Your Comments

Usually, I don't leave comments, but this is by far the coolest topic we've had! :D Kind of tricky...but really fun to play around with. It deserves the comment.

I don't get why you're waiting till next lecture to introduce flux - I think it's a relaly helpful concept. Also, the lectures lose all of their use when you can't listen to them; the closed captioning ain't worth nothin'.

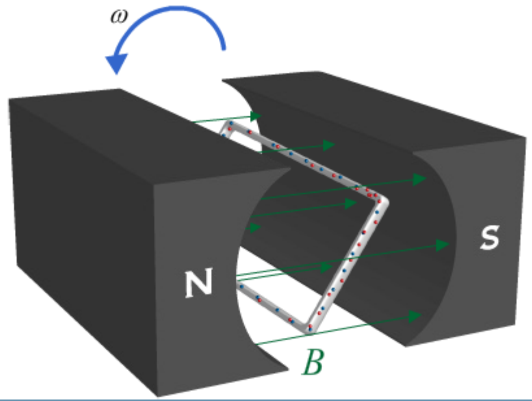
I never knew I could get this eMOTIONAL about Physics!

The final exam schedule was posted today. For 212 can we choose to take either the regularly scheduled final or the conflict as we could for 211?

Dear Professor, It's cool that we now know how to make motors, but lets be honest no one signs up for engineering to make motors.....We signed up to learn how to make electric guns and laser cannons. I didn't see those on the syllabus and I was wondering when we will learn to make those. Sincerely, Your excited student

I'M SO EXCITED FOR EOH!!! Please post this comment so everyone will know to come check out the awesome Bioengineering exhibits!!!! WOOO BMES! <3 And also Engineers Without Borders! :) See you at Engineering Open House!

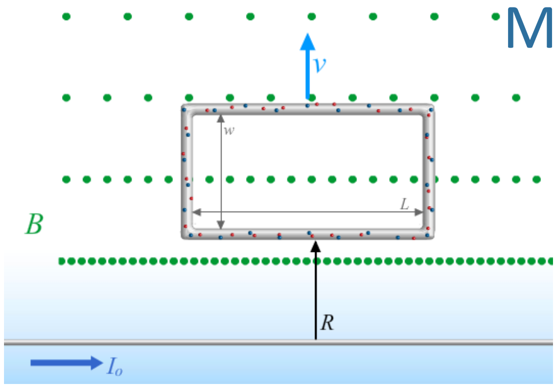
i emailed you about a quiz over a weeks ago and still haven't received a response. This isn't the old days where it takes weeks for a response in the mail. this is EMAIL!!! Either 1) you read it and forgot to respond or 2) you are just being disrespectful and don't want to respond. I was expecting a response. I am sorry, but I am a little upset and stressed out for upcoming tests.

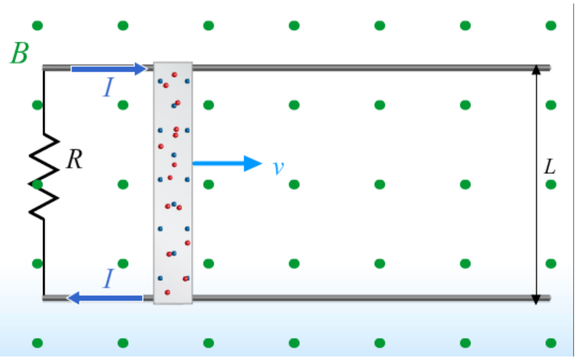


Physics 212
Lecture 16

Today's Concept:

Motional EMF

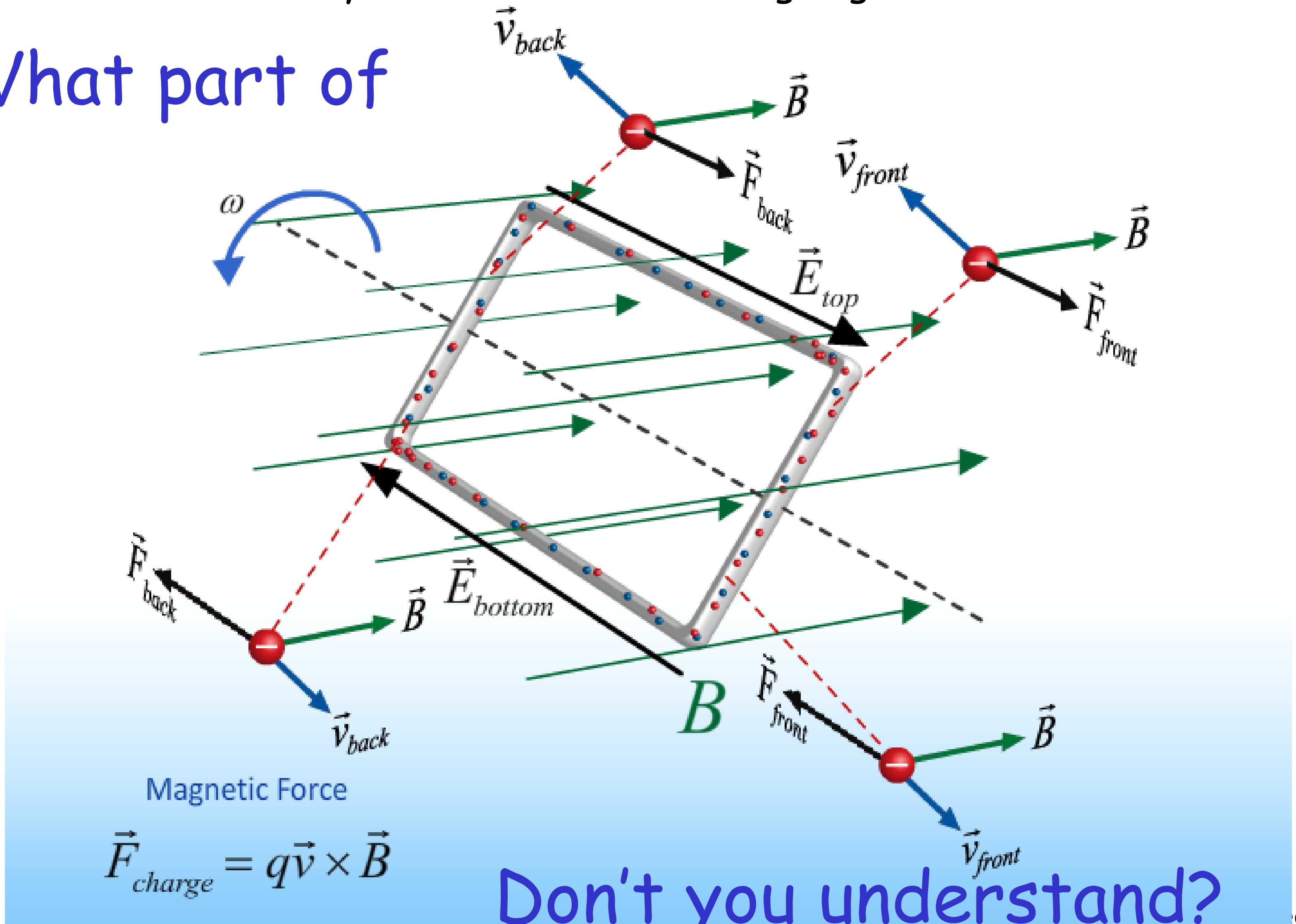




Some Confusion?

HOLE-Y CRAP. That was a lot thrown at us all at once. Hopefully you're going to go nice and slow over this in lecture. Especially that Generator slide. It was so convoluted I barely understood what was going on.

What part of



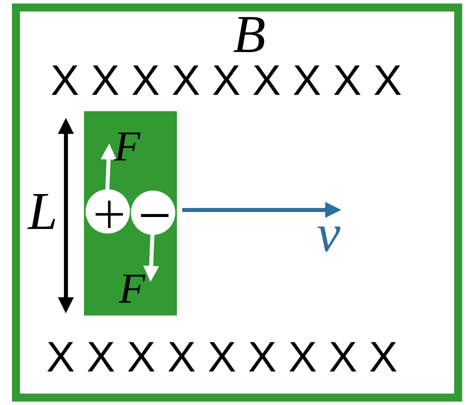
Don't you understand?

The Big Idea

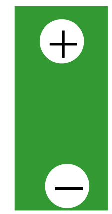
When a conductor moves through a region containing a magnetic field:

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

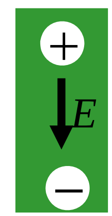
$$\vec{F} = q\vec{v} \times \vec{B}$$



These forces produce a charge separation in the conductor



This charge distribution creates an electric field in the conductor

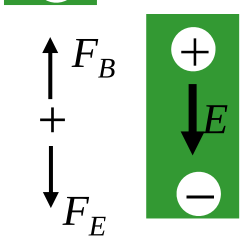


The equilibrium distribution is reached when the forces from the electric and magnetic fields cancel

$$qvB = qE$$

$$\Downarrow$$

$$E = vB$$

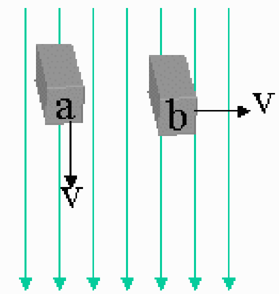


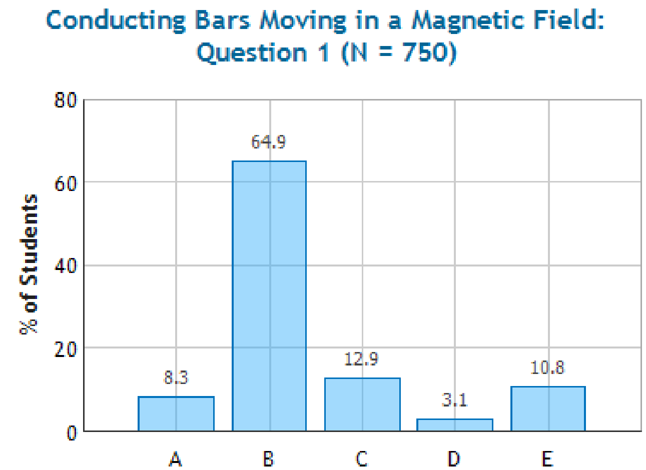
The equilibrium electric field produces a potential difference (*emf*) in the conductor

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

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?

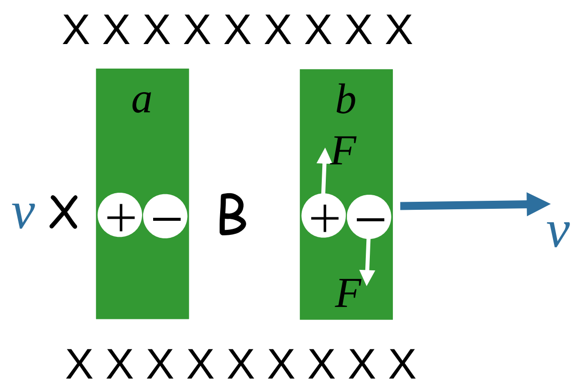
A. A motional emf exists in the bar for case (a), but not (b)

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



$F_a = 0 \qquad F_b = qvB$

Bar a

No force on charges

No charge separation

No E field

No emf

Bar b

Opposite forces on charges

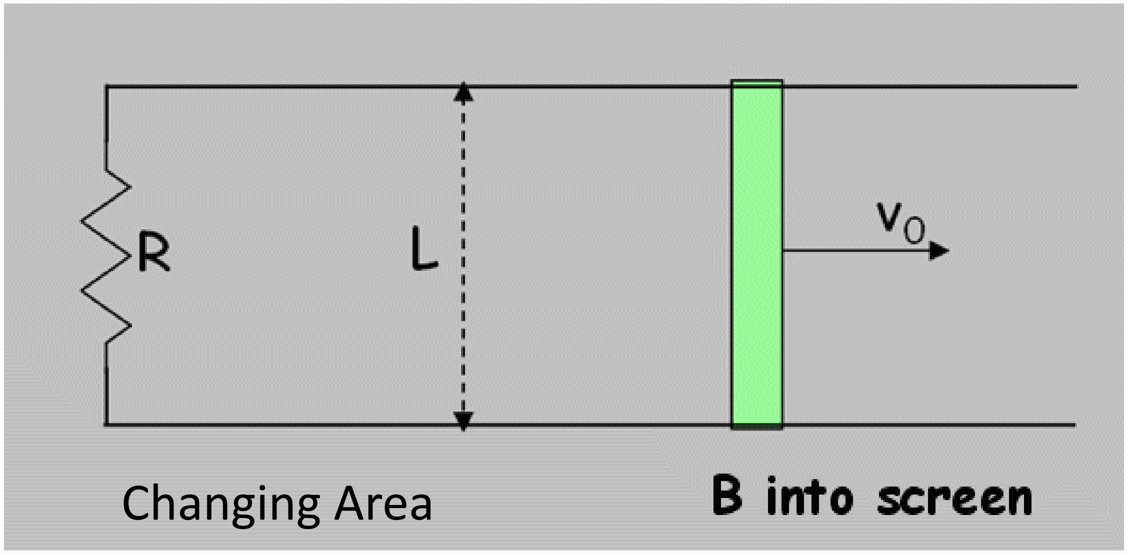
Charge separation

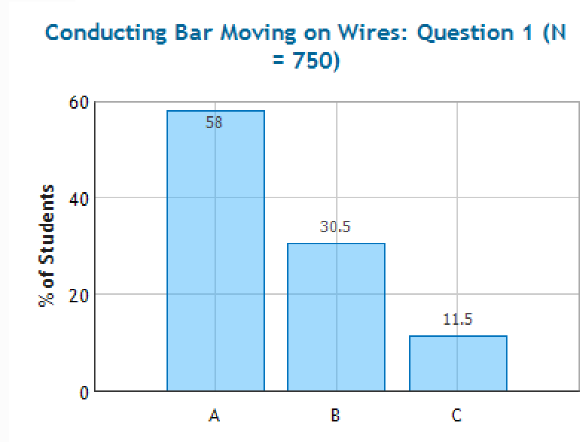
$E = vB$

$emf = EL = vBL$

CheckPoint 2a

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



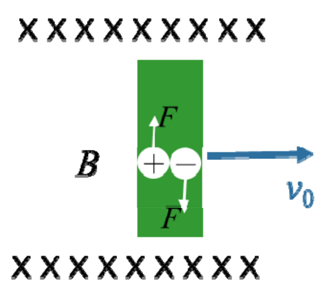


The entire apparatus is placed in a uniform magnetic field pointing into the screen, and the bar is given an initial velocity to the right.

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

A. going up

B. going down



$F_b = qv_0B$

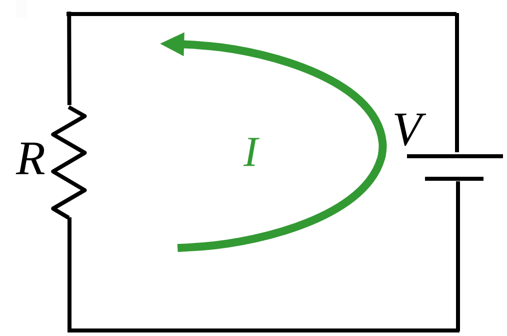
Opposite forces on charges

Charge separation

$E = v_0B$

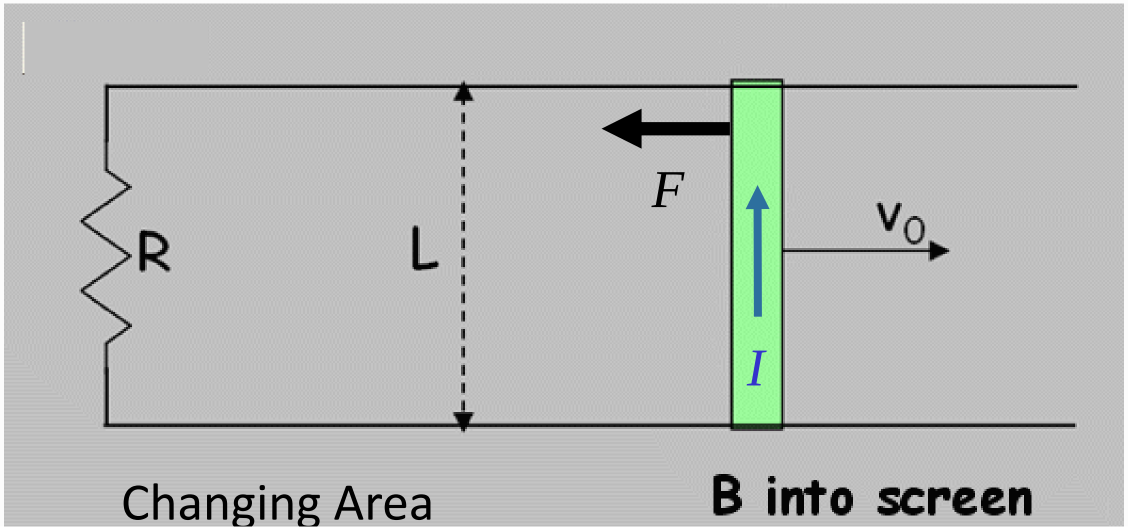
$emf = EL = v_0BL$

Equivalent circuit



CheckPoint 2b

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



Energy

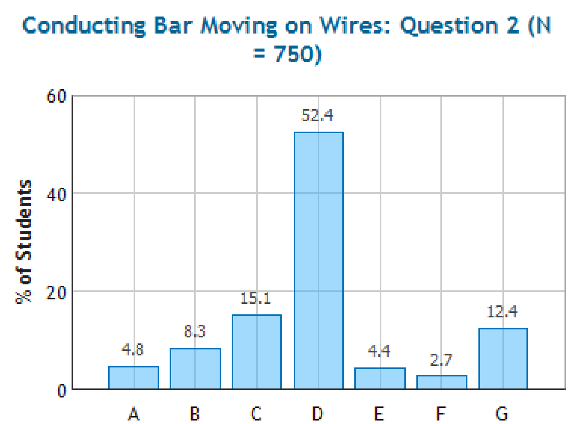
External agent must exert force F to the right to maintain constant v

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



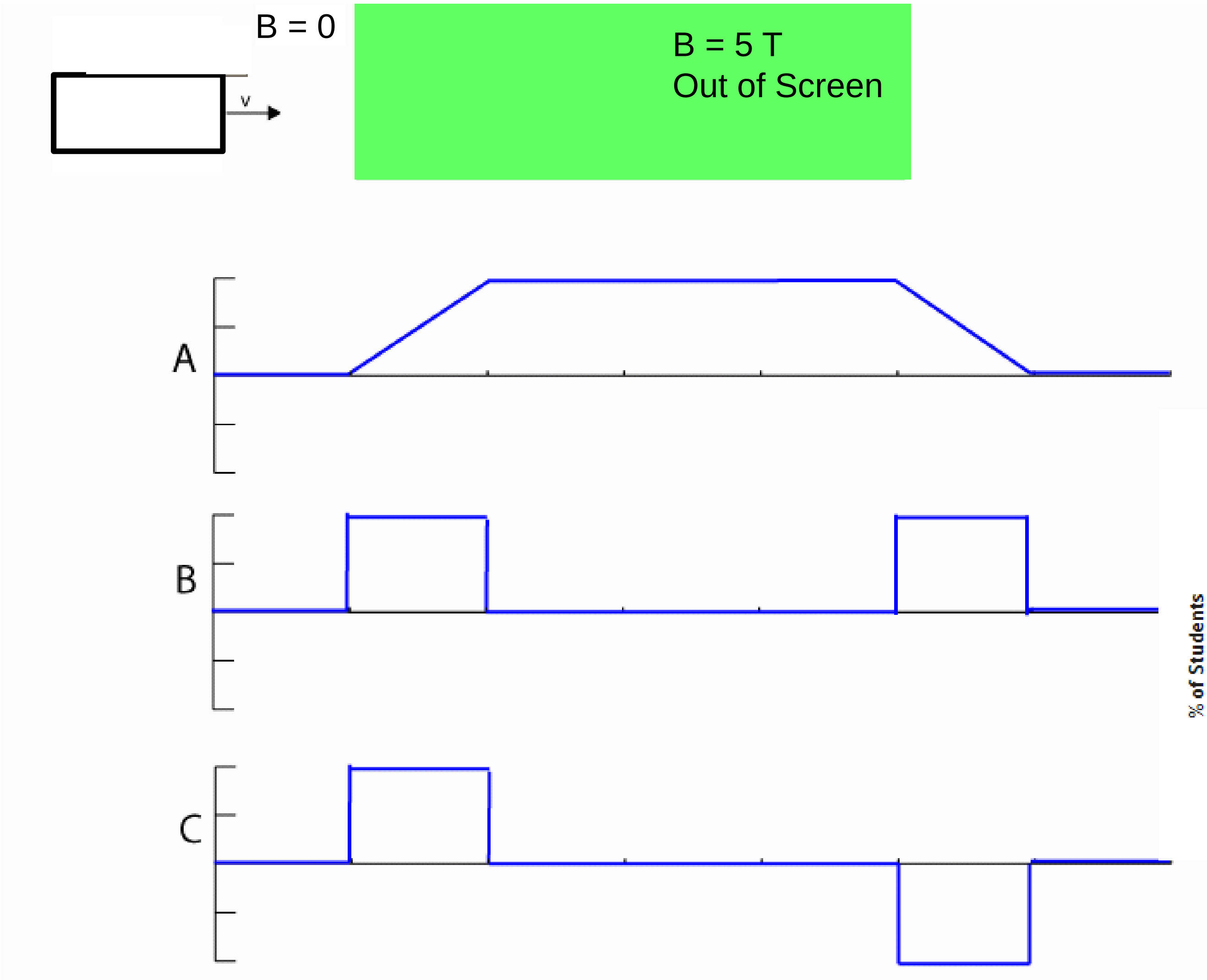
Counterclockwise Current

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

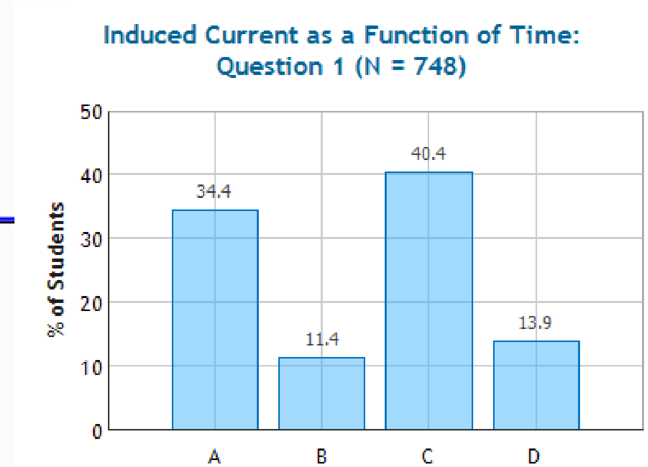
$$F = \left(\frac{vBL}{R}\right)LB \longrightarrow P = Fv = \left(\frac{vBL}{R}\right)LBv = I^2R$$

CheckPoint 5

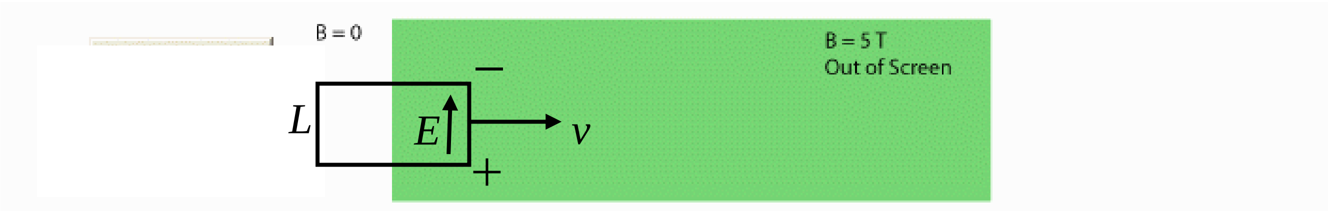
A wire loop travels to the right at a constant velocity. Which plot best represents the induced current in the loop as it travels from left of the region of magnetic field, through the magnetic field, and then entirely out on the right side?

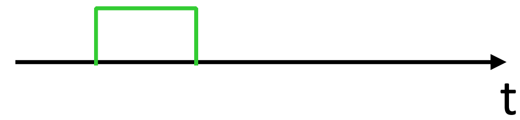


Let's step through this one



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?

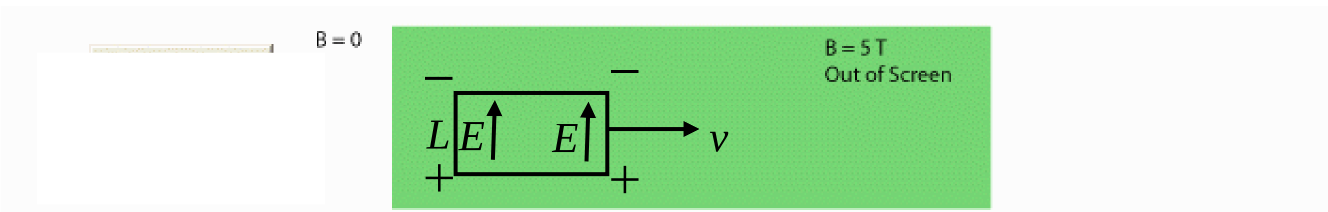


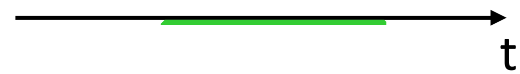


Only leading side has charge separation

$emf = BLv$ (cw current)

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?

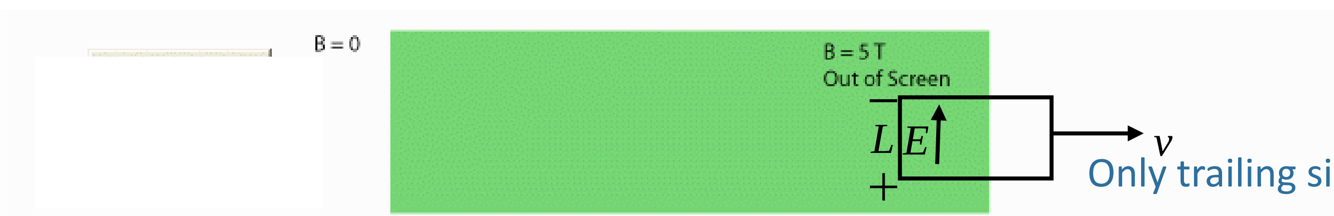




Leading and trailing sides have charge separation

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

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?

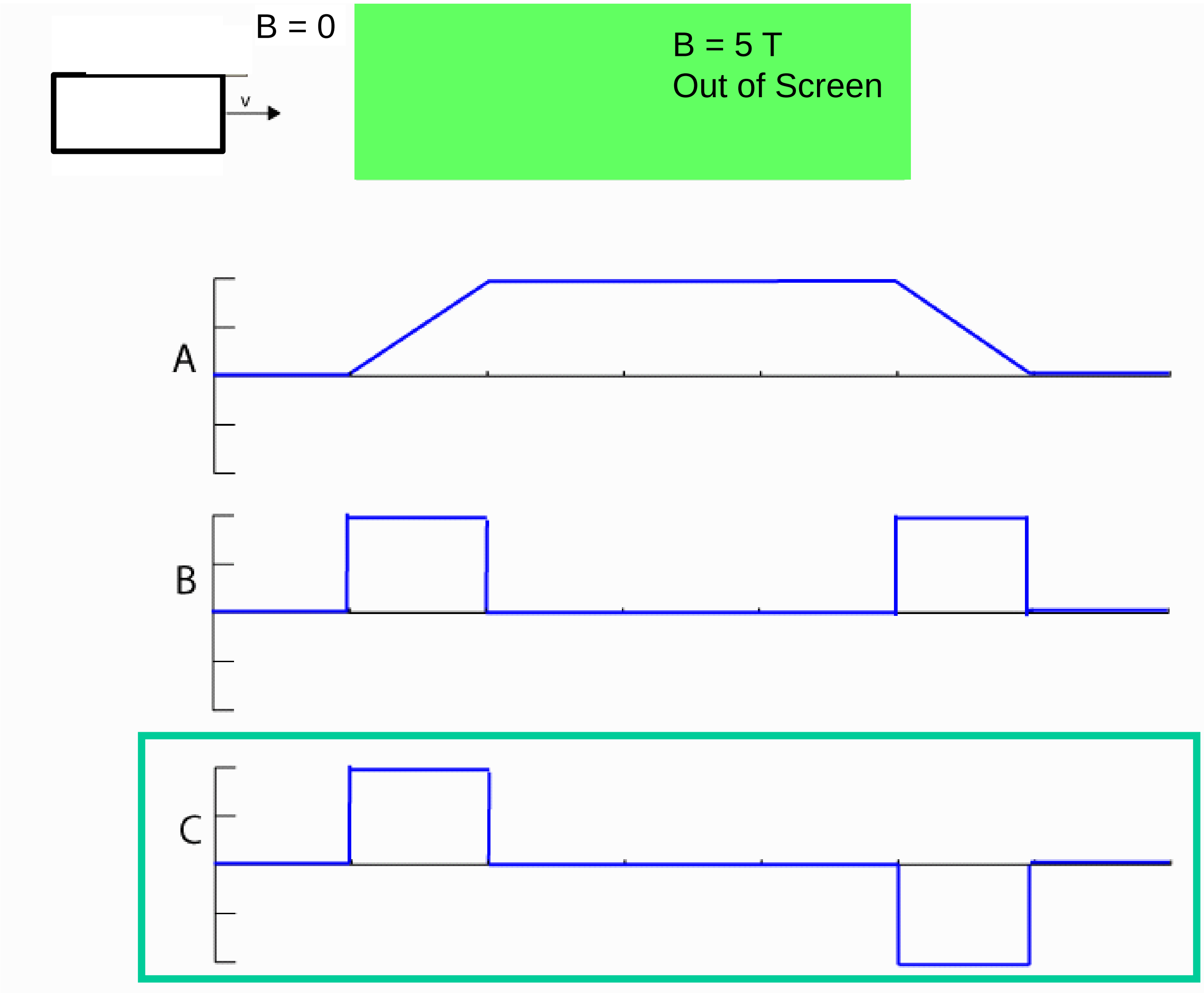


Only trailing side has charge separation

$emf = BLv$ (ccw current)

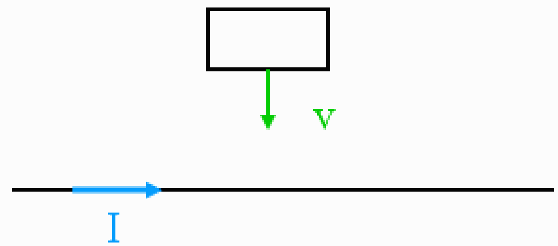
CheckPoint 5

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?



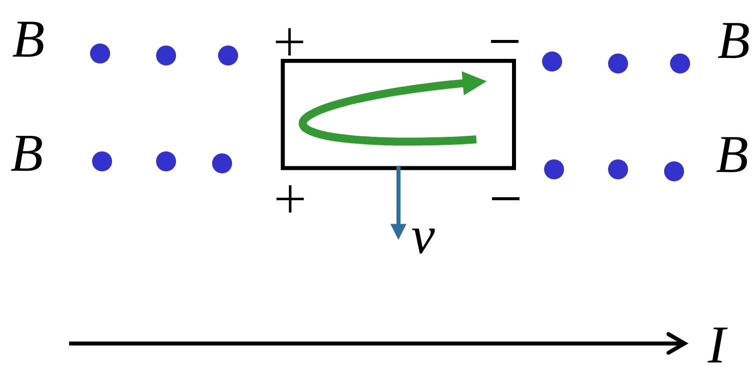
Changing B Field

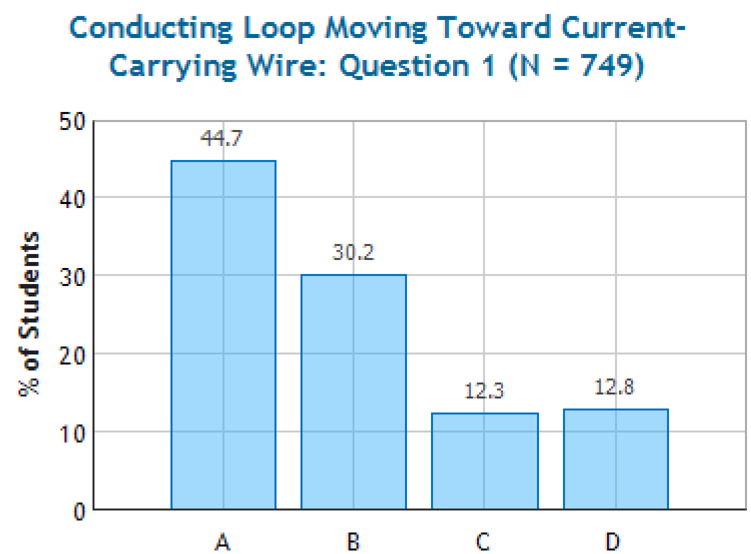
A conducting rectangular loop moves with velocity *v* toward an infinite straight wire carrying current as shown.



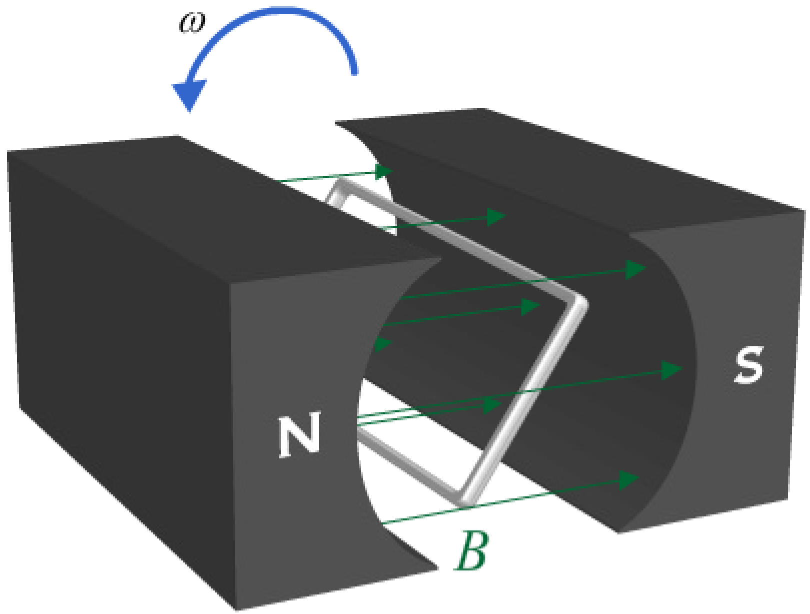
What is the direction of the induced current in the loop?

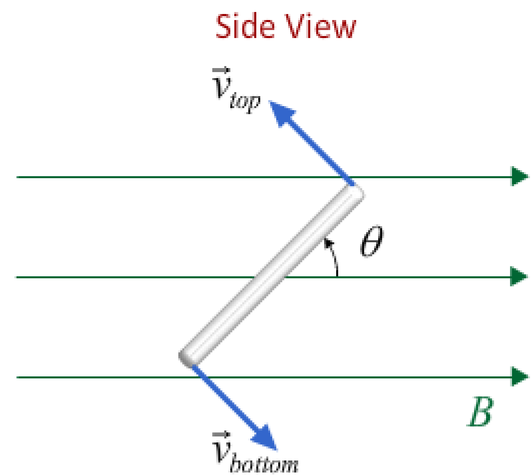
A. clockwise
B. counter-clockwise
C. there is no induced current in the loop





Generator: Changing Orientation





On which legs of the loop is charge separated?

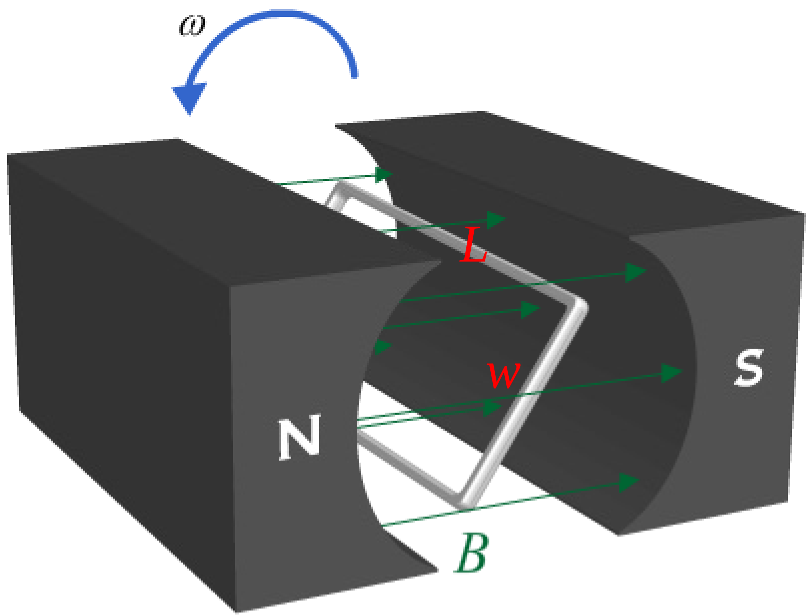
A) Top and Bottom legs only
B) Front and Back legs only
C) All legs
D) None of the legs

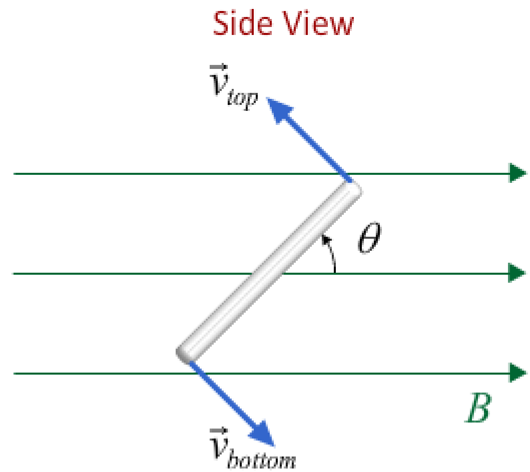
$\vec{v} \times \vec{B}$

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

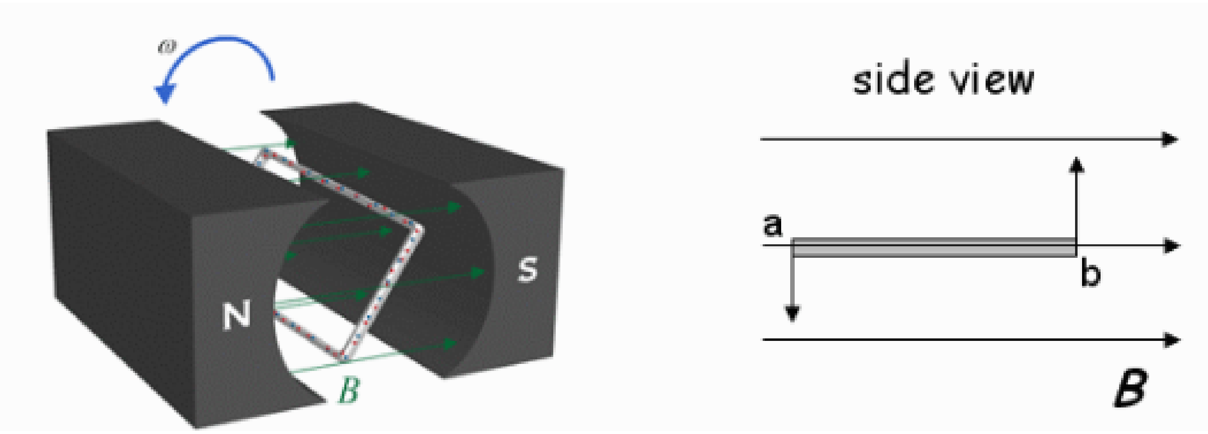
$$\vec{v} \times \vec{B}$$

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

$$\varepsilon = 2EL$$

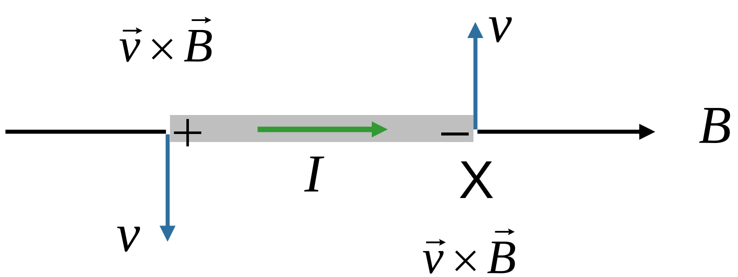
Changing Orientation

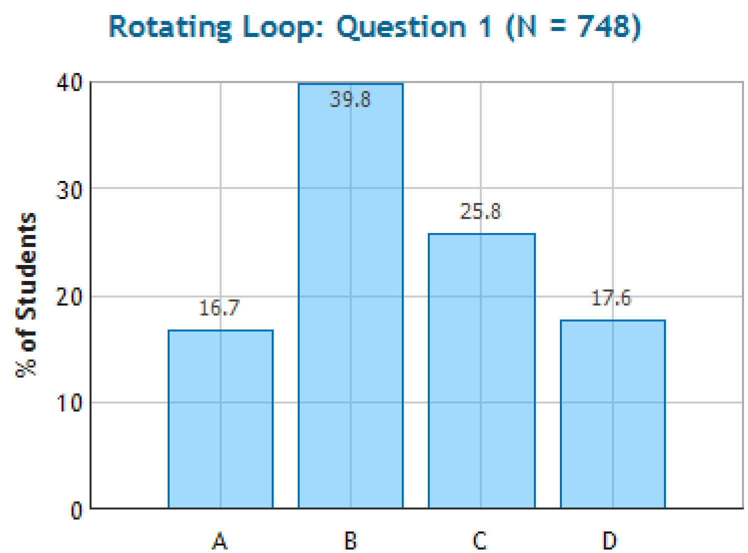
A rectangular loop rotates in a region containing a constant magnetic field as shown.



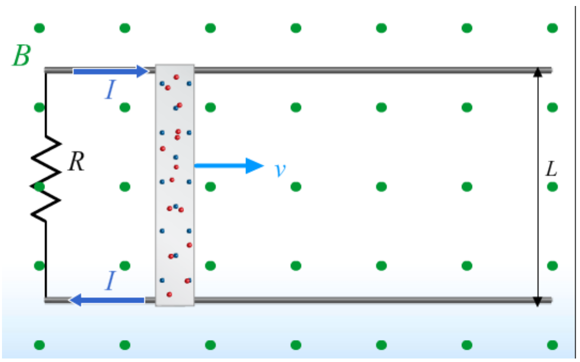
The side view of the loop is shown at a particular time during the rotation. At this time, what is the direction of the induced (positive) current in segment *ab*?

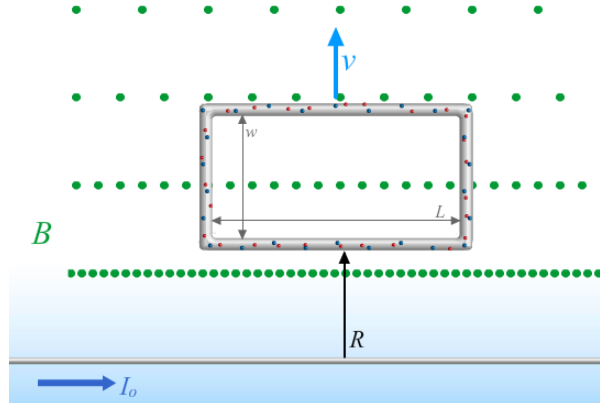
A. from *b* to *a*
B. from *a* to *b*
C. there is no induced current in the loop at this time

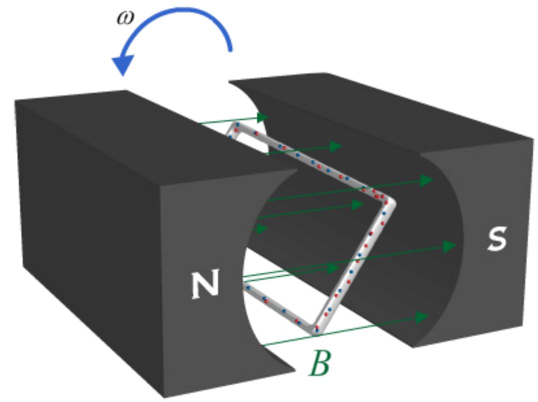




Putting it Together







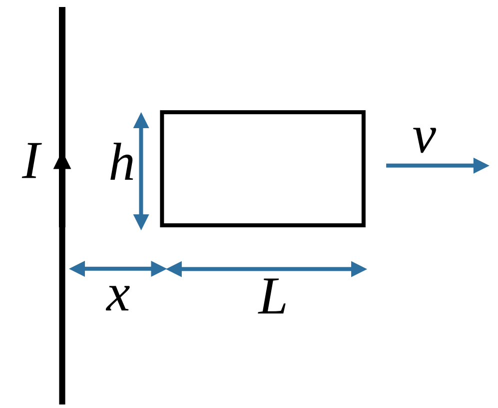
Faraday's Law

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

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 $8\ \text{amps}$. 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:

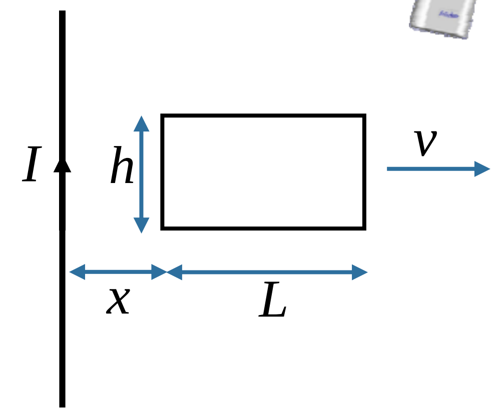
Calculate B field due to wire.

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 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

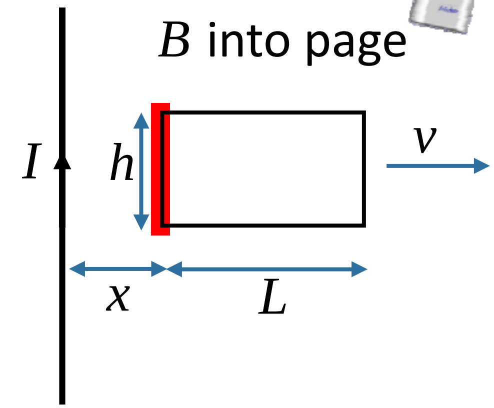
C) Left

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

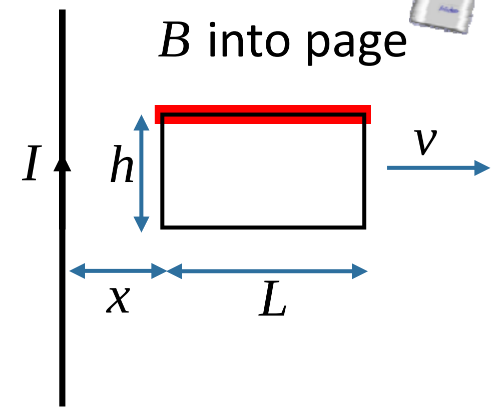
B) Top is negative

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

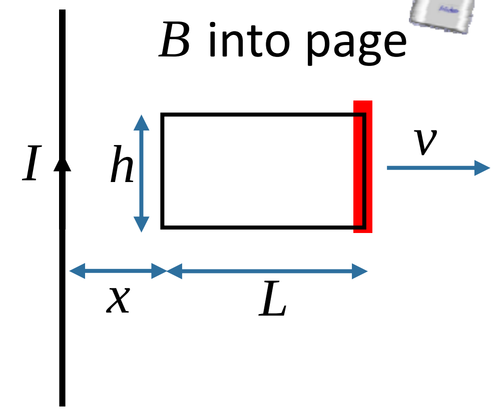
C) Zero

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

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

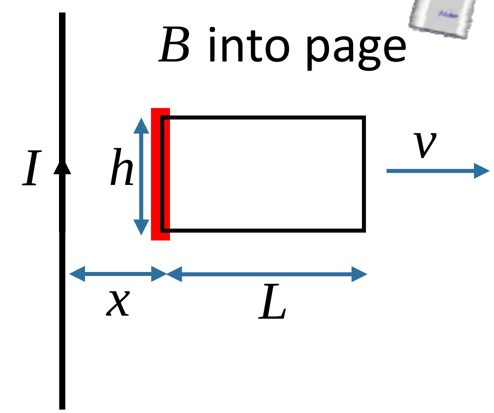
B) top is negative

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) $\varepsilon_{left} = \frac{\mu_o I}{2\pi x} L v$

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

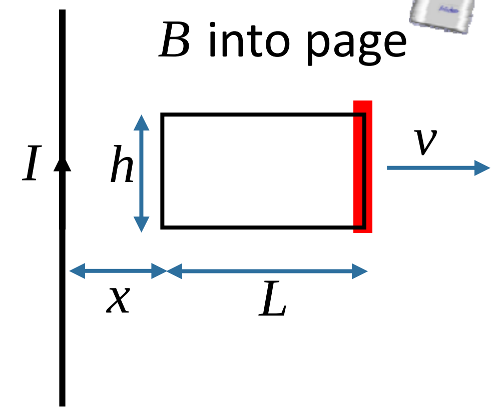
C) $\varepsilon_{left} = \frac{\mu_o I}{2\pi (L+x)} L v$

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

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

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

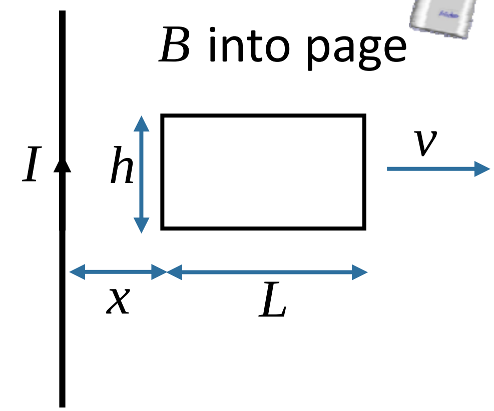
C) $\varepsilon_{right} = \dfrac{\mu_o I}{2\pi(h+x)} Lv$

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

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

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

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

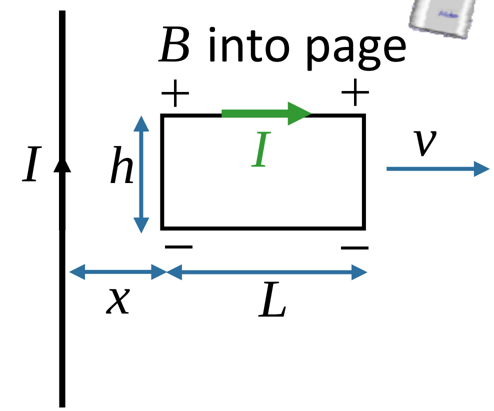
C) $\varepsilon_{loop} = 0$

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

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

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

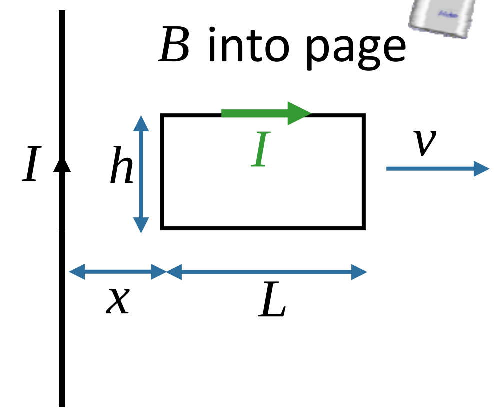
B) Counterclockwise

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

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 amps.



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

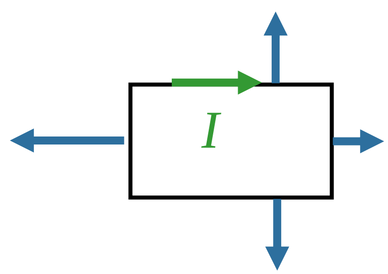
A) UP

B) DOWN

C) LEFT

D) RIGHT

E) $F = 0$



Total force from B
Points to the left !