TECHNICAL UNIVERSITY OF LIBEREC
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LA1 – measurement protocol

THE DENSIMETER

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Introduction:

The goal of this experiment is to construct a densimeter using a prismatic metal beam with two strain gauges attached and properly connected to a data acquisition card.

A strain gauge is an electrical element that, when deformed, changes its electrical resistance. In our experiment we used one of many different ways to connect a strain gauge, the so called half-bridge. In this case we only use two strain gauges as opposed to the full-bridge connection where we use four. Although the full-bridge (using four elements) is more accurate the half-bridge is sufficient for the needs of this experiment and it's much more economical, because the strain gauges are relatively expensive.

The use of the bridge allows us to measure the strain as a difference in voltage and thanks to the circuit of the data acquisition card the voltage is amplified for easier recognition of the changes.

The experiment:

The configuration of the strain gauges on the prismatic metal beam is on the following picture:

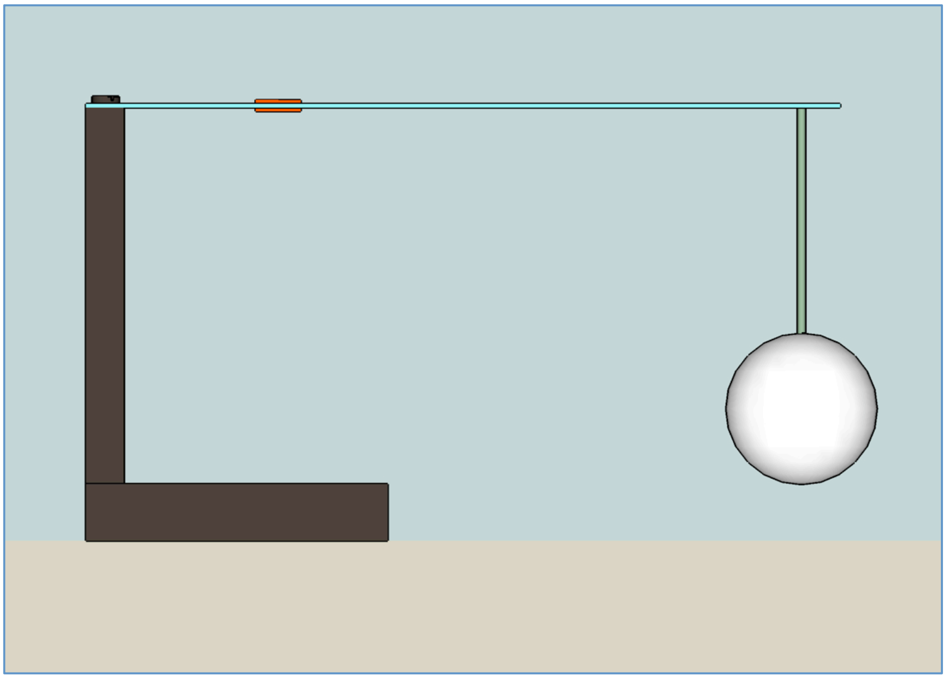

Figure 1: Model of the experiment

As can be seen on the picture, it's needed to glue the strain gauges as precisely as possible on the opposite sides of the given metal beam. Almost on the edge of the beam there is a rod with a table-tennis ball attached to it.

In this experiment we consequently submerge the ball in cups with different types of liquid (distilled water, Coca-Cola, Coca-Cola Light, liquid soap and ethanol) and use the mentioned DAQ card to measure the differences in the voltage on the strain gauges. Using the specialized application on the PC we save the measured data to a text file and use them later on for further processing and calculations.

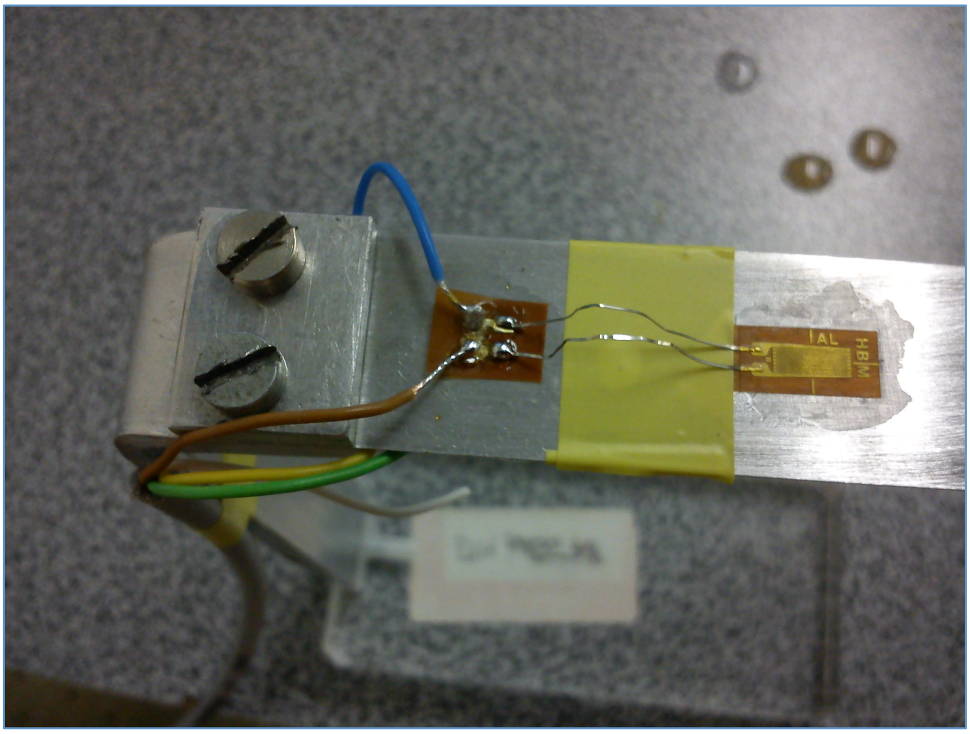

Figure 2: The glued strain gauge with soldered wires

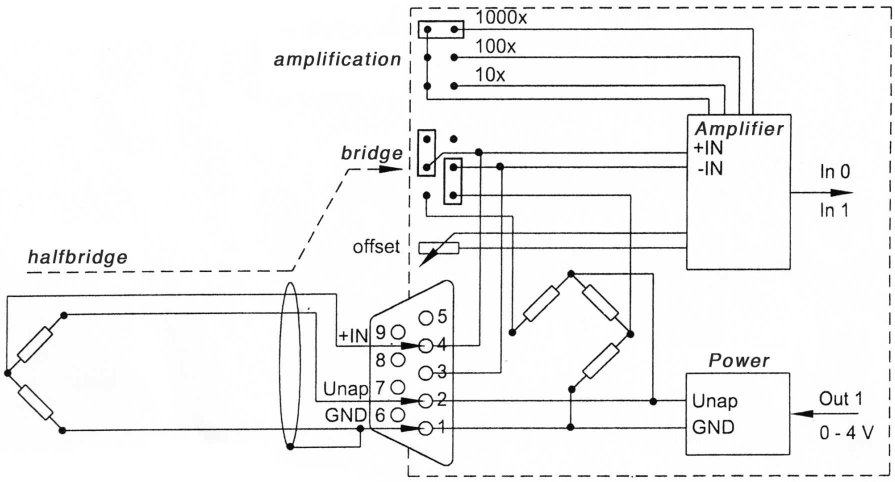

Figure 3: The wiring diagram for the half-bridge

The measurements and the given values:

After completion of the densimeter we should check we don't have any short circuits and everything is soldered correctly. If everything works we can connect the cable to the DAQ card using the 9-pin RS-232 connector and set up the software for measuring.

At first, we should measure the offset, which is the value of the measured voltage of just the plain densimeter, not submerged to any fluid. This value can be used for calibration of the strain gauges (the used software is able to do the calibration for us). In my case, the **offset** was **-0.18**.

Afterwards, we can finally start measuring the strain of the beam when the table-tennis ball is submerged to the different liquids. The charts generated with the measured values follow:

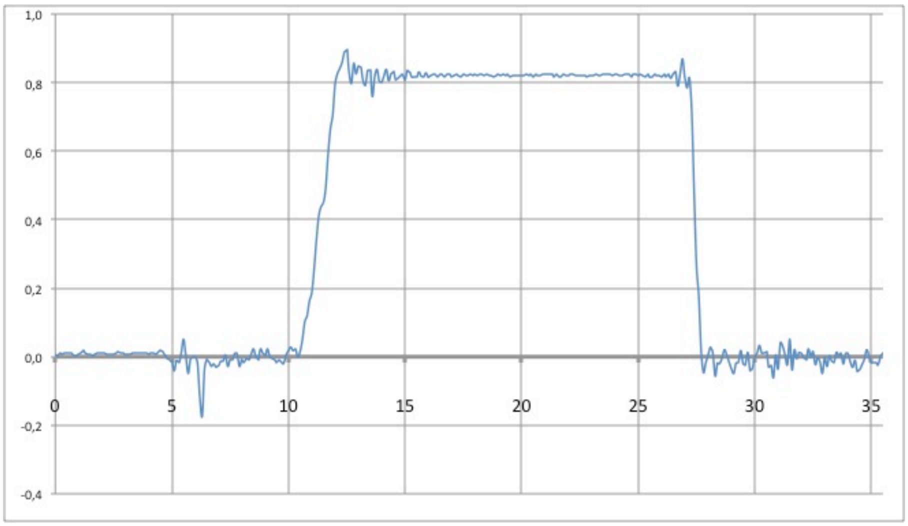

Figure 4: The chart for distilled water

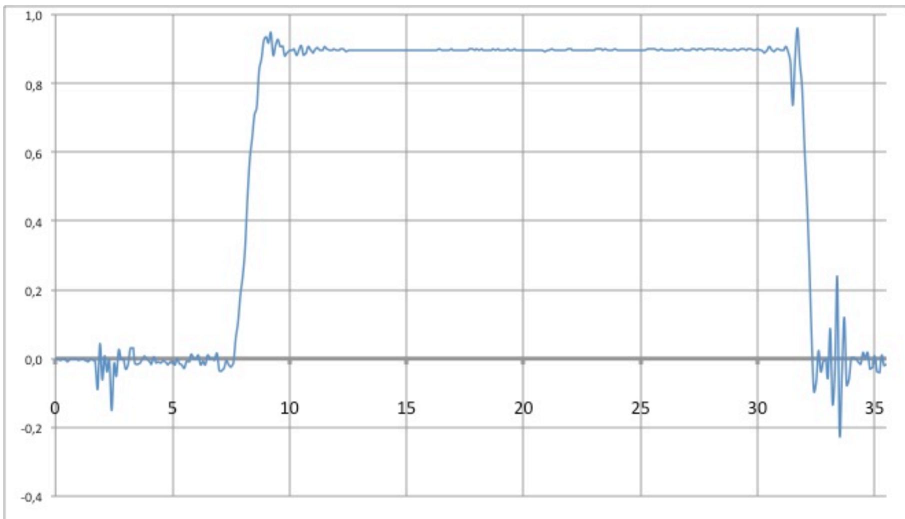

Figure 5: The chart for Coca-Cola

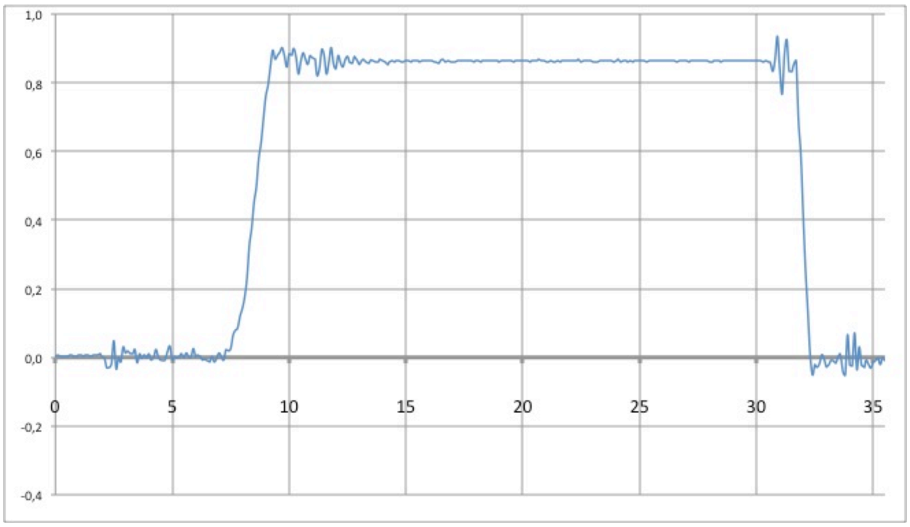

Figure 6: The chart for Coca-Cola Light

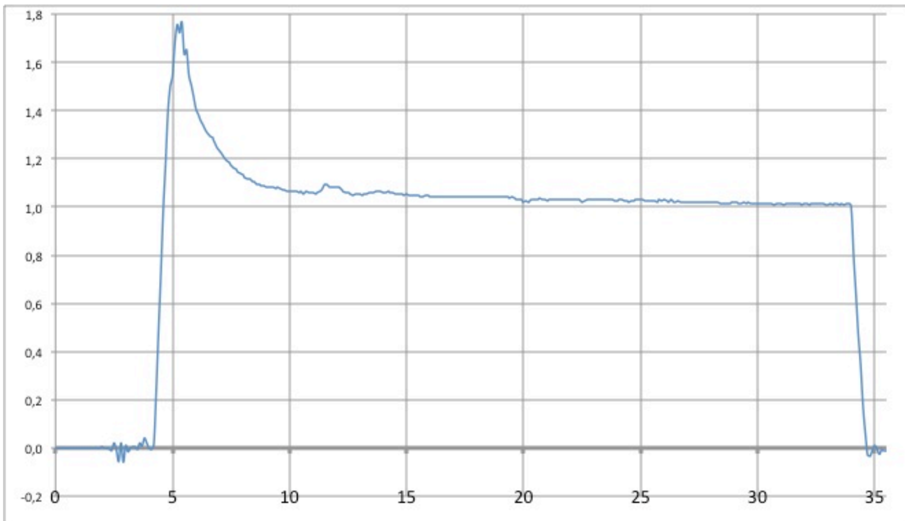

Figure 7: The chart for liquid soap

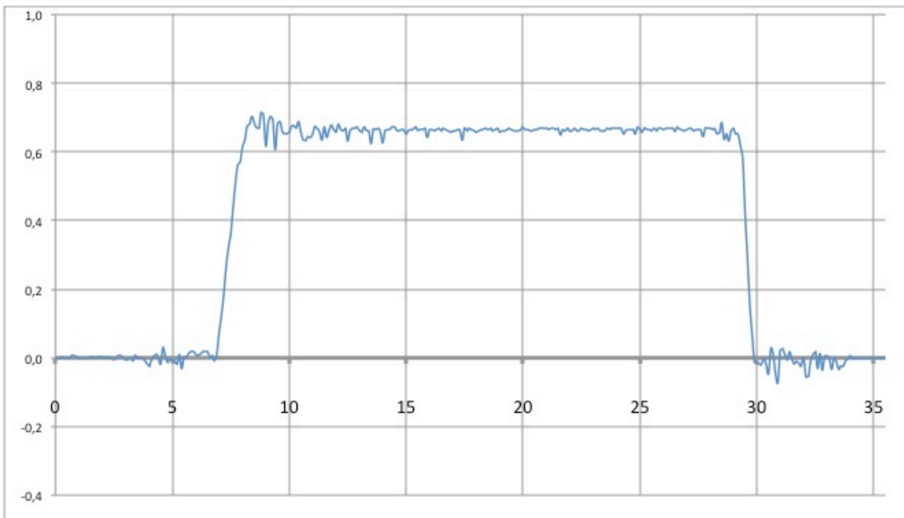

Figure 8: The chart for ethanol

The other given values needed for the following calculations are:

Width of the beam: b = 20.00 mm
Height of the beam: h = 0.93 mm
Length of the beam: l_0 = 14.80 mm
Young modulus of aluminum: E_{Al} = 70 GPa
Gauge factor of the strain gauge: K = 2.08
Radius of the ball: r = 20 mm

The equations needed:

Volume of a sphere: $V = \frac{4}{3} \cdot \pi \cdot r^3$

Density: $\rho = \frac{1}{V \cdot g} \cdot \frac{E_{Al} \cdot b \cdot h^2}{6 \cdot l_0} \cdot \varepsilon$

Strain: $\varepsilon = \frac{M_0}{J_y} \cdot \frac{h}{2} = \frac{2 \cdot \Delta U}{UK}$

Moment: $M_0 = F_{vz} \cdot l_0$

Moment of inertia: $J_y = \frac{1}{12} \cdot b \cdot h^3$

Using the equations above, we can calculate the strain (**ε**) that is needed to compute the density of measured liquids. The results are in the following table:

	Measured ΔU [V]	Strain	Density [kg/m^3]
Distilled water	0.82	0.263	1091.24
Coca-Cola	0.90	0.288	1194.98
Coca-Cola Light	0.86	0.275	1141.04
Liquid soap	1.01	0.323	1340.20
Ethanol	0.67	0.214	887.93

To check how precise my measurement was I had simply looked up the densities for the distilled water and ethanol, which are easy to find and are commonly known. The densities are 999.97 kg/m^3 for the distilled water and 789 kg/m3 for the ethanol.

Conclusion:

By simply comparing the respective values we can immediately see, that our measurement was not very precise. It gave us a general idea of the difference between the densities of the measured liquids, but it could not be used as a trustworthy densimeter. The strain gauges are very sensitive and the voltage differences are so low, that they have to be amplified (in our case by 1000 times). That and the inaccuracies in gluing the strain gauges on to the metal beam are the main reasons, why the whole measurement is not so precise.