Designing a Low Energy House

Activity 4_1: Light heats up objects. Why and how?

General problem:
Building a low energy house needs a very accurate planning Step in which all possible heat dispersion phenomena must be carefully investigated in order to realize appropriate devices to save the thermal energy produced both by traditional heating systems and/or from direct exposure to the Sun. The design of a thermodynamically efficient house needs knowledge and competences in several topics. In particular, it is important to know the characteristics of the building materials for what concerns the storage of thermal energy and even more important the understanding of all those factors which contribute to the collection of thermal energy available from the surrounding environment.
Introductive questions:
1) Describe some cases of heating produced by a light source: ____________________ ____________________ ____________________ ____________________ 2) How is it possible to measure the effects produced by the light incident on an object surface? ____________________ ____________________ ____________________ 3) Can the same light source, placed at the same distance from two different objects, produce heating up to different temperatures? YES, because:____________________ ____________________ ____________________ NO, because:____________________ ____________________

4) Think about an experiment you could realize in your classroom in order to give an experimental answer to the previous question:

Sketch your experimental setup of measurement in the following:

Target of your experiment:

Construction of an home-made radiometer

Material needed for each group:

- 2 aluminium cans;
- 3 surface temperature sensors, with PC interface;
- White and black paint;
- Scissor, scotch tape and ruler.

Procedure:

Use the scissor to cut an aluminium can and make three rectangular plates having the same dimensions (7 cm) x (4 cm), measured by the ruler. Paint of black one of the plates and white another one and leave unpainted the third. As soon as the paint dries, scotch the tip of the surface temperature sensor to the back of each plate and fix them on a polystyrene support suitably shaped (see figure). Connect the temperature sensor to the PC through the laboratory interface and you will be ready to start your measurements of light radiation.

A 400 W halogen lamp, as that one shown in figure, can be used as light source to be placed at a certain distance from the plate of the home-made radiometer.

2) Design your experiment to measure the effects of light radiation; describe briefly which experiment you intend to perform using an home-made radiometer:

Sketch your experimental setup of measurement in the following:

Target of your experiment:

Experiment:

Required: home-made radiometer, halogen lamp, ruler, chronometer.

Procedure: Place the unpainted radiometer at an horizontal distance of 30 cm from the halogen lamp switched off, with the surface of the plate placed vertically and centred in front of the lamp. Start the measurement of the surface temperature of the radiometer plate and wait 10 seconds before switching on the lamp for further 30 seconds, illuminating the radiometer. Then switch off the lamp and remove it from the view of the radiometer. Continue the measurement until the temperature of the radiometer does not reach again the initial temperature.

Question n. 1: Why the radiometer increases its surface temperature?

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Question n. 2: Which transport mechanisms of light energy do you think could be responsible of the rise in temperature observed during this experiment?

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Question n. 3: Which is, in your opinion, the most relevant transport mechanism of light energy during this experiment?

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Question n. 4: How is it possible to distinguish between the several transport mechanism of light energy during this experiment?

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Discuss the results of your experiment with the other members of your working group. After that, share your conclusions with the other students in the classroom and with your teacher, trying to find the physical quantities which are more relevant to the description and to the interpretation of the observed phenomena. Report, in the following, the final conclusions coming from the discussion within the extended group of students.

Generalize the results:

Activity 4_2: Not only visible light heats up the objects!

Problem question:

Could the heating of a house be produced by external sources of energy different from the visible light?

Questions:

1) Describe some cases of heating produced by sources of energy different from the visible light:

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2) Design your experiment to measure the effects of thermal radiation produced by a not-visible light source; describe briefly which experiment you could perform by using the home-made radiometer previously described:

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Sketch your experimental setup of measurement in the following:

Suggested experiment:

Required:

Home-made radiometer, halogen lamp, ruler, chronometer, filter for visible light. In the absence of the filter, it is possible to realize an home-made filter for visible light by assembling sun-exposed and developed color photographic film or the opaque magnetic support inside a floppy disk.

Procedure:

Step 1: Place the radiometer at an horizontal distance of 30 cm from the halogen lamp switched off, with the surface of the plate placed vertically and centred in front of the lamp. Start the measurement of the surface temperature of the radiometer plate and wait 10 seconds before switching on the lamp for further 30 seconds, illuminating the radiometer. Then switch off the lamp and remove it from the view of the radiometer. Continue the measurement until the temperature of the radiometer does not reach again the initial temperature.

Step 2: Repeat the experiment exactly as described in step 1, but this time by filtering completely the visible light coming from the halogen lamp.

Step 3: Compare the results with those obtained in the presence of visible light.

Question n. 1: Why the surface temperature of the radiometer increases even in the absence of visible light?

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Question n. 2: Try to put your hand in front of the lamp with visible light filtered. What do you feel when the lamp is switched on and then back switched off?

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Question n. 3: In the absence of visible light, who transmits the energy that causes the rise of surface temperature of the radiometer?

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Activity 4_3: Who suffers more from the effects of thermal radiation?

Problem question:

Which characteristics should a material have in order to absorb more thermal radiation?

Experiment:

Required:

Home-made radiometers (black painted, white painted and an unpainted one), halogen lamp, ruler, chronometer, filter for visible light.

Procedure:

Step 1: Place the three radiometers at the same horizontal distance (30 cm) from the halogen lamp switched off, with the surface of the plates placed vertically and centred in front of the lamp. Start the measurement of the surface temperature of the radiometer plate and wait 10 seconds before switching on the lamp for further 30 seconds, illuminating the radiometer. Then switch off the lamp and remove it from the view of the radiometer. Continue the measurement until the temperatures of the radiometers do not reach again the initial temperatures.

Step 2: Compare the results obtained by using different radiometers.

Questions:

Question n. 1: Why the surface temperature of the black-painted radiometer increases more than the white-painted one?

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Question n. 2: Why the surface temperature of the white-painted radiometer increases less than the unpainted one?

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Step 3: Repeat the experiment as described in step 1, but this time by filtering completely the visible light coming from the halogen lamp.

Question n. 3: In the absence of visible radiation, which of the three radiometers reaches the highest temperature? Motivate your answer.

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Suggestion for an in depth experiment:

1) Execute the same experiment as described in part (I), using this time two home-made radiometers with the plates made of the same material (aluminium), having the same surface area exposed to visible radiation but different thickness.

Question: Which of the two radiometers, exposed to visible light for the same amount of time, reaches the highest temperature? Why?

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2) Execute the same experiment as described in part (I), using this time two home-made radiometers with the plates having the same surface area exposed to visible radiation and same thickness but made of two different materials.

Question: Which of the two radiometers, exposed to visible light for the same amount of time, reaches the highest temperature? Why?

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List the characteristics that your home-made radiometer should have in order to be the most efficient detector of thermal radiation:

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Activity 4_4: Do we measure invisible radiation?

Problem question:

We have measured the effects of the transfer of thermal energy by the radiation coming from a lamp switched on. What happens in the presence of hot objects?

Experiment:

Required:

Home-made radiometer, 50 cl plastic bottle, ruler.

Procedure:

Step 1: Start the measurement of the surface temperature of the radiometer plate and wait 10 seconds before placing the plastic bottle filled with hot water at an horizontal distance of 20 cm from the radiometer plate, vertically and centred with respect to the bottle (see figure).

Step 2: After 500 seconds from the beginning of the experiment, turn the radiometer up to 90 degrees with its plate facing upward (see figure) and continue to measure the surface temperature of the radiometer for further 500 seconds.

Step 3: After 1000 seconds from the beginning of the experiment, remove the bottle from the radiometer view and continue the measurement of the surface temperature of the radiometer for further 500 seconds.

Compare the temperature variation measured during the step 1 with those observed in step 2 and 3; discuss what observed during the whole experiment with the other members of the working group.

Report your comments in the following:

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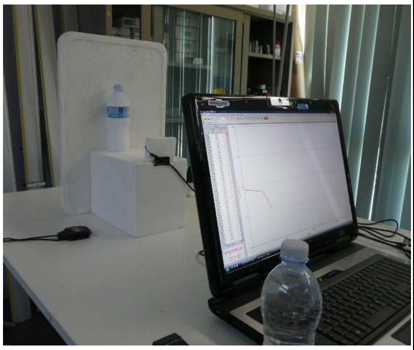
Problem: We have experienced the transfer of thermal energy by the radiation coming from hot objects. What happens in the presence of cold objects?

Suggestion for an experiment of deepening:

Required:

Home-made radiometer, 2 plastic bottles (50 cl), ruler.

Procedure:



Step 1: Measure the ambient temperature for 200 seconds without placing any object in front of the radiometer. After this time interval, place a plastic bottle filled with iced water at an horizontal distance of 20 cm from the radiometer (see figure). In this configuration, continue to measure the radiometer temperature for further 500 seconds.

Step 2: After 700 seconds from the beginning of the experiment, remove the bottle from the radiometer view and continue the measurement of the surface temperature of the radiometer for further 500 seconds.

Step 3: By continuing the measurement, place a plastic bottle filled with hot water at an horizontal distance of 20 cm from the radiometer and continue the measurement of the surface temperature of the radiometer.

Step 4: After further 300 seconds, turn the radiometer up to 90 degrees with its plate facing upward and continue the measurement of the temperature for the last 200 seconds.

Compare the temperature variation measured during step 1 up to step 4 and discuss what observed during the whole experiment with the other members of the working group.

Report your comments in the following:

Activity 4_5: Can we see the Infrared radiation?

Problem question:

All objects with a temperature above the absolute zero emit thermal radiation. But, what is thermal radiation? Thermal radiation is the light which is emitted by an object because of the thermal motion of its atoms and it depends on the object temperature. An object at a very high temperature (above 600° C) emits visible thermal radiation. At lower temperatures, an object do not emit visible light but it radiates an invisible light called Infrared radiation. We cannot see Infrared radiation by our naked eyes, but some special electronic devices can. What instruments can we use to see Infrared radiation? Why could be so important to see Infrared radiation?

Experiment:

Required: Computer with webcam, a television with its IR remote control.

Procedure:

Step 1: Start the experiment by observing the front of a IR remote control. You can see a very little lamp (led) which must be pointed towards the television in order to select your favourite channel. When you press the button of the remote control an infrared signal is transmitted from the led to the television.

Question 1: By looking at the remote led, can you see any light when pressing the button?

Question 2: Can the infrared signal of the remote control cross the glass of a window? Try with different materials (transparent plastic bottle, black plastic bag, etc.)

Step 2: Point the remote control in front of the webcam and press a button.

Question: Can your webcam see any light by looking at the remote led?

Step 3: Switch off all the visible light sources (total darkness) and point the remote control in front of your eyes.

Question: Can you see any light?

Step 4: With all the visible light sources still switched off (total darkness), point the remote control towards a book placed on the table.

Question: Can you see the book by using your webcam?

Discuss what observed during the whole experiment together with the other members of the working group and report your comments in the following:

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Problem: We have experienced the source of invisible infrared light from a remote control. But any object with a temperature above the absolute zero emits infrared radiation. Can we use some special instruments to see infrared radiation coming from warm objects? What kind of applications could we think about the detection of infrared radiation?

See the slide-show movie at: www.uop-perg.unipa.it/establish/videoIR1_eng2.wmv

Discuss what observed during the slide-show together with the other members of your working group.

Report your comments in the following:

A deepening question: Why the webcam cannot see the infrared radiation coming from warm objects? Investigate the physics of near and far infrared.

FINAL DISCUSSION AND CONCLUSION

Let's go back to the initial problem: A low energy house

For any of the developed activities, summarize what did you learn at the end of each one and the path you have followed to draw your conclusions:

In light of what experienced, which expedients could you suggest to the designer of a low energy house in order to project a house that is efficient from the energy saving point of view: