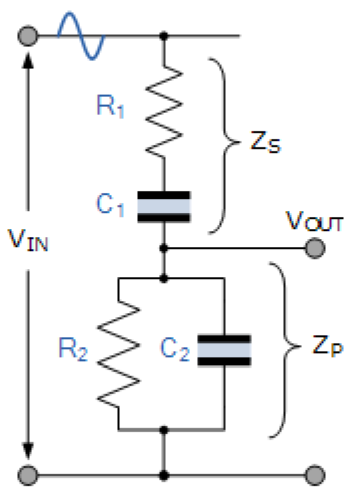
Ph411 Classroom Quiz, 02/13/2017 – this is a "self-proctored quiz" because Dr. Tom must show up in a hospital in Salem in the morning. The quiz consists of three tasks. The solutions should be turned in on Wednesday, at the 9:00 class meeting.

The first two tasks are related to the so-called "RC oscillators". Oscillators, a.k.a. "RC signal generators", are analog electronic devices that can produce AC output signals of fixed or tunable frequency. They have a wide range of practical applications and even now, in the "digital age", they are quite popular because of their simple design. Essentially, such an oscillator consists of an amplifier with a **positive** feedback loop that sends the output signal back to the amplifier's input. If the amplifier is "inverting" – i.e., the output signal is shifted by 180° relative to the input signal – the "feedback loop" also must shift the signal by 180° in order to make the feedback positive. In contrast, If the amplifier is "non-inverting", i.e., the output signal is **in-phase** with the input – then the feedback loop should feed back a signal with zero phase shift.

A popular class of RC signal generators are those using the so-called "Vien Bridge" in the feedback loop. The circuit diagram is shown below:



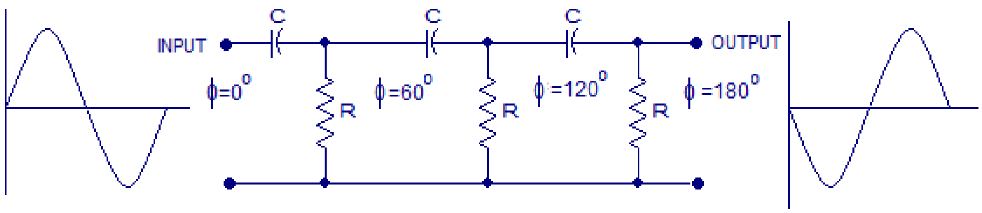
For such a circuit, there is a single so-called "resonant frequency" for which the input frequency and the output frequency are precisely in phase.

So, the **TASK #1** is the following: assuming that $R_1 = R_2 = R$, and $C_1 = C_2 = C$, find the "resonant frequency", and show that for this frequency the amplitude of the output signal is exactly 1/3 of that of the input signal.

Hints: Note that the circuit in question is in fact a "voltage divider" consisting of two impedances denoted in the figure as Zs and Zp. Zs is a simple series connection, Zs = R + ($-j/\omega C$), and Zp is a parallel connection (R || $-j/\omega C$) = [R × ($-j/\omega C$)]/[R + ($-j/\omega C$)].

Now, use the expression for the voltage divider to obtain V_{out} = CFE $\times$ V_{in} (where "CFE" means "a complex fractional expression") . And when is the phase shift between V_{out} and V_{in} exactly zero? Well, only if CFE is a positive **real** number, i.e., when the imaginary part of CFE becomes zero. So, with the above hints all you need, I believe, is to do some complex number algebra, and you'll have the answers!

TASK #2. Another important RC phase shifter is shown below. It's important, because in the near future you will use it in an oscillator you are supposed to build and to study.



Three stage RC phase shift network

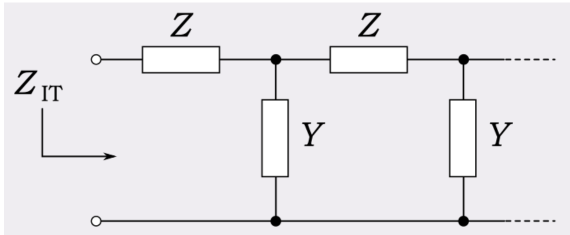
In contrast to the "Vien Bridge", in this circuit the "resonant frequency" is the one that results in a phase shift of exactly 180° (so, to obtain an oscillator you will combine it with an inverting amplifier).

Your task is to find the "resonant frequency" for given values of R and C, and to show that for this frequency V_{out}/V_{in} = 1/29.

Hints: The algebra here is far more challenging than in TASK #1, and it is easy "to get lost in the woods" if one doesn't get a "push" in the right direction at the beginning. I don't want you to spend to much time for trying, re-trying, re-retrying… I simply want you to know how this circuit can be solved, and therefore I am simply telling you where you may find the answer: namely, go to the site:
http://science.oregonstate.edu/~giebultt/COURSES/ph412

then click on the "Click here" in the lowermost line, and next scroll down the list that shows up, until you find "Phase shift oscillator, theory (handwitten notes used in class on 01/26/2015)." Then, read the notes; in the quiz solution you may simply write: "I read and I understood how to solve the circuit in question".

TASK #3. Consider an infinite "ladder" in which the upper "side rail" is a chain of elements with impedance Z, and the "rungs" are elements of impedance Y:



Z_{IT} is the "equivalent impedance" of the entire infinite chain (in analogy to the equivalent resistance of an infinite "ladder" made of resistors R, which we discussed early in the course).

On Wednesday after the Valentine's day, I want us to examine the properties of such ladders consisting of elements with **purely imaginary** impedances (e.g., with capacitors as the Z elements, and inductors as the Y elements – or vice versa); you will see such chains are AC signal filters with very interesting properties! But in order to speed up our work in Wednesday, I would like you to do the following. Please assign numbers to the Z and the Y elements: 1 to the leftmost Z and Y, 2 to the next Z and next Y, and so on.

Now, suppose that an AC signal is connected to the left-side terminals of the "ladder". AC currents will start flowing in all Z and Y elements, and, accordingly, there will be an AC voltage across every Z and Y. Suppose that voltage across the "rung" Y_{i-1} , where i is an arbitrary index, is V_{i-1} ; show that the voltage across the next rung, V_i , is:

$$V_i = V_{i-1}\,(1 - Z/\,Z_{IT}).$$

All you will need for that are the Ohm's and Kirhoff' Laws. But if you get confused, you may simply go to the Web site:

http://science.oregonstate.edu/~giebultt/COURSES/ph411_old

then click on "Click here for lecture notes", and then on:

Six extra pages after Page 92.