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The thermal behaviour of objects in the presence of absorbed and emitted e.m. radiation:

Experiments & models

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How can materials interact with radiation?

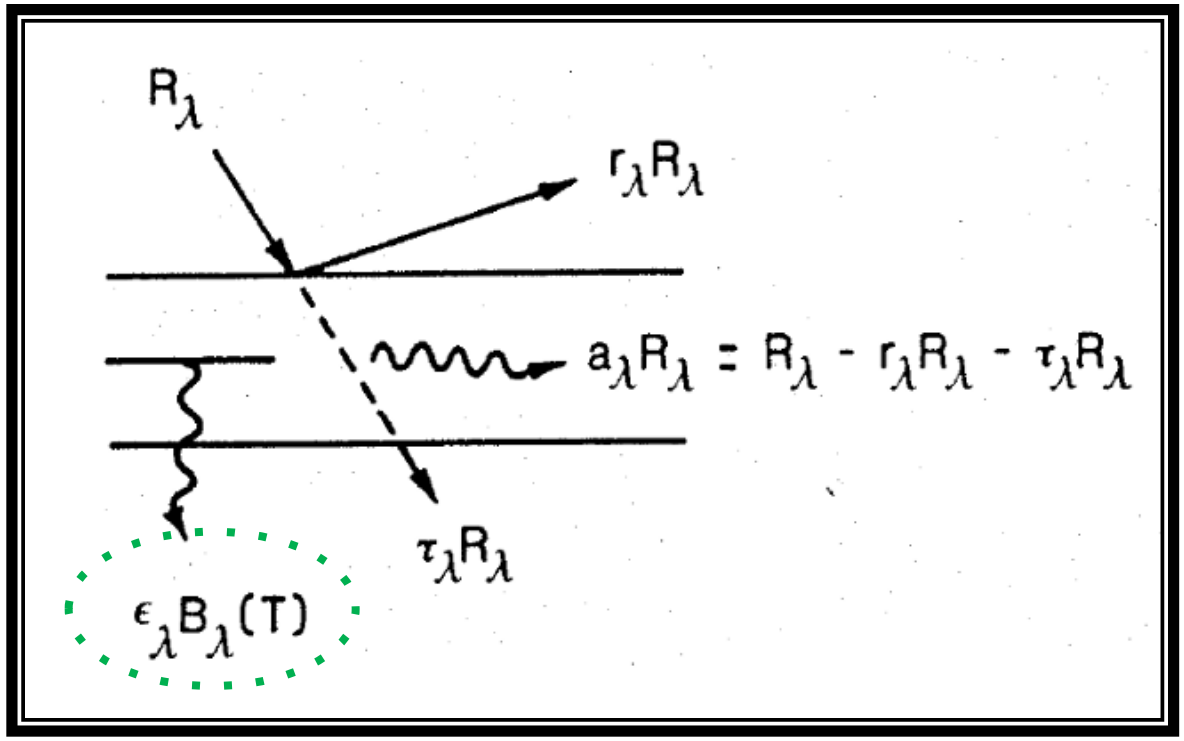
absorbance

reflectance

transmittance

ε emissivity

(λ wavelength)



CONSERVATION OF ENERGY DICTATES THAT:

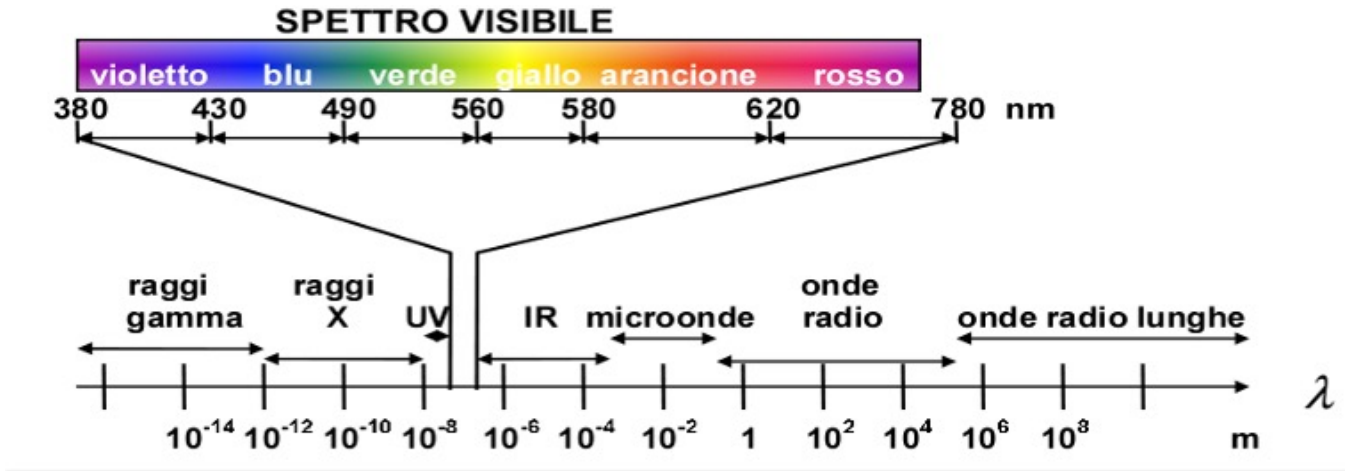
$$a_\lambda + r_\lambda + t_\lambda = 1$$

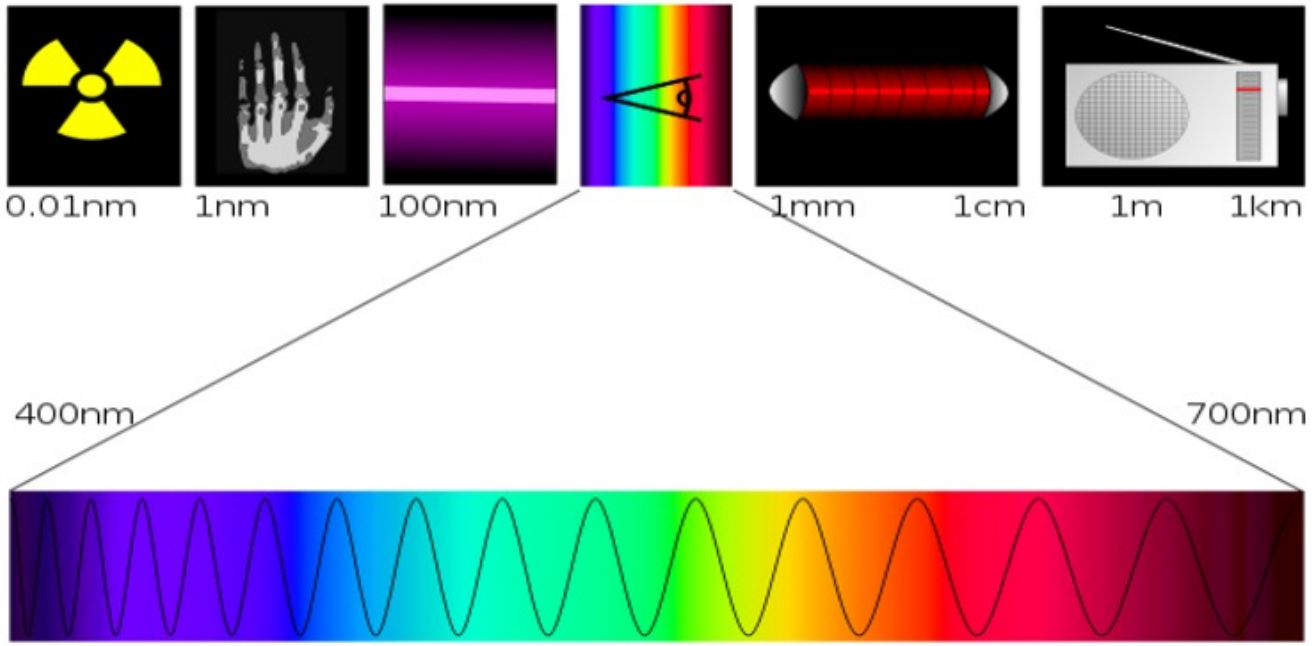
Materials and properties (*)

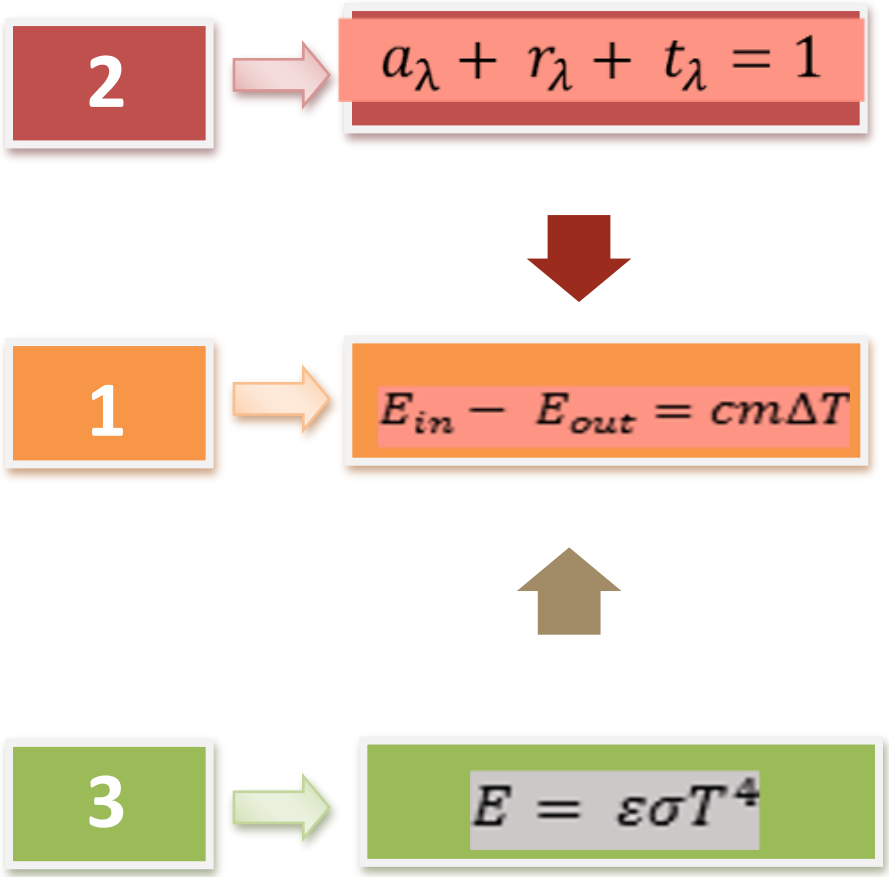
'Quality' object	Absorbance (a)	Transmittance (t)	Reflectance (r)	Budget report
Black (perfectly)	$a=1$	$t=0$	$r=0$	$a=1$
White (perfectly)	$a=0$	$0<t<1$	$0<r<1$	$t+r=1$
Transparent (perfectly)	$a=0$	$t=1$	$r=0$	$t=1$
Grey	$0<a<1$	$0<t<1$	$0<r<1$	$a+t+r=1$
Opaque	$0<a<1$	$t=0$	$0<r<1$	$a+r=1$
Glossy	$a\approx 0$	$t\approx 0$	$r\approx 1$	$r\approx 1$

(*)= at a fixed wavelength ()

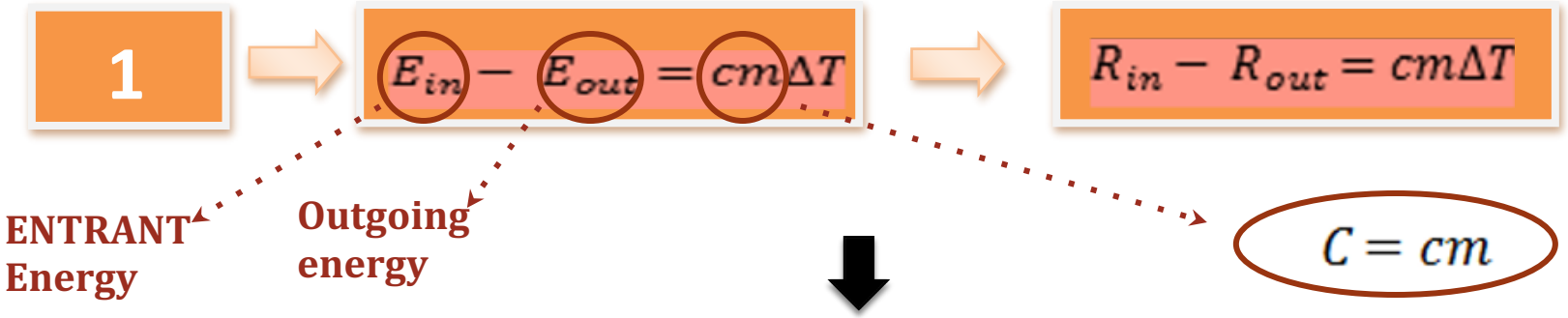
SPECTRE E.M.







3 RELATIONSHIPS



Energy balance that can be related to the first principle of TD by making some assumptions:

- The first principle is expressed in a way that emphasises the law of conservation of energy that is valid in every situation (in which the energy entering the system minus the energy leaving the system is only found in terms of the change in internal energy).

- The change in energy ($\Delta U=cm\Delta T$) of the system is only manifested in terms of the change in T of the system (situations where there are phase transitions and/or internal chemical reactions are not considered).

- The mode of energy exchange between the system and the environment occurs ONLY through *radiation*.

- The equilibrium condition is expressed in terms of $\Delta T=0$ which implies, in terms of the energy balance, that all radiation entering is equal to all radiation leaving.

2 ⇨ $iR_\lambda = a_\lambda R_\lambda + r_\lambda R_\lambda + t_\lambda R_\lambda$ ⇨ $a_\lambda + r_\lambda + t_\lambda = 1$

Energy balance, which emphasises incoming radiation and establishes how the radiation affecting an object is 'distributed':

a = part of radiation **absorbed**

r = part of **reflected** radiation

t = part of radiation **transmitted**

From this relationship, it is possible to define the "properties of bodies"

3

$$E = \varepsilon \sigma T^4$$

Experimental law that emphasises the radiation leaving a body and states that it is proportional to:

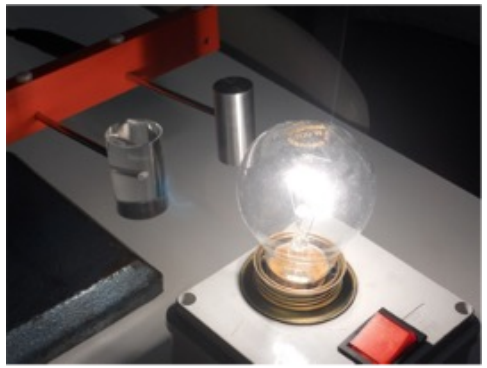
= **emissivity**

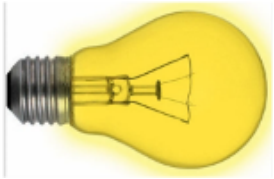
= Stefan-Boltzmann constant

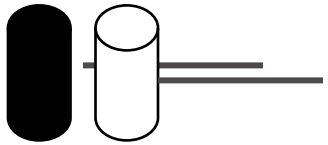
T^4 = fourth power of temperature

This 'E' is NOT energy but represents the power emitted per unit area [W/m^2].

THE EXPERIMENT







EXPERIMENTAL MATERIAL:

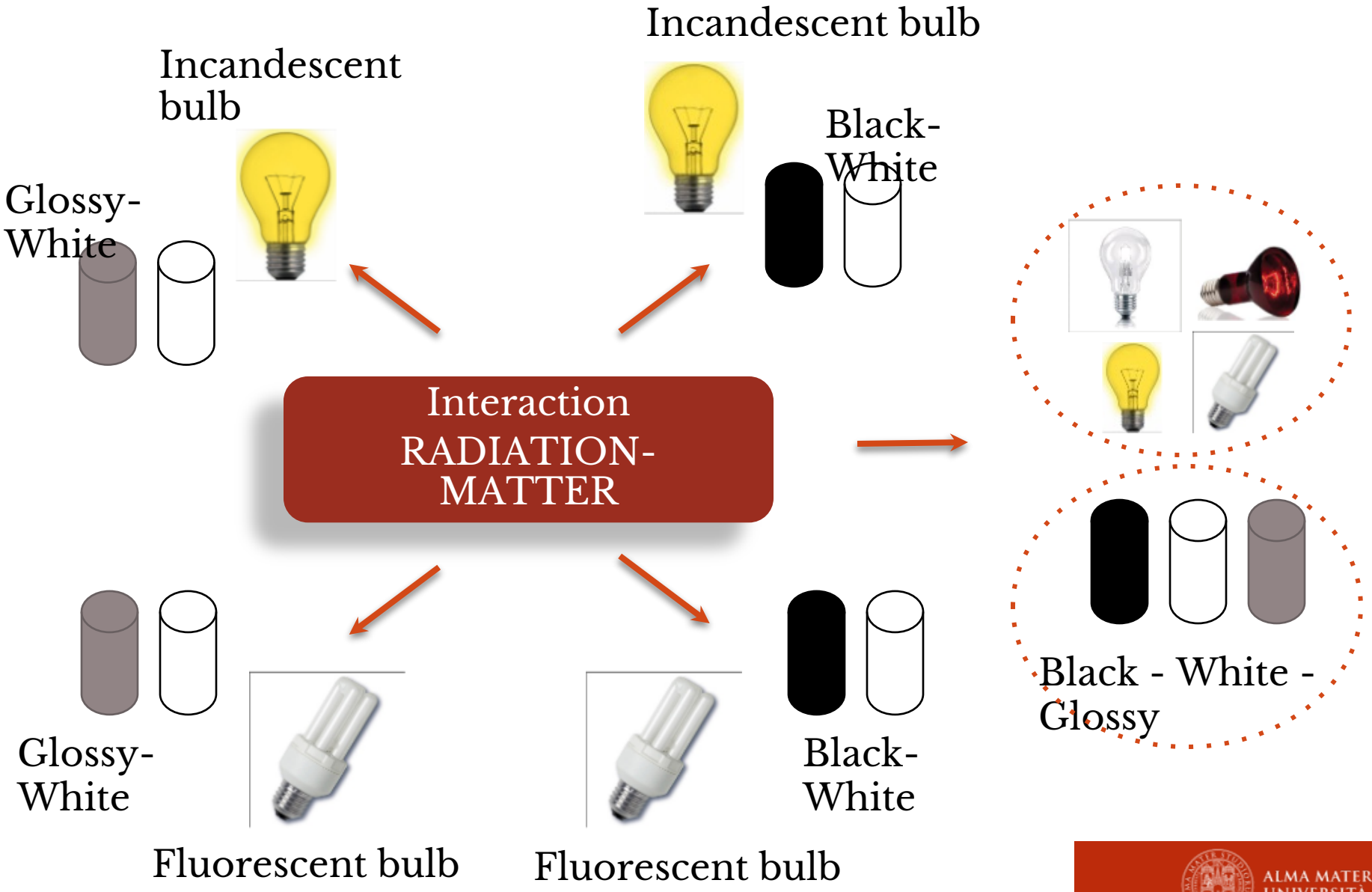
- 1 bulb
- 2 aluminium cylinders, same hea capacity and different colours
- 2 temperature sensors
- 1 graphical interface
- LP3 software

CHARACTERISTICS AND PHYSICAL ASSUMPTIONS UNDERLYING THE EXPERIMENT:

- each cylinder has a central hole into which the T sensor is inserted (the assumption is made that T is uniform throughout the cylinder);
- the cylinders are made of the same material [aluminium, $c_a \approx 900$ J/(Kg°K)], same mass (same volume) ... or rather they have the same **heat capacity** (J/K) :

$$C=mc$$

The protagonists of the experiment

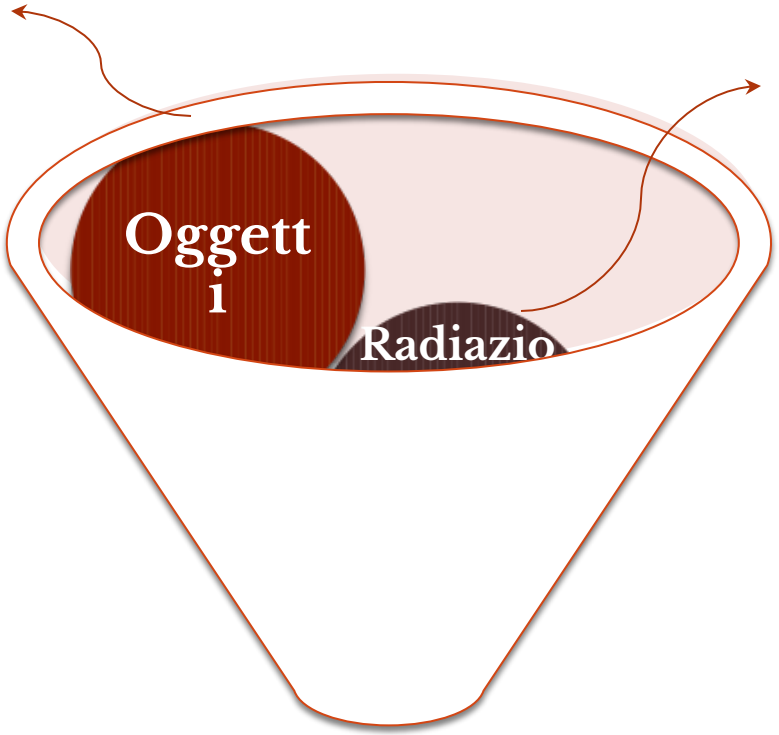


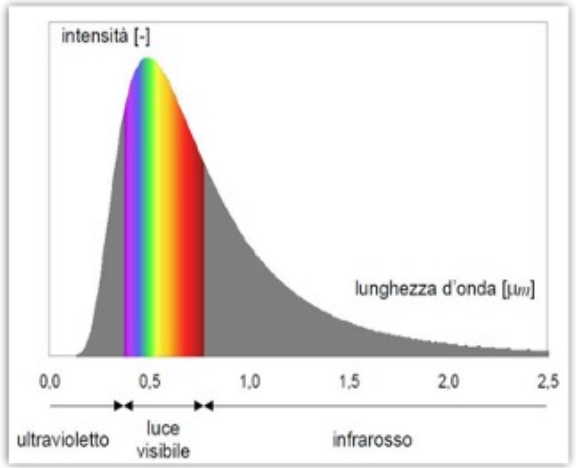
EXPERIMENT in progress

...

GROUP WORK!!!

The protagonists of the process/phenomenon

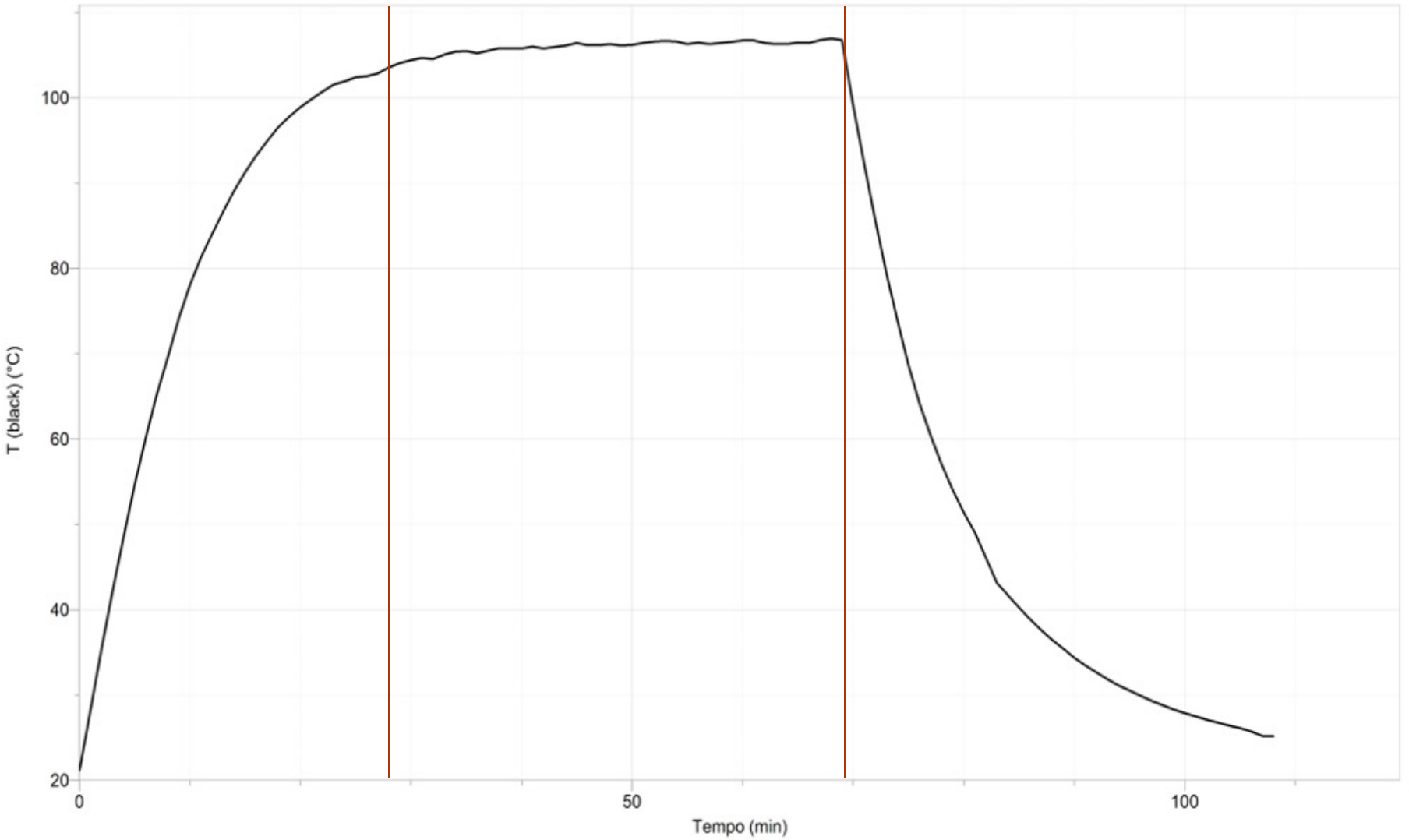




Interazione RADIAZIONE-MATERIA

WHAT KIND OF GRAPH DO WE EXPECT TO OBTAIN?

HOW DO WE EXPLAIN IT?



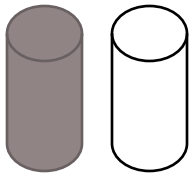
Rin > Rout

Rin = Rout

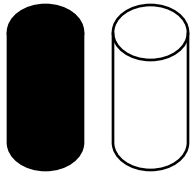
Rin < Rout

The object ... the cylinders

Glossy-White

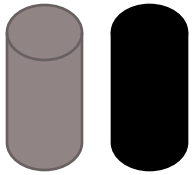


Black-White

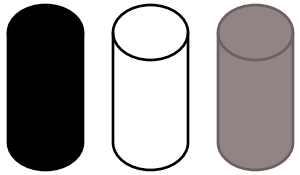


SUBJECT

Glossy - Black

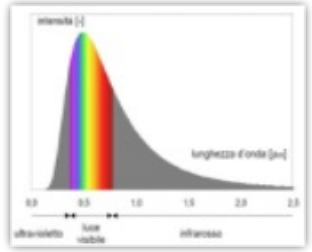


Black - White - Glossy

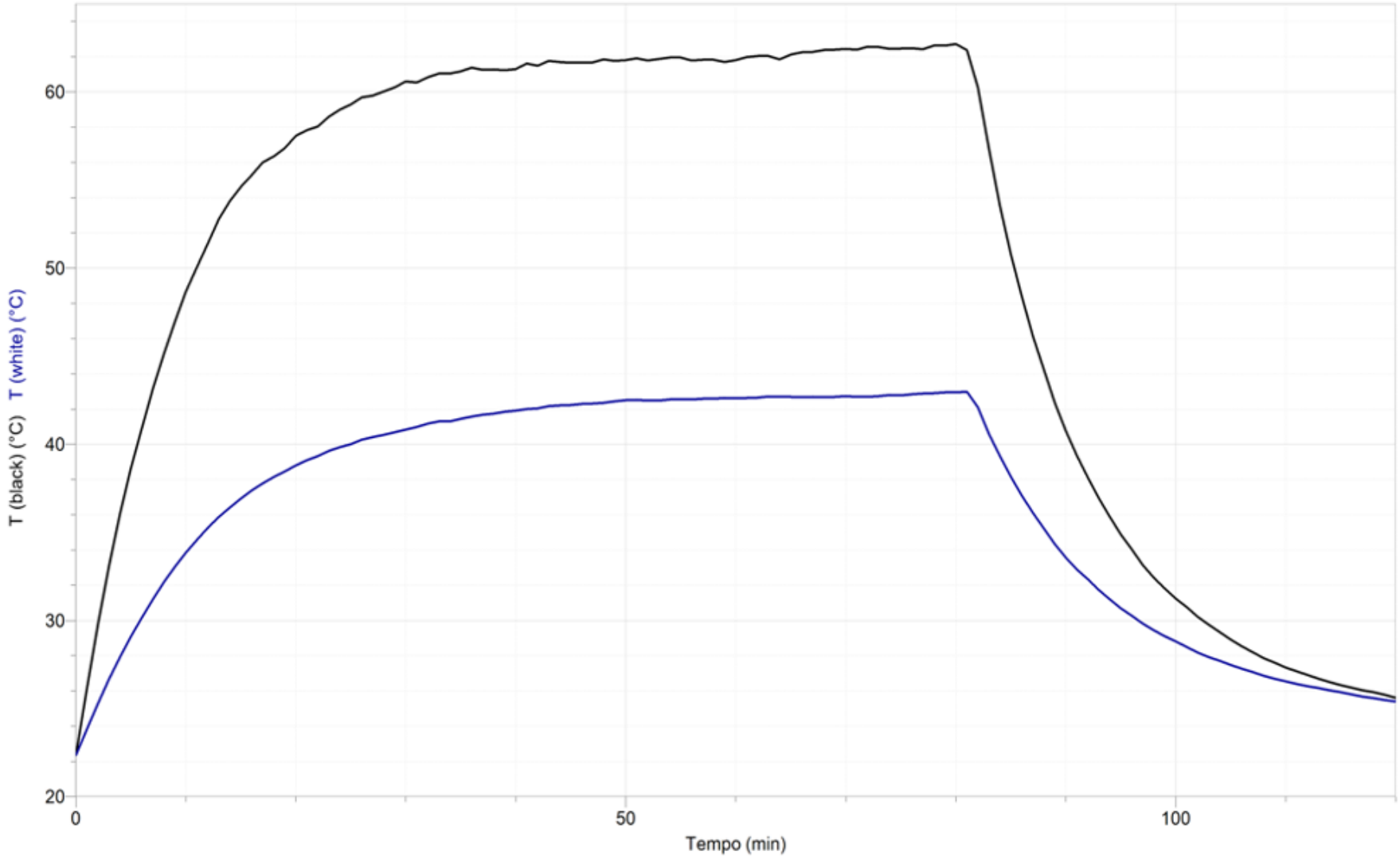


We keep the e.m. radiation fixed, so same bulb.

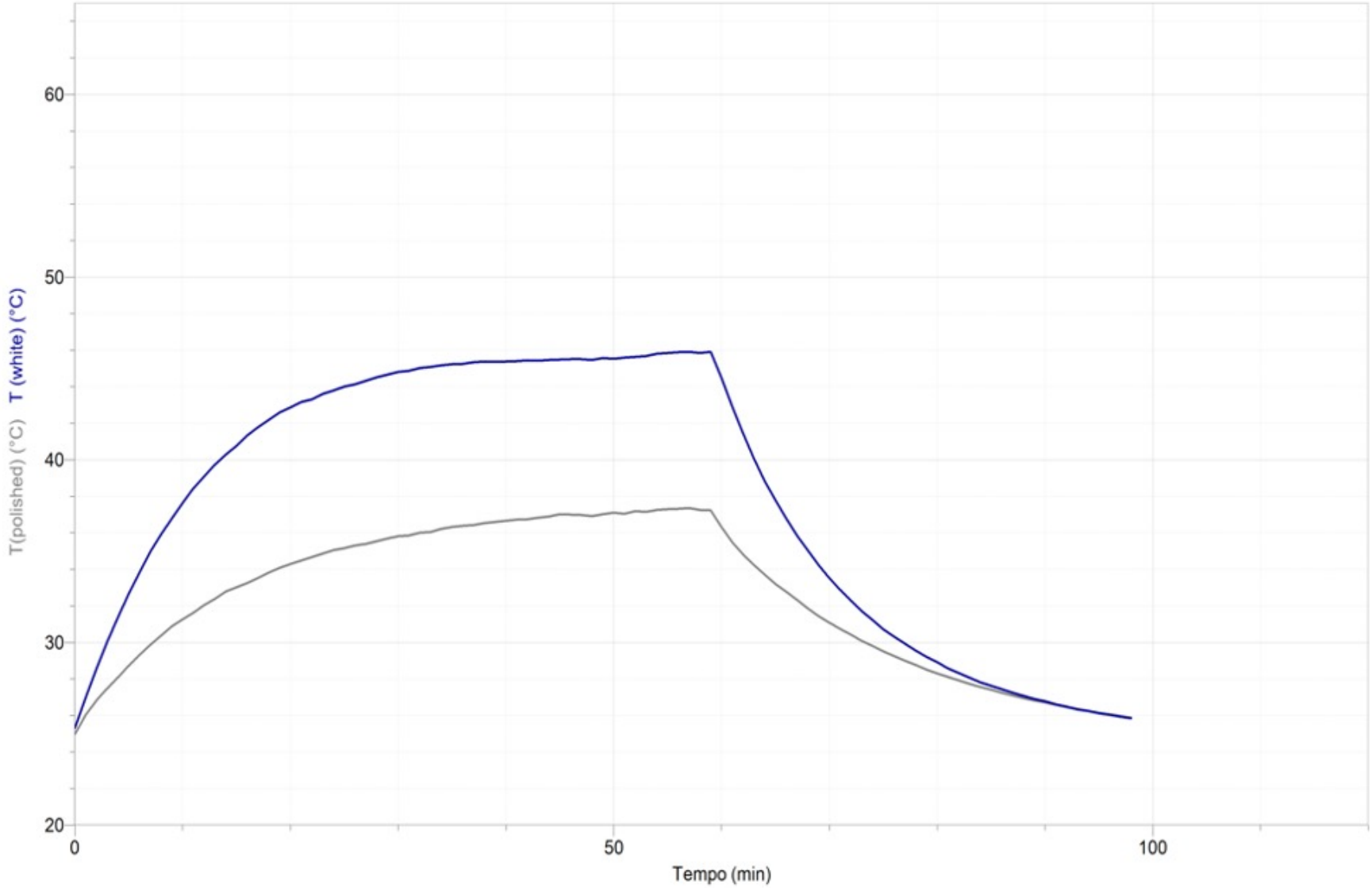
Radiation Electro-magnetics



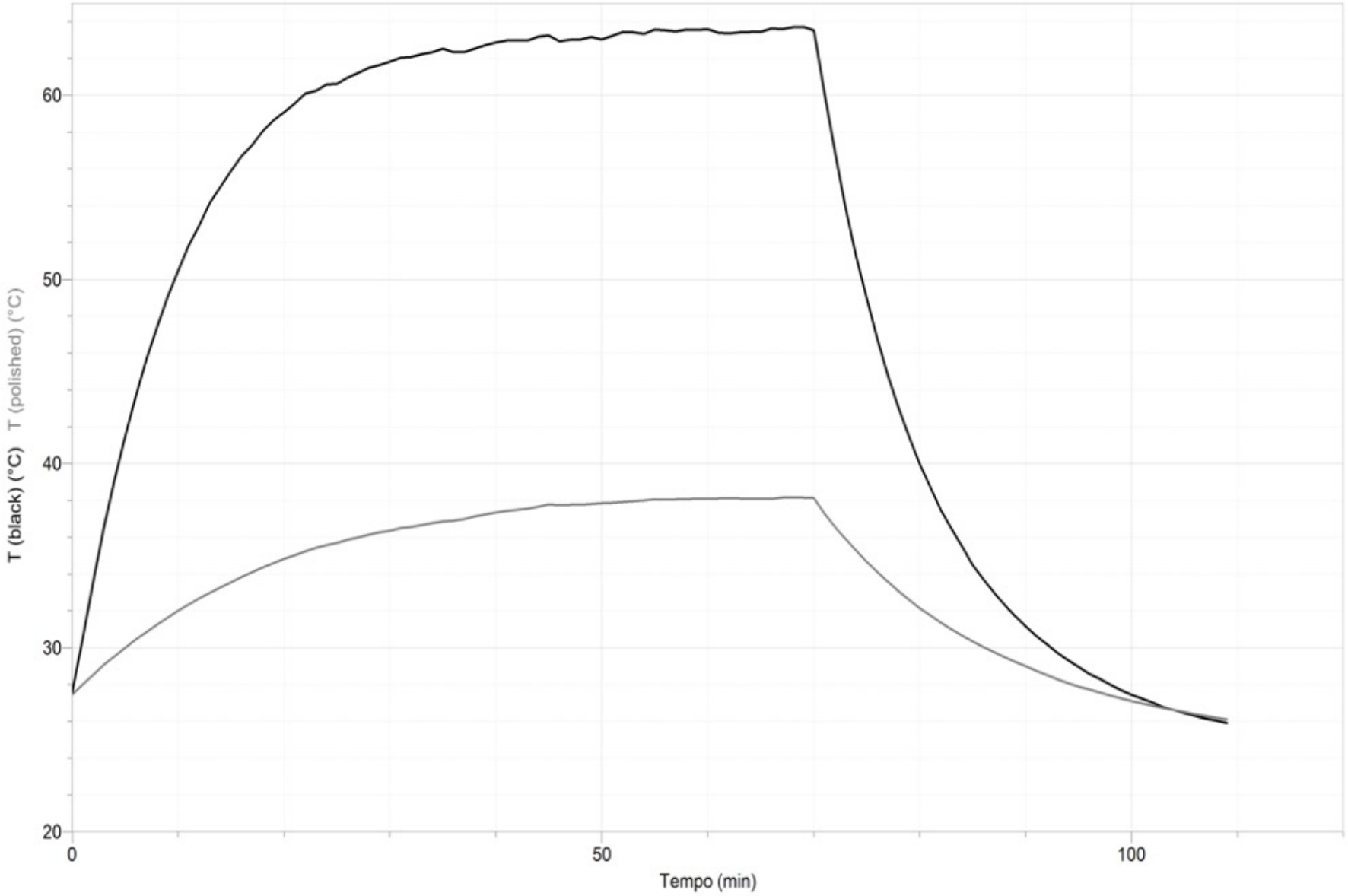
BLACK - WHITE



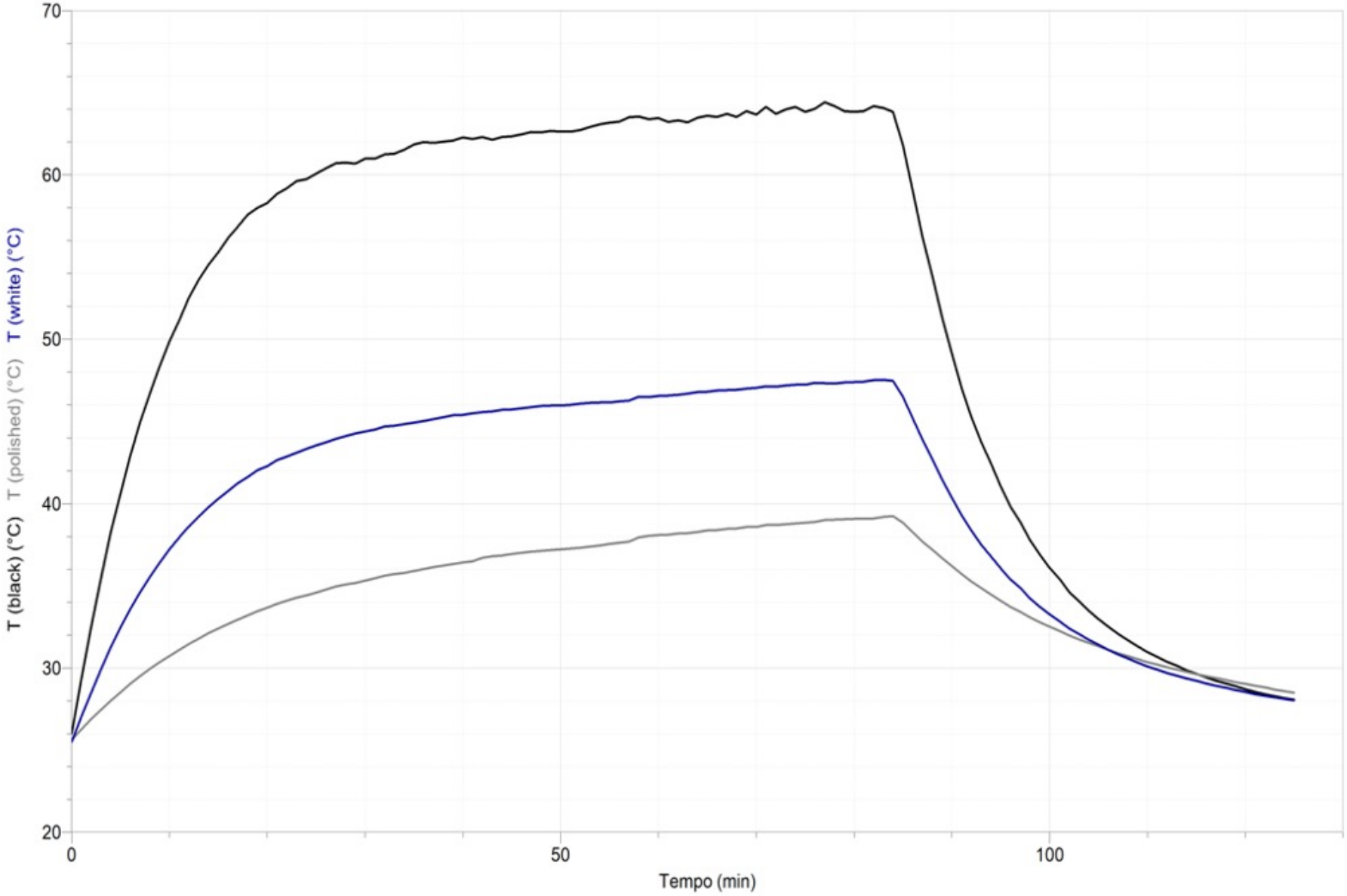
WHITE - GLOSSY



BLACK - GLOSSY

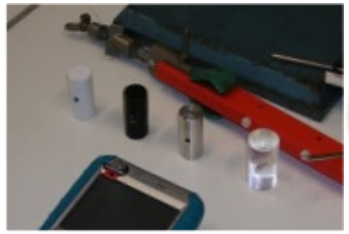


BLACK - WHITE - GLOSSY

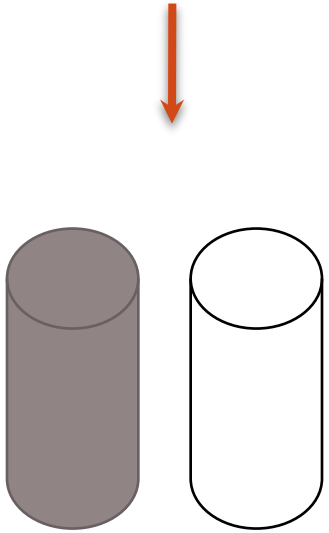


Radiation ... light bulbs

We keep the objects fixed, so same pair of cylinders.

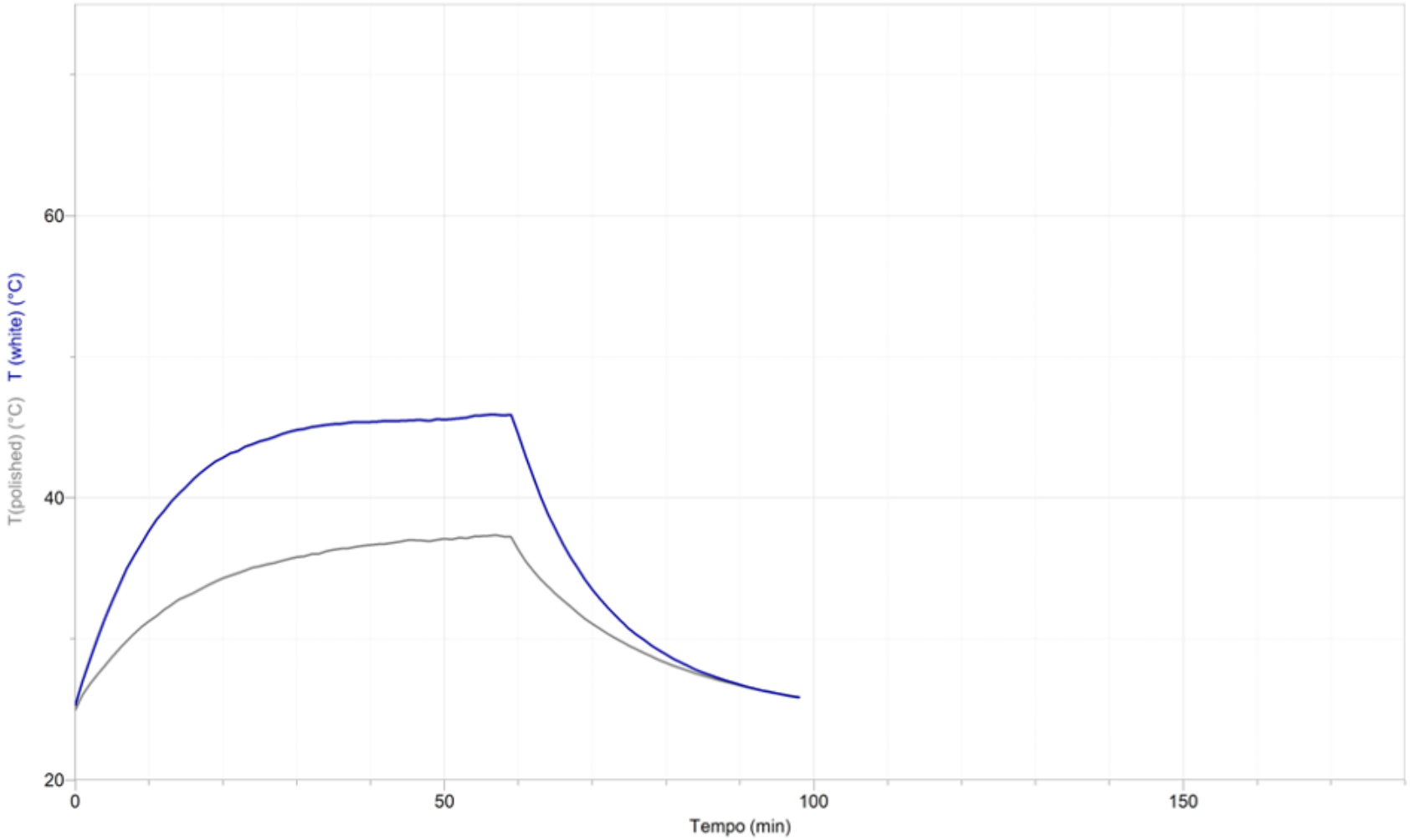


Objects

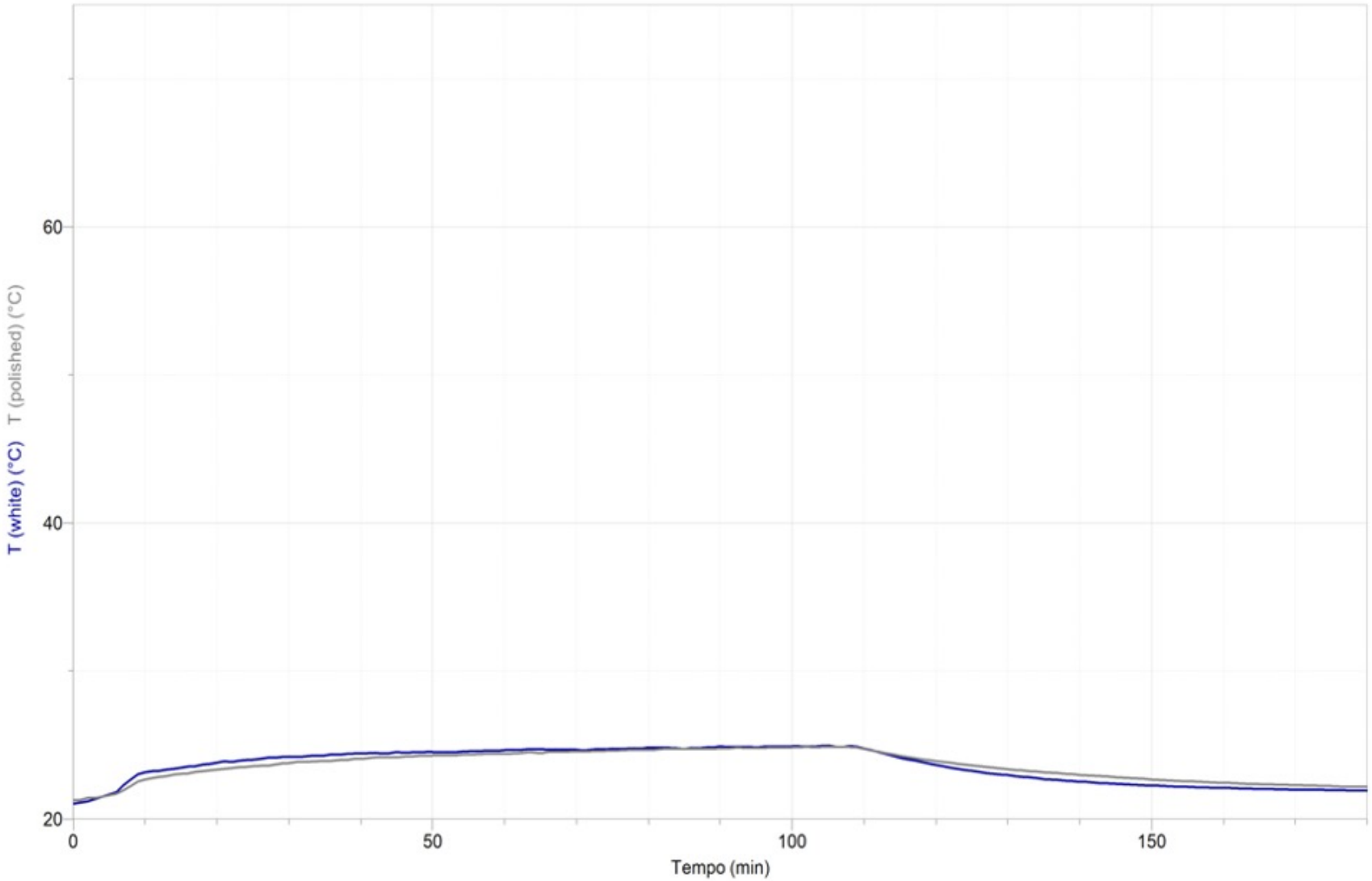


Radiation Electro-magnetics

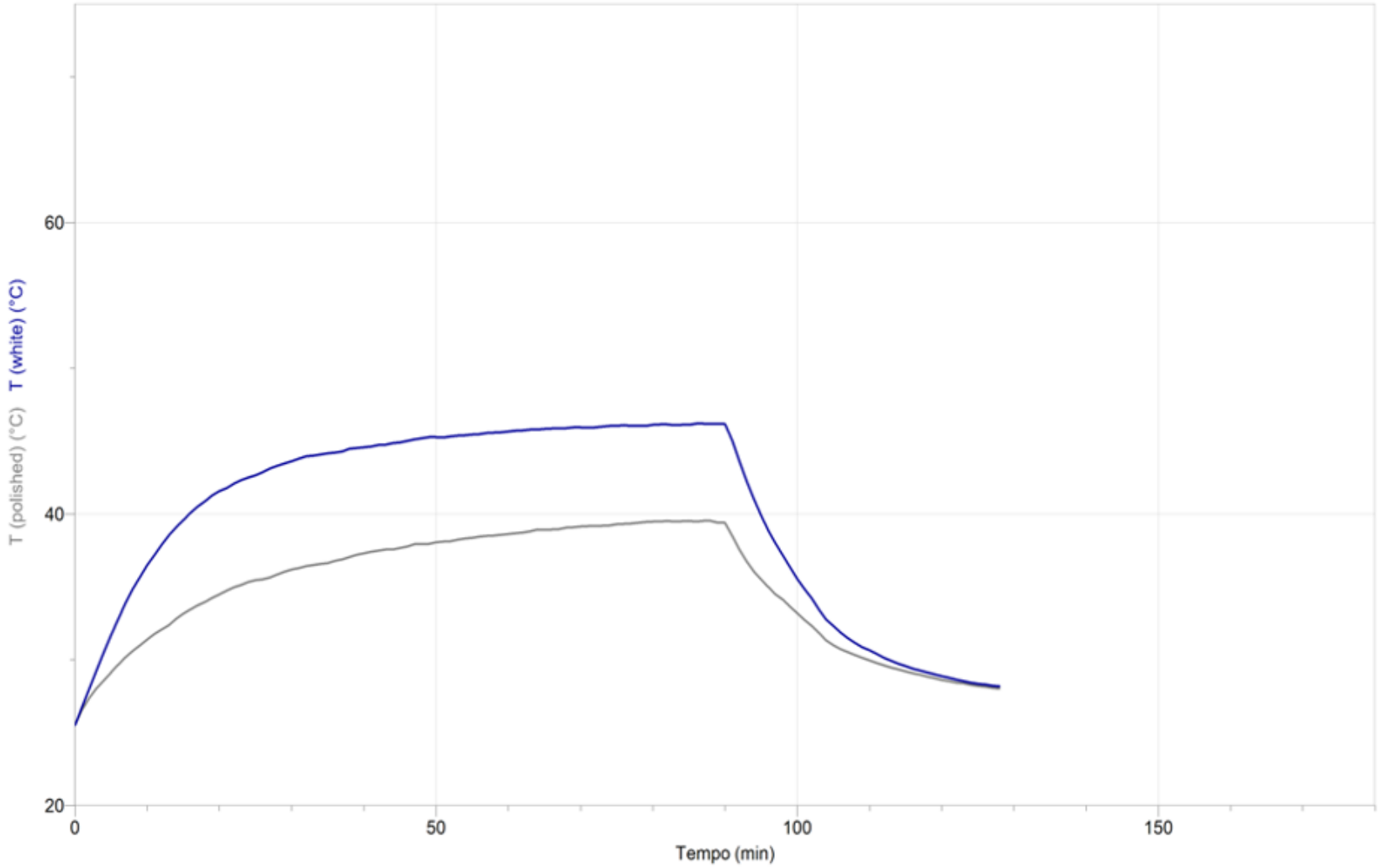
Incandescent bulb



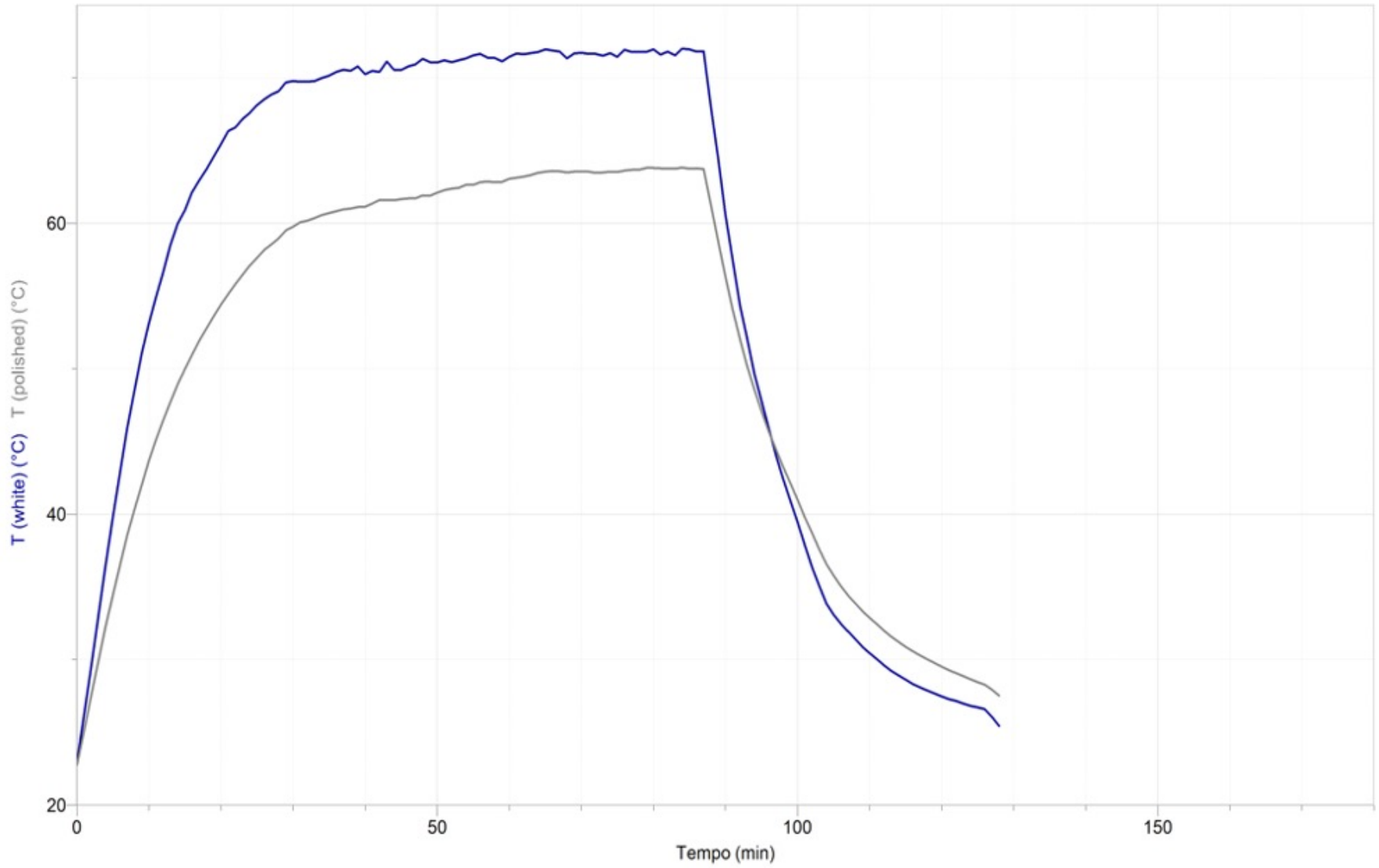
Eco Bulb



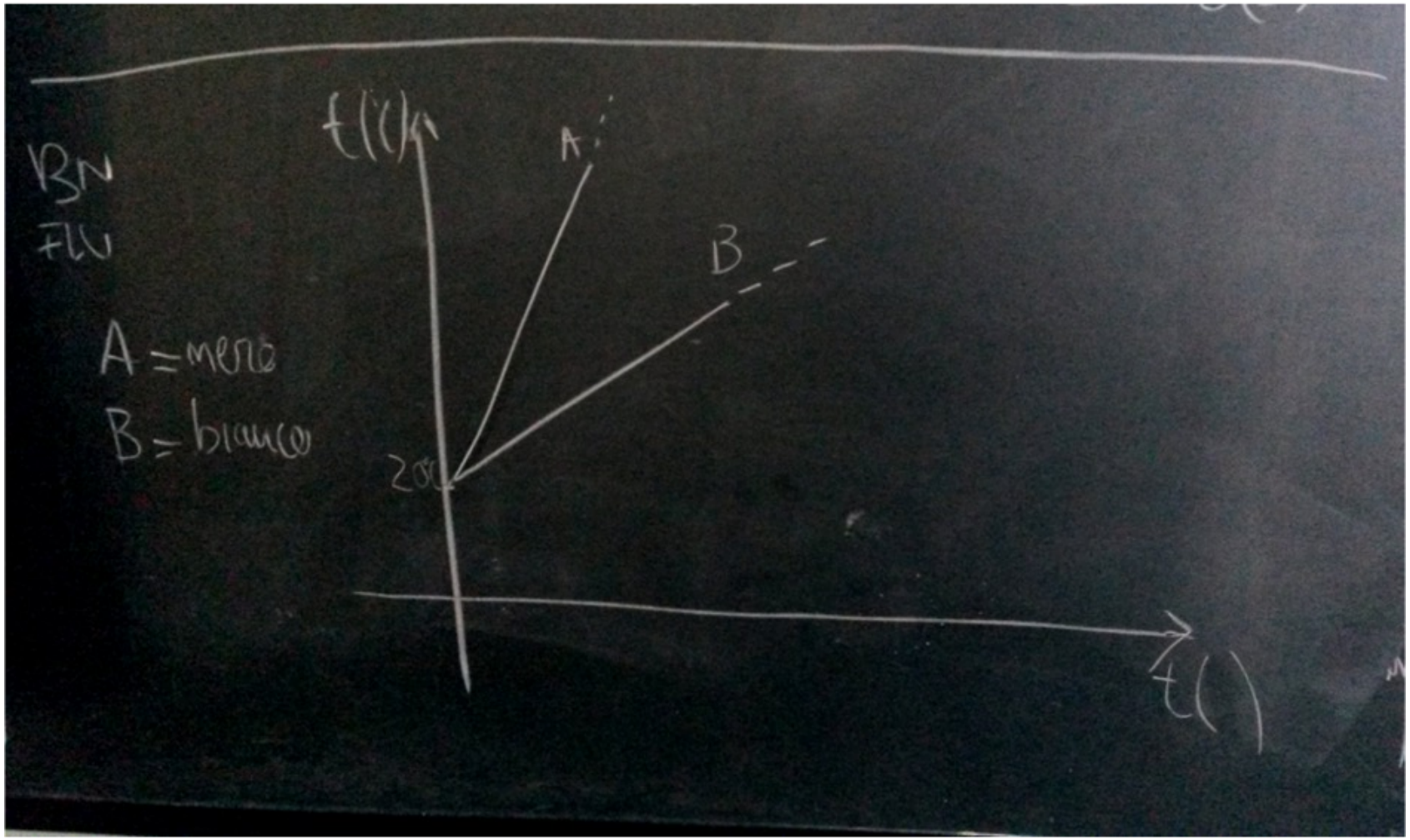
Halogen bulb



IR bulb

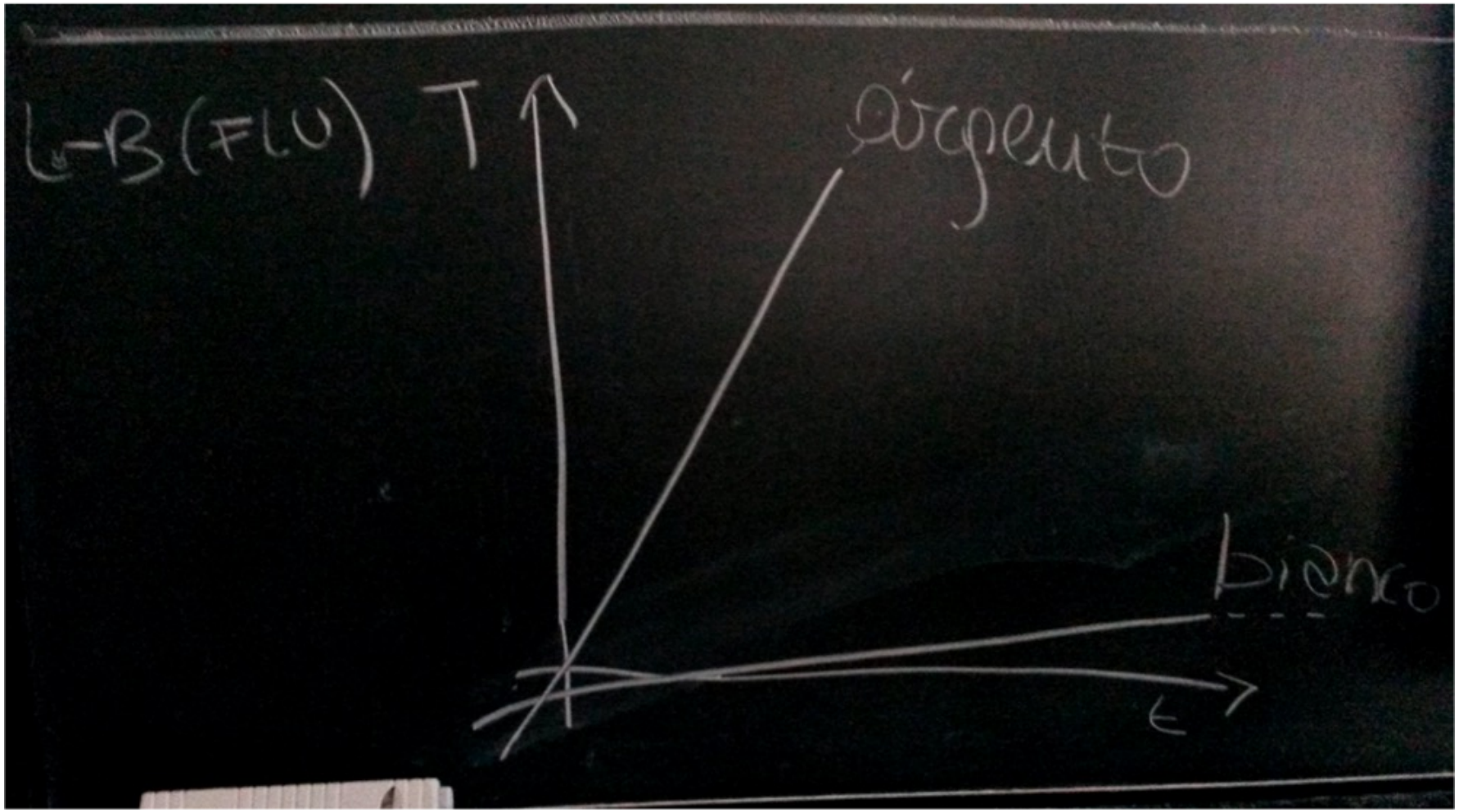


Examples of students' predictions



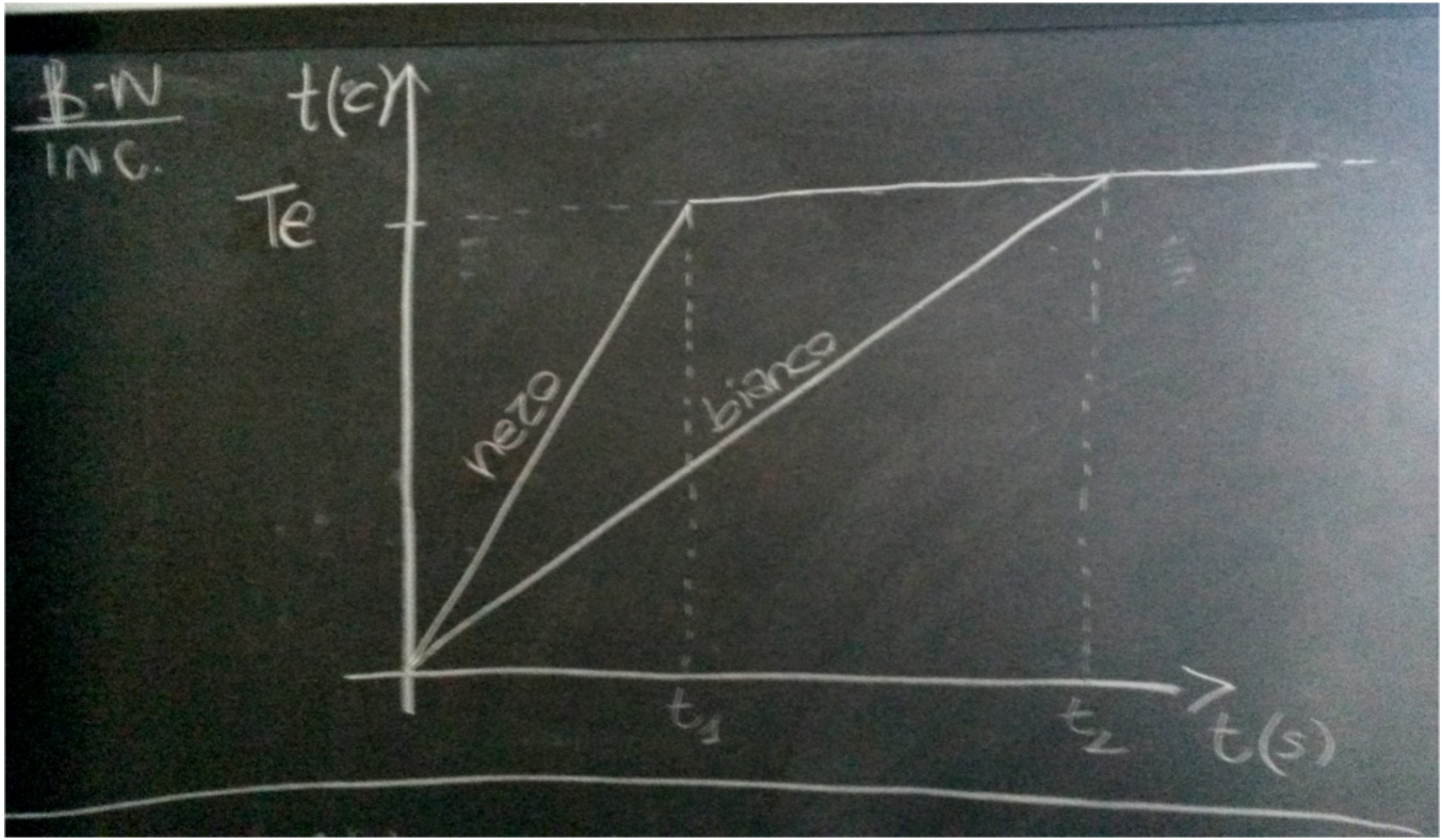
Bulb: FLUORESCENCE

Cylinders: WHITE & BLACK



Bulb: FLUORESCENCE
Cylinders: WHITE & GLOSSY

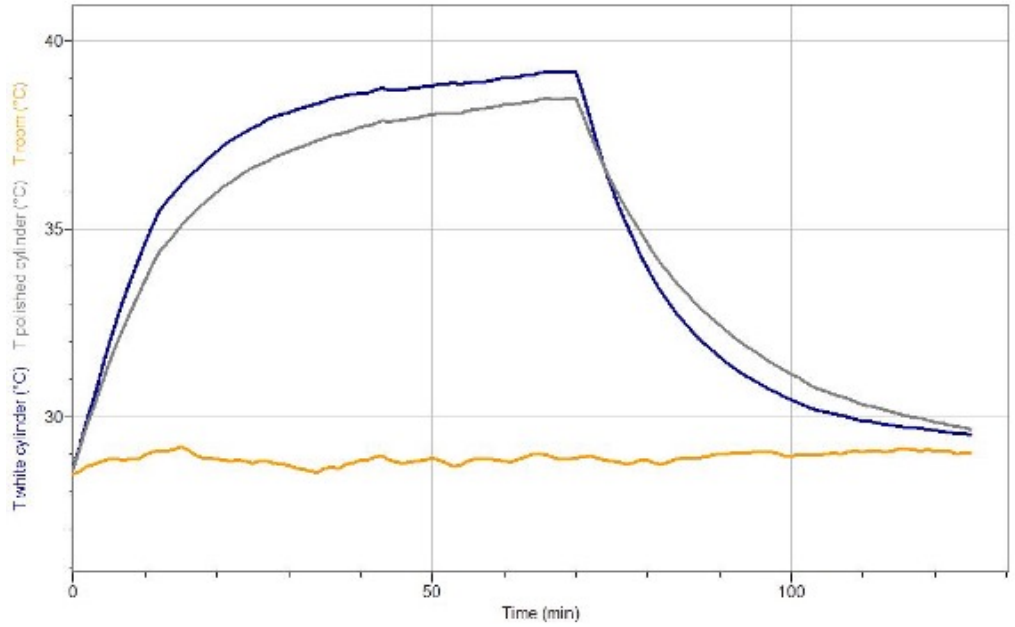
Bulb: INCANDESCENCE
Cylinders: WHITE & GLOSSY



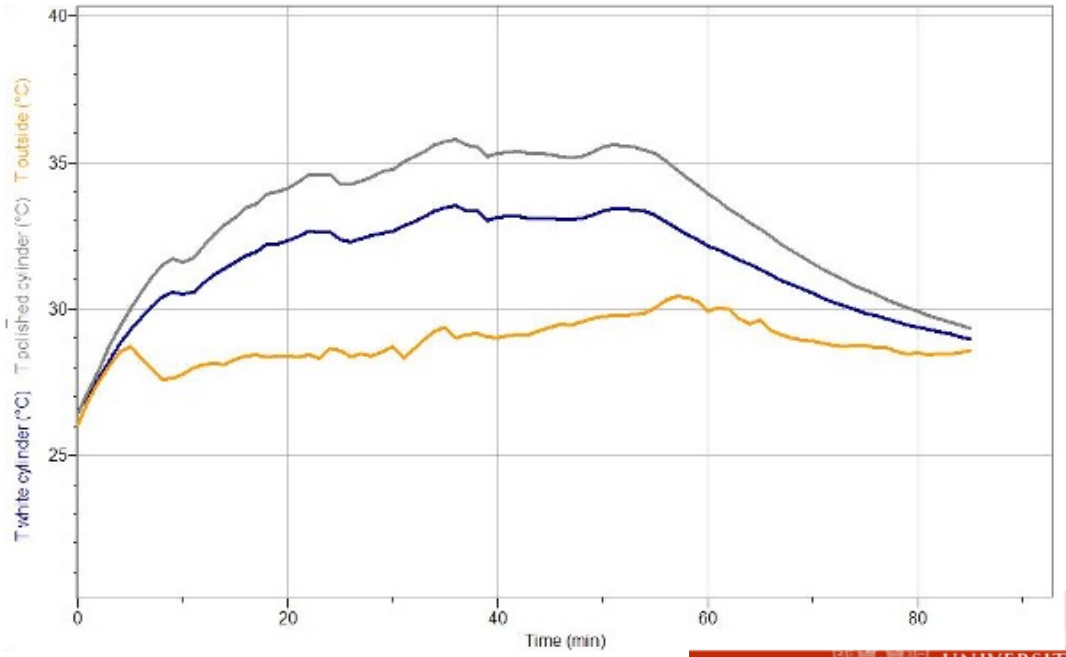
Bulb: INCANDESCENCE

Cylinders: WHITE & BLACK

... a 'strange' result



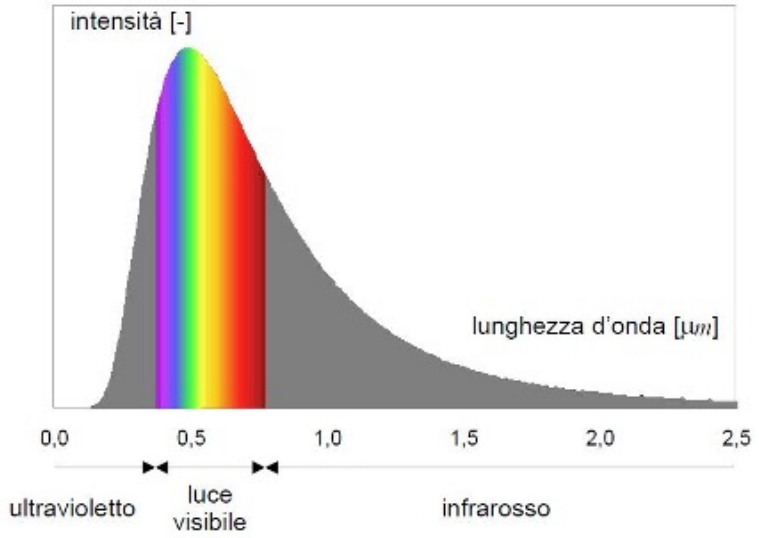
Graph of white and polished cylinders exposed to incandescent lamp light.



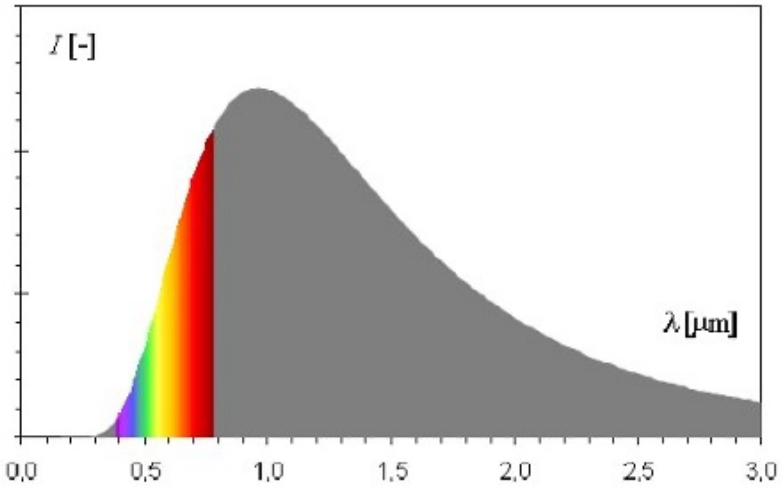
Graph of white and shiny cylinders exposed to sunlight

Light spectrum

Solar spectrum

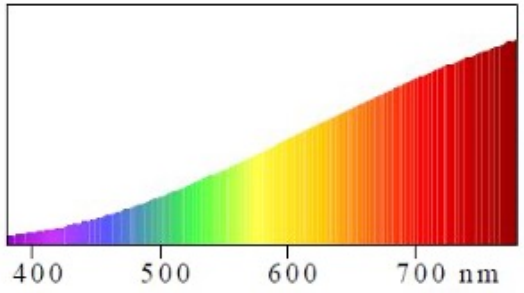


Incandescent lamp spectrum

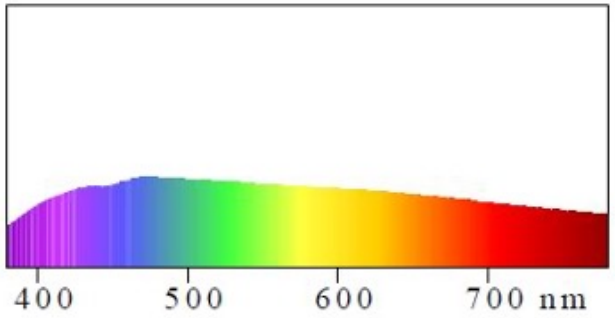


Working hypothesis

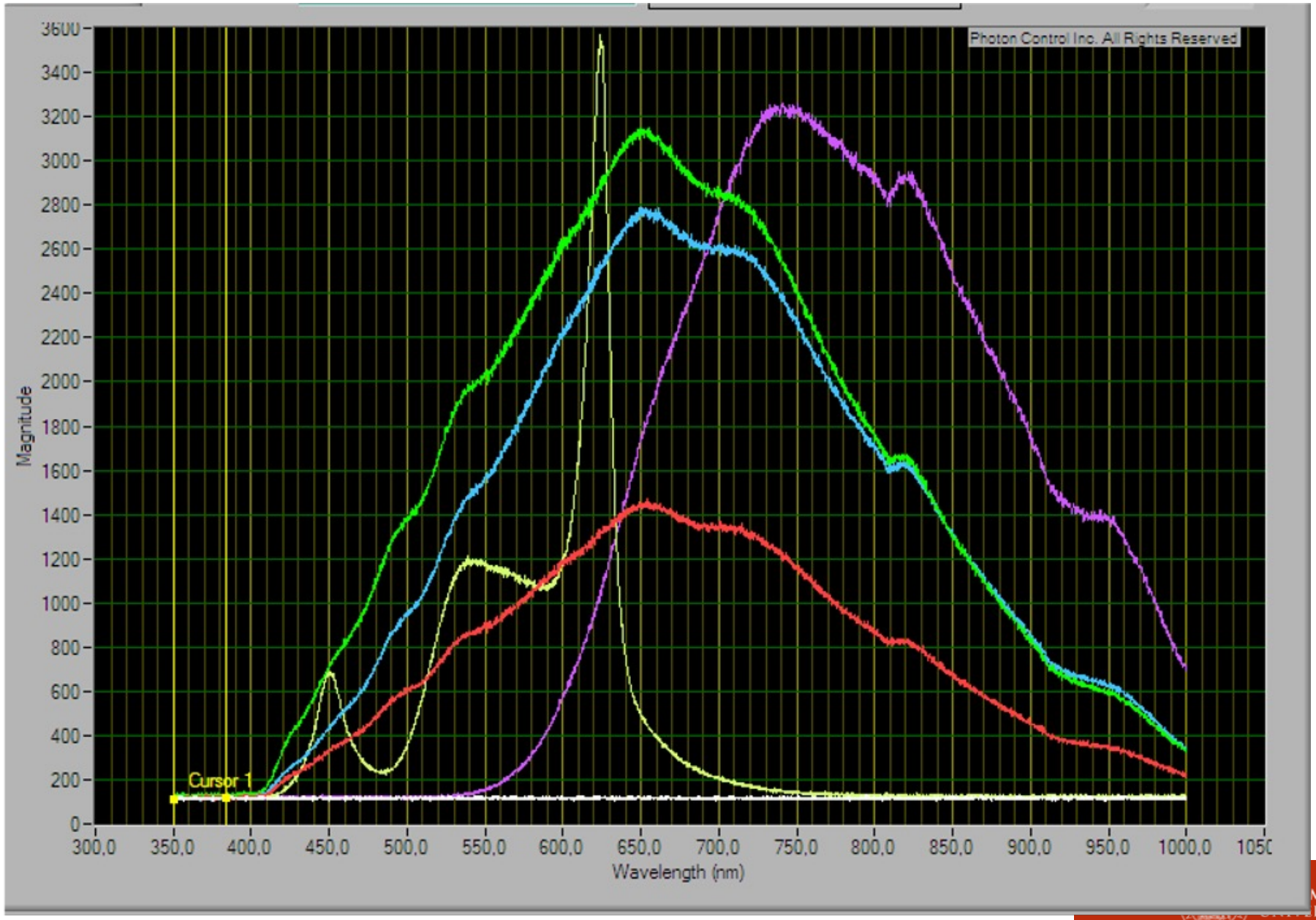
. . . we try to expose to the IR



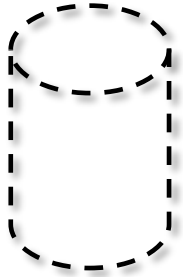
. . . we try to shield the IR



Bulb spectrum



Plexiglass cylinder ... 'transparent'?



We add a new plexiglass cylinder to our experiment.

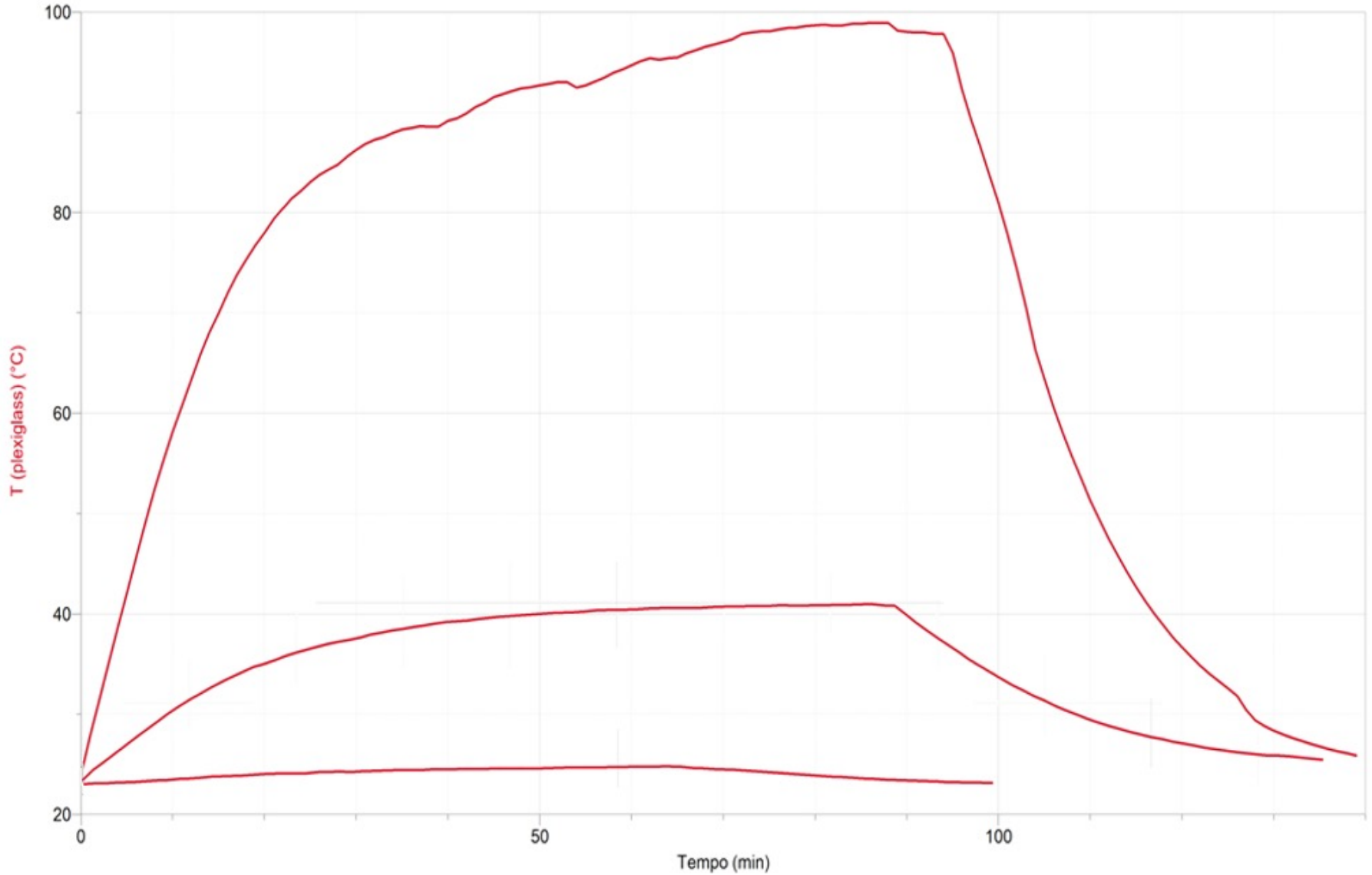
(Plexiglass cylinder has the same heat capacity as aluminium cylinders)

What do we expect to happen?

How will the plexiglass cylinder react to the three different radiations?

...

What does transparent mean?



The property of ***transparency*** is therefore not an 'absolute' property

...

For example, the plexiglass cylinder is 'black' in infrared,
while being 'transparent' to the visible

Optical behaviour depends on the spectral region being considered

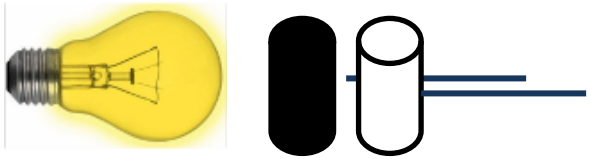
It can also be said that:

Heat *'passes through' only if it heats the material through which it passes,*

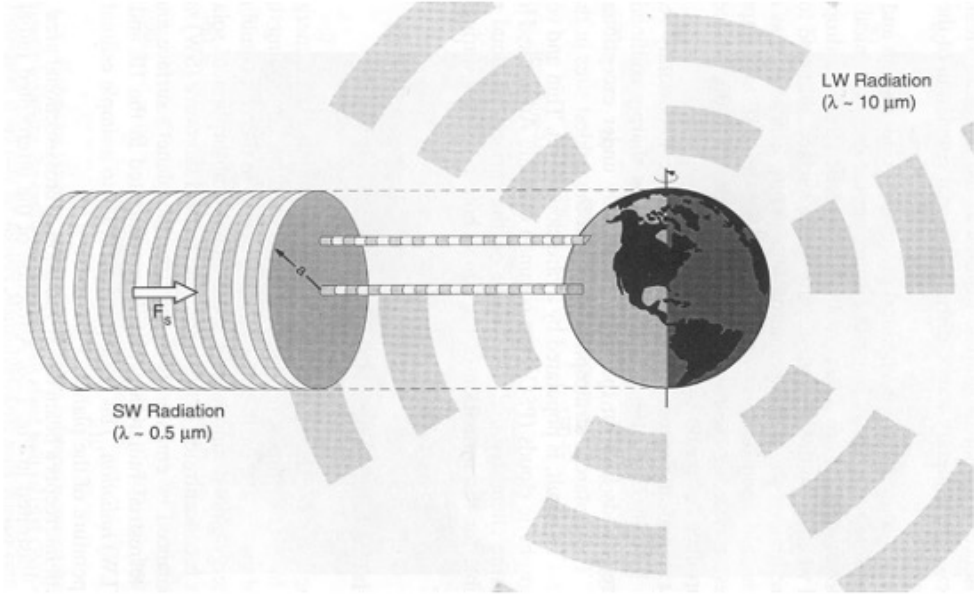
radiation *'passes' only if it does not heat.*

From EXPERIMENTS to MODEL

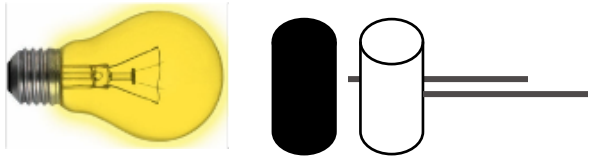
From the cylinders ...



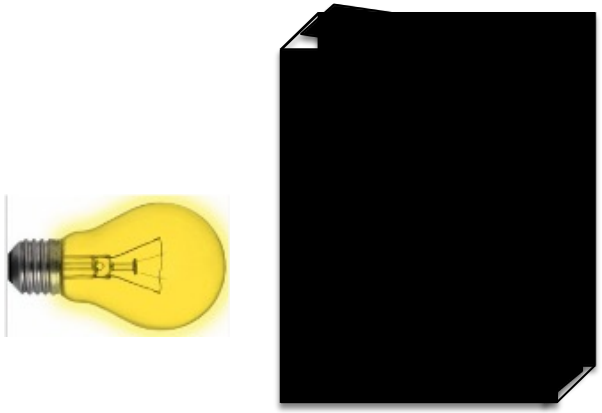
... to the planetary model



NEXT STEP ...



Interaction
RADIATION-MATTER



GREENHOUSE EFFECT
'energy balance'

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