Problem 1.
From professor's old slides

A long thin solenoid of length l_1 and cross-sectional area A_1 contains N_1 closely packed turns of wire. Wrapped around it is an insulated coil of N_2 turns. Assume all flux from coil 1 (the solenoid) passes through coil 2, and calculate the mutual inductance.

Given

l_1
A_1
N_1
N_2

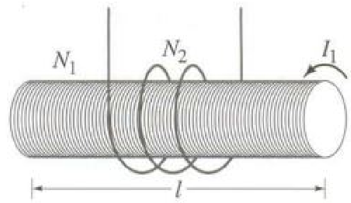

Figure 1: given

Solution

When solving this type of problems, we always ask ourselves "which (something) causes the change?" To find the EMF in coil 2, we start by writing the general formula and ask "which flux?" The flux through the coil itself. "Which current induces the EMF?" The current in coil 1 changes, thus changing coil 1's magnetic field and inducing EMF in coil 2.

$$|\mathcal{E}_2| = N_2 \frac{d\phi_2}{dt} = M \frac{di_1}{dt}$$

$$M i_1 = N_2 \phi_2 \tag{1}$$

Then to find phi, we know that $\phi = BA$, but which B and which A? The flux passing through coil 2 comes from the magnetic field of coil 1, so:

$$\phi_2 = B_1 A_2$$

We can consider that $A_2 = A_1$ since they are wrapped around each other.

$$\phi_2 = B_1 A_1 = \mu_0 N_1 i_1 A_1 / l_1 \tag{2}$$

Thus from equations (1) and (2),

$$N_2 \mu_0 N_1 i_1 A_1 / L_1 = M i_1 \implies \boxed{M = \frac{\mu_0 N_1 N_2 A_1}{l_1}}$$

Problem 2.
University Physics, Problem 65

In the circuit shown in the figure, switch S is closed at time $t = 0$ with no charge initially on the capacitor.

a. Find the reading of each ammeter and each voltmeter just after S is closed.

b. Find the reading of each ammeter and each voltmeter a long time after S is closed.

Solution

Part (a)

At $t = 0$ we replace inductors by gaps and capacitors by wires.

$V_5 = 0$ (voltage across a wire)

$V_4 = V_5 = V_2 + V_3 \implies V_4 = 0$ (in parallel)

$A_3 = 0$

$A_2 = 0 \implies V_3 = IR = 0; V_2 + V_3 = 0 \implies V_3 = 0; \implies$ (gap, therefore no current)

$A_1 = A_4 = V/R_{eq} = 0.8\text{A}$

$V_1 = 0.8 \cdot 50 = 40V$

Part (b)

At $t \to \infty$ we replace inductors by gaps and capacitors by wires.

$V_2 = 0$ (voltage across a wire)

$A_4 = 0$ (gap, therefore no current)

$A_1 = V/R_{eq} = 40/(33.3 + 50) = 0.48\text{A}$

$V_1 = 0.48 \cdot 50 = 24V$

$V_3 = V_4 = V_5 = 0.48 \cdot 33.3 = 16V$ (in parallel)

$A_2 = V_3/R = 16/100 = 0.16A$

$A_3 = V_4/R = 0.16/50 = 0.32A$