Physics 202, Lecture 16

Today’s Topics

- Reminder of Lenz’s and Faraday’s Laws
- Motional EMF
- Electric Generators

Lenz’s Law (Reminder)

- The emf due to change of magnetic flux tends to create a current which produces a magnetic field to compensate the change of original magnetic flux.
  - Note: Real current may or may not generated.
  - Lenz’s law is a convenient way to determine the direction of the emf due to magnetic flux change.

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 $\frac{d\Phi_B}{dt}$</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>
</tr>
</tbody>
</table>

Note: “Current” may not actually produced if no circuit

Quizzes/Exercises: Determine Direction Of emf

- Indicate the direction of emf in the following cases:
  - $|B|$ increases
  - $|B|$ decreases
  - $|B|$ decreases

path outside $B$
Demo: Jumping Ring and more

- V switch on and the ring jumps
- conducting ring

Faraday’s Law (Reminder)

- The emf induced in a “circuit” is proportional to the time rate of change of magnetic flux through the “circuit”.

![Image of Faraday’s Law]

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

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

Methods to Change Electric Flux

\[ \mathcal{E} = - \frac{d\Phi_B}{dt} = \frac{d(BA\cos\theta)}{dt} \]

- Change of \( \Phi_B \rightarrow \text{emf} \)
- To change \( \Phi_B \):
  - Change \( B \rightarrow \text{emf produced by an induced E field} \)
  - Change \( A \rightarrow \text{motional emf} \)
  - Change \( \theta \rightarrow \text{motional emf} \)
  - Combination of above

Lenz’s Law and Motional emf

- A consequence of Lenz's law is that motional emf would always tend to prevent the relative between a conductor and the magnetic field

![Image of Lenz’s Law and Motional emf]
Moving Rod: Motional emf

- If a conducting segment are in relative motion (cut through) with a magnetic field, an emf is produced.
  - Motional emf is produced by the magnetic force on the free particles inside the conductor
  - Faraday's law is also valid for this type of emf

Exercise:
show that the motional emf in the left fig. is $\mathcal{E} = Blv$

Electric Generator

$$\mathcal{E} = -N \frac{d\Phi_B}{dt} = -N \frac{d(AB \cos \theta)}{dt} = NAB \omega \sin(\omega t)$$

$\theta = \omega t$

Force on the Moving Rod
Changing B

Imagine \( \frac{dB}{dt} = c > 0 \)

ε = \(-\frac{d\Phi_B}{dt} = -A \frac{dB}{dt} = -Ac = -\pi r^2 c \)

ε = \(-\oint Edl = -2\pi rE \)

\( E = \frac{rc}{2} \)

Induced E is not a Conservative Force

- 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.

\[ \oint E \cdot ds = -\frac{d\Phi_B}{dt} \] valid for any closed path