MASSACHVSETTS INSTITVTE OF TECHNOLOGY
Department of Electrical Engineering and Computer Science

6.002 – Electronic Circuits
Fall 2001

Problem Set 8

Issued: October 25, 2001 Due: November 2, 2001

Readings:

- Agarwal & Lang Sections 14.1 to 14.3 for Thursday, October 25.
- Agarwal & Lang Sections 14.4 and 14.5 for Tuesday, October 30.
- Agarwal & Lang Section 14.6 for Thursday, November 1st.

Problems:

1. Figure 1 below shows the circuit diagram of a magnetic stimulator made by an international biomedical electronics company. The pulsed magnetic field generated by the transducer coil (represented by the inductor) can be used in a variety of medical treatments involving nerve stimulation.

   Operation of the circuit is as follows: Ideal switches S_1 and S_2 are initially open, and the capacitor is precharged to a voltage V_x between 0 and $1000V$ ($v_C(t = 0) = V_x$). At $t = 0$, switch S_1 is closed to initiate the magnetic pulse. When the capacitor voltage v_C reaches zero, switch S_2 (made with a diode) is also closed.

   Calculate the following:

   (a) The time response of the coil current after the switch S_1 is closed and before the capacitor voltage reaches zero.

   (b) The peak coil current for $V_x = 1000V$.

   (c) The time t_1 at which the capacitor voltage reaches zero and S_2 is closed.

   (d) The time response of the coil current after the switch S_2 is closed. (Note: some medical treatments require a magnetic field with a fast rise and a slow fall.)

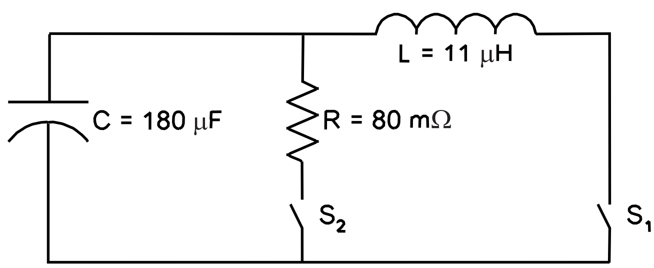

Figure 1: Circuit diagram for a magnetic nerve stimulator.

2. A&L Chapter 13 Problem 1 (pp. 813-814).

3. Figures 2(a) and 2(b) below show capacitor charging circuits. In both cases, operation is as follows: the capacitor is initially discharged. At $t = 0$ the ideal switch S is closed. It is re-opened as soon as the charging current reaches zero again. (Note: in the inductive circuit, the switch is opened at the first zero crossing after $t = 0^+$.)

   (a) Sketch the charging current and capacitor voltage for the resistive charger of Figure (a). What is the final voltage on the capacitor? How much energy is stored on the capacitor, and how much is dissipated in the charging process?

   (b) Sketch the charging current and voltage for the inductive charger of Figure (b). What is the final voltage on the capacitor? How much energy is stored on the capacitor, and how much is dissipated in the charging process?

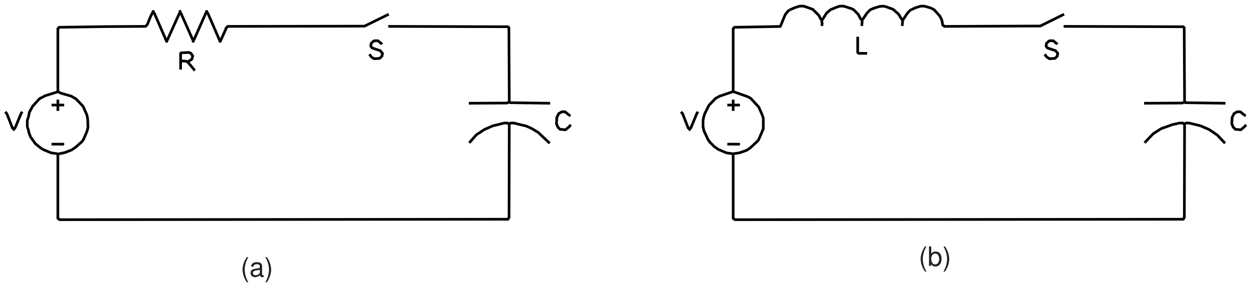

Figure 2: Capacitor charging circuits. (a) Resistive. (b) Inductive.

4. Real capacitors do not exhibit ideal behavior. Figure 3 below shows a circuit model that better represents the performance of a real capacitor. L_{ESL} is the Equivalent Series Inductance (ESL) of the capacitor, while R_{ESR} is the Equivalent Series Resistance (ESR) of the capacitor. Typical parameter values for a United Chemi-Con U767D Series 35 V electrolytic capacitor are $C = 2200\mu F$, $R_{ESR} = 20m\Omega$, and $L_{ESL} = 18nH$.

   Find an expression for the impedance of a real capacitor based on this model. Compare the impedance of this electrolytic capacitor to an ideal capacitor of the same capacitance at $60Hz$, $60kHz$, and $6MHz$. How do the real and ideal cases compare at these frequencies?

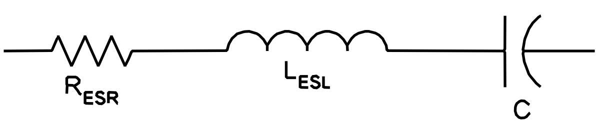

Figure 3: A model for a real capacitor including equivalent series inductance and equivalent series resistance.

5. Figure 4 below shows a circuit model for the utility supplying one phase of an AC induction motor. The motor system parameters are $R_s = 0.08\Omega$, $L_{ls} = 1mH$, $L_m = 40mH$, $L_{lr} = 1mH$, $R_r = 0.1\Omega$, and $R_x = 33\Omega$. If the utility voltage is $170\cos(377t)$, what is the current into the motor?

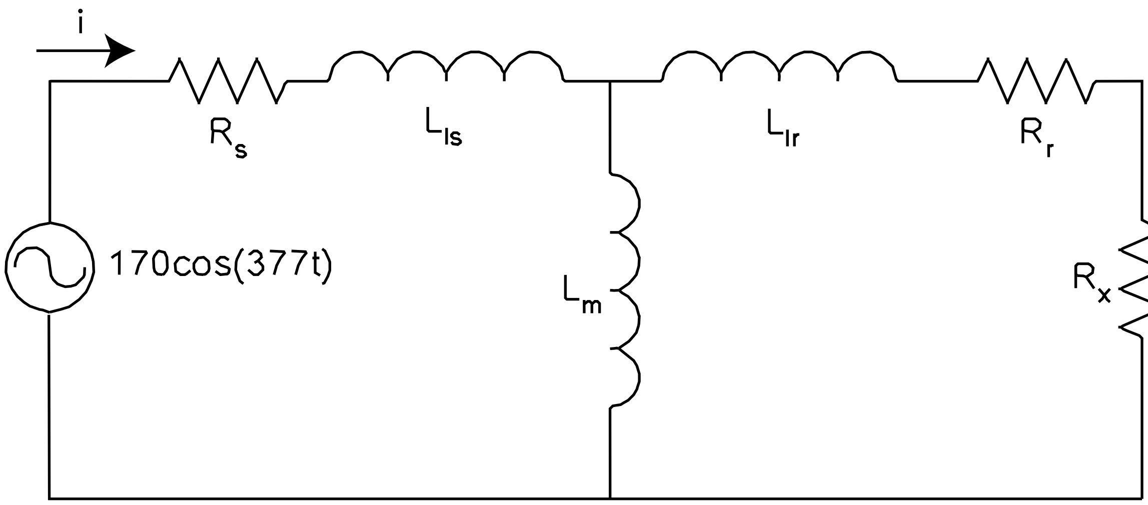

Figure 4: A Circuit model for one phase of an induction motor being driven by the utility.