Task 312

Determining Capacitance

Preliminary requirements

Before reading this instruction and carrying out the experiment find information about:

1. What is a capacitor (condenser)?
2. What is the capacitance of capacitor and what is its unit?
3. Derive formulas describing capacitance of plate and spherical capacitors.
4. Alternating current (AC) circuit. Electric impedance. How capacitor behave in AC circuit.
5. Wheatstone bridge. The method of determining unknown impedance. Find a condition for balanced bridge.
6. Ohm's law and Kirchoff's circuit laws (Kirchoff's rules) for electric AC and DC circuits.

Literature

- R. Resnick, D. Halliday: *Physics*, part 1 , John Wiley and Sons, Inc., New York 1973
- H.D. Young, R.A. Freedman, *University Physics: with modern physics*, Addison-Wesley Publ. Co, San Francisco 2000.
- E. Hecht, *Physics: Calculus*, Brooks/Cole Thomson Learning 2000.

The aim of a task

1. Getting to know one of the method of determining capacitance.
2. Becoming familiar with Wheatstone bridge.

Description of the method of measurements

In this task Wheatstone bridge is used to determine capacitance of capacitors. General scheme of such bridge shows Picture 1. It consists of two legs one with two component parts of known impedance Z_1 and Z_2. The other leg consists of element Z_x which impedance is to be determined and one of adjustable impedance Z_4. The point of balance of a bridge (i.e. the state in which voltage between opposite points (C, D on the Picture 1) is zero and no current flows through galvanometer) provides

$$Z_x = \frac{Z_1}{Z_2} Z_4 , \qquad (1)$$

Given impedances Z_1, Z_2, and Z_4 one can determine an unknown impedance Z_x.

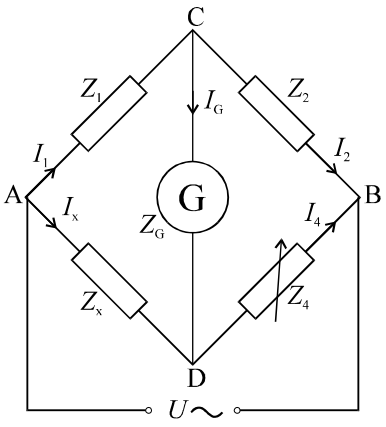
Description of apparatus

Bridge used in this task is shown on Picture 2. Elements of known impedances are resistors R_1 and R_2 and condenser of adjustable capacitance C_4. Unknown is capacitance of condenser C_x. Adjusting capacitance C_4 one can achieve a point of balance i.e. the state that through galvanometer G does not flaw any current (or it is minimal). Then the equality (1) holds. In this particular case the equality (1) takes the form:

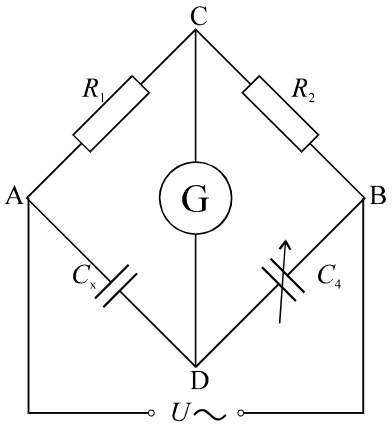
$$C_x = \frac{R_1}{R_2} C_4 . \qquad (2)$$

Given R_1, R_2 and C_4 from formula (2) one can determine capacitance of condenser. In the same way one can

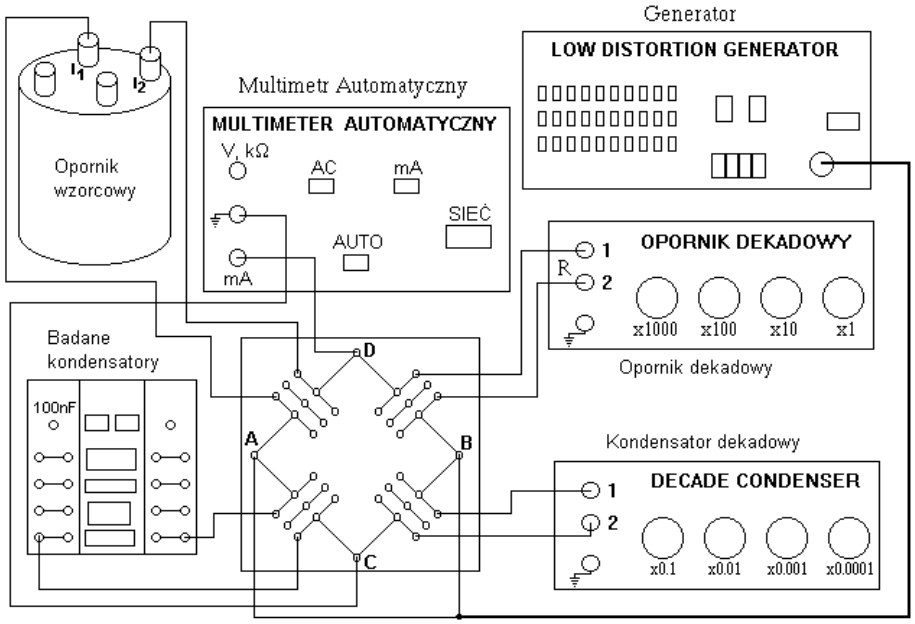
determine capacitance of a system of capacitors.



Picture 1. General scheme of Wheatstone's bridge. (Z_G means impedance of galvanometer)



Picture 2. Scheme of a system used in a task.



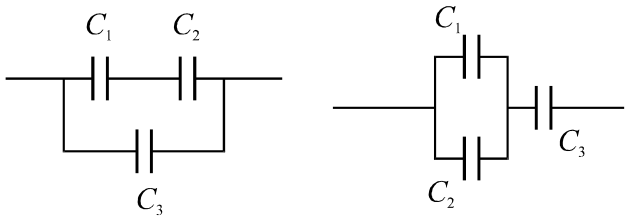
Picture. 3. Used apparatus

Picture 3 depicts used apparatus. As a resistor R_1 it is used resistor denoted on the picture by "opornik wzorcowy" , its resistance is 1kΩ. Resistor R_2 is a decade resistor "opornik dekadowy". Condensers (C_x) which capacitance is to be determined are placed on a plate. Adjustable capacitor C_4 is decade condenser. Galvanometer is realised by automatic multimeter. Bridge is powered by generator.

The course of measurements

1. Assemble the circuit according to pictures 2 and 3.
2. Adjust a value of resistance of decade resistor between 250 ÷ 750Ω.
3. Ask a teacher for permission to turn the power on. Select sinusoidal power on a generator (turn the switch "~" on) of frequency 1kHz (standard frequency for such measurements).
4. On automatic multimeter turn on "auto" mode (if auto mode is on then diode should light on).
5. Adjust a capacitance of decade condenser in order to obtain a minimal current flowing through the automatic multimeter.
6. Note the capacitance C_4 already adjusted.

7. Analogously carry out measurements for other condensers.
8. Repeat measurements for different parallel configurations of capacitors.
9. Repeat measurements for different capacitors connected in series.
10. Determine capacities of systems of condensers depicted on Picture 4 or any other discussed with a teacher



Picture. 4. Suggestions of systems of condensers.

11. Determine accuracy of measurements ΔC_4 in the following way:
   a) note capacitance C_1 for which the current flowing through multimeter achieve a minimal value (because of inaccuracy of a system it is impossible to get zero current through galvanometer and the minimal value is achieved in some capacitance range),
   b) note capacitance C_2, for which the value of current grows noticeably,
   c) as an accuracy of determined capacitance ΔC_4 take:

$$\Delta C_4 = \left| C_2 - C_1 \right| . \tag{3}$$

12. Results of measurements write down in a table

Number of capacitor	$R_1 = 1000\ \Omega$		$R_2 =$	
	C_4 [μF]	ΔC_4 [μF]	C_x [μF]	ΔC_x [μF]
parallel connection				
Connection in series				
system 1				

13. Note class k_1 of resistor R_1 and class k_2 of decade resistor R_2. Also note maximal value of resistance R_{2max} available to adjust on a decade resistor.

Report preparation

Report should include:
1. Short description of the idea of the method of measurements.
2. Table consisting results of measurements.
3. Calculations:
   a) capacitance of condensers from formula (2),
   b) capacitance of parallel configuration and connections in series,
   c) capacitance of systems of condensers depicted on Picture 4,
   d) values determined from formula (2) for line and parallel connections of condensers compare with values determined from respective formulas for parallel connections and connections in series of

condensers

4. Calculation of errors:

The value of error of capacitance C_x can be determined from

$$\Delta C_x = C_x\left(\frac{\Delta R_1}{R_1} + \frac{\Delta R_2}{R_2} + \frac{\Delta C_4}{C_4}\right), \tag{4}$$

where ΔR_1 and ΔR_2 are

$$\Delta R_1 = \frac{k_1 R_1}{100}, \tag{5}$$

$$\Delta R_2 = \frac{k_2 R_{2\max}}{100}. \tag{6}$$

5. For each of a measured condenser write down the final capacitance as

$$C = C_x \pm \Delta C_x.$$

6. Conclusions

The last but not least point of a report. You are asked to comment:

- the used method,
- your results,
- their precision, accuracy.