

Thermal measurements

facts and artifacts

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Thermal measurements - facts and artifacts

- ▶ An informal tutorial for the OWL type
- ▶ A very extensive topic
- ▶ not all details can be treated
- ▶ A more complete version can be downloaded from
- ▶ <http://www.eet.bme.hu/~farkas/SEMI26>



Other useful link is

<http://www.ipes.ethz.ch/ipes/2002thermal/thermisch.html>

Thermal measurements - facts and artifacts



- ▶ *“already the ancient Greek”*
– a nice start for a scientific story
- ▶ but this story is much older



Thermal measurements - facts and artifacts



- ▶ *“already the ancient Greek”*
– Oops, may be, this is an artifact?

Thermal measurements - facts and artifacts



- ▶ OK, we corrected the measurement error

How it began



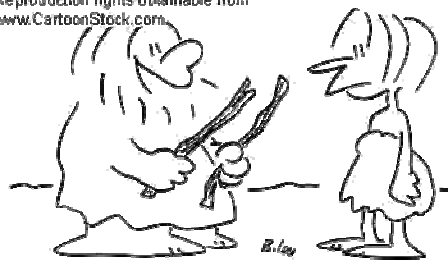
Thermal engineers



Thermal management, thermal measurements ...

- ▶ Success from the start
- ▶ and also some mistakes, some failures, some fakes

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"ACCORDING TO MY THEORY, IF I RUB
THESE TWO STICKS TOGETHER LONG
ENOUGH, I'LL GET A WHEEL!"

....and engineers in time and space

- ▶ We usually consult
 - thermal engineers
 - material engineers
 - mechanical engineers

- ▶ Electrical engineers are newcomers
 - with odd language, odd habits ☺

- ▶ Material engineering
- ▶ Mechanical engineering – an ancient story again



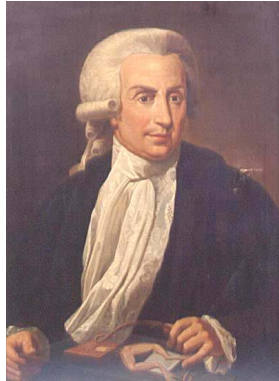
**Mechanical
engineering**



**Material
engineering**

The newcomers

- ▶ Luigi Galvani
- ▶ 1737 - 1798



- ▶ count Alessandro Volta
- ▶ 1745 - 1827



The newcomers

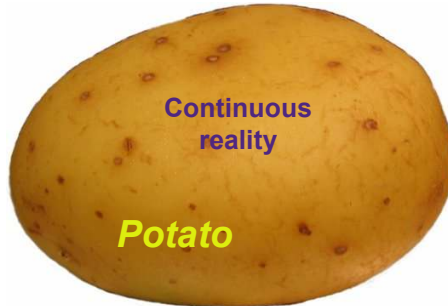
- ▶ André-Marie Ampère
- ▶ 1775 - 1836



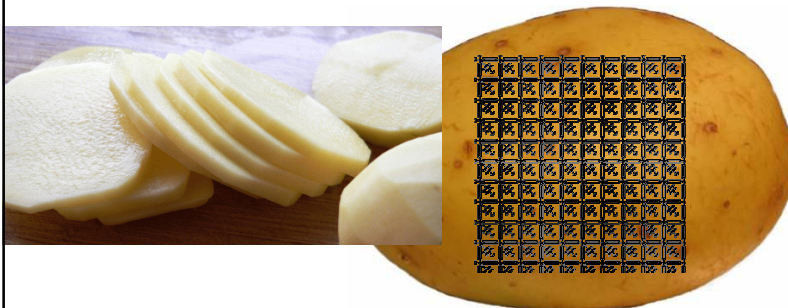
- ▶ Georg Simon Ohm
- ▶ 1789 - 1854



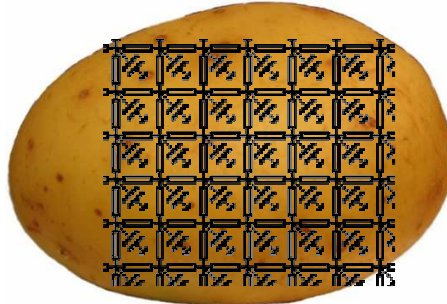
- ▶ Electronics engineers are people of



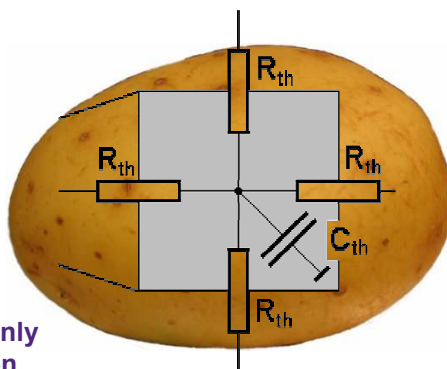
- ▶ Electronics engineers are people of
 - discretized brain



- ▶ Electronics engineers are people of
 - discretized brain
 - linearized brain



- ▶ Electronics engineers are people of
 - discretized brain
 - linearized brain



Linearized:

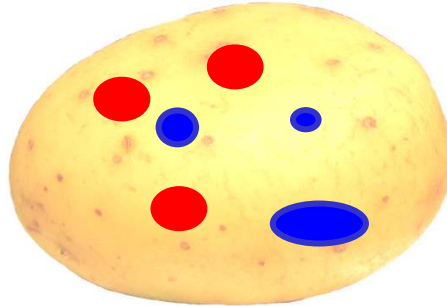
A Bear of Very Little Brain can only count until **ONE** when making a Taylor series

Task 1

- ▶ We applied heaters here and there
- ▶ We created sensors
- ▶ and the time passes
- ▶ How much is the temperature ?

Heaters

Sensors

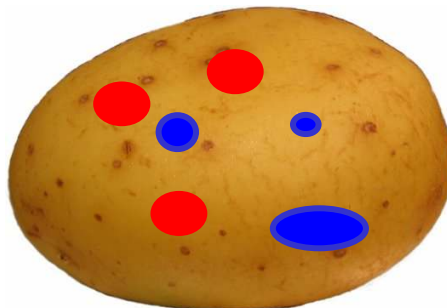


Task 2

- ▶ We measure the temperature response in time
- ▶ What is the structure ?

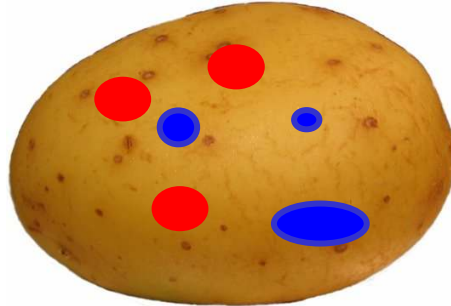
Heaters

Sensors



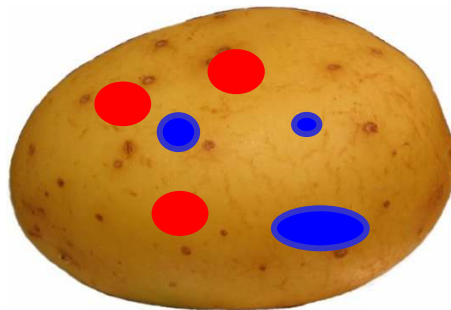
Excitation and measurement

- ▶ Heating is typically electric, when we have wires towards our system
- ▶ but what before?
- ▶ Sensors can be
- ▶ contact or non-contact type



Excitation and measurement

- ▶ Heaters can be
 - pointwise (chip?, laser)
 - surface (solar irradiation)
 - volume (induction, microwave)
- ▶ Sensors can be
 - pointwise (chip, thermocouple)
 - surface (LCD, infrared)
 - volume ???



Sensors of our time

- ▶ Thomas Johann Seebeck
- ▶ 1770 - 1831



An ambitious project

- ▶ Mapping of temperature distribution in pharmaceutical microwave vacuum drying

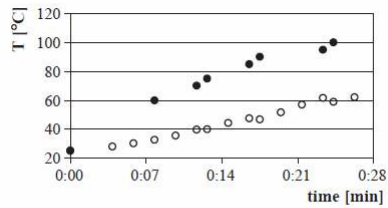
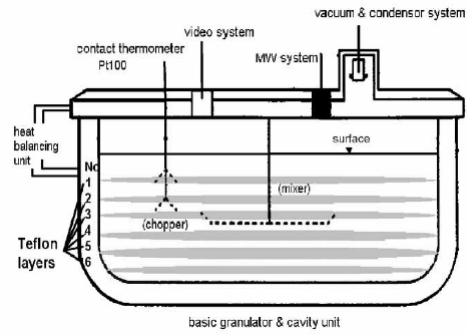


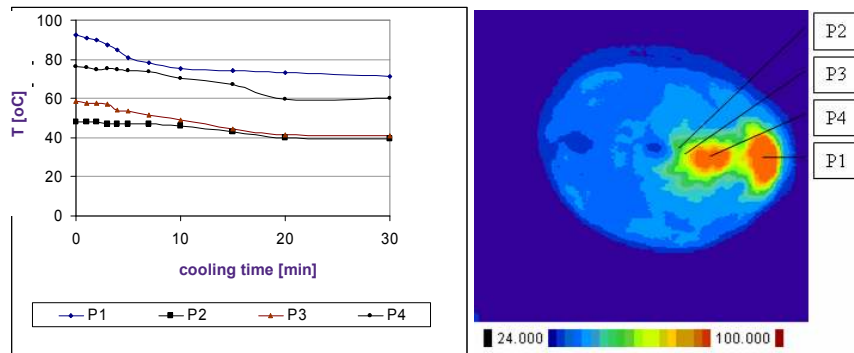
Fig. 2. Temperature–time curve of cornstarch. The contact thermometer fitted into the chopper arm (Pt100) (O) was operating during the running process, hot-spot surrounding temperature (●) is measured immediately after microwaves were switched off (6.3 kg, 50 mbar, 1.2 kW, 2450 MHz). (Three replications were used to generate each data point.)



Modified arrangement



Results in time and space

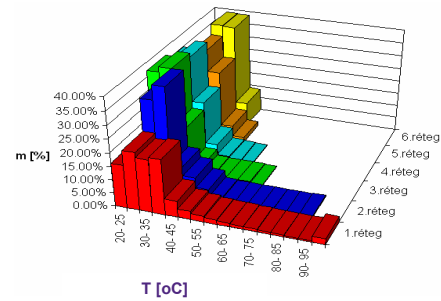
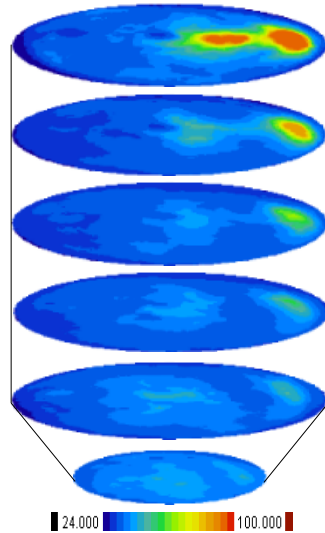


Few critical points in time

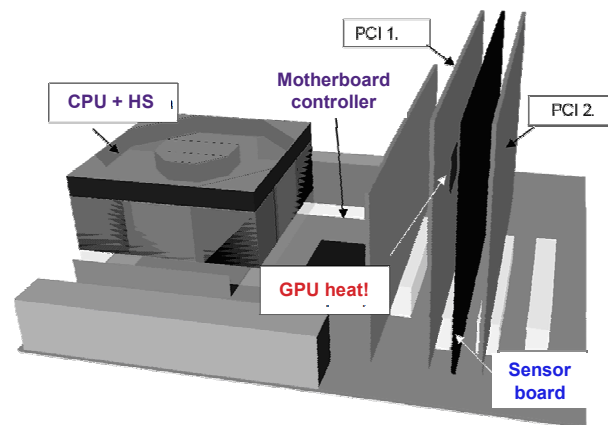
Temperature map in several slices

Results in 2.5D space

Corn starch, 1,2kW, after 15 min treatment

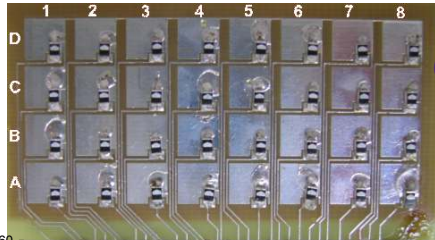


One dimension less ...



- ▶ Temperature map in time of PCBs in a computer
- ▶ IR camera cannot be placed between boards

One dimension less ...



(Before painted BLACK)

