**Experimental Competition - Problem No. 2**
**Black box**

## APPARATUS AND MATERIALS

1. A double beam oscilloscope.

2. A function generator capable to generate sine, triangle and square waves over the 0.02 Hz to 2 MHz range.

3. A "Black box" with two groups of connectors: the ABCD group and A'B'C'D' group. Besides, there are also two connectors for the standard resistor $R_{\mathrm{n}} = 5\,\mathrm{k\Omega}$, which is isolated from the two groups.

4. Conductors of negligible resistance.

5. Graph paper.

*Warning:* You are not allowed to open the black box.

## EXPERIMENT

In the black box, there are two groups of passive elements (that are elements of the types: resistor $R$, capacitor $C$ or inductor (induction coil) $L$). The first group consists of three elements $Z_1$, $Z_2$, $Z_3$ connected in a star circuit as shown in Figure 1. The elements are led out to the connectors A, B, C and D, with A – the common connector of the ABCD group. The second group consists of three elements $Z_1'$, $Z_2'$, $Z_3'$ connected in the same manner to connectors A', B', C' and D', with A' – the common connector of the A'B'C'D' group (see Figure 2).

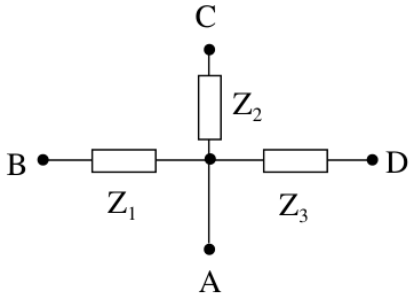



Figure 1

**1.** By using the oscilloscope and the function generator, determine the type and the parameter (that is resistance of $R$, capacity of $C$, inductivity of $L$) of each of the elements $Z_1$, $Z_2$, $Z_3$ and $Z_1'$, $Z_2'$, $Z_3'$.
***[5.0 pts]***

**2.** Connect five points B, C, B', C' and D' together. We obtain a new black box with terminals DD'A' (called DD'A').

a. Draw the electric circuit of this black box.

b. Apply a sine wave from the generator to connectors D and A'.

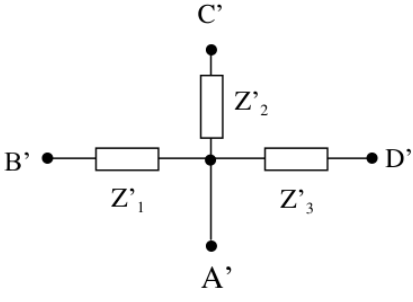


Figure 2

Plot a graph of the ratio of the voltage amplitudes $K = \frac{U_{D'A'}}{U_{DA'}}$ and the phase shift $\varphi$ between these voltages as functions of the frequency $f$ of the signal.

c. The graphs possess a particular point at a certain frequency $f_0$. Determine the value of the frequency $f_0$, the ratio $K = \frac{U_{D'A'}}{U_{DA'}}$ and the phase shift $\varphi$ at this frequency.

d. Derive the relation between $f_0$ and the parameters of the elements in the black box and calculate the values of $f_0$. ***[5.0 pts]***