

**Problem 1 (4 points)**

Explain principles of operation and draw schematics of a mass spectrometer. Write corresponding expressions showing: what physical quantity(s) can be measured by a mass spectrometer?

**Problem 2 (5 points)**

Explain principle of measurements of:

- 2.1 (2 points) Distance to remote objects located further than few km from the observer (e.g. flying airplane);
- 2.2 (3 points) Lattice constant (interatomic distance) in solids.

**Problem 3 (6 points).**

Electric circuit is presented in Fig. I. Points A and B are connected through an ammeter with zero impedance. Points C and D are connected to a voltage source, which can supply DC or AC voltage  $V$ . Assume negligible resistance of the inductance  $R(L_2) = 0$ .

3.1 (3 points) Voltage source is in an AC mode:  $V = V_0 \sin(\omega t)$ . What are the parameters of the circuit, when the bridge is balanced:  $I_A = 0$ ?

3.2 Voltage source is in a DC mode:  $V = V_0 = \text{const}$ .

3.2.1 (2 points) What is the current  $I_A$  passing through the ammeter?

3.2.2 (1 point) What are the parameters of the circuit, when the bridge is balanced:  $I_A = 0$ ?

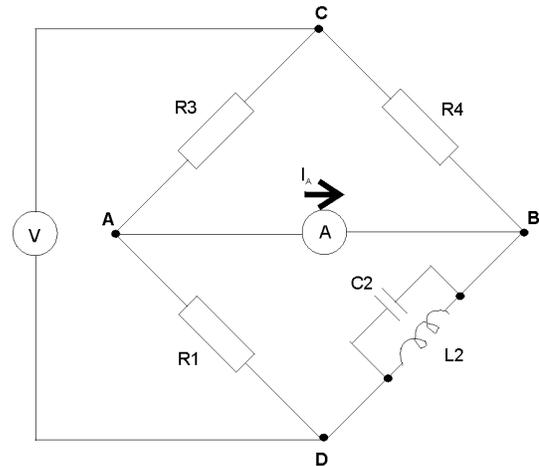


Fig. I

**Problem 4 (5 points)**

4.1 (2 points) Propose schematics, plot of  $|V_{out}/V_{in}|(\omega)$  dependence and write expressions explaining operation of a low-pass RC filter.

4.2 (2 points) Plot phase  $\phi(\omega)$  diagram of the low-pass RC filter, where  $\phi$  is the phase angle between the voltage on the resistor and the voltage on the capacitor, and  $\omega$  is the frequency of the signal.

4.3 (1 point) What is the slope of the attenuation above the cut frequency of the low-pass RC filter? What methods can you propose to make this slope higher?

**Problem 5 (5 points)**

5.1 (1 point) Explain principle of operation of a differential thermocouple.

5.2 (1 point) Draw dependence of the resistance on temperature for a metal resistor. What temperature scale can be measured with this type of sensor? What biasing mode (voltage or current) is preferable to be used at low temperatures? Why?

5.3 (1 point) Draw dependence of the resistance on temperature for a semiconductor. What temperature scale can be measured with this type of sensor? What biasing mode (voltage or current) is preferable to be used at low temperatures? Why?

5.4 (2 points) What are the problems of measuring temperatures at  $T < 1$  K? What methods can you suggest to measure cryogenic temperatures?