Concept:

Motional EMF
Hopefully I will understand more after lecture. May be time to open the book.

can we go over the conducting loop moving toward current-carrying wire using the right hand rule? Thanks.
I could follow what we were doing up to this point, but thank goodness spring break is coming so I can work on this Conducting Loop Moving Toward Current-Carrying Wire was tricky... The prelecture didn't give much of an explanation.
I never knew I could get this emotional over Physics...

Railguns.
can we go over the rotating loop one again?
please touch on motional emf more
The rotating loop in the generator portion of the prelecture and checkpoint was difficult to understand. Also, how did do you get from current from velocity?
Honestly I just skip through it for today as I have to do the homework
I am very very confused. What are all the things that are happening???
that was a lot of information gone over really fast
The Plan

• Really odd formula coming: \[ \mathcal{E} = -\frac{d\Phi_B}{dt} \]

• Spend a bit of time seeing that it makes sense (See prelecture for additional info.)

• Do two examples problem in detail.

• Move on to use formula.
Motional EMF

Motion of a conductor through B field can cause potential difference. 
(Remark Hall Effect clicker question?)

\[ \vec{F} = q\vec{v} \times \vec{B} \]

\[ \Delta V = EL \]

\[ \Delta V = vBL = \varepsilon \]
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 statements is true?

A. A motional emf exists in the bar for case (a), but not for case (b)
B. A motional emf exists in the bar for case (b), but not for case (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)
Which of the following statements is true?

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

A) The bar has to be moving in the same direction as the magnetic field in order to have motional emf.

B) Since bar a is moving parallel to the magnetic field, the protons and electrons inside of it remain undisturbed.

C) Even though bar a doesn't have a magnetic force on it, there is still an electric field in it that can create an emf

D) Neither bar moves parallel to the magnetic field
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
What we thought......

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

A. going up
B. going down

The electromotive force (EMF) is given by:

\[ E = vB \]

Bar:

Opposite forces on charges:

Conducting Bar Moving on Wires: Question 1 (N = 39)

Equivalent circuit:

\[ \varepsilon = E_L = vBL = \Delta V \]
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
D. left
E. into the screen
F. out of the screen
The current through this bar results in a force on the bar. The direction of the force depends on the direction of the current (counterclockwise) and the magnetic field acting on the bar.

- **A.** down
- **B.** up
- **C.** right
- **D.** left
- **E.** into the screen
- **F.** out of the screen

**Counter-clockwise Current**

\[ F = I\vec{L} \times \vec{B} \]

Where \( F \) points to the left,

\[ P = Fv = \left( \frac{vBL}{R} \right)LBv = I^2R \]
A 10cm conducting bar (green) rests on two frictionless wires connected by a resistor \( R = 50\Omega \). The entire apparatus is placed in a uniform magnetic field of 0.5 T pointing into the screen.

The bar is pulled to the right by a force, \( F \), at a velocity of 8m/sec.

What is the current through the resistor?

What is the force required to keep the bar moving at this constant velocity?
We just found that increasing the area of the loop contained in a fixed magnetic field created a current in the loop. But a current in a loop induces its own magnetic field!!

Which way will this induced magnetic field point in this case?

A) left  
B) right  
C) Into the page  
D) Out of the page
Motional EMF

Motion of a conductor through B field can cause potential difference.  
*(Remember Hall Effect clicker question?)*

\[ \vec{F} = q \vec{v} \times \vec{B} \]

\[ \Delta V = E L \]

\[ \Delta V = vBL = \varepsilon \]

\[ qvB = qE \]

\[ E = vB \]
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 of the field on the right side.
Checkpoint 2 (step-by-step)

Only front edge wire has change separation. Current is counter-clockwise.

Both edges have change separation. $\mathbf{E}$ cancel each other out.

Only rear edge wire has change separation. Current is clockwise.
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 of the field on the right side.

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**Checkpoint 2**

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 of the field on the right side.

![Diagram of induced current as a function of time](image)

**Induced Current as a Function of Time:**

**Question 1 (N = 39)**

- **A**
- **B**
- **C**
Two identical rectangular wire loops have the same velocity \( v \) but different orientations, as shown below. They enter a region with uniform magnetic field \( B \) pointing out of the page (i.e., green square).

Compare the emf induced in loop 1 (emf\(_1\)) with the emf induced in loop 2 (emf\(_2\)) at the instant shown.

A) \( \text{emf}_1 > \text{emf}_2 \)
B) \( \text{emf}_1 = \text{emf}_2 \)
C) \( \text{emf}_1 < \text{emf}_2 \)
A conducting rectangular loop moves with velocity $v$ **towards** an infinite straight wire carrying current as shown.

In what direction is the induced current in the loop?

A. clockwise  
B. counterclockwise  
C. There is no induced current in the loop
In what direction is the induced current in the loop?

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

\[ \vec{F} = q\vec{v} \times \vec{B} \]

\( F \) points to left on upper and lower edges but is greater on lower edge
On which legs of the loop is an E field formed along their length?

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
At what angle $\theta$ is \textit{emf} the largest?

A) $\theta = 0$

B) $\theta = 45^\circ$

C) $\theta = 90^\circ$

D) \textit{emf} is same at all angles

\[ \varepsilon = 2EL = 2 \frac{F}{q} L = 2L\vec{v} \times \vec{B} = 2L\left(\frac{w}{2}\right)\omega AB \cos \theta = \omega AB \cos(\omega t) \]

\[ = v \]

Largest for $\theta = 0$ (\textit{v} perp to $B$)
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
A rectangular loop \((h = 0.3 \text{ m} \ L = 1.2 \text{ m})\) with total resistance of 5W is moving away from a long straight wire at a velocity of 9 m/sec. The wire carries total current 8 amps.

What is the induced current in the loop when it is a distance \(x = 0.7 \text{ m}\) from the wire?

- **Conceptual Analysis:**
  
  Long straight current creates magnetic field in region of the loop.

  Vertical sides develop \(\text{emf}\) due to motion through B field

  Net \(\text{emf}\) produces current

- **Strategic Analysis:**
  
  Calculate \(B\) field due to wire.

  Calculate motional \(\text{emf}\) for each segment

  Use net \(\text{emf}\) and Ohm’s law to get current
A rectangular loop \((h = 0.3m \ L = 1.2 \ m)\) with total resistance of \(5 \Omega\) 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
What is the emf induced on the left segment?

A) Top is positive
B) Top is negative
C) Zero

A rectangular loop \((h = 0.3 \text{ m} \ L = 1.2 \text{ m})\) with total resistance of \(5 \Omega\) 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 \(x = 0.7 \text{ m}\) from the wire?
A rectangular loop \((h = 0.3m \ L = 1.2 \ m)\) with total resistance of \(5\Omega\) 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 \textit{emf} induced on the top segment?

A) left is positive  
B) left is negative  
C) Zero
A rectangular loop \((h = 0.3 \text{m} \ L = 1.2 \text{ m})\) with total resistance of 5\(\Omega\) 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 \(x = 0.7 \text{ m}\) from the wire?

What is the \textit{emf} induced on the right segment?

\begin{itemize}
  \item[A)] top is positive
  \item[B)] top is negative
  \item[C)] Zero
\end{itemize}
Note that the loop is moving with a constant velocity. \( \Rightarrow F_{\text{net}} = 0 \).

What are the magnetic forces on the four edges of the loop?

Something must be doing positive work on the loop to keep it moving at constant \( v \).
A rectangular loop \((h = 0.3 \text{ m} \quad L = 1.2 \text{ m})\) with total resistance of \(5\Omega\) is moving away from a long straight wire carrying total current \(8 \text{ amps}\).

What is the direction of the induced current?

A) Clockwise

B) Counterclockwise
We just found that decreasing the strength of a magnetic field contained in a fixed loop created a current in the loop. But a current in a loop induce its own magnetic field!!

Which way will this induced magnetic field point?

A) left
B) right
C) Into the page
D) Out of the page
Faraday’s Law

\[ \Phi \equiv \vec{B} \cdot \vec{A} \]

\[ \mathcal{E} = -\frac{d\Phi}{dt} \]

Notice the minus sign!!!