Today's Topics
- Faraday's Law (Ch 31)
- Review Lenz's Law
- Demos
- Faraday's Law Explained
- Motional Emf
- Expected Preview: Ch 31

Review: Faraday's Law of Induction
- The emf induced in a “circuit” is proportional to the time rate of change of magnetic flux through the “circuit”.

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

- Notes:
  - “Circuit”: any closed path
  - does not have to be real conducting circuit
  - The path/circuit does not have to be circular, or even planar

Review: Direction of Induced emf
- \( \mathcal{E} > 0 \), same as nominal direction
- \( \mathcal{E} < 0 \), opposite
- Note that the nominal direction of \( \mathcal{E} \) and the direction of vector A follows right hand rule

Review: Lenz's Law
- Lenz’s law in plain words: the induced emf always tends to work against the original cause of flux change

<table>
<thead>
<tr>
<th>Cause of ( d\Phi_B/dt )</th>
<th>“Current” due to Induced ( \mathcal{E} ) will:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increasing B</td>
<td>generate B in opposite dir.</td>
</tr>
<tr>
<td>Decreasing B</td>
<td>generate B in same dir.</td>
</tr>
<tr>
<td>Relative motion</td>
<td>subject to a force in opposite direction of relative motions</td>
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</tbody>
</table>

Note: “Current” may not actually produced if no circuit
Examples of Lenz’s Law

Demo: Eddy Current

Demo: Guillotine Machine

Let's see how a Physicist (me) would do it.

Methods to Change Electric Flux

\[ E = -\frac{d\Phi_B}{dt} \quad \text{uniform} \quad B \]

- Change of \( \Phi_B \) → emf
- To change \( \Phi_B \):
  - Change \( B \) → emf produced by an induced E field
  - Change \( A \) → motional emf
  - Change \( \theta \) → motional emf
  - Combination of above
**Lenz Law for Moving Rod in B Field**

- In the setting below, a magnetic force is acting against the motion of the moving rod. No matter which direction it moves.

  \[ \text{Use Lenz Law to explain it.} \]

**Motional emf of a Sliding Bar**

- When the conducting bar is moving, the electrons inside is subject to a magnetic force:
  - Show that for the motion below, electrons are subject a force downwards.
  - Show the magnitude of the force is $evB$ per electron.

- Now electrons are moving downwards and accumulate at the lower end of the bar.

  \[ \text{This would create an electric field } E \text{ in direction shown.} \]
  \[ \text{The electric field } E \text{ applies an upward force } F_E = eE. \]
  \[ \text{When balance } F_E = F_B \rightarrow E = evB. \]

  \[ \text{The voltage (emf) is } \varepsilon = vLB. \]

**Moving Rod Again**

- When forming a closed circuit, the induced emf drives a current in the rod in direction as shown.

  \[ \text{Exercise: use } F_B = ILXB \text{ to verify the direction of } F_B \text{ as shown.} \]

**Use Faraday's Law to Calculate Motional emf**

- Faraday's Law: $\varepsilon = -\frac{d\Phi}{dt}$, $\Phi = BA$, $A = \pi r^2$

\[ \rightarrow \frac{d\Phi}{dt} = B \frac{dx}{dt} = B\nu = |\varepsilon| \]
What Produces emf? Induced Electric Field

- Whenever a magnetic field varies in time, an electric field is induced.

**Notes:**
- Induced E is not a conservative field.
- Induced E can exist in a location where no B field exists.
- Induced E is independent of circuit.