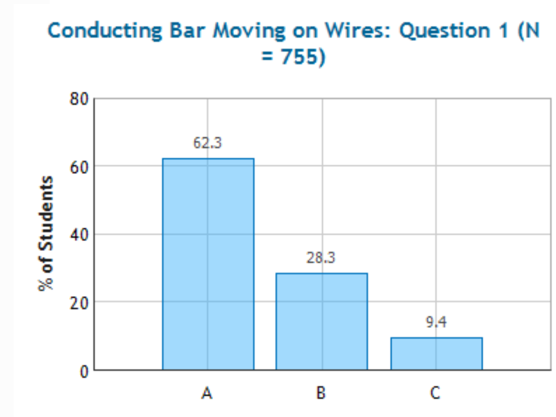
$E = vB$

$emf = EL = vBL$

CheckPoint 2a

A conducting bar (green) rests on two frictionless wires connected by a resistor as shown.



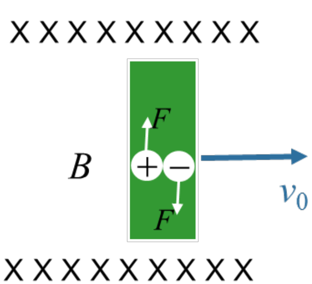


The entire apparatus is placed in a uniform magnetic field pointing into the screen, and the bar is given an initial velocity to the right.

The motion of the green bar creates a current through the bar

A. going up

B. going down



$F_b = qv_0B$

Bar

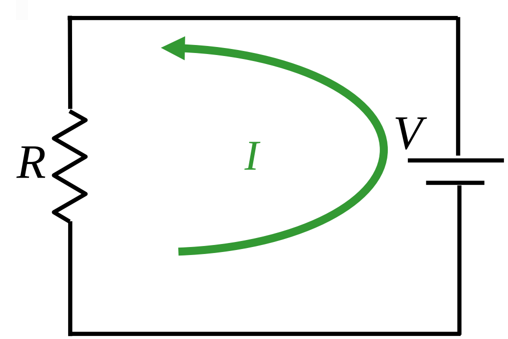
Opposite forces on charges

Charge separation

$E = v_0 B$

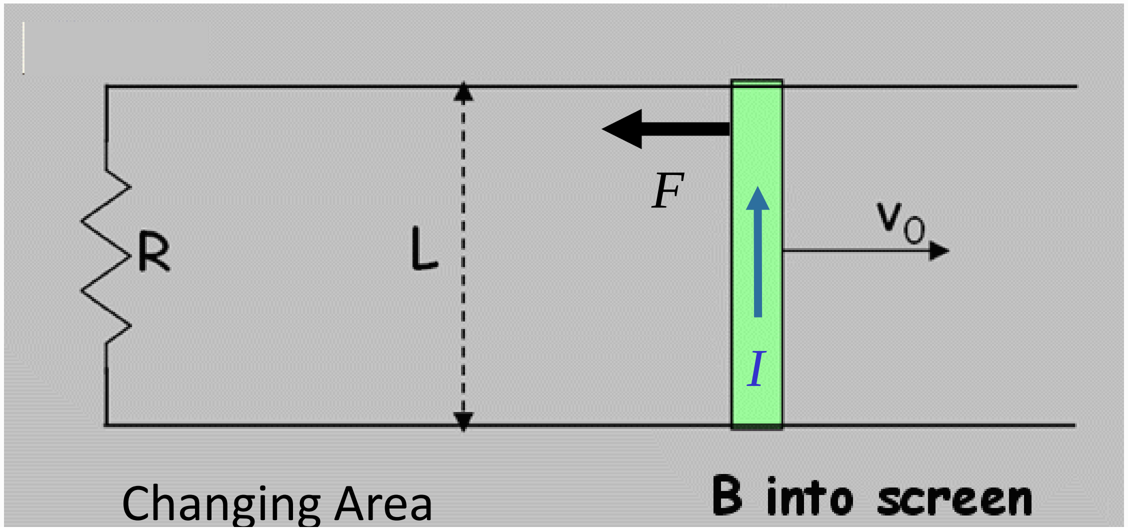
$emf = EL = v_0 BL$

Equivalent circuit



CheckPoint 2b

A conducting bar (green) rests on two frictionless wires connected by a resistor as shown.



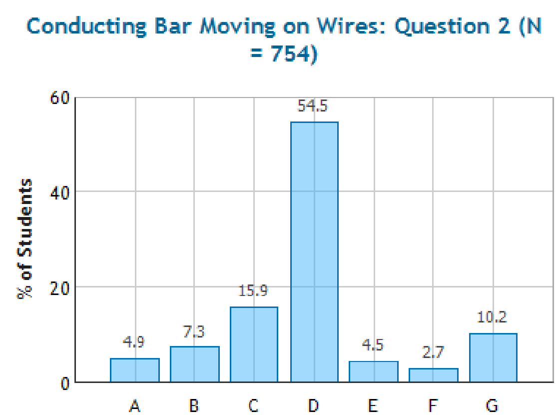
The entire apparatus is placed in a uniform magnetic field pointing into the screen, and the bar is given an initial velocity to the right.

The current through this bar results in a force on the bar

A. down
B. up
C. right
$\boxed{\textbf{\textit{D.}}\ \text{left}}$
E. into the screen

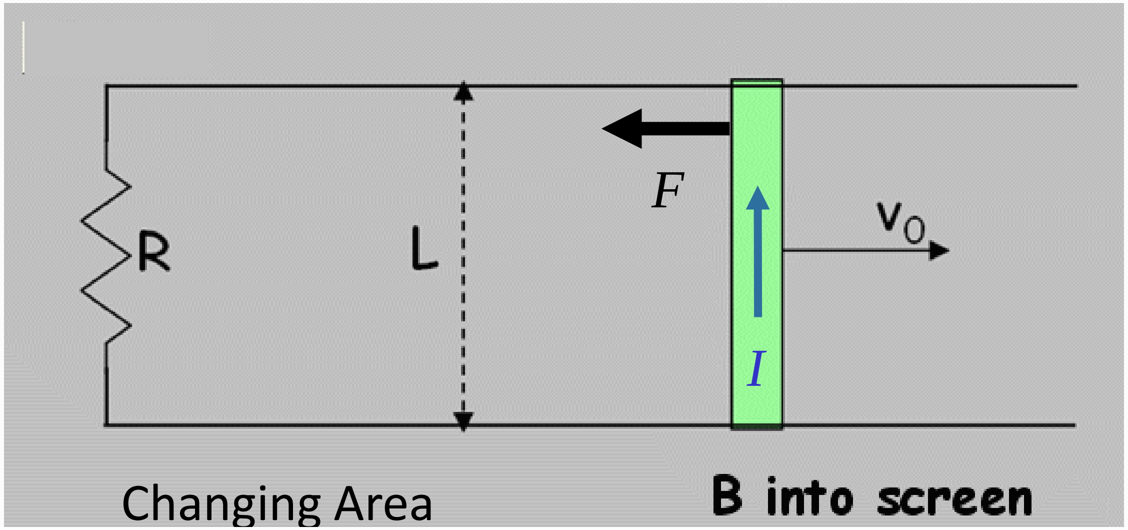
Current up through bar

$$\vec{F} = I\vec{L} \times \vec{B} \longrightarrow F \text{ points to left}$$



CheckPoint 2b

A conducting bar (green) rests on two frictionless wires connected by a resistor as shown.



Energy

External agent must exert force F to the right to maintain constant v

This energy is dissipated in the resistor!

The entire apparatus is placed in a uniform magnetic field pointing into the screen, and the bar is given an initial velocity to the right.

The current through this bar results in a force on the bar

A. down
B. up
C. right
D. left
E. into the screen

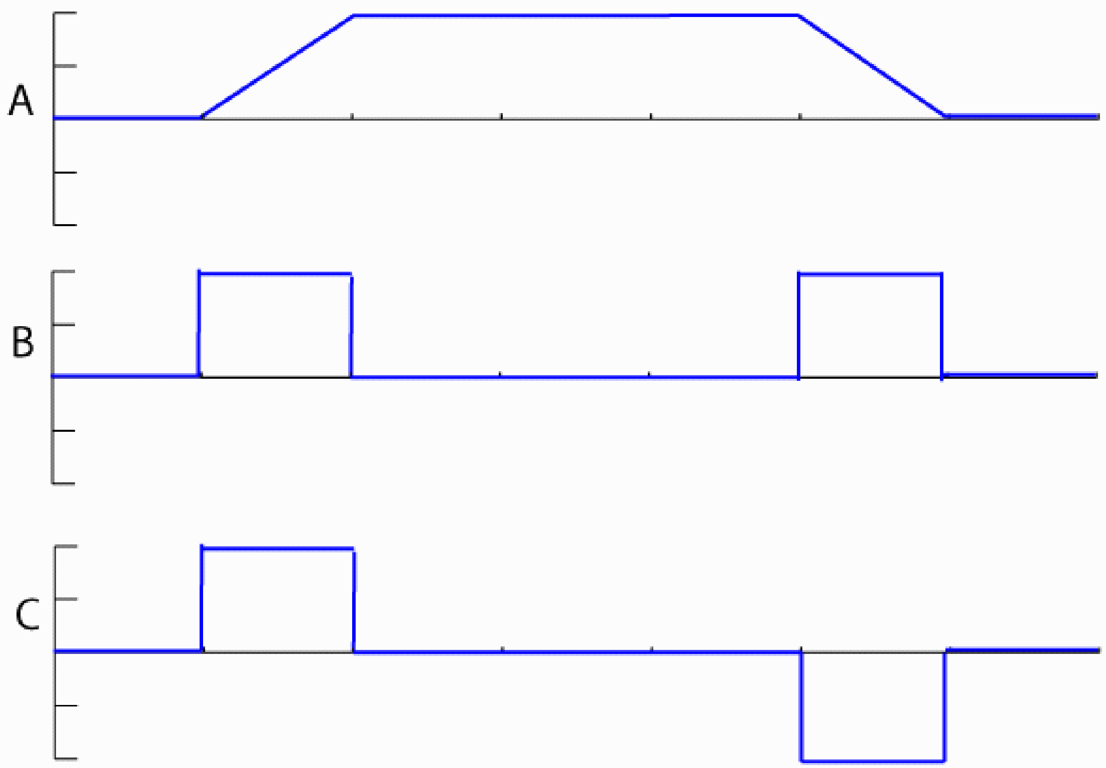
Current up through bar

$$\vec{F} = I\vec{L} \times \vec{B} \longrightarrow F \text{ points to left}$$

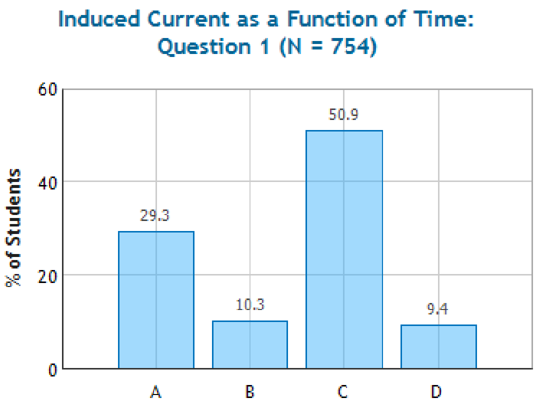
$$F = \left(\frac{vBL}{R}\right)LB \longrightarrow P = Fv = \left(\frac{vBL}{R}\right)LBv = I^2R$$

CheckPoint 5

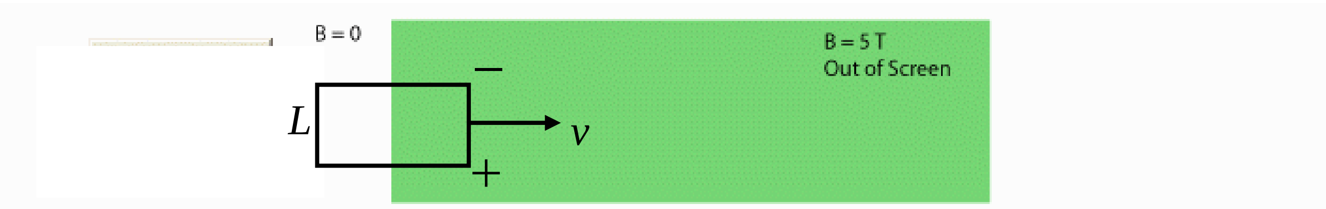
A wire loop travels to the right at a constant velocity. Which plot best represents the induced current in the loop as it travels from left of the region of magnetic field, through the magnetic field, and then entirely out on the right side?

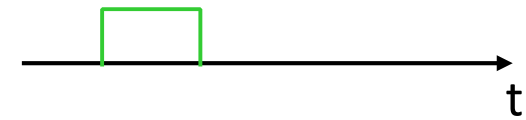


Let's step through this one



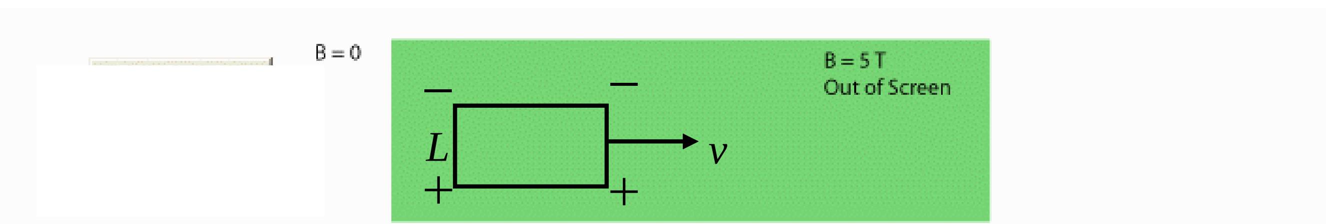
A wire loop travels to the right at a constant velocity. Which plot best represents the induced current in the loop as it travels from left of the region of magnetic field, through the magnetic field, and then entirely out on the right side?





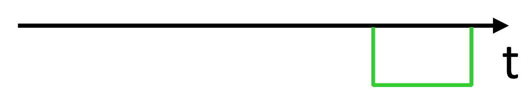
Only leading side has charge separation

$emf = BLv$ (cw current)



Leading and trailing sides have charge separation

$emf = BLv - BLv = 0$ (no current)

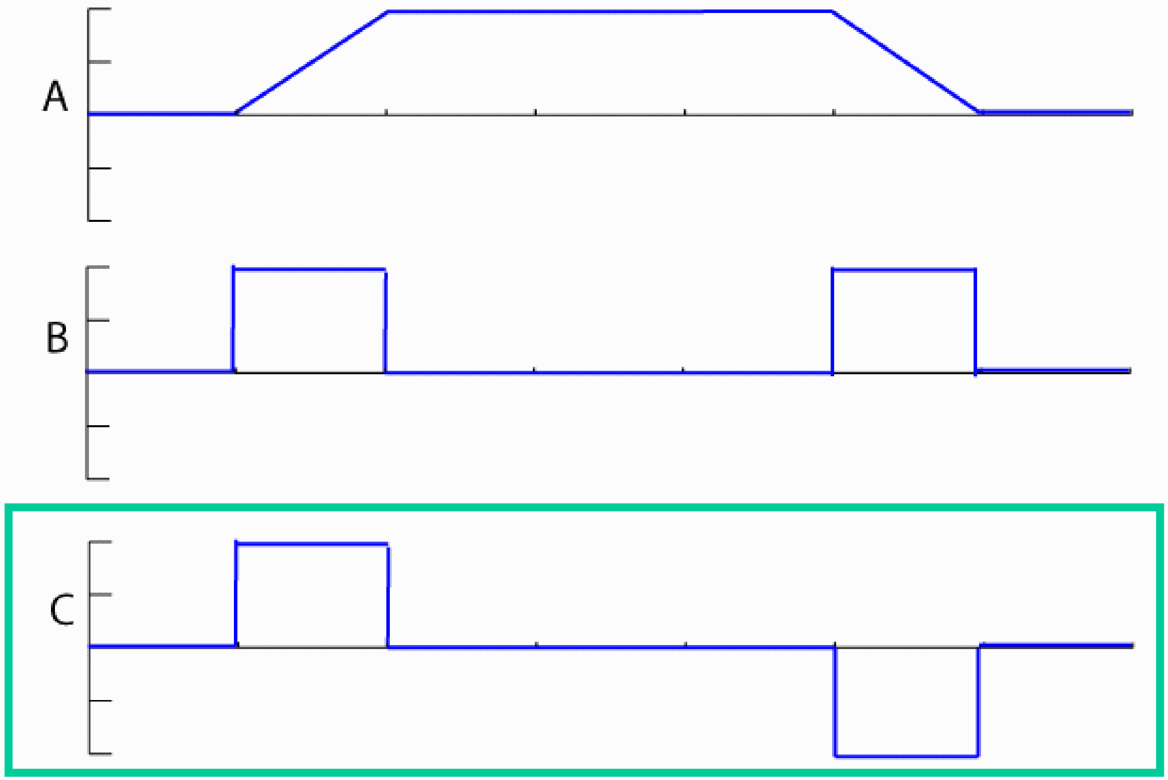


Only trailing side has charge separation

$emf = BLv$ (ccw current)

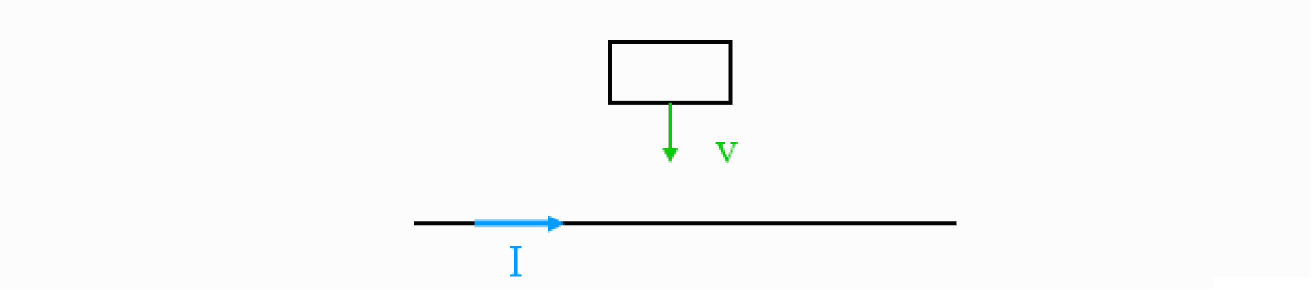
CheckPoint 5

A wire loop travels to the right at a constant velocity. Which plot best represents the induced current in the loop as it travels from left of the region of magnetic field, through the magnetic field, and then entirely out on the right side?



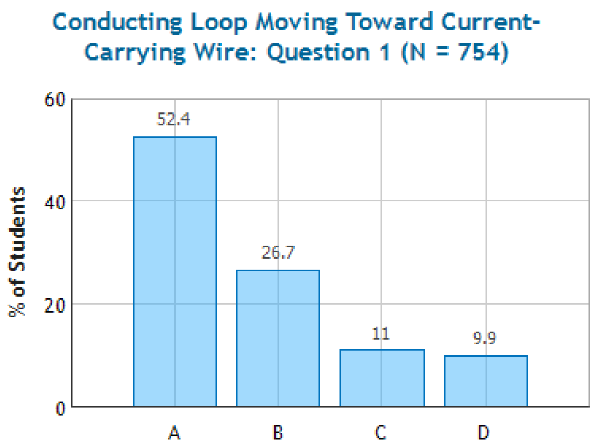
Changing B Field

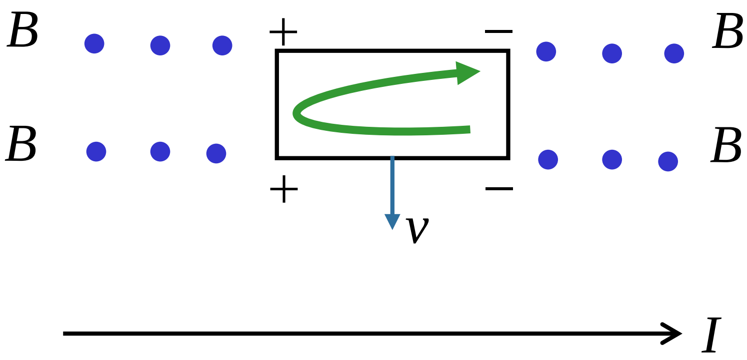
A conducting rectangular loop moves with velocity *v* toward an infinite straight wire carrying current as shown.



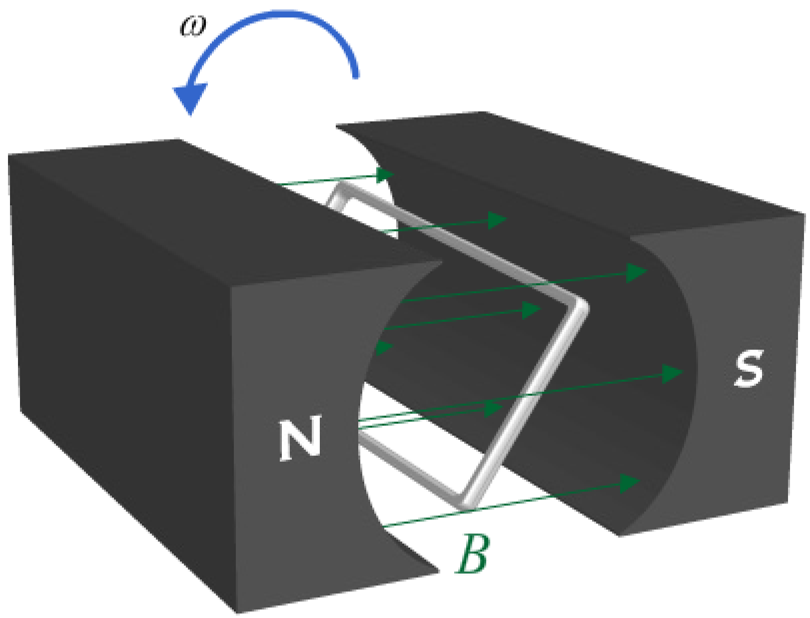
What is the direction of the induced current in the loop?

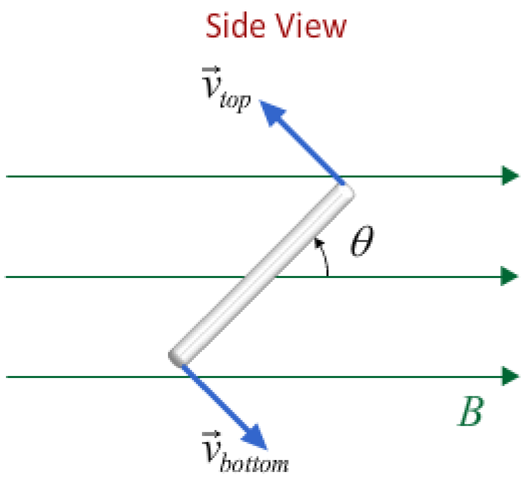
A. clockwise
B. counter-clockwise
C. there is no induced current in the loop





Generator: Changing Orientation





On which legs of the loop is charge separated?

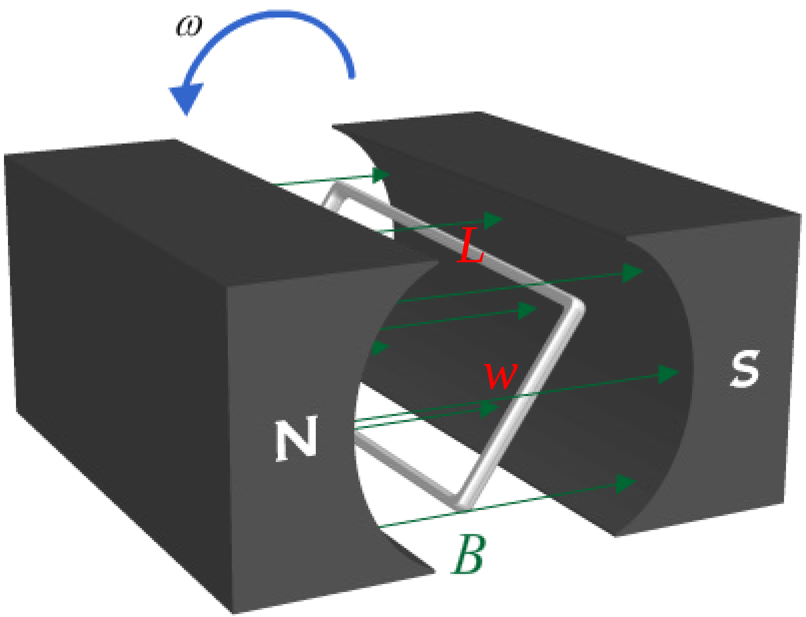
A) Top and Bottom legs only
B) Front and Back legs only
C) All legs
D) None of the legs

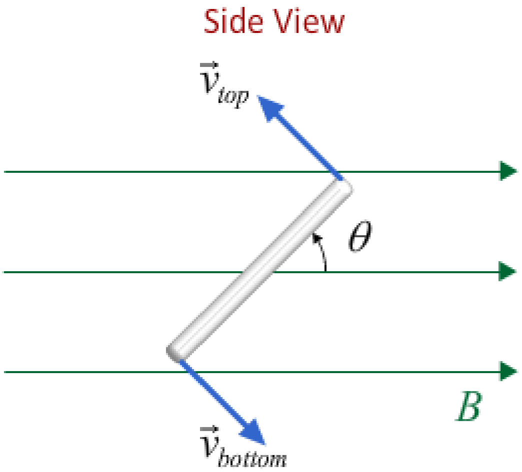
$\vec{v} \times \vec{B}$

Parallel to top and bottom legs

Perpendicular to front and back legs

Generator: Changing Orientation





At what angle θ is emf the largest?

A) $\theta = 0$

B) $\theta = 45^o$

C) $\theta = 90^o$

D) emf is same at all angles

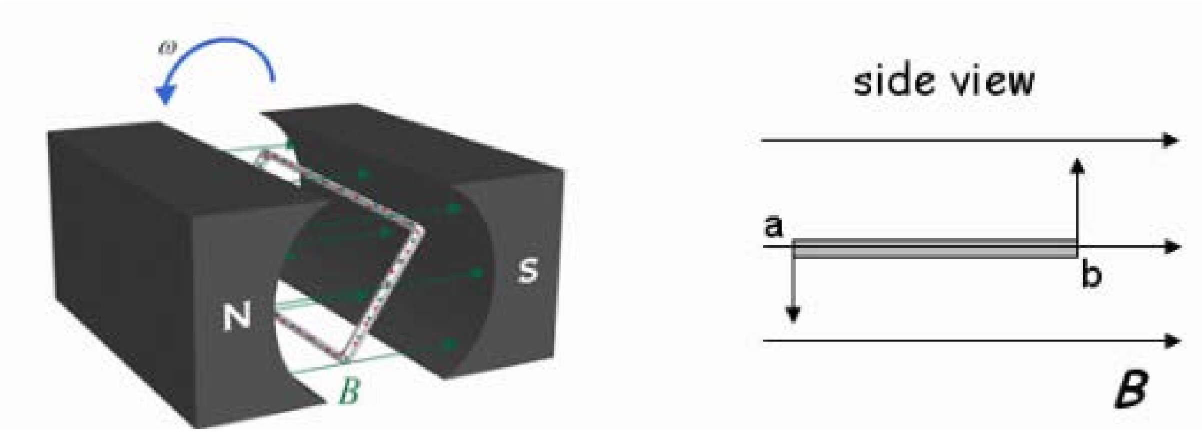
$\vec{v} \times \vec{B}$

Largest for $\theta = 0$ (v perp to B)

$\varepsilon = 2EL$

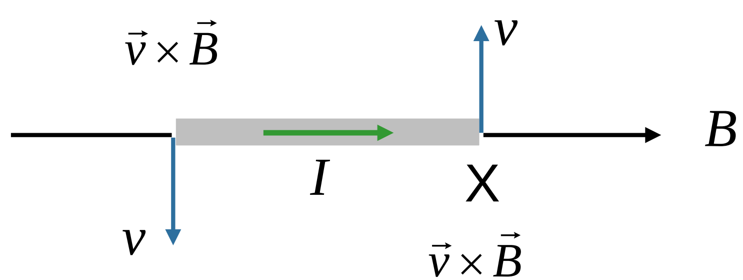
Changing Orientation

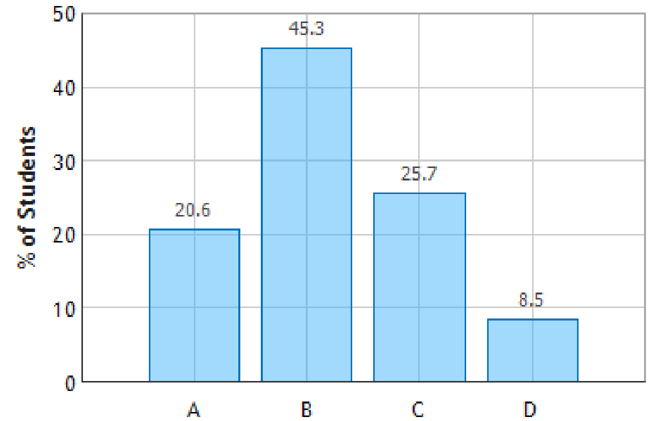
A rectangular loop rotates in a region containing a constant magnetic field as shown.



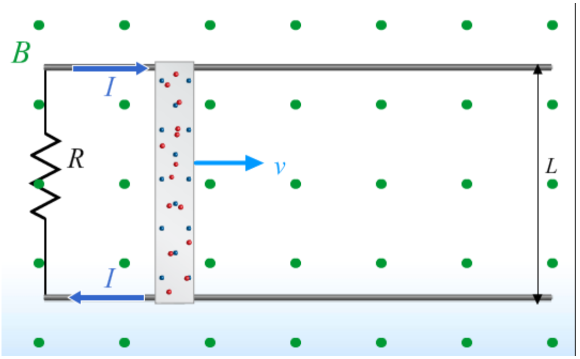
The side view of the loop is shown at a particular time during the rotation. At this time, what is the direction of the induced (positive) current in segment *ab*?

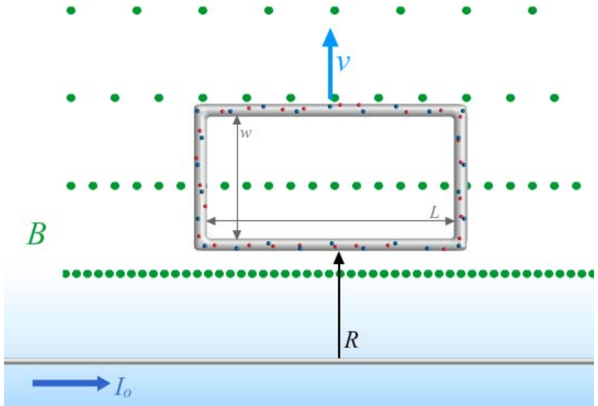
A. from *b* to *a*
B. from *a* to *b*
C. there is no induced current in the loop at this time

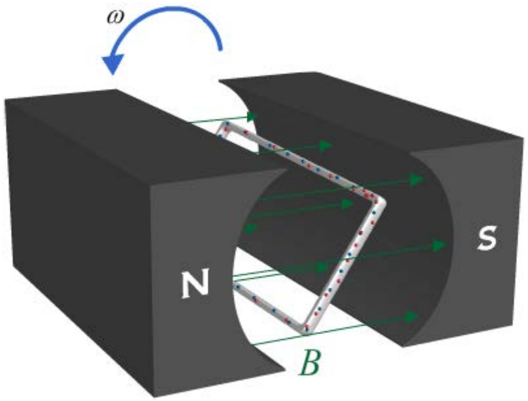




Putting it Together







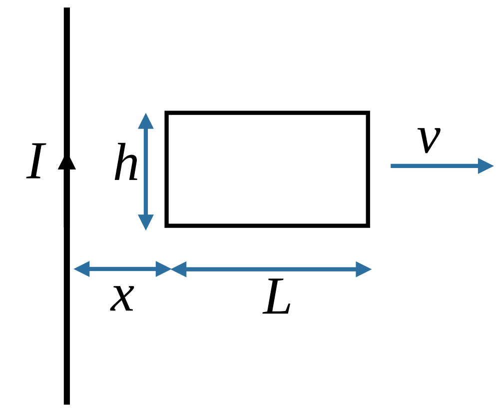
Faraday's Law

$$\Phi \equiv \int \vec{B} \cdot d\vec{A} \qquad \varepsilon = -\frac{d\Phi}{dt}$$

We will study this law in detail next time !

Example Problem

A rectangular loop $(h = 0.3m\ L = 1.2\ m)$ with total resistance of 5Ω is moving away from a long straight wire carrying total current 8 amps. What is the induced current in the loop when it is a distance $x = 0.7\ m$ from the wire?



Conceptual Analysis:

Long straight current creates magnetic field in region of the loop.

Vertical sides develop *emf* due to motion through B field

Net *emf* produces current

Strategic Analysis:

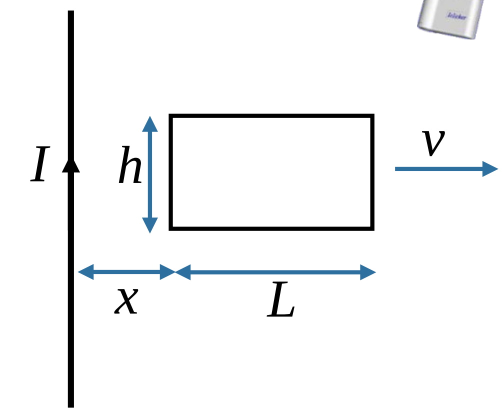
Calculate B field due to wire.

Calculate motional *emf* for each segment

Use net *emf* and Ohm's law to get current

Example Problem

A rectangular loop $(h = 0.3m\ L = 1.2\ m)$ with total resistance of 5Ω is moving away from a long straight wire carrying total current $8\ \text{amps}$. What is the induced current in the loop when it is a distance $x = 0.7\ m$ from the wire?



What is the direction of the B field produced by the wire in the region of the loop?

A) Into the page

B) Out of the page

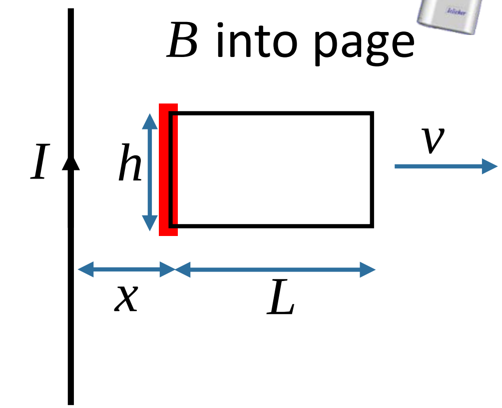
C) Left

D) Right

E) Up

Example Problem

A rectangular loop $(h = 0.3m\ L = 1.2\ m)$ with total resistance of 5Ω is moving away from a long straight wire carrying total current 8 amps. What is the induced current in the loop when it is a distance $x = 0.7\ m$ from the wire?



What is the *emf* induced on the left segment?

A) Top is positive

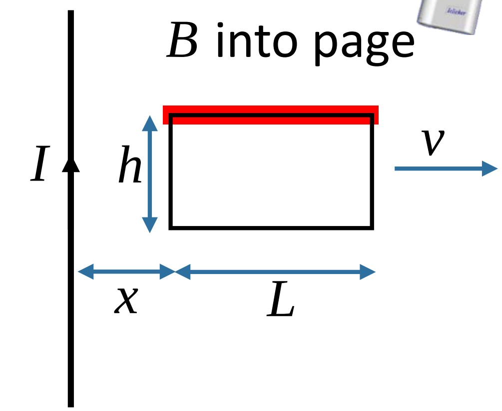
B) Top is negative

C) Zero

$$\vec{v} \times \vec{B}$$

Example Problem

A rectangular loop $(h = 0.3m \; L = 1.2 \; m)$ with total resistance of 5Ω is moving away from a long straight wire carrying total current 8 amps. What is the induced current in the loop when it is a distance $x = 0.7 \; m$ from the wire?



What is the *emf* induced on the top segment?

A) left is positive

B) left is negative

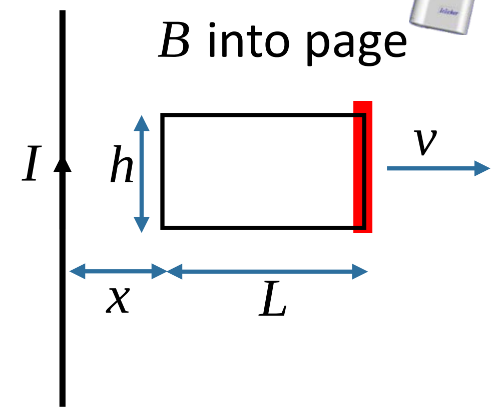
C) Zero

$$\vec{v} \times \vec{B}$$

perpendicular to wire

Example Problem

A rectangular loop $(h = 0.3m\ L = 1.2\ m)$ with total resistance of 5Ω is moving away from a long straight wire carrying total current 8 amps. What is the induced current in the loop when it is a distance $x = 0.7\ m$ from the wire?



What is the *emf* induced on the right segment?

A) top is positive

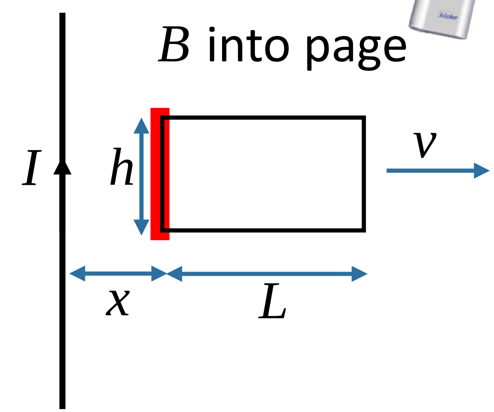
B) top is negative

C) Zero

$$\vec{v} \times \vec{B}$$

Example Problem

A rectangular loop ($h = 0.3m$ $L = 1.2$ m) with total resistance of 5Ω is moving away from a long straight wire carrying total current 8 amps. What is the induced current in the loop when it is a distance $x = 0.7$ m from the wire?



Which expression represents the *emf* induced in the left wire?

A) $$\varepsilon_{left} = \frac{\mu_o I}{2\pi x} Lv$$

B) $$\varepsilon_{left} = \frac{\mu_o I}{2\pi x} hv$$

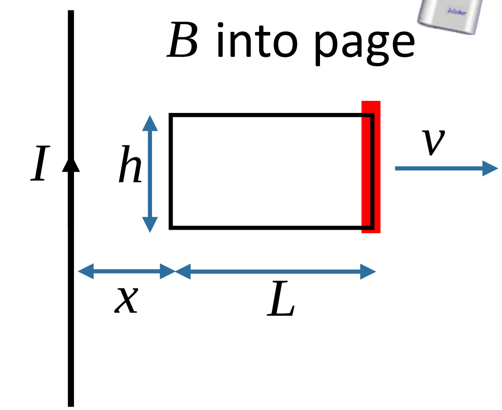
C) $$\varepsilon_{left} = \frac{\mu_o I}{2\pi(L+x)} Lv$$

$$qvB = qE \rightarrow E = vB \rightarrow \varepsilon = Eh = vBh$$

$$B = \frac{\mu_o I}{2\pi x} \rightarrow \varepsilon = \frac{\mu_o I}{2\pi x} hv$$

Example Problem

A rectangular loop $(h = 0.3m\ L = 1.2\ m)$ with total resistance of 5Ω is moving away from a long straight wire carrying total current 8 amps. What is the induced current in the loop when it is a distance $x = 0.7\ m$ from the wire?



Which expression represents the *emf* induced in the right wire?

A) $\varepsilon_{right} = \dfrac{\mu_o I}{2\pi(L+x)} hv$

B) $\varepsilon_{right} = \dfrac{\mu_o I}{2\pi x} hv$

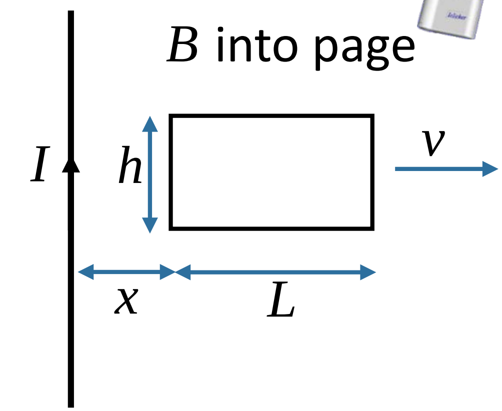
C) $\varepsilon_{right} = \dfrac{\mu_o I}{2\pi(h+x)} Lv$

$$qvB = qE \rightarrow E = vB \rightarrow \varepsilon = Eh = vBh$$

$$B = \frac{\mu_o I}{2\pi(L+x)} \rightarrow \varepsilon = \frac{\mu_o I}{2\pi(L+x)} hv$$

Example Problem

A rectangular loop $(h = 0.3m\ L = 1.2\ m)$ with total resistance of 5Ω is moving away from a long straight wire carrying total current 8 amps. What is the induced current in the loop when it is a distance $x = 0.7\ m$ from the wire?



Which expression represents the total *emf* in the loop?

A) $\varepsilon_{loop} = \frac{\mu_o I}{2\pi x} hv + \frac{\mu_o I}{2\pi (L + x)} hv$

B) $\varepsilon_{loop} = \frac{\mu_o I}{2\pi x} hv - \frac{\mu_o I}{2\pi (L + x)} hv$

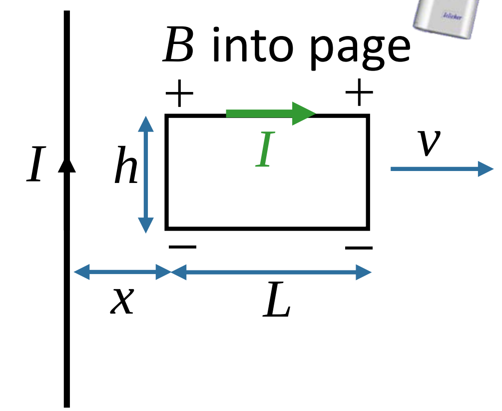
C) $\varepsilon_{loop} = 0$

$$I_{loop} = \frac{\varepsilon_{loop}}{R}$$

$$I_{loop} = \frac{\mu_o I}{2\pi R} hv \left(\frac{1}{x} - \frac{1}{L + x} \right)$$

Follow-Up

A rectangular loop $(h = 0.3m\ L = 1.2\ m)$ with total resistance of 5Ω is moving away from a long straight wire carrying total current 8 amps.



What is the direction of the induced current?

A) Clockwise

B) Counterclockwise

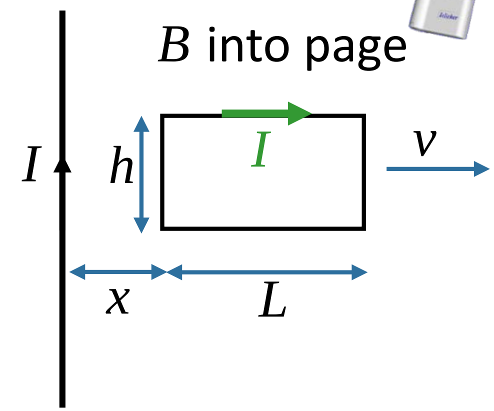
$$\varepsilon_{left} > \varepsilon_{right}$$

Clockwise current

Follow-Up

A rectangular loop $(h = 0.3m\ L = 1.2\ m)$ with total resistance of 5Ω is moving away from a long straight wire carrying total current $8\ \text{amps}$.

B into page



What is the direction of the force exerted by the magnetic field on the loop?

A) UP

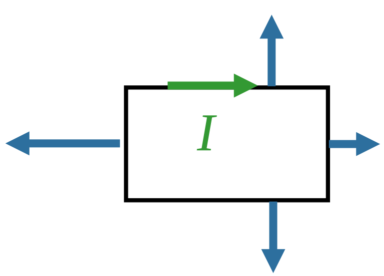
B) DOWN

C) LEFT

D) RIGHT

E) $F = 0$

B into page



Total force from B
Points to the left !