Temperature

Edgar Méndez Lango
emendez@cenam.mx
Termometría, CENAM
México

CENAM
CENTRO NACIONAL DE METROLOGÍA
TERMOMETRÍA

Content

Concept of Temperature

Zero-th Law

References; ITS-90

Thermometers

Traceability

Heat conduction

Experimental

Open problems

Subjective scale

Temperature:

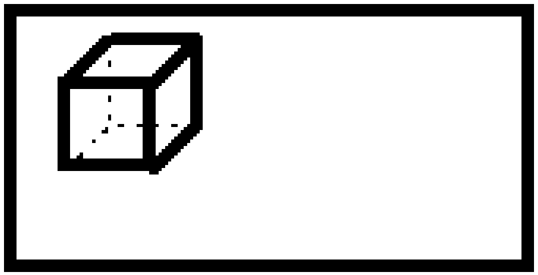
Property of a body that determines if it is hot or cold

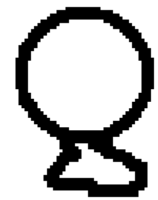
Subjective Scale:

Set of bodies that can be arranged from coldest to hottest

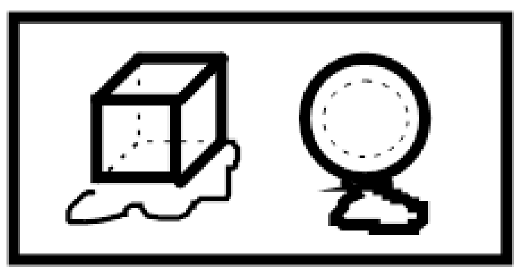
Uncertainty of the subjective scale

Experiment





Ice cube in an adiabatic container; balloon at room temperature



Both of them in the adiabatic container

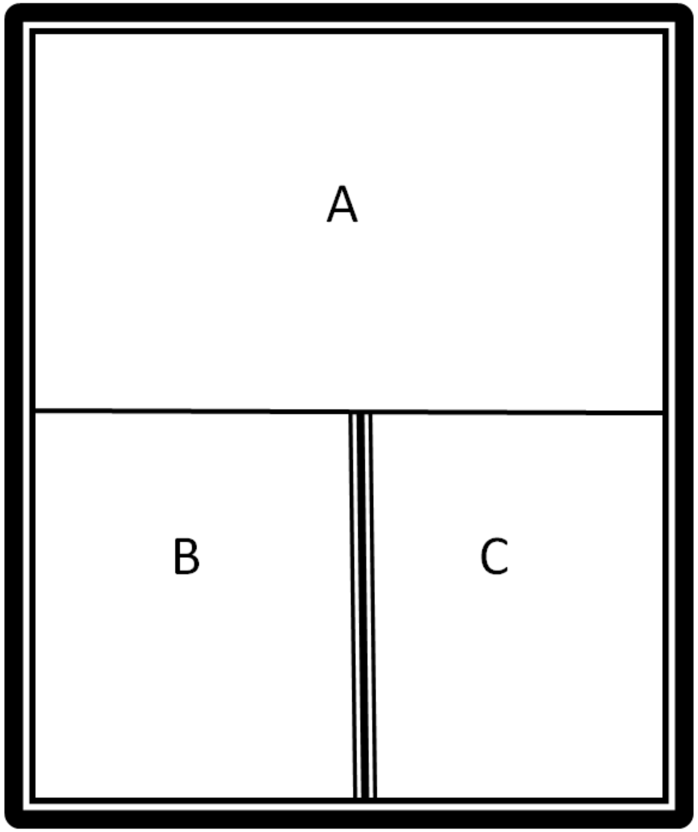
Equilibrium

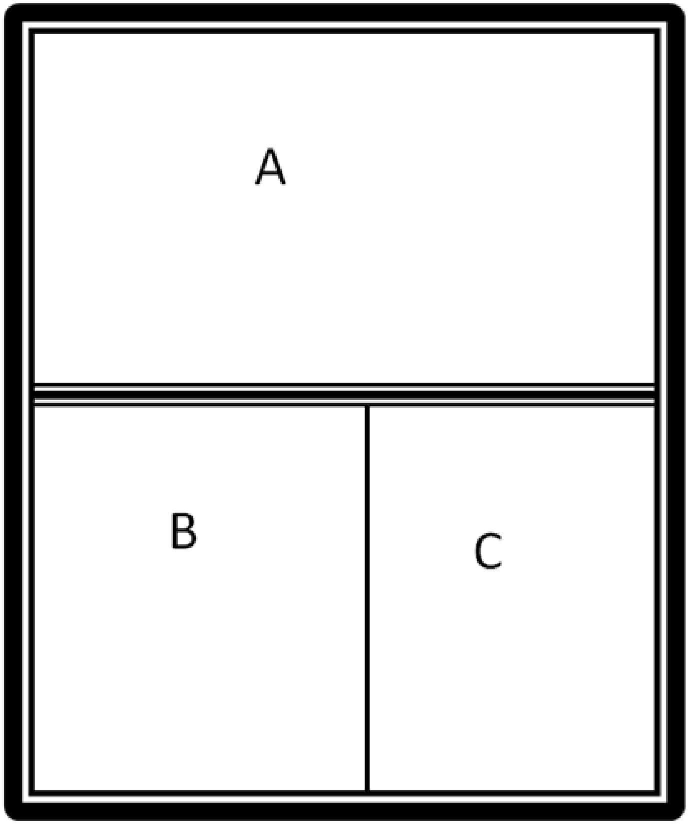
A system is said to be in equilibrium when its contents cannot change their condition of their own accord.

Such a change can only be brought about through some action in the surroundings.

Ref. E. E. Anderson *Thermodynamics* PWS Publishing Co. 1994, p. 15

Zero-th law





Temperature

Physical property that describes
if thermal equilibrium holds.

Two objects are in thermal equilibrium,
if and only if,
they are at the same temperature

References

Clinical thermometer:	0.1 °C
Industrial laboratory:	0.01 °C
Calibration laboratory:	0.001 °C
And so on…	

Equilibrium

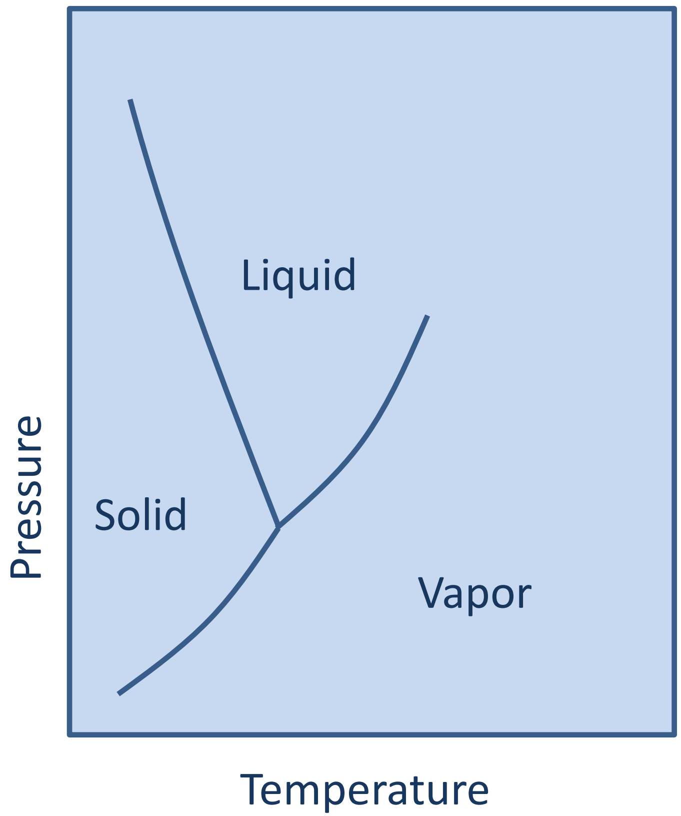
Mechanical: 2 points

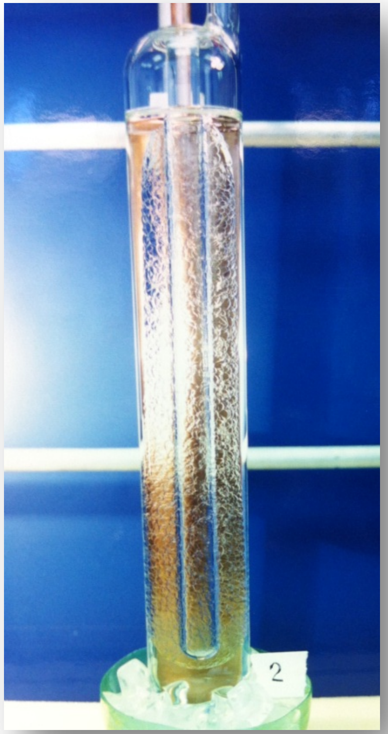
Mechanical: 1 point

Thermal: 1^{st} control

Thermal: 2^{nd} control

Fixed points





CENTRO NACIONAL DE METROLOGÍA
TERMOMETRÍA

ITS-90 fixed points

Table 1. Defining fixed points of the ITS-90

Number	Temperature T_{90}/K	Temperature t_{90}/°C	Substance[a]	State[b]	$W_r(T_{90})$
1	3 to 5	−270,15 to −268,15	He	V	
2	13,8033	−259,3467	e-H_2	T	0,001 190 07
3	≈17	≈ −256,15	e-H_2 (or He)	V (or G)	
4	≈20,3	≈ −252,85	e-H_2 (or He)	V (or G)	
5	24,5561	−248,5939	Ne	T	0,008 449 74
6	54,3584	−218,7916	O_2	T	0,091 718 04
7	83,8058	−189,3442	Ar	T	0,215 859 75
8	234,3156	−38,8344	Hg	T	0,844 142 11
9	273,16	0,01	H_2O	T	1,000 000 00
10	302,9146	29,7646	Ga	M	1,118 138 89
11	429,7485	156,5985	In	F	1,609 801 85
12	505,078	231,928	Sn	F	1,892 797 68
13	692,677	419,527	Zn	F	2,568 917 30
14	933,473	660,323	Al	F	3,376 008 60
15	1234,93	961,78	Ag	F	4,286 420 53
16	1337,33	1064,18	Au	F	
17	1357,77	1084,62	Cu	F	

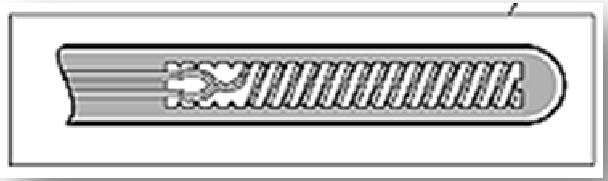
CENTRO NACIONAL DE METROLOGÍA
TERMOMETRÍA

Thermometer

To measure temperature

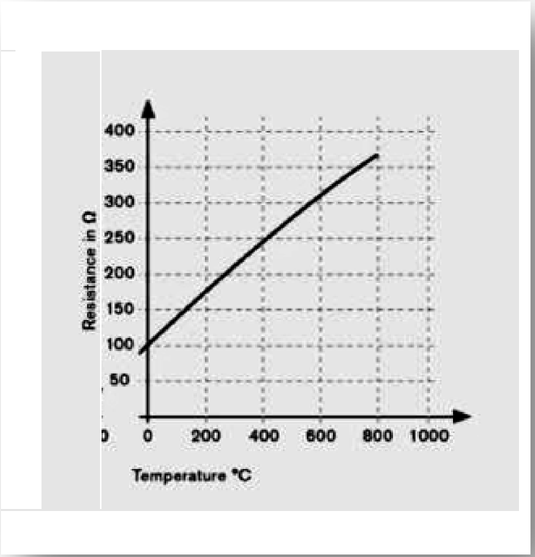
Three parts are needed:

a sensor,

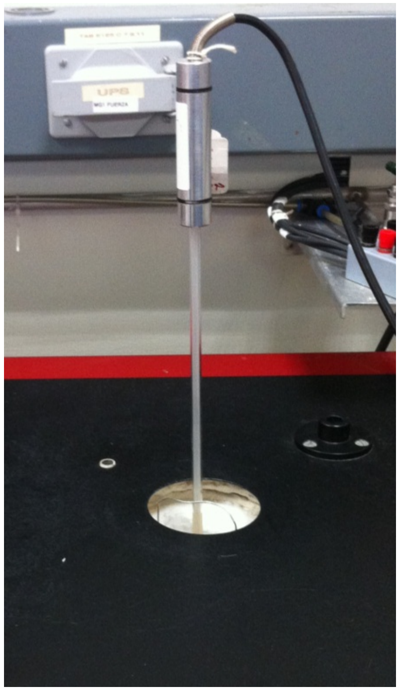


a readout and

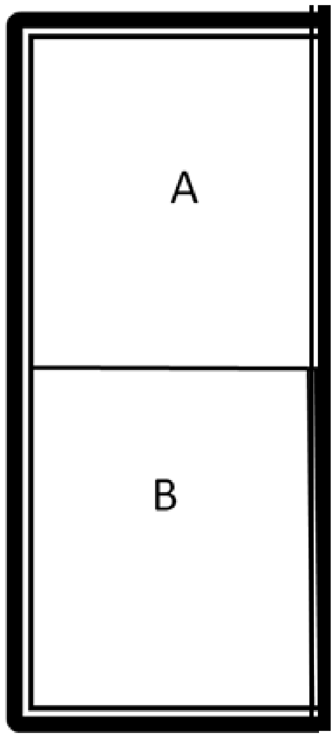
a table.

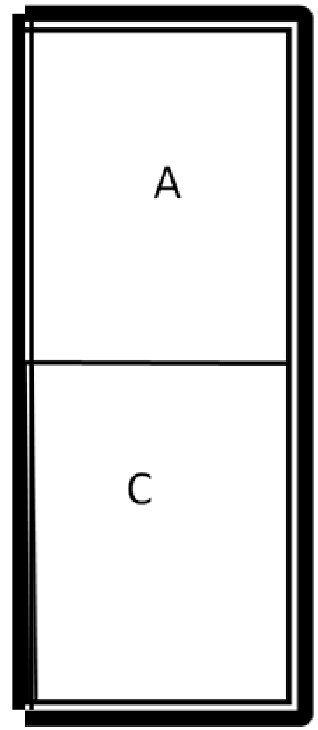


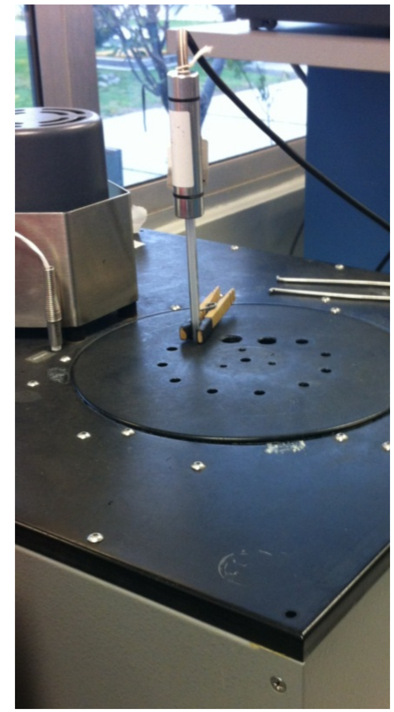
Traceability



PRT under
calibration



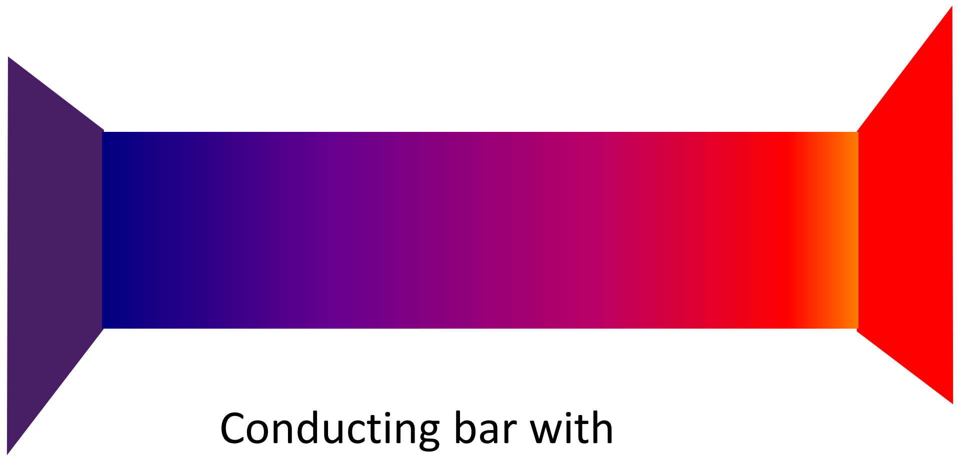




PRT in use

Heat conduction

Heat source
C
temperature
tc

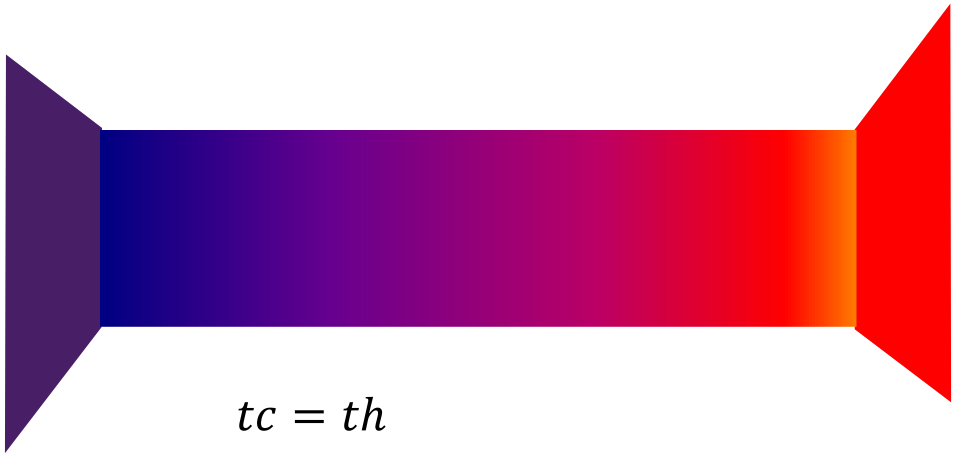


Heat source
H
temperature
th

Conducting bar with cross section A and length L

Heat conduction

Heat source
C
temperature
tc



Heat source
H
temperature
th

$$tc = th$$

$$\nabla t = th - tc$$

$$\left.\begin{aligned} \dot{q} &\propto \nabla t \\ \dot{q} &\propto A \\ \dot{q} &\propto \frac{1}{L} \end{aligned}\right] \longrightarrow \dot{q} = \lambda \frac{A \, \nabla t}{L}$$

CENTRO NACIONAL DE METROLOGÍA
TERMOMETRÍA

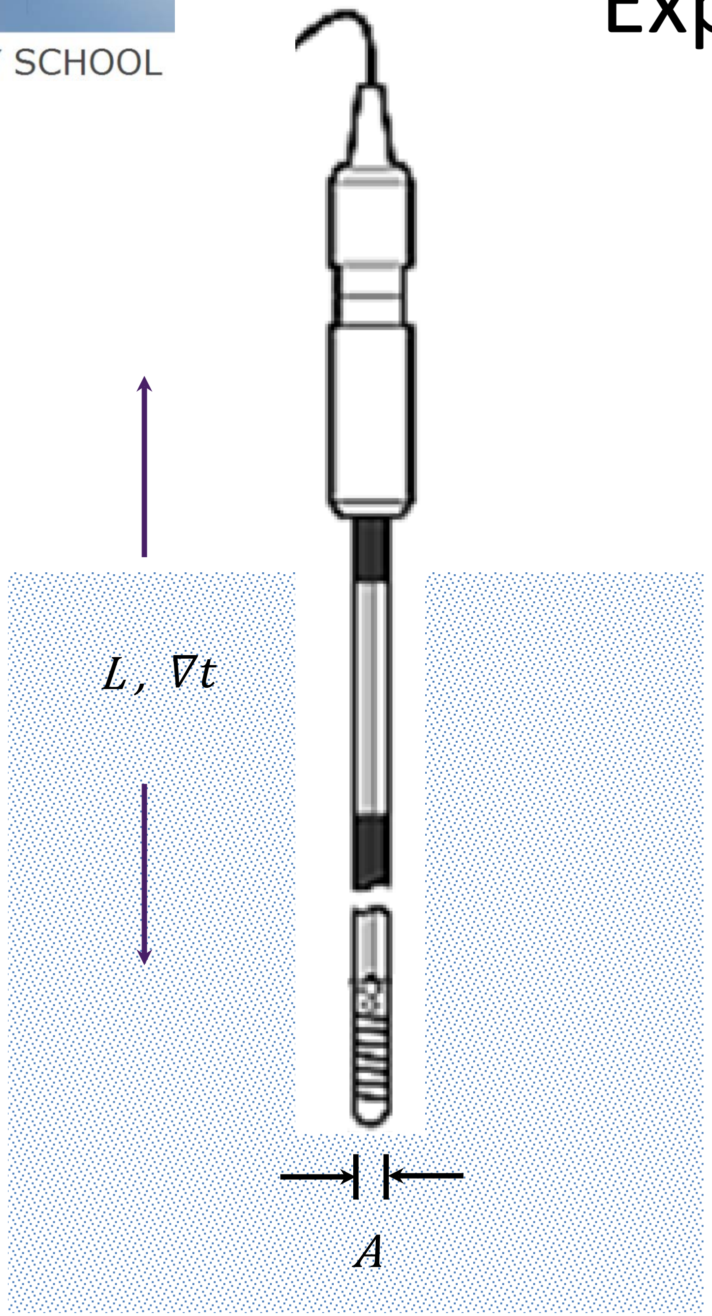
Experimental

A thermometer measures its own temperature

It is the duty of a metrologist to design the experimental setup to ensure that the thermometer is in thermal equilibrium with the object or media under study.

Experimental case I immersion

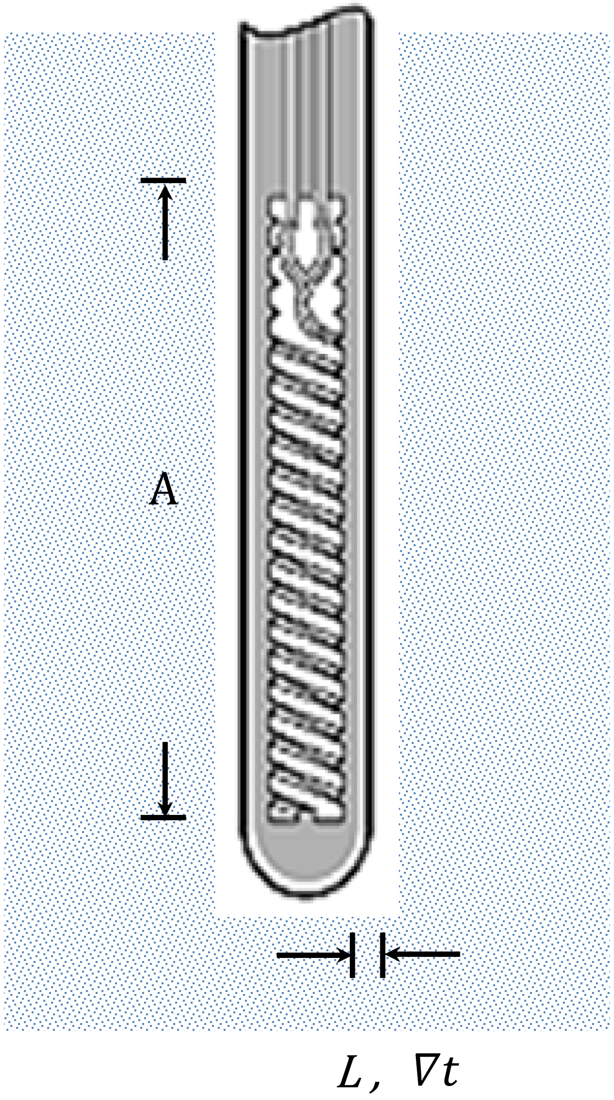
$$\dot{q} \rightarrow \min$$



$$\dot{q} = \lambda \frac{A \, \nabla t}{L}$$

CENTRO NACIONAL DE METROLOGÍA
TERMOMETRÍA

Experimental case II
Thermal contact



$$\dot{q} \rightarrow \max$$

$$\dot{q} = \lambda \frac{A \nabla t}{L}$$

CENAM
CENTRO NACIONAL DE METROLOGÍA
TERMOMETRÍA

"Open problems"

Since temperature is an equilibrium concept there is not such a term for systems with thermal gradients.

Several experiments require the knowledge of surface temperature, but contact thermometers work better when they are imbedded thus, this situation requires special attention.

CENAM
CENTRO NACIONAL DE METROLOGÍA
TERMOMETRÍA