

C-3. LRC and AC Circuits

Teaching Notes

THE MAIN POINT

1. Visualize energy flow in LRC and AC circuits.
2. Apply ideas from earlier in the course to solve LRC and simple AC circuit problems.

SAMPLE LESSON PLAN

Discussion Questions 1-3...20 minutes in groups, 15 minutes GSI-led discussion & boardwork.
 Problem 1 10 minutes in groups, 5 minutes GSI-led discussion & boardwork.
 Problem 2 10 minutes in groups, 5 minutes GSI-led discussion & boardwork.
 Problem 3 20 minutes in groups, 15 minutes GSI-led discussion & boardwork.

GENERAL TEACHING SUGGESTIONS

Physics vs. formulas. Historically, students in Physics 7B have viewed the topic of AC circuits as nothing but a mess of confusing formulas. It's hard to blame them for that. For one thing, there *are* a great many formulas. And for another thing, the homework problems in this chapter of the textbook tend toward the unimaginative. (This is not to mention that the course is typically moving along at a pretty good clip right about now.)

One way to put the physics back into LRC and AC circuits is to talk about them as the oscillators that they are. I made an attempt at this one semester when I wrote an AC circuit cheat-sheet for my students; it was organized primarily according to whether the circuits are damped or undamped, and secondarily according to whether they are driven or undriven.

If you make this kind of distinction in section, be sure to illustrate your taxonomy with examples from everyday life---or at least from 7A. ("Mass on spring," "mass on spring immersed in oil," or what have you.)

Energetics. Talking about AC circuits as oscillators leads naturally into another way of emphasizing the physics of the situation, namely by focusing on the *energetics* of the circuit. This is especially helpful for LC and LRC circuits. The goal is for your students to be able to describe the ebb and flow of current and charge as a corresponding energy trade between the inductor and the capacitor. Discussion Questions 2 and 3 deal with this picture. Similarly, in Problem 3, peak values of current and charge are found using energy ideas, rather than stock oscillation formulas.

Visualizing the current oscillation. It takes some sophistication to be able to look at a sinusoidal $i(t)$ graph and see a periodically reversing current. Make sure everyone understands that when the $i(t)$ graph crosses the t -axis, it means that the current in the circuit *halts* and then *switches direction*. It's kind of like a yo-yo, or a washing-machine rotor or something.

SAMPLE MINI-LECTURE AND BOARD SUMMARY

I would not do much lecturing at the start of section. Later on you may find yourself talking quite a bit anyway, as you summarize the various discussion questions.

Note that if your students have not yet heard a lecture on AC circuits, then you may have to provide them with a formula or two as they go through the problems. (Make sure to have these at your fingertips, so that you don't end up modeling bad behavior in section by flipping through the text in search of an equation.)

REMARKS ON THE DISCUSSION QUESTIONS AND PROBLEMS

Discussion Question 1

This question asks for a “dynamical” explanation of current oscillation in a simple LC circuit. It takes a mature understanding to tell a story like this on your own. So you will probably have to lead people through it by asking leading questions.

For example, have them start the LC circuit with a certain amount of charge on the capacitor plates, and no current flowing. (Naturally they should have a picture in front of them.) Then ask what happens when you close the switch. Then ask how the inductor feels about this. And so on. (You might want to look at the *Solutions to Discussion Questions* for some other ideas on how to present this material.)

Discussion Question 2

A good way to approach this question is to start with the same initial condition you used in Discussion Question 1. That is, suppose there is some charge initially on the plates, and no current flowing. Then, as before, ask leading questions about where the energy is now, and what happens next, and where the energy is then, and so on. (Presumably this will go smoother if you have just done Discussion Question 1. See the Sample Lesson Plan above.)

Discussion Questions 3 and 4 make good follow-ups. (See the Sample Lesson Plan above.)

Discussion Question 3

This is a good follow-up to Discussion Question 2. (See the Sample Lesson Plan above.) See if your students can answer it without any hand-holding.

Discussion Question 4

This is a good follow-up to Discussion Questions 2 and 3. (See the Sample Lesson Plan above.) See if your students can answer it without any hand-holding.

Discussion Question 5

This is a good problem to show the students exactly what role inductors and capacitors play in AC circuits! Try to get the students to explain *physically* why the inductor stops high frequencies and why the capacitor stops low frequencies. If they are having problems, ask what happens if the frequencies are *really* big or *really* small.

Discussion Question 6

This is harder than it looks. One way to get your students started is to ask them to look at the circuit diagrams, and put them into two categories: oscillating circuits, and non-oscillating circuits. (If they're comfortable with the "energy trading" picture, they should be able to guess that a circuit can only oscillate if it has both an inductor and a capacitor. Hint at this if necessary.) Note that *three* of the graphs correspond to oscillating circuits, since one of the graphs is a resonance curve.

Problem 1

One goal of this problem is simply to review the rules for adding capacitors and inductors in series and parallel.

However, the more important goal of the problem is to emphasize that the resonant frequency formula, $\omega_{res} = 1/\sqrt{LC}$, like all physics formulas, is really just a *template*, or a *mnemonic*, or (as I like to say) a *slogan*. It's not a substitute for thinking.

Notice that the inductors in this circuit "add separately" from the capacitors, making it quite easy to combine the components. Caution your students that in general, adding AC circuit components is a non-trivial exercise. Draw a complicated circuit with the components "mixed together," and emphasize that the methods you just used to find ω_{res} would not work with this circuit. (In fact, chances are, you have drawn a circuit with *more than one* resonant frequency. But you don't have to mention this.)

Problem 2

This problem shows how energy ideas can be used to analyze the behavior of a resonant circuit. (See *Energetics* in the General Teaching Suggestions above.)

Draw lots of pictures when you discuss this problem at the board. Draw the circuit at the initial time, with a strong E-field between the capacitor plates. Point to all the energy stored there. Then draw the circuit after a quarter-cycle, when the current is strong. Draw the strong B-field in the coils of the inductor. Point to all the energy stored there. Next, draw the circuit after a half-cycle, when the current stops and the capacitor is "full" again. And so on.

Problem 3

This problem is good if you want to explicitly show your students why LC circuits act the way they do. I like doing this problem simply because it's the first time they really get to work with a second-order ODE and look at wave motion in this class!

Problem 4

IMPORTANT!! This was meant to be a *challenge problem* and not a regular problem. *DONT DO THIS PROBLEM IN SECTION!*