UBC Physics 102

Lecture 13

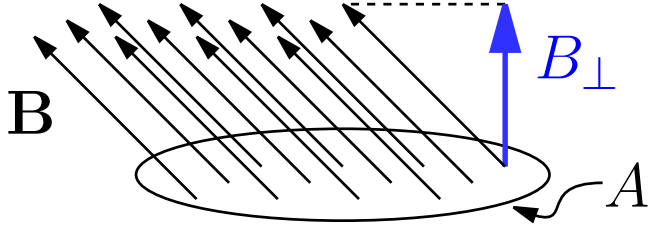
Rik Blok

Outline

- Faraday's law and Lenz's law
- Emf in a moving conductor
- Transformers
- Self-inductance
- Energy storage
- End

Faraday's law and Lenz's law [Text: Sect. 29-1,2]

- **Definition:** *Magnetic flux*



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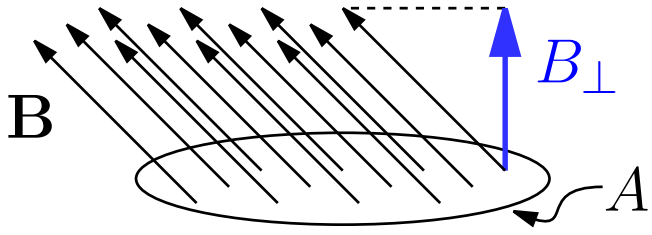

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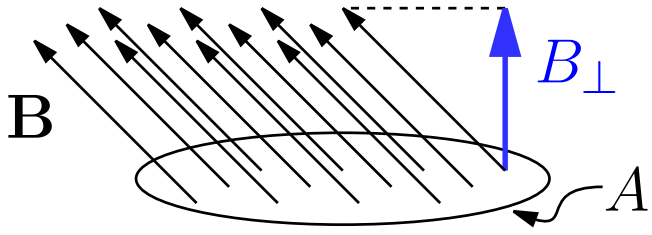

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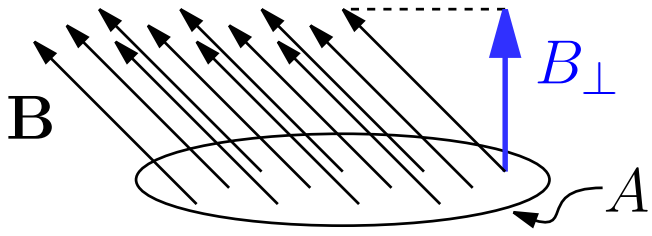

  - Quantity of B-field passing through area A.

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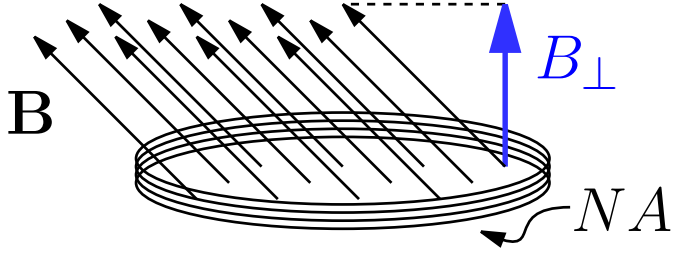
  - Like Φ_E used in Gauss's law but don't need closed surface.
  - Don't get to choose surface, is defined by a loop of wire.

Faraday's law and Lenz's law, contd

- **Definition:** *Magnetic flux, contd*



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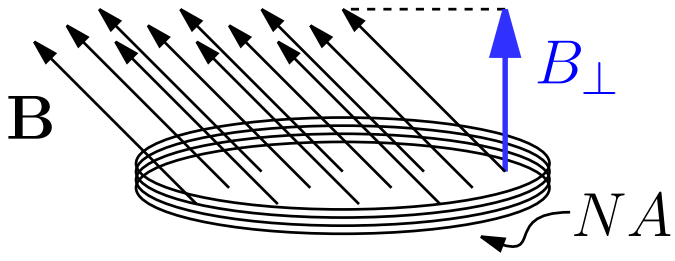

  - If we have a coil with N loops then same B goes through all so

$$\Phi_B = NB_\perp A.$$

Faraday's law and Lenz's law, contd

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Faraday's law and Lenz's law, contd

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- **Definition:** *Induced current/emf*
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- **Definition:** *Lenz's law*
  - Induced emf (and current) in direction that opposes change in flux.

Faraday's law and Lenz's law, contd

- **Discussion: Induced magnetic field**

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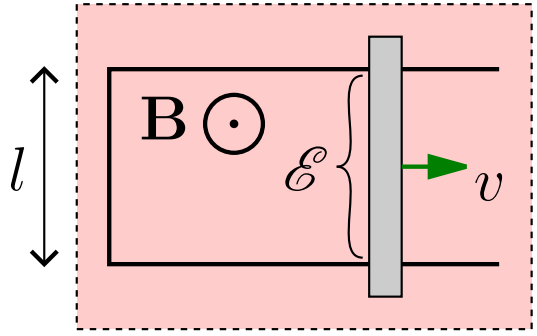

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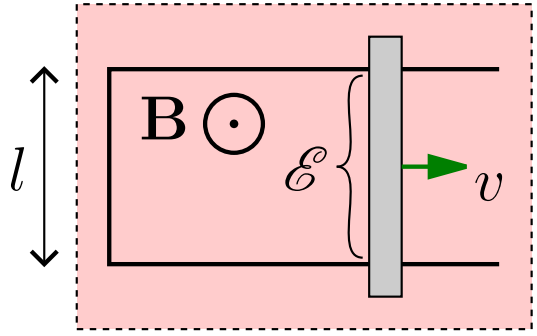

$$\frac{dA}{dt} = lv.$$

  - Emf is (ignoring sign)

$$\mathscr{E} = \frac{d}{dt}\Phi_B = B\frac{dA}{dt} = Blv.$$

Emf in a moving conductor, contd

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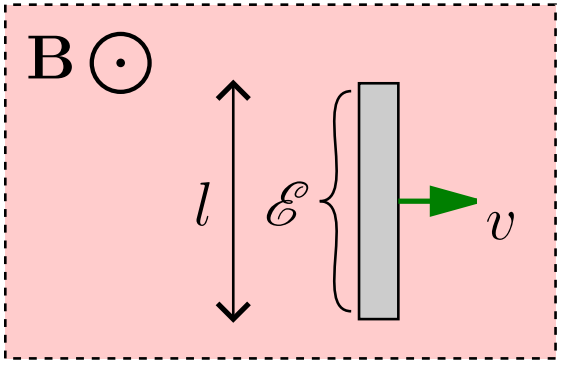

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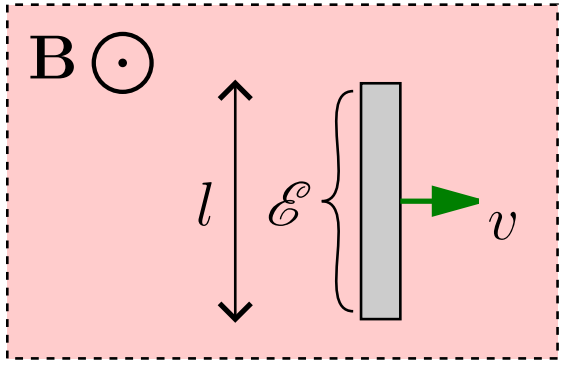

  - Force on electrons, $\boxed{F = qvB}$ (up). So E-field in rod (down) is

$$E = \frac{F}{q} = vB.$$

Emf in a moving conductor, contd

- **Discussion: Moving conductor, contd**

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  - $\mathbf{E}$ uniform so emf (voltage, $\boxed{V = -E_l l}$, ignoring sign)

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Transformers [Text: Sect. 29-6]

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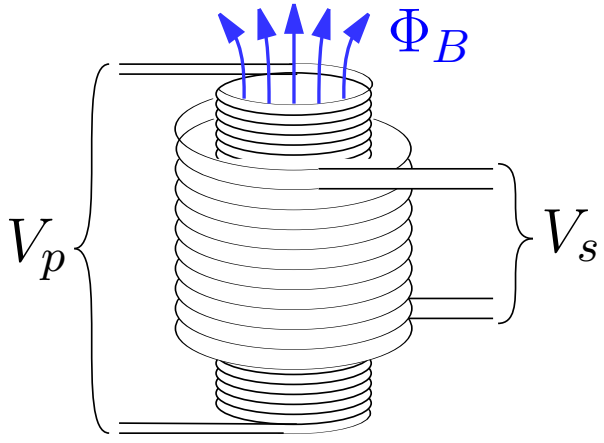

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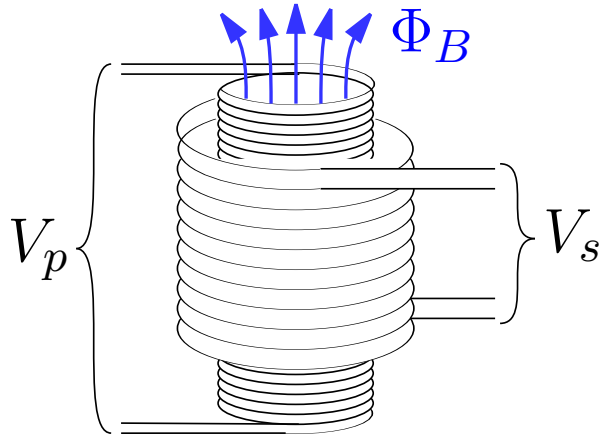

  - Primary coil with voltage V_p generates flux:

$$V_p = N_p \frac{d\Phi_B}{dt}.$$

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  - If transformer efficient then power transferred from primary to secondary, $P_p = P_s$ or $I_p V_p = I_s V_s$.

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  - Emf "impedes" change in current.

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  - Self-inductance is proportionality constant, L.
  - Property of object: depends on shape, size, etc. For solenoid,

$$L = \frac{\mu_0 N^2 A}{l}.$$

Self-inductance, contd

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  - Consider gradually ramping up current $\hat{I}$ through inductor from zero to I.
  - Emf induced $\mathscr{E} = -L\frac{d\hat{I}}{dt}$. Power used by inductor,

$$P = \left|\hat{I}\mathscr{E}\right| = L\hat{I}\frac{d\hat{I}}{dt}.$$

Energy storage, contd

- **Derivation: Energy storage, contd**

Energy storage, contd

- **Derivation: Energy storage, contd**
  - Power not lost to heat, but stored as potential energy,

$$\begin{aligned} U &= \int P\,dt = \int L\widehat{I}\frac{d\widehat{I}}{dt}dt \\ &= L\int_0^I \widehat{I}\,d\widehat{I} \end{aligned}$$

$$U = \frac{1}{2}LI^2.$$

End

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