CP2 ELECTROMAGNETISM

https://users.physics.ox.ac.uk/~harnew/lectures/

LECTURE 18:

TRANSFORMER, MAGNETIC ENERGY

Neville Harnew[1]

University of Oxford

HT 2022

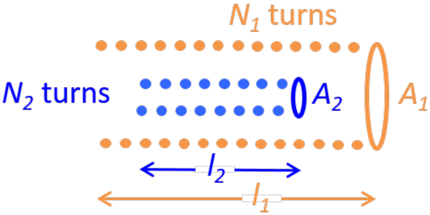
$$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$$
$$\nabla \cdot \mathbf{B} = 0$$
$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$
$$\frac{1}{\mu_0}\nabla \times \mathbf{B} = \mathbf{J} + \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t}$$

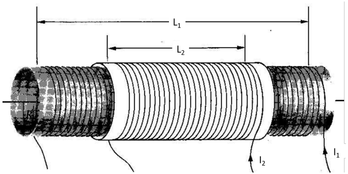
[1] With thanks to Prof Laura Herz

OUTLINE : 18. TRANSFORMER, MAGNETIC ENERGY

18.1 Coaxial solenoids sharing the same area

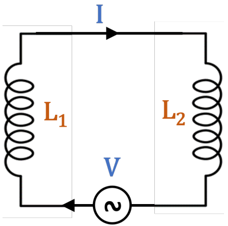
From before : mutual inductance between coils :

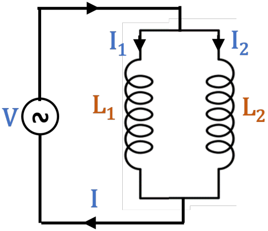




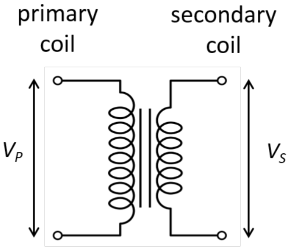
In general circuits may not be tightly coupled, hence
$M = k\sqrt{(L_1\,L_2)}$ where $k < 1$. k is the *coefficient of coupling*.

18.2 Inductors in series and parallel





18.3 The transformer

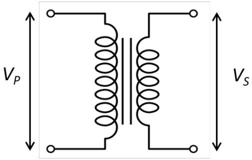


- Transformer will step up or step down applied voltage V_P by the winding ratio
- Ideally there is no power dissipated in the transformer if coils have zero resistance

Transformer summary

primary coil

secondary coil



Primary coil creates flux which permeates secondary coil, coupling their voltages:

Voltage Ratio:

$$\frac{V_S}{V_P} = \frac{\mathrm{d}\Phi_S}{\mathrm{d}\Phi_P}\frac{N_S}{N_P}$$

Current Ratio:

$$\frac{I_S}{I_P} = \frac{\mathrm{d}\Phi_P}{\mathrm{d}\Phi_S}\frac{N_P}{N_S}$$

18.4 Energy of the magnetic field

Consider the energy stored in an inductor L :

- Change in current results in a back EMF $\mathcal{E}$

Summary of energy in E and B fields

Electric field energy

Magnetic field energy