Lenz's law

Select LEARNING OBJECTIVES:

- Apply Len's law to determine the direction of the induced current.

TEXTBOOK CHAPTERS:

Boxsand :: magnetic induction

WARM UP: Faraday's law questions?

Using Faraday's law combined with Ohm's law we can determine the value of the induced current, but not the direction of the current. To find the direction of the induced current we rely on Lenz's law. In the mathematical representation, Lenz's law is the minus sign that appears in Faraday's law as shown below.

$$\bar{\mathcal{E}} = -N\frac{\Delta \Phi^B}{\Delta t}$$

LENZ'S LAW

Notice that the above expression is no different than Faraday's law as introduced previously. Here, we drop the absolute value signs around each side. My favorite quote that summarizes Lenz's law is from David J. Griffiths, "Nature abhors a change in flux". Griffiths' statement basically says that nature will do it's best to maintain the current value of flux through a given surface area. For a loop of wire, the only way for nature to resist a change in flux, is to induce a current around the loop that attempts to maintain the initial value of flux. The goal now is to find a procedure to find the direction of the induced current given the fact that nature wants to maintain its current state of flux through a given area. Throughout my studies I have stumbled across 3 different methods to find the direction of induced current. I listed each of these methods below as method A, B, and C. Method A and C are basically the same except method A is more explicit while method C skips a few steps because they are done mentally. My suggestion is to pick your favorite method and stick with it. My favorite is method B.

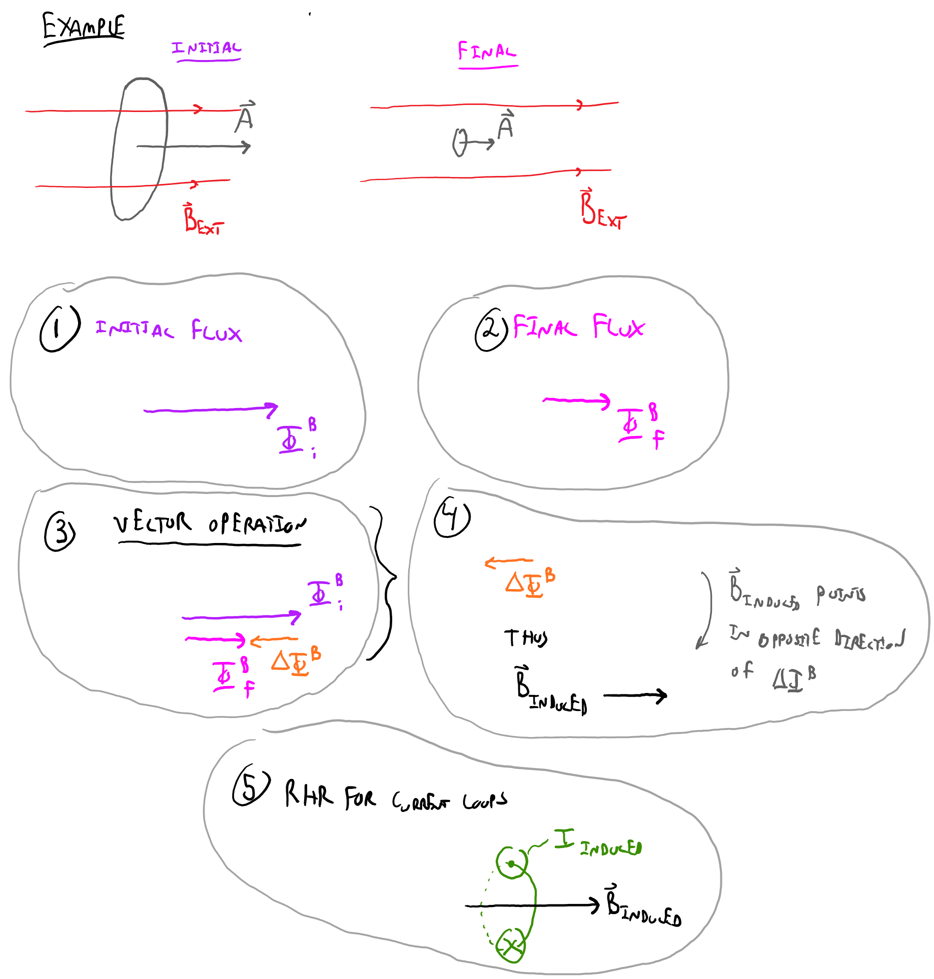
- *Method A: Find direction of $B_{induced}$, and thus $I_{induced}$*

    1) Find "direction" and magnitude of Φ_i^B (same direction as the initial parallel component (w.r.t. the area vector) of the external magnetic field). Create "vector" representations of initial flux.
    2) Find "direction" and magnitude of Φ_f^B (same direction as the final parallel component (w.r.t. the area vector) of the external magnetic field). Create "vector" representations of final flux.
    3) Use rules for vector subtraction to find "direction" of $\Delta\Phi^B$ (points from initial to final).
    4) Induced magnetic field points in opposite direction of $\Delta\Phi^B$.
    5) Use RHR for current loops to determine direction of $I_{induced}$.

EXAMPLE

INITIAL

FINAL



- *<u>Method B:</u> Define positive direction of current, find if Ɛ is negative or positive.*

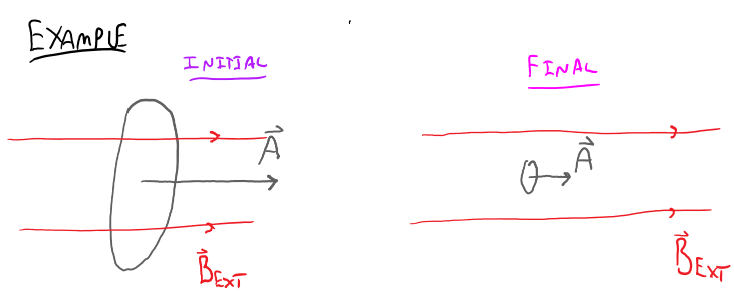
  (1) *Use right hand and align thumb in the direction of the initial parallel component* (w.r.t. the area vector) *of the external magnetic field. Your fingers now curl in the positive "direction" (either ccw, or cw).*

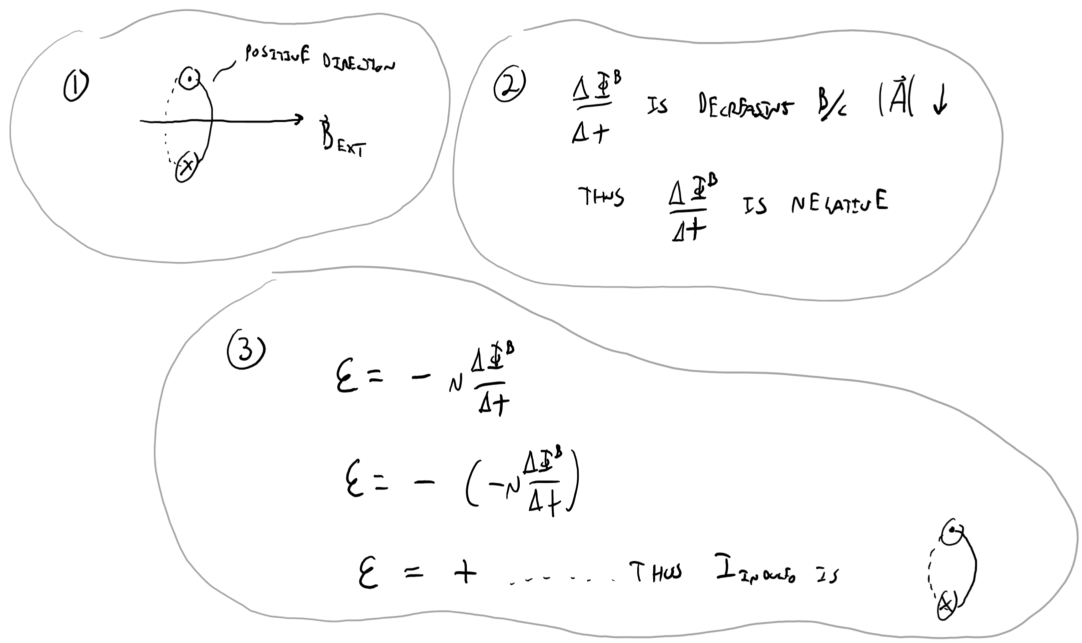
  (2) *Determine if the magnetic flux is increasing or decreasing.*

  i. *If increasing,* $\frac{\Delta\Phi^B}{\Delta t}$ *is positive.*

  ii. *If decreasing,* $\frac{\Delta\Phi^B}{\Delta t}$ *is negative.*

  (3) *Find if Ɛ is negative or positive. If positive, induced current is in direction of the positive direction defined in step 1; if negative, induced current is in the opposite direction of the positive direction defined in step 1.*





- *Method C: Induced current flows in direction such that the induced magnetic field tries to maintain the initial flux.*

  (1) Determine the initial "direction" and magnitude of the magnetic flux.
  (2) Determine if the magnetic flux is increasing or decreasing.
  (3) Use RHR for current loops to find direction of the induced magnetic field which will try to maintain the original flux magnitude and direction. Your fingers are now curling in the direction of the induced current.