General Physics: Electromagnetism, Problem Set 12

Exercise 1 :

Two ideal solenoids are made of two pieces of wire of the same thickness $t = 1$ mm but different lengths. Solenoids are tightly wound without gaps between the coils. The larger solenoid of diameter $D_1 = 4$ cm is made from the wire of the length $L_1 = 8$ m, and the smaller solenoid of diameter $D_2 = 2$ cm is made from the wire of the length $L_2 = 2$ m. Note, that this these are not the lengths of the solenoids, but the lengths of the wires used to make them. The smaller solenoid is fully inserted into the larger one. Determine the mutual inductance of the two solenoids M_{21}. $\mu_0 = 4\pi \cdot 10^{-7}$ H/m.

Exercise 2 :

At $t = 0$, a 12.0 V battery is connected in series with a 220 mH inductor and a total of 30 Ω resistance, as shown in the figure below.

1. What is the current at $t = 0$?
2. What is the time constant?
3. What is the maximum current?
4. How long will it take the current to reach half its maximum possible value?
5. At this instant, at what rate is energy being delivered by the battery and
6. At what rate is energy being stored in the inductor's magnetic field?

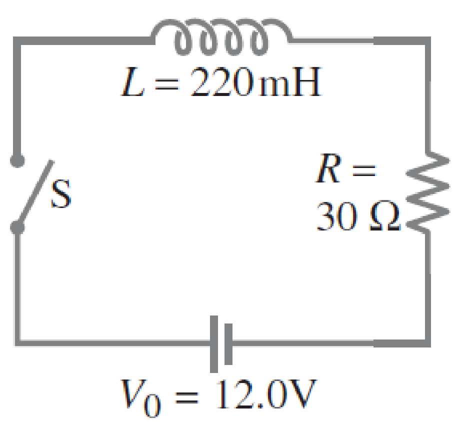

Figure 1: RL circuit.

Exercise 3 :

In the circuit below, the switch S is closed at $t = 0$.

a) Write down the differential equations for the currents in the circuit and find the equivalent RL circuit;

b) Compute the expression of the currents $i_1(t)$ and $i_2(t)$ flowing in the two inductances at a generic time t.

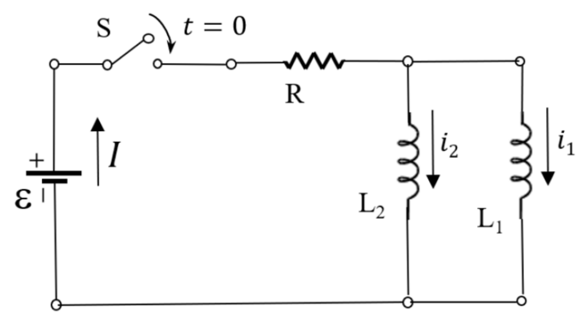

Figure 2: RL circuit.

Exercise 4 :

A 1200 pF capacitor is fully charged by a 500 V dc power supply. It is disconnected from the power supply and is connected, at t=0, to a 75 mH inductor. Determine:

1. The initial charge on the capacitor;
2. The maximum current;
3. The frequency f and period T of oscillation;
4. The total energy oscillating in the system.

Exercise 5 :

Figure 3 shows a coil of N_2 turns and radius R_2 surrounding a long solenoid of length l_1, radius R_1, and N_1 turns.

1. What is the mutual inductance of the two coils?
2. If $N_1 = 500\,\text{turns}$, $N_2 = 10\,\text{turns}$, $R_1 = 3.10\,\text{cm}$, $l_1 = 75.0\,\text{cm}$, and the current in the solenoid is changing at a rate of $200\,\text{A/s}$, what is the emf induced in the surrounding coil?

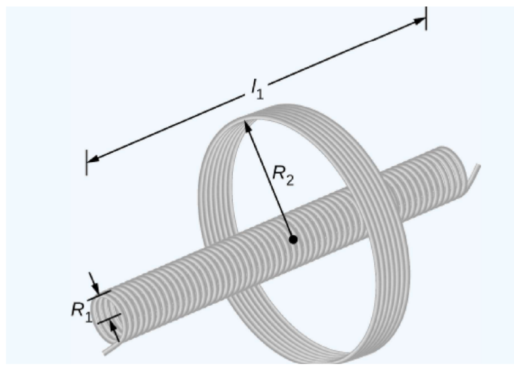

Figure 3: A solenoid surrounded by a coil.

Exercise 6 :

Figure 4 shows two long, concentric cylindrical shells of radii R_1 and R_2. This configuration is a simplified representation of a coaxial cable. The capacitance per unit length of the cable has already been calculated.

1. Determine the magnetic energy stored per unit length of the coaxial cable, and
2. Use this result to find the self-inductance per unit length of the cable.

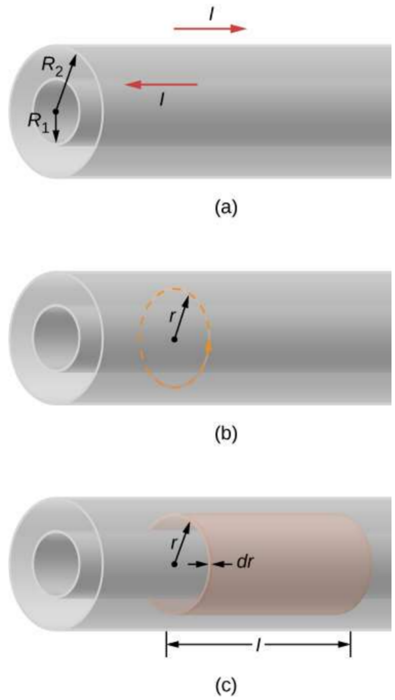

Figure 4: (a) A coaxial cable is represented here by two hollow, concentric cylindrical conductors along which electric current flows in opposite directions. (b) The magnetic field between the conductors can be found by applying Ampère's law to the dashed path. (c) The cylindrical shell is used to find the magnetic energy stored in a length l of the cable.