Massachusetts Institute of Technology
Experimental Study Group

Physics 8.022, Spring 2011

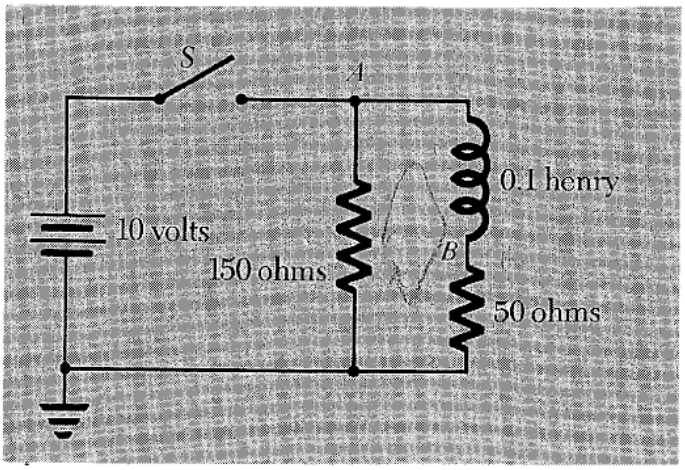
Problem Set 10
RLC circuits, AC circuits

Due: Wednesday, April 27th, 10 pm

Problem 1: Purcell 7.17

7.17 In the circuit shown in the diagram the 10-volt battery has negligible internal resistance. The switch S is closed for several seconds, then opened. Make a graph with the abscissa time in milliseconds, showing the potential of point A with respect to ground, just before and then for 10 milliseconds after the opening of switch S. Show also the variation of the potential at point B in the same period of time.

Figure 1: Purcell 7.17



PROBLEM 7.17

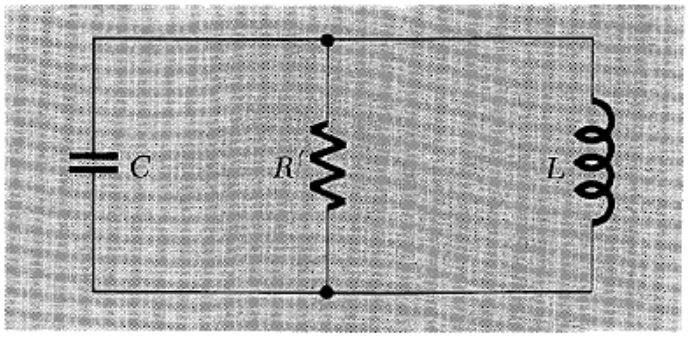
Figure 2: Figure Purcell 7.17

Extra question — By grounding this circuit, we make the switch safer to operate. Describe why a large spark jumps across the switch when it is not grounded, and why the spark does not happen when it is grounded.

Problem 2: Purcell 8.4

8.4 In the resonant circuit of the figure the dissipative element is a resistor R' connected in parallel, rather than in series, with the LC combination. Work out the equation, analogous to Eq. 2, which applies to this circuit. Find also the conditions on the solution analogous to those that hold in the series RLC circuit. If a series RLC and a parallel $R'LC$ circuit have the same L, C, and Q, how must R' be related to R?

Figure 3: Purcell 8.04



PROBLEM 8.4

Figure 4: Purcell 8.04

Problem 3: Purcell 8.7

A resonant cavity of the form illustrated is an essential part of many microwave oscillators. It can be regarded as a simple LC circuit. The inductance is that of a toroid with one turn. Find an expression for the resonant frequency of this circuit and show by a sketch the configuration of the magnetic and electric fields. Hint: the capacitor is composed by the upper and lower disks

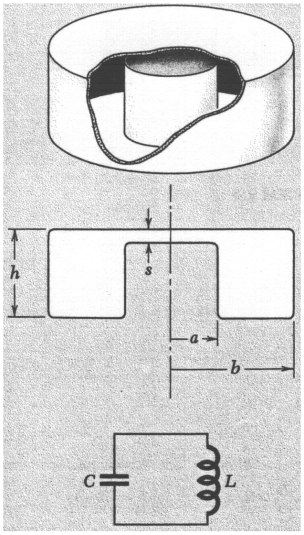


Figure 5: Purcell 8.7

Problem 4: Purcell 8.9

8.9 Using Eqs. 10 and 13, express the effect of damping on the frequency of a series RLC circuit. Let $\omega_0 = 1/\sqrt{LC}$ be the frequency of the undamped circuit. Suppose enough resistance is added to bring Q from ∞ down to 1000. By what percentage is the frequency ω thereby shifted from ω_0?

Figure 6: Purcell 8.09

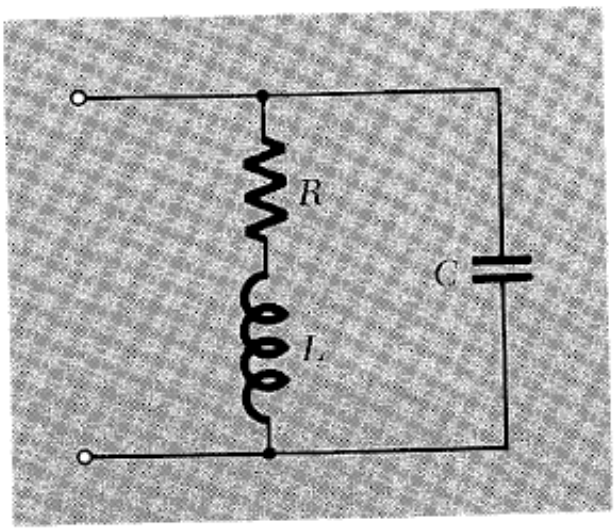


Figure 7: Purcell 8.09

Problem 5: Purcell 8.12

8.12 Let $V_{AB} = V_B - V_A$, in this circuit. Show that $|V_{AB}|^2 = V_0^2$ for any frequency ω. Find the frequency for which V_{AB} is 90° out of phase with V_0.

Figure 8: Purcell 8.12

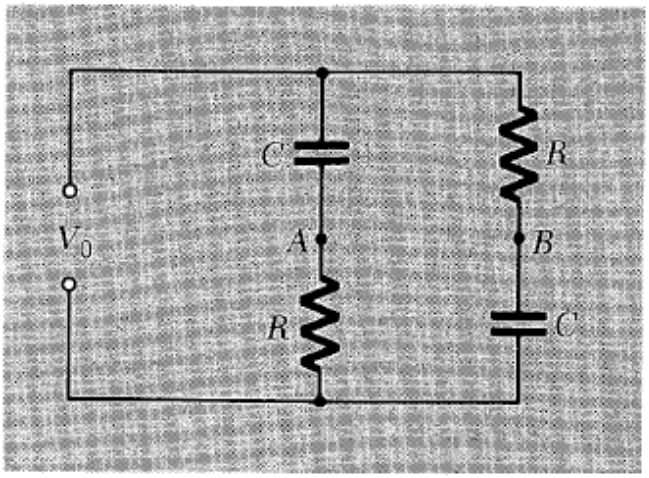


Figure 9: Purcell 8.12

Problem 6: Purcell 8.16

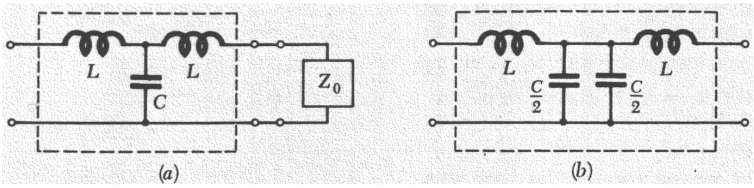


Figure 10: Purcell 8.16

An impedance Z_o is to be connected to the terminals on the right. For given frequency ω find the value which Z_o must have if the resulting impedance between the left terminals is Z_o. The required Z_o is a pure resistance R_o provided $\omega^2 < 2/LC$. What is Z_o in the special case $\omega = \sqrt{2/LC}$?

Problem 7: Optional Purcell 8.10

8.10 Is it possible to find a frequency at which the impedance at the terminals of this circuit will be purely real?

Figure 11: Purcell 8.10

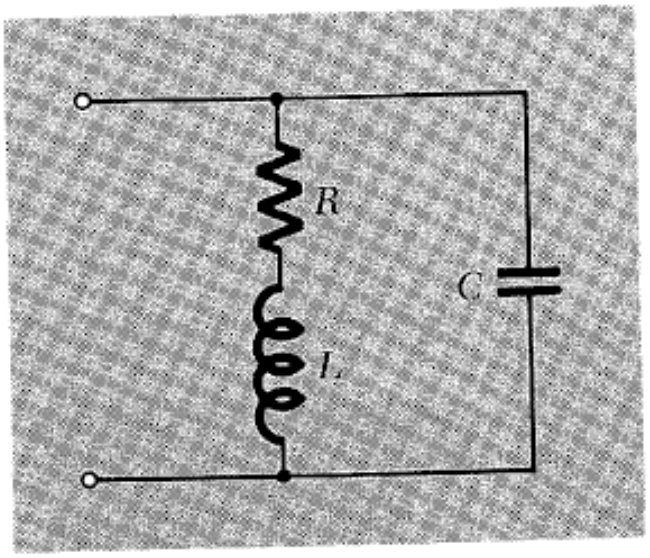


Figure 12: Purcell 8.10

Problem 8: Optional Purcell 8.13

8.13 Show that, if the condition $R_1R_2 = L/C$ is satisfied by the components of the circuit below, the difference in voltage between points A and B will be zero at any frequency. Discuss the suitability of this circuit as an ac bridge for measurement of an unknown inductance.

Figure 13: Purcell 8.13

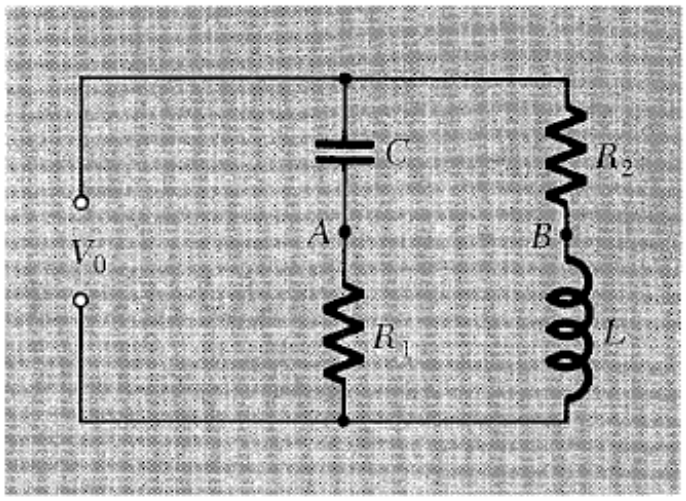


Figure 14: Purcell 8.13

Problem 9: Optional Purcell 8.14

8.14 In the laboratory you find an inductor of unknown inductance L and unknown internal resistance R. Using a dc ohmmeter, an ac voltmeter of high impedance, a 1-microfarad capacitor, and a 1000-Hz signal generator, determine L and R as follows: According to the ohmmeter, R is 35 ohms. You connect the capacitor in series with the inductor and the signal generator. The voltage across both is 10.1 volts. The voltage across the capacitor alone is 15.5 volts. You note also, as a check, that the voltage across the inductor alone is 25.4 volts. How large is L? Is the check consistent?

Figure 15: Purcell 8.14