Wednesday 8th March - Tools for Materials Science - Challenge n°8 - 40'

USE OF IR THERMOMETER AND THERMAL CAMERA

IR (Infra-Red) thermometers and thermal cameras make contactless measurements of the temperature of objects. This means that they are not based on thermal equilibrium between tool and object as classical thermometers. Actually they measure the emissivity of the surface and from this they deduce the temperature. Therefore to use these tools correctly it's extremely important to understand how the emissivity of an object may change based on a few parameters such as: colour, material, texture, viewing angle, radiation wavelength. ***Let's make some tests!***

1. On the desk you have a **Leslie cube**. This is a cube whose sides have different colour, texture and material.
   Fill the cube with hot water and put the rubber stopper with the thermometer inserted: you will be able to monitor the internal temperature of the water which after a few minutes - once thermal equilibrium has been reached – will actually be the temperature of the whole system (cube + water).
   - All the side faces should be at the same temperature: check with the thermocouple.
   - Take the IR gun and point it at each side (keep it perpendicular to the cube surface).
   - fill in **Table 1** with your readings.
   - Take a **picture** of the cube with the thermal camera. What do you notice?

Q1. What can you say about the change of temperature readings due to colour and texture? Answer basing on data and picture collected above.

2. **Viewing angle – 2A –** On the desk you also have a paper goniometer. Position the ***black opaque side*** of the cube in the middle, so that 0°C coincide with the perpendicular to this side. Then move the IR gun step by step and take readings at different angles from 0° to 90°. [*At least 5 different angles, starting from 0°;. the last reading will be with the IR gun almost parallel to the cube surface*]. Fill in **Table 2A**.

3. **Viewing angle – 2B –** Repeat previous point A now shooting photos with the thermal camera pointing at the cube at different viewing angle. BUT before taking measurements:
   a. **"lock" the temperature scale** on the right of the screen [*just touch the temperature either the upper or the lower one: they will turn gray and a closed lock will appear. This will prevent the camera from recalibrating each time and it will be possible to compare temperatures in the different measurements*.]
   b. Choose the **right value for the emissivity** parameter [*Reflective (smooth) surfaces, opaque ones: choose "opaque". To do this touch the screen and chose the "wheel" → "other parameters"…*]

   Fill in **Table 2B**.

4. **Viewing angle – 3A – 3B –** Repeat point 2A and 2B below now with the ***shiny metal side***. Use both IR gun and thermal camera but remember to change the emissivity parameter (choose reflective) and be aware of reflections (perpendicular may not be the best option for shooting!). Fill in **Table 3A & 3B.**

Q2. Theoretically the intensity of the radiation emitted by a black body is the same in every direction. Is it the same with real objects? Is there a specific angle beyond which readings are no more reliable? Answer basing on the data collected below.

☞ **OUTPUT WANTED: ->Answer to questions Q1, Q2 + picture(1) with thermal camera + Tables**
PLEASE NOTE: Leave all pictures made by the thermal camera in the camera memory !

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Answer sheet

GROUP N°___________

Ch.8 --- USE OF IR THERMOMETER AND THERMAL CAMERA

Table 1	Colour and texture of the faces			
TEMPERATURE (°C) measured by:	1: Shiny metal -> smooth	2: White opaque -> rough	3: Black lucid -> smooth	4:Black opaque -> rough
IR thermometer				
thermocouple				

Q1.

Table 2A	***Black opaque side***		
Angle (°)	**T_{IR}** (°C) temperature: -> whit ***IR Gun***	**T** (°C) "real" temperature: -> whit ***Thermocouple***	**Error %** = = **100 x (T-T_{IR})/T**
			%
			%
			%
			%
			%

Table 2B	***Black opaque side***		
Angle (°)	**T_{IR}** (°C) temperature: -> whit ***Thermal Camera***	**T** (°C) "real" temperature: -> whit ***Thermocouple***	**Error %** = = **100 x (T-T_{IR})/T**
			%
			%
			%
			%
			%

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Answer sheet

GROUP N°___________

Ch.8 --- USE OF IR THERMOMETER AND THERMAL CAMERA

Table 3A	*Shiny Metal Side*		
Angle (°)	T_{IR} (°C) temperature: -> whit ***IR Gun***	**T** (°C) "real" temperature: -> whit ***Thermocouple***	**Error %** = = **100 x (T-T_{IR})/T**
			%
			%
			%
			%
			%

Table 3B	*Shiny Metal Side*		
Angle (°)	T_{IR} (°C) temperature: -> whit ***Thermal Camera***	**T** (°C) "real" temperature: -> whit ***Thermocouple***	**Error %** = = **100 x (T-T_{IR})/T**
			%
			%
			%
			%
			%

Q6.

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Teacher's notes

Technical notes:

- *If you have more time at your disposal you can introduce the experiment (data collection) with some more qualitative activity such as the following one:*
  5. On the desk you have a soft drink can. Put it into boiling water and take it out after some minutes so it reaches a uniform high temperature. Use tongs. Now with the IR thermometer gun measure the temperature in different spots of the can: different colour, different position (bottom, top, side surface)
     Q1. What do you notice? Is colour important? And shape?
     Q2. If you test the can with a surface temperature probe (multimeter thermocouple) are the readings the same as with the IR gun?

- *If you have more time at your disposal you can conclude the experiment with the following more qualitative activity:*
  6. **Transmission –**with the thermal camera test different materials for IR transmission.
     Q1. Is it the same with Visible Light? Is glass a clear (=transmitting) material for IR? And what about a black litter plastic bag? Investigate and test different samples!

Organizational notes:

- Each student will keep a copy of the students' sheet but the group will collectively fill in the answer sheet and give it over to the teacher in charge at the end of the lab.

Correction grid

Question or Request	Note	Max. score
Table 1	2 points if table filled (data collected)	3
Q1	Evaluate if answer are well motivated: 3 points if answer well based on the data collected	4
Table 2A/B 3A/B	• 1,5 points for each table filled (data collected; calculation done); • 1 more point for each table if there are NOT evident mistakes (i.e. unit e/o calculation wrong)	2,5*4 = 10
Q2	Evaluate if answer are well motivated: 3 points if answer well based on the data collected	3

* **Pictures**: are the pictures meaningful? [*To evaluate the "meaningful" see also the "Picture Description" on the Answer Sheet*] Are they focusing on significant details or clearly showing the apparatus structure or the investigation results? Are they aesthetically beautiful?

Key to Answer

Q1. Rough surfaces have a higher emissivity than smooth ones, this is due to the enhanced effect due to multiple reflections. Dark colours have a higher emissivity. Metals may appear to be at a lower temperature because of their high reflectance.

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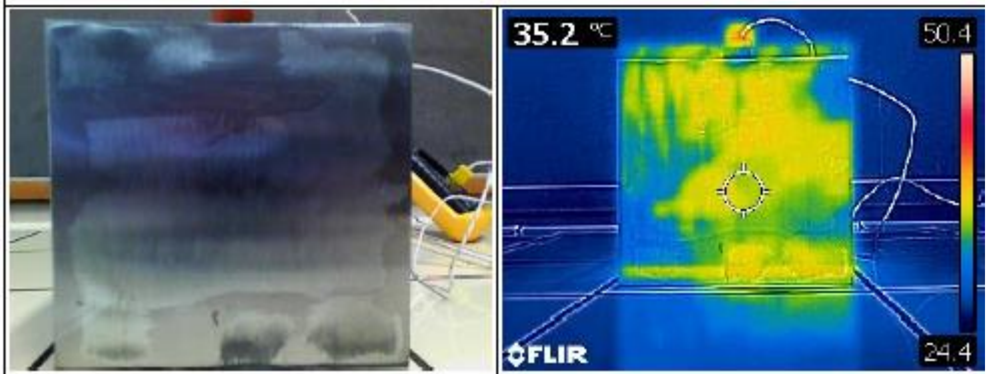
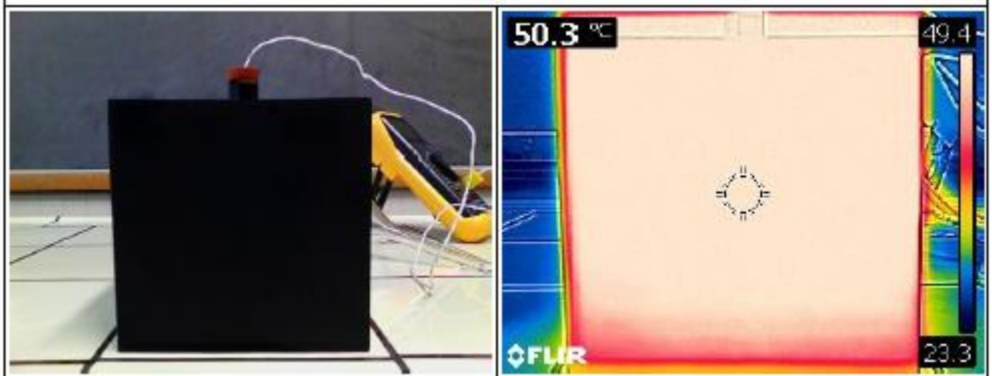
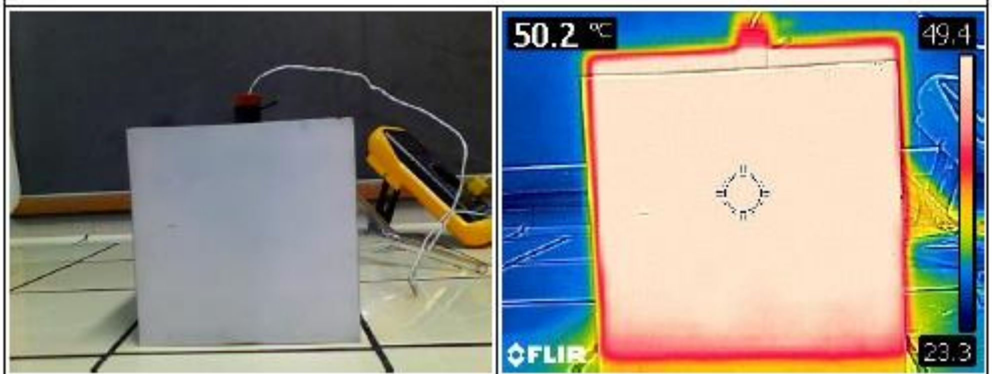
1 = GRIGIO METALLIZZATO (LISCIO)



2 = NERO OPACO (RUVIDO)



4 = BIANCO OPACO (RUVIDO)



<u>Q2.</u> Angle is very important when you work with thermal cameras or IR thermometers, and this is even more true with metal surfaces. Till 40° 45°, readings are almost stable while beyond that angle there's a great difference between metals (T increases and finally drops at angles quite near 90°)and non metals (drops immediately).

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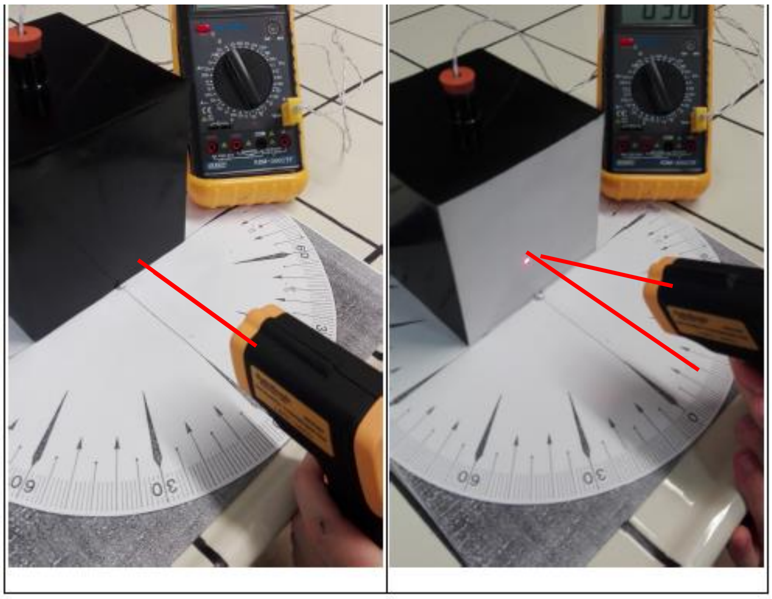

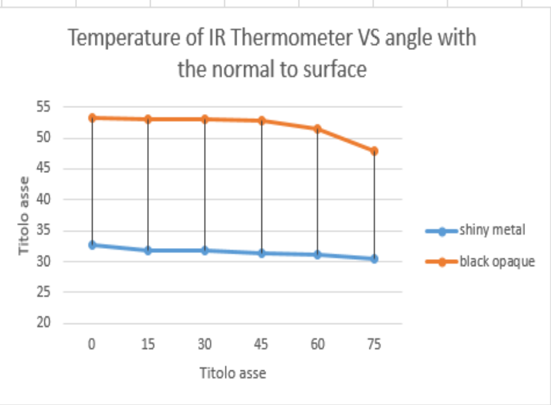

Theoretical Introduction

A) <u>Emissivity of an object</u>

We speak of thermal *radiation* because each object at a temperature above 0K emits electromagnetic waves whose intensity and wavelength configuration strongly depend on the temperature of the object and its characteristics (colour, texture, etc).

Emissivity is the ratio between the actual emission of a specific surface and the emission of a black body at the same temperature. Such a ratio is always<1 (the black body is as ideal model) and in real life the emitted radiation is not isotropic nor is independent of the material

What's important for IR emission is not the bulk but rather the surface of the object with its characteristic smoothness, colour and kind of material .

Shiny mirror-like surfaces usually have a very low emissivity (typical of metal sheets) while rough ones as a rule have a very high emissivity. Sometimes surfacs may be structured with periodical grooves just to enhance their emissivity

B) **Transmittance** . Something which is clear in the VIS and transmits all the light may not do the same in IR. Water, glass, some types of plastic, are VIS clear and IR opaque. Vice versa black opaque objects blocking VIS may be completely clear to IR.Therefore when we shoot a glass pane with the thermal camera it may happen that the camera is recording only its surface temperature plus possible reflected IR in the surroundings , but may NOT be able to see any thermal source behind the pane This is something that should be very clear to everyone operating with a thermal camera..

You surely will have noticed that in IR photos everyone wearing glasses actually seems to be wearing sunglasses. This is caused by the opaqueness of glass which screens the IR emission from the eyes. Actually glasses have almost no contact with the face, so there's no way to heat up the lenses just by contact ,so they look very cold!

C) **Reflection-** Exactly like VIS, IR also can be reflected .The thermal camera records the reflected images and this may bring to possible mistakes in pictures interpretation and correct temperature reading. Take an IR snapshot of yourself in front of a mirror: do you think the colour you see represents the real temperature of the mirror?

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Almost all metals have a high reflectance in the IR even when they are not shiny/good VIS reflectors.This is for instance the case of rough metal surfaces.

When we talk of reflection we have also to take into account the diffused reflection which happens when the wavelength of the incident radiation is of the same order of the roughness and spikes in the texture of the not so shiny surfaces

MoM Resources

- FCh2_TEACH_EN_Cool roofs
- Leslie_Cube_stud_research_IT.pdf
- Cool rooves_stud_research_IT.pdf
- FCh1TEACH_EN_window film for solar control
- Ch8_TEACH_EN_ IR_selffolding_materials_

References

- Vollmer, M.; Möllmann, K.-P. *Infrared Thermal Imaging: Fundamentals, Research and Applications*, 1st ed.; Wiley-VCH: Berlin, 2010
- Charles Xie *Visualizing chemistry with Infrared Imaging* Free Download at https://energy.concord.org/~xie/proposals/ir_narrative_final.pdf
- Charles Xie and Edmund Hazzard, *Infrared Imaging for inquiry based learning* Free Download at http://energy.concord.org/publication/ir_tpt.pdf

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