FREQUENTLY ASKED QUESTIONS

May 6, 2003

Administrative Questions

Is the practice quiz representative of the quiz we'll be getting?

According to Prof. Roland, the first quiz is probably more quantitative than the real quiz will, but the second quiz is posted is more representative.

Will answers to labs and psets be put online?

I don't know; I hope so. I think at least some have been posted.

Content Questions

Is AMP the only experiment that will be covered on the quiz?

Yes, I think so.

Can you explain problem 4 of Quiz A?
The 5kΩ pot is the calibration pot. Using the voltage dividers, it provides the variable voltage at the input via the calibration circuit. As you turn the pot, you generate a range of voltages at the input of the amplifier. The voltage output as a function of input voltage should be roughly linear, with a slope which is the gain of the amplifier.

Can you explain the function and importance of a voltage divider and how it relates to experiment AMP?
See FAQ 17 for a detailed voltage divider discussion. Voltage dividers are used to, well, divide voltages. They're used in circuits to put particular voltages in particular places. For instance, experiment AMP has a variable voltage divider (the calibration circuit) to put a range of different voltages on the input to the amplifier.

What do we need to know about M and L problems?
The review slides are probably your best guide. You need to know definitions, physical meaning, how they relate the the demos, and how to calculate

in the example cases given, as well as (for L) applications to RL circuits.

How did the radio demo with the 2 loops work? How did it give a signal?

See FAQ 13 for the answer to this one.

Can you explain the Jacob's ladder demo?

This was a demo of transformer action. The primary coil had a small number of loops (about 200), and the secondary coil (connected to the "Jacob's ladder") had a large number of loops (about 10^4). The transformer relation (based on equating rate of change of flux through both coils) is that $V_s/V_p = N_s/N_p$. So if the ratio of secondary to primary loops is high, you get a big secondary voltage out of a small primary one (just like your HVPS). The Jacob's ladder secondary voltage is high enough to ionize air.

Can you explain the melting nail demo?

This is also a demo of transformer action. In this case the primary coil is the same, $N_p = 200$, but the secondary, with a nail in it, has only 1 loop, $N_s = 1$. The voltage through the secondary coil is therefore smaller by a factor of 200. The *power* is the same in both coils, however, because energy must be conserved (remember problem 1 of pset 9). Since $P = IV$, the currents are therefore inversely proportional: $I_s/I_p = N_p/N_s$. So we get a very large current through the small loop, and this current is enough to melt the nail. (Do not use $V = IR$ here: it's AC, and we know nothing about resistance of either coils– in fact we neglect resistance).

Can you explain the levitating coil demo?

See FAQ 15 for the answer to this one.

How do you determine phase shifts of LC, RLC circuits?

You can use the equations in point 5 of the AC Equation Summary. The phase shift depends on the component values (R, L, C) as well as the angular frequency ω.

What happens to impedance and phase shift when there is no R, since $\tan\phi = \frac{\omega L - 1/\omega C}{R}$: when $R = 0$, then isn't this undefined?

To understand this, look at how $\tan\phi$ varies as a function of ϕ. It goes to $-\infty$ at $\phi = -\pi/2$ and $+\infty$ at $\phi = +\pi/2$. The $R = 0$ case corresponds to either of these cases. Notice that $\phi = 90°$ is equivalent to $\phi = -90°$ for continuous waves (peaks and troughs opposite each other... either one could be is "lagging" or "leading").

How do you know whether the equation for $I(t)$ is $I_0 \sin(\omega t - \phi)$ or $I_0 \sin(\omega t + \phi)$?

It's a convention to write the former. You could write the latter, just with $-\phi$, and the physics would be the same.

What exactly is impedance?

It's a sort of "AC resistance". The current in an AC RLC circuit follows "Ohm's Law for AC", $I_0 = V_0/Z$, where impedance Z plays the role of resistance. The bigger Z, the less current amplitude for a given voltage amplitude: in that sense it "impedes current". Unlike for regular DC Ohm's Law, Z depends on frequency.

In today's AC concept problem, why does the source have to do net work?

This problem involved a resistor, which dissipates energy as heat when current goes through it. So the circuit loses energy. Since energy must be conserved in the universe, that energy must be provided by the power supply doing work.

On the review slides for RL circuits: why to $I(t)$ and $\varepsilon(t)$ go in opposite directions? On the graph, which $I(t)$ increases, $\varepsilon(t)$ decreases.. why?

The induced EMF $\varepsilon(t)$ depends on the *rate of change* of current. It's highest when the slope of I vs t is highest. As $I(t)$ increases in this case, its slope is decreasing. So $\varepsilon(t)$ decreases.

How would you solve problems involving RLC elements in parallel? Will we have to do this kind of problem?

You could solve in the same way as for series: write down the loop rule and solve the DE's for the loops. It may be a difficult solution, though. You won't have to do this (except possibly for conceptual-type problems like today's concept problem).

Were all the mechanical analogies just to help us understand AC

circuits, or do we have to know how to relate them to AC circuits for the exam?

Both. They are to help you understand, and you should also understand the mechanical analogy idea for the quiz.

Can you explain the mechanical analogy to resonance?

In the spring analogy, L is like the mass, C is like the spring, R is like a damping friction, and $V(t)$ is like your hand pushing and pulling it. Imagine you're pushing at any old frequency. The spring is going to oscillate at that frequency. At resonance, you are pushing at the *natural* frequency of the spring: the frequency it would oscillate at ($\sqrt{k/m}$) if nobody were pushing it. If you push at this frequency, you can get very large amplitude oscillations.

In the swing (or pendulum) analogy: L is like mass, C related to gravitational potential energy, R like damping friction. Imagine you are pushing your baby brother on a swing. You can push him back and forth at any frequency you like. Put if you push in such a way that your pushes are timed exactly with the natural swinging frequency (e.g. push hard forward just when he's turning around and about to swing naturally forward), your brother will start to swing with a very large amplitude (and will start to scream with either joy or fear...) This is physically analogous to the maximum current at resonance: the power supply is pushing current back and forth at exactly the natural frequency, and current amplitude will be maximum.

How do you determine the amplitude of current at resonance?

Use AC Ohm's Law. When the current amplitude is maximum, the impedence is just R, and the maximum I_0 is just V_0/R.

What do you mean by "energy is dissipated in R"?

The power in a resistor, I^2R, is energy per time that gets converted to heat. It's "dissipated" since it leaves the circuit and is no longer useful as electrical energy.

Why did you say $P_{\rm rms} = I_{\rm rms}^2 R$? Why does this have to be rms?

Because $P = I^2/R$, the power dissipated in an AC circuit will vary along with $I(t)$. But what we really care about is the *average* power. For $I = I_0 \sin \omega t$, the average power is $\overline{P} = \overline{I_0^2 R \sin^2 \omega t}$. The average over time of a sine wave comes out to 1/2, so $\overline{P} = \frac{1}{2} I_0^2 R$ (see Fig 25-20 in your text). So $\overline{P} = I_{\mathrm{rms}}^2 R$.

Where does the the wave equation come from? How do I show it's true?

We did not derive this wave equation (although one can... and the text derives wave equations for E and B from Maxwell's equations). You will not need to "show the wave equation is true", but you do need to understand that the *solution of the wave equation is a wave function*, i.e. a sinusoid. For instance, the kind of problem you may have for the quiz (similar to those in the practice quizzes) is one where you have to show that a plane wave of the form $D(x, y) = A \sin(2\pi x/\lambda - \omega t)$ is a solution to the wave equation $\frac{\partial^2 D}{\partial x^2} = \frac{1}{v^2} \frac{\partial^2 D}{\partial t^2}$. To do this, just plug D into both sides, and show that the LHS equals the RHS.

How much do we need to know about div and curl?

These will not be covered on the quiz. They were just introduced as part of the derivation of the wave equations that come from Maxwell's equations in differential form.

Why wasn't the Maxwell equation stuff gone over in class? How much should we really know about this?

Probably just due to lack of time. You won't have to derive any of the Maxwell equations for the quiz. The really important concept is just that wave equations follow from Maxwell's equations in vacuum, and *these wave equations predict waves in E and B of speed $c = 1/\sqrt{\epsilon_0 \mu_0}$*. You need to understand hat the solution to the wave equation is a plane wave, and be able to show that a plane wave is a solution. See also the review slides (for anything *not* marked "not on quiz").

Do we need to *have* the derivation of Maxwell's and wave equations?

You mean on your formula sheet? Probably not.

I'm still confused about Maxwell's equations in vacuum, and the differential form of Maxwell's equations.

The differential form of Maxwell's equations is just another way of writing them – it's the same old Maxwell's equations, just in different mathematical clothes. In vacuum, they are simplified: you just put $\rho = 0$ and $\vec{J} = 0$ (there's no "stuff" in vacuum, so no charge density, or current density.

How do you calculate I_d?

Usually you can just get it straight from the definition, $I_d = \epsilon_0 d\Phi_E/dt$. Calculate electric flux, and take its time derivative.

When do you use the modified form of Ampère's Law?

You need it when you have a case of changing electric flux, but not necessarily an actual current. The classic case is a capacitor being charged: there's no actual, physical, current between the plates, but there's an "effective" current (the displacement current) due to the changing electric field between the plates.

How do you draw EM waves?

This is sort of hard to draw on a 2-dimensional blackboard (at least for someone with my drawing skills). You have a wiggle in E in one plane, and a wiggling B perpendicular to it and in phase with it. See Figure 32-9 in your text, which does a better job.

If you have an em wave $E = E_0 \cos(kz - \omega t)$, how do you find ω? How do you get it out of the cosine?

In the kind of problems we'll be seeing, usually you can just read off the ω from the equation – it's just the thing that's the coefficient of t.

In general, the ω can be anything; it's determined by the thing that's causing the excitation of the fields. For instance, in a transmitter, the ω of the transmitted wave is dictated by the frequency of the power supply (we'll be seeing this soon for experiment MW).

If you have an em wave, how do you find the direction of the $\vec{B}$ field?

You know that for a plane wave, $\vec{B}$ must be perpendicular to both the direction of propagation, and $\vec{E}$. The direction of $\vec{B}$ must be such that $\vec{E} \times \vec{B}$ is the direction of propagation (note that the cross-product direction follows the right hand rule). Actually we haven't seen this explicitly yet but it's coming soon.

Tidbits

Lots of examples of resonance: http://www.exploratorium.edu/xref/phenomena/resonance.html