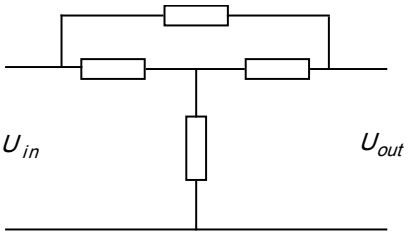
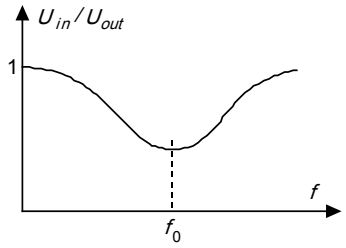
Problem 3

An electronic frequency filter consists of four components coupled as in the upper figure. The impedance of the source can be neglected and the impedance of the load can be taken as infinite. The filter should be such that the voltage ratio U_{out}/U_{in} has a frequency dependence shown in the lower where U_{in} is the input voltage and U_{out} is the output voltage. At frequency f_0 the phase lag between the two voltages is zero.



In order to build the filter you can choose from the following components:

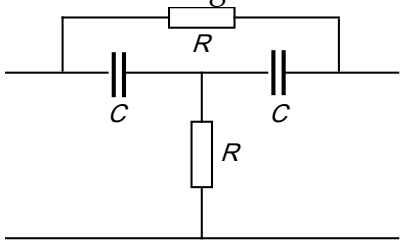
2 resistors, 10 kΩ
2 capacitors, 10 nF
2 solenoids, 160 mH (iron-free and with neglible resistance)



Construct, by combining four of these components, a filter that fulfils the stated conditions. Determine the frequency f_0 and the ratio U_{out}/U_{in} at this frequency for as many component combinations as possible.

Solution:

The conditions at very high and very low frequencies can be satisfied with for example the following circuit



Using either the graphic vector method or the analytic jω method we can show that the minimum occurs för a frequency $f_0 = \frac{1}{2\pi RC}$ when the ratio between the output and input voltages is 2/3. Switching the resistors and the capacitors gives a new circuit with the same frequency f_0. Another two possibilities is to exchange the capacitors for solenoids where we get $f_0 = \frac{R}{2\pi L}$. There are further eight solutions with unsymmetric patterns of the electronic components.