# Cylindrical capacitor

J. Kuthan, O. Sodomka

## Setting of the project

The subject of measurement is the number of turns of an electromechanical actuator. Adjust the model using the known force characteristic and compare how many turns the actuator has.

Points of assignment of the semester project

- Describe the function of the device. (2b)
- Describe the mathematical model of the actuator, including boundary conditions (derive modified equations describing the behavior of the field for each region and boundary). (4b)
- Create a magnetic field model in Comsol. Consider the relative permeability of 300 for both the core and iron circuit. (5b)
- Test the convergence of the model. Describe your own procedure with added results. (4b)
- Using the measured static characteristic, adjust the model and find out the approximate number of turns. (5b)

### Description of the measured device

A load cell is attached to the measuring device and the actuator is fixed to the bottom plate. The current 1 A passes through the actuator during the measurement. Subsequently, the core of the actuator is pulled out in small steps with a force gauge and the force acting on it is read.

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Tabulka 1: Measured static characteristic

| shift ( mm) | force ( N) | | shift ( mm) | force ( N) |
|---|---|---|---|---|
| 0.00 | 230.0 | | 1.00 | 23.0 |
| 0.10 | 117.0 | | 1.50 | 14.8 |
| 0.20 | 83.2 | | 2.00 | 11.1 |
| 0.30 | 64.9 | | 2.50 | 8.8 |
| 0.40 | 52.5 | | 3.00 | 7.2 |
| 0.50 | 44.2 | | 3.50 | 6.5 |
| 0.60 | 38.0 | | 4.00 | 5.8 |
| 0.70 | 33.0 | | 4.50 | 5.1 |
| 0.80 | 29.0 | | 5.00 | 4.5 |
| 0.90 | 25.7 | | 12.82 | 3.5 |



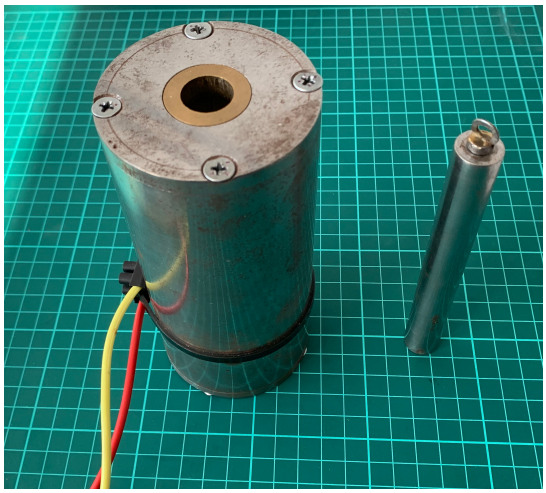
Measured device. : From:https://www.voltworld.cz/merici-technika-1/mereni-neelektrickych-velicin/prislusenstvi-pro-silomery.

1. Advantageously use the Parametric Sweep function during the simulation.
2. The fineness of the mesh in the air gap around the moving core is important.
3. The zero position indicates a fully inserted core. Due to the strong nonlinearity of the force, we do not recommend calibrating the model in the extreme positions.

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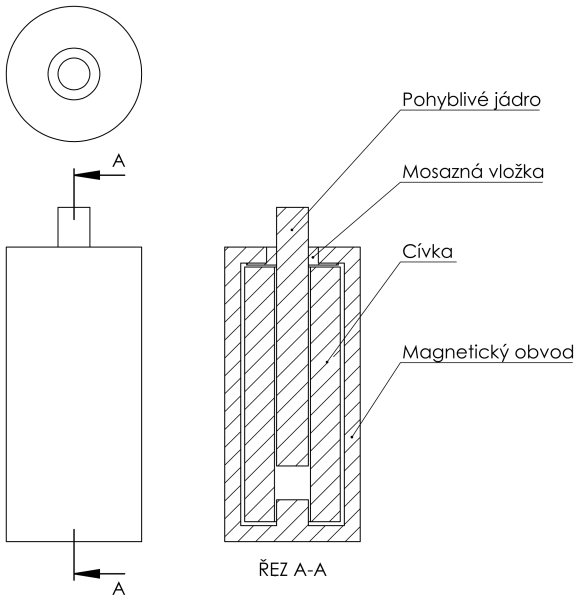
Obrázek 1: Photo of the actuator with the core removed

In the picture on the right, the types of materials are distinguished by color. Magnetic circuits are highlighted in matt gray. The brass with a brushed surface is a brass insert and the copper brown is the conductive coil of the actuator.

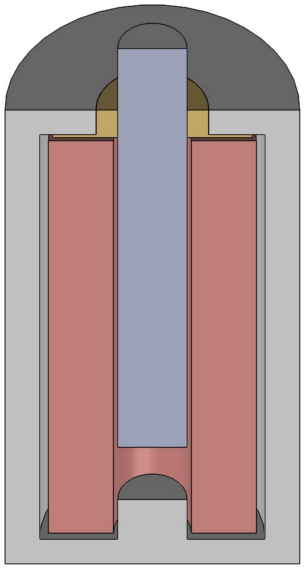
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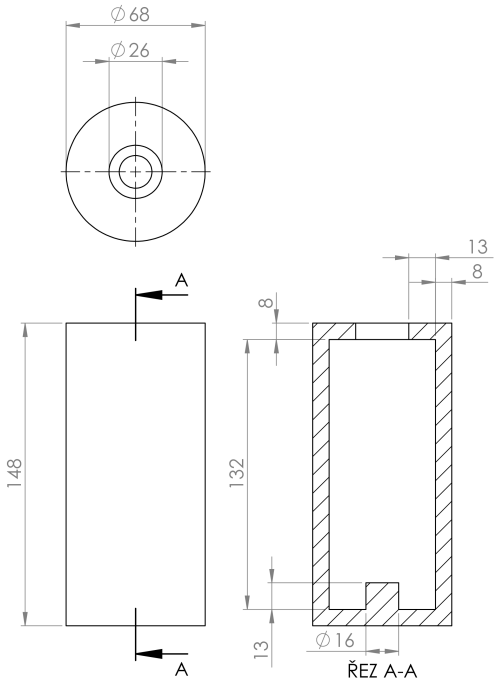
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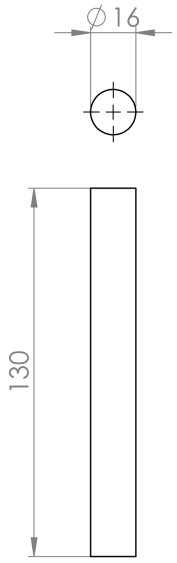

(a) Actuator assembly drawing



(b) 3D model of measuring device




(c) Drawing of the magnetic circuit of the coil

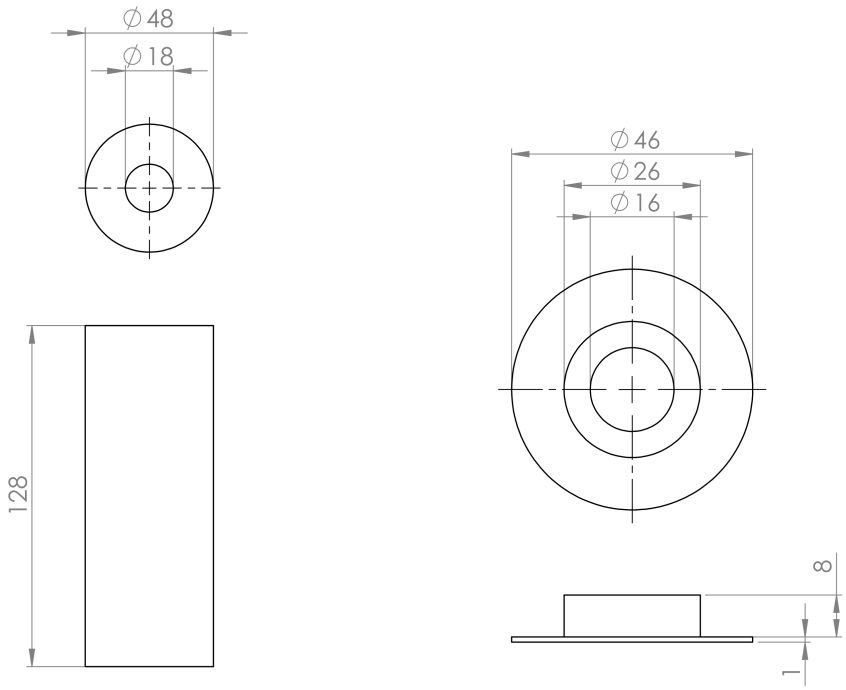



(d) Drawing of the movable core of the actuator

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(e) Drawing of a copper coil (f) Drawing of a brass insert

Obrázek 2: Technical drawings and dimensions of the device

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# Měření permitivity

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## Setting of the project

The subject of the measurement is the relative permission of the unknown material. The measurement was shown in a plate capacitor with a Teflon lid.

Body zadání semestrálního projektu

- Describe the function of the device. A Teflon lid is attached to the upper electrode, look up the relative permittivity of the lid in the physical tables. (2b)
- Describe the mathematical model of the measuring device, including the boundary conditions. (Derived modified equation describing the field behavior for each region and boundary) (4b)
- Create an electrostatic field model in Comsol. (5b)
- Perform convergence analysis of the model. (Describe your own procedure with added results) (4b)
- Using the measured capacity, adjust the model and estimate the permittivity of the unknown material. (5b)

## Description of the measured device

Two capacity measurements were performed. First without the unknown material inserted, i.e. air, to calibrate the model, and then the capacity was measured again with the unknown material inserted.

Tabulka 2: Table of measured capacities

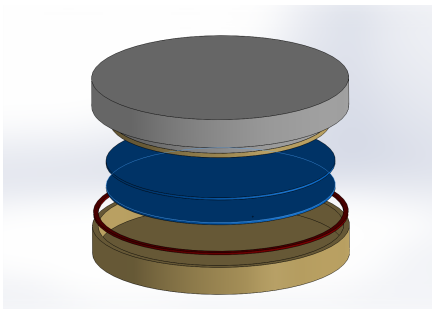
| | |
|---|---|
| Capacity without material (air) | 31.18 pF |
| Capacity with inserted material | 40.40 pF |



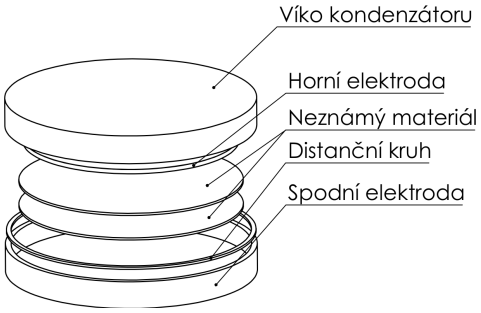
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(a) Drawing of the measuring capacitor assembly

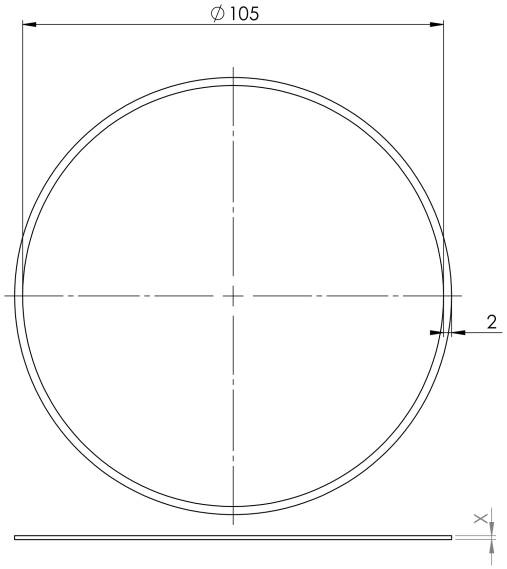



(b) 3D model of a measuring device

## Measurement procedure

In the figure on the left, the types of materials are distinguished by color. The gray matte color is the Teflon part of the lid. Brass with a brushed surface are capacitor electrodes and cobalt blue is an unknown material.

A spacer ring of unknown height $X$ is used to accurately calibrate the capacity of the air condenser. The spacer ring is made of teflon.

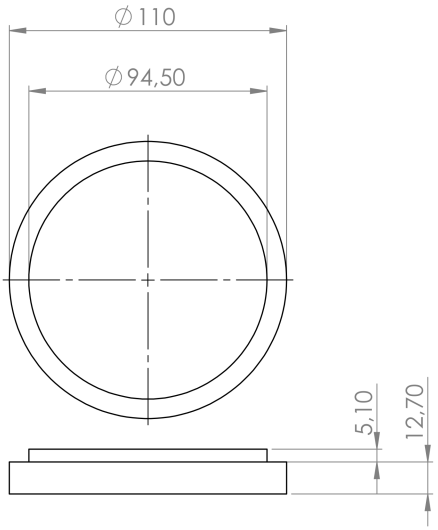



Drawing of the spacer circle

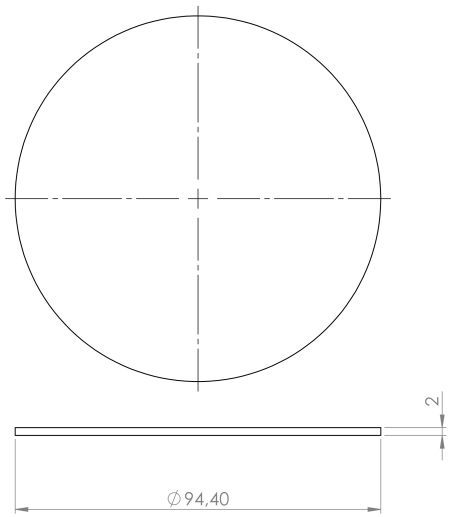
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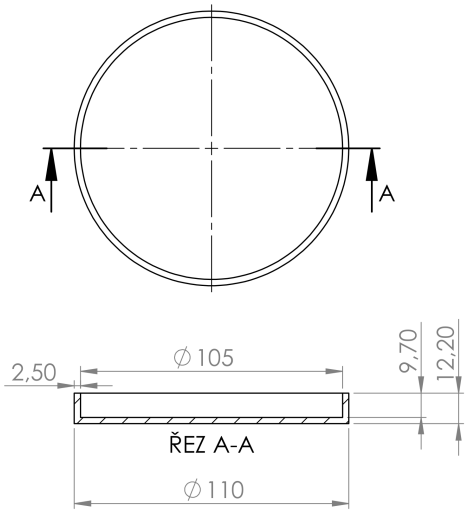
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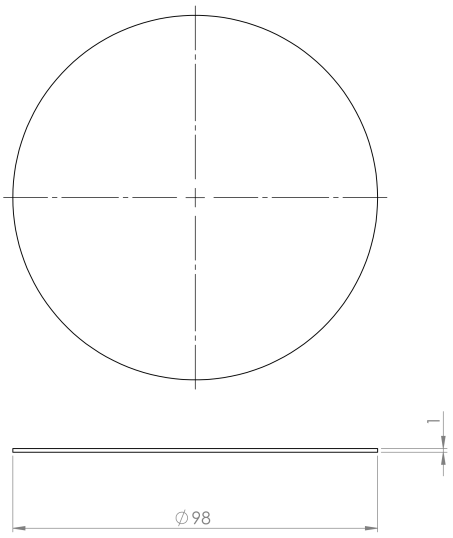

(c) Drawing of a teflon lid




(d) Drawing of the upper electrode




(e) Drawing of the lower electrode




(f) Drawing of an unknown element

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# Measurement of heat transfer

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## Setting of the project

The subject of the measurement is the thermal conductivity of a metal cylinder made of unknown material. The measurement was performed with a set of sensors on the surface of the roller, the roller was heated by a ceramic body inserted from above.

Points of assigngment of the semester project

- Describe the function of the measuring device. (2b)
- Describe a mathematical model of the roller temperature field, including boundary conditions (Derived modified equation describing the behavior of the field for each region and boundary). (Consider the specific heat capacity of the material 880 $unit Jkg^{-1}K^{-1}$.) (5b)
- Create a temperature field model using Comsol Multiphysics. (4b)
- Converge the model. (Describe your own procedure with added results) (4b)
- Estimate the thermal conductivity of the material by comparing the model with the measured values. (5b)

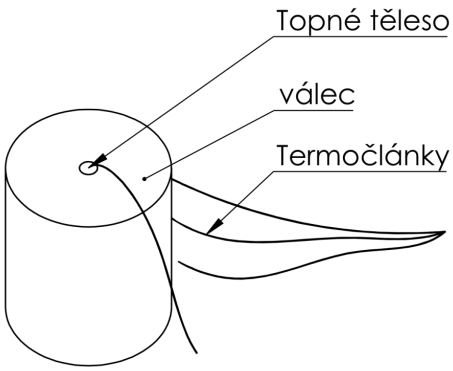
### Description of the measured device

The cylinder was heated with a ceramic body with a constant heat output of 40 W. The thermocouples recorded the temperature on the surface of the roller for 10 seconds for 6 minutes after switching on the heating. The metal roller weighs 323.78 g. When entering the boundary conditions of heat transfer, take into account the pad on which the roller was attached and that the measurement took place in a room heated to 22 °C with standing air.

1. A transient must be used to determine the evolution of temperature over time.
2. It is important to calculate the material density to simulate the transient.
3. Conversion of heat output for the boundary condition of heat flow $q\,[\mathrm{W/m^2}]$ supplied by the body. Resp. determine the correct amount of heat output passing through the shared surface of the rollers.

In the figure on the right, the types of materials are distinguished by color. The gray color is a metal roller, the black color is a heating element.

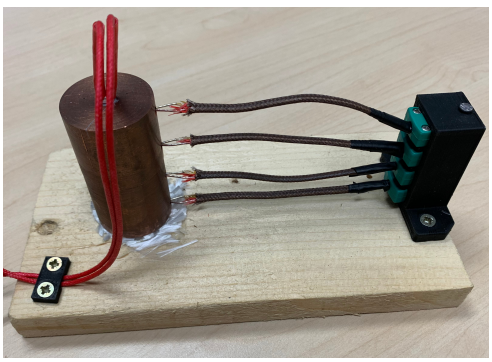
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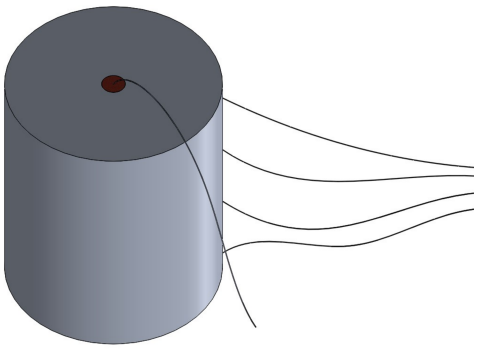

Obrázek 3: Draw of construction

Tabulka 3: Measured heating characteristic

| time (s) | T0 (°C) | T1 (°C) | T2 (°C) | T3 (°C) |
|---|---|---|---|---|
| 0 | 23.13 | 22.58 | 23.72 | 23.23 |
| 10 | 23.19 | 22.77 | 24.37 | 23.78 |
| 20 | 23.65 | 23.43 | 25.56 | 24.71 |
| 30 | 24.38 | 24.23 | 26.63 | 25.49 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| 360 | 50.15 | 51.14 | 55.33 | 46.62 |



(a) Fotografie měřícího zařízení



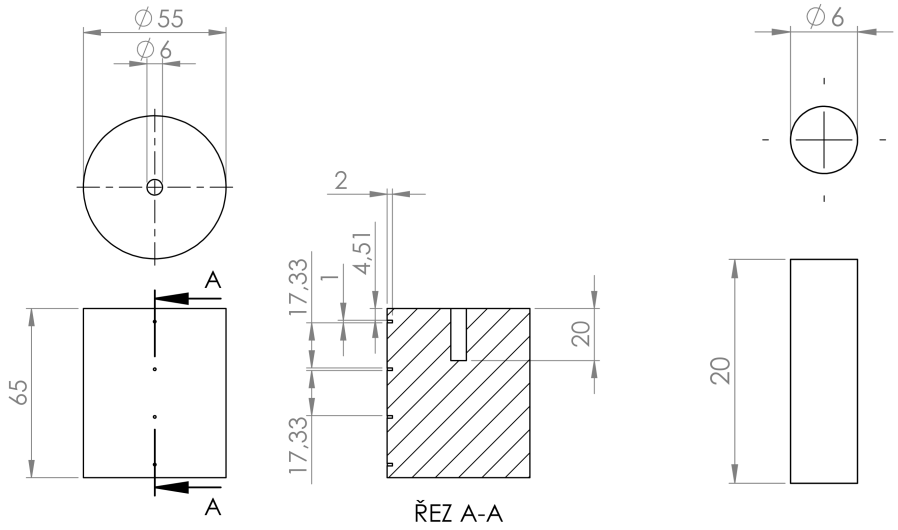
(b) 3D model sestavy

Technical drawings and dimensions of the device

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(c) Drawing of a metal cylinder with positions of temperature sensors

(d) Drawing of the heating element

Technical drawings and dimensions of the device

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