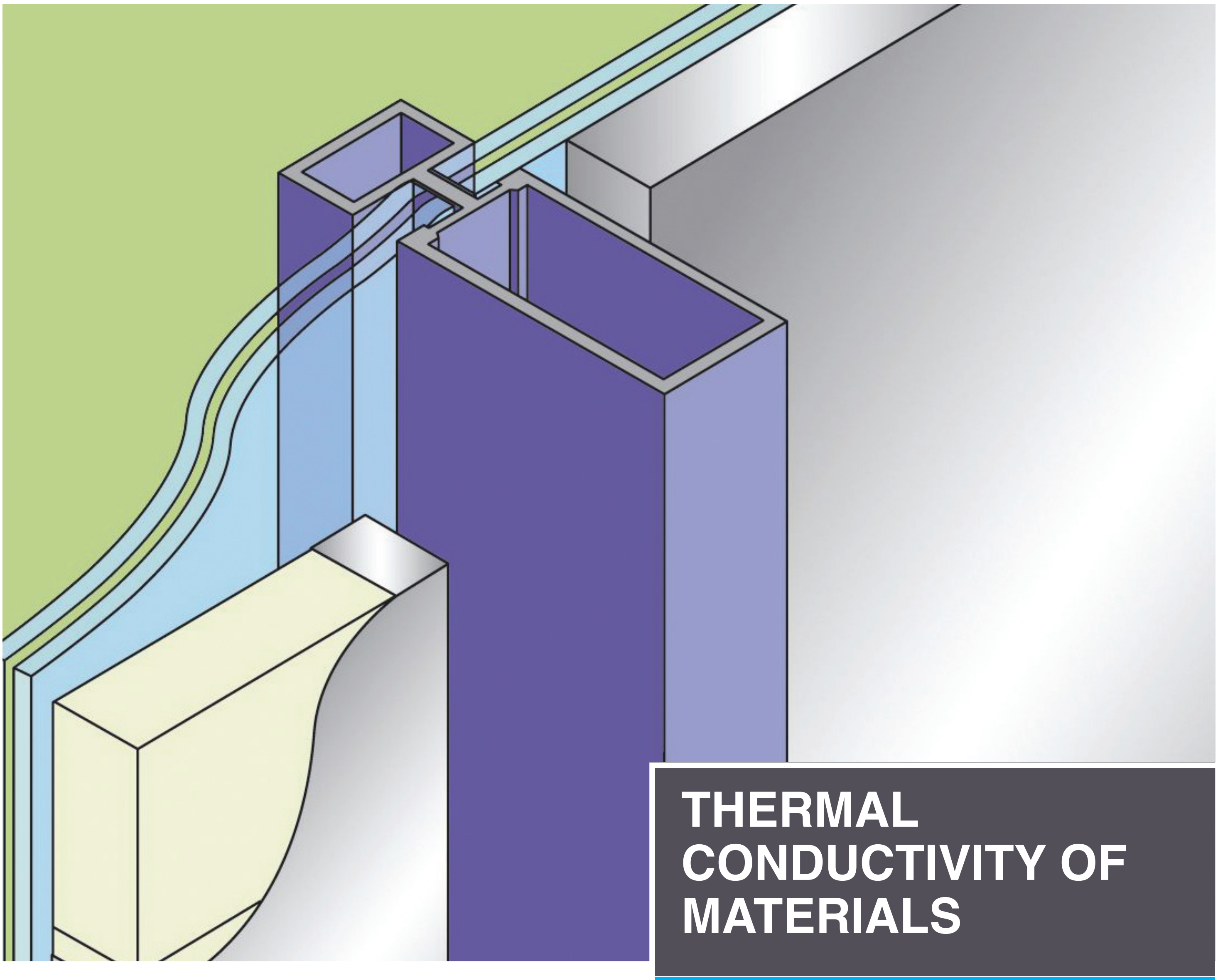

THERMAL CONDUCTIVITY OF MATERIALS

TEACHING AND LEARNING ACTIVITIES

ADAPTED VERSION

MATERIALS SCIENCE PROJECT

UNIVERSITY-SCHOOL PARTNERSHIPS FOR THE DESIGN AND IMPLEMENTATION OF RESEARCH-BASED ICT-ENHANCED MODULES ON MATERIAL PROPERTIES

SPECIFIC SUPPORT ACTIONS

FP6: SCIENCE AND SOCIETY: SCIENCE AND EDUCATION

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THERMAL CONDUCTIVITY OF MATERIALS

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CONTENTS

UNIT 1: THERMAL CONDUCTION IN EVERYDAY LIFE

In everyday life there are many situations where it is important to account for heat losses, rise or fall of the temperature, time needed to have the temperature rise or fall

1.1 HOUSE INSULATION

In this part we shall focus on house insulation problems.

1.1.1. ACTIVITY: Heat losses

You are at home in Naples and you would like to have an inner temperature of about 20° C, but this is not always possible.

Why?

Identify the house's parts in which there could be heat losses from the inside to the outside

FIGURE W1

1.1.2. ACTIVITY: Materials for house insulation

Which materials would you use for the walls? For the windows? For the doors?

Explain

Observe the snow on the rooftops of the two houses (circled in red). According to your opinion, which rooftop has a better thermal insulation?

Explain

FIGURE W2

1.2 CUPS FILLED WITH LIQUID (PLASTIC & GLASS)

Here you will consider first a situation that may occur to you at the school buffet and then you will perform an experiment where

a) you will study the thermal interaction between 2 equal quantities of water, having the same temperature, during their cooling down in cups made of different materials,
b) you will investigate in which cup the temperature drop is greater.

1.2.1. PREDICTION: "A day at school"

In a cold winter day, you went with your friends to the school buffet and ordered hot chocolates to drink. The drinks had the same temperature and were served in different cups.

Which cup of hot chocolate would you choose, in order to be able to hold it without getting burned?

Glass cup ☐ *Metal cup* ☐ *Plastic cup* ☐

Provide a brief explanation of your choice:

....

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....

After a while, in which cup would the chocolate cool down faster?

....

Give a brief explanation describing your point of view:

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1.2.2. EXPERIMENT: Measuring water temperature drop in different materials' cups

Your teacher pours 60 ml of hot water in each cup.

Prediction of initial temperature values
Which is the initial temperature of the water in each cup?

Water temperature in the plastic cup: ....

Water temperature in the glass cup: ....

Experiment to test prediction: Measuring temperature values

Put a thermometer in each cup and write down the temperature values:

Water temperature in the plastic cup: ……………………………

Water temperature in the glass cup: ……………………………

In each small glass basin there are 120 ml of water at room temperature.
You will now put each cup, together with its thermometer, in the respective basin, allowing these two quantities of water having different temperatures to interact.

Prediction of water temperature drop
In which cup do you think the water temperature will drop faster?
In the plastic cup: …………………………… In the glass cup: ………………………………

Experiment to test prediction: measure of water temperature drop in time
Preparation of the experimental setup

Make sure that the thermometers do not get in contact with the cups' inner walls. They should remain constantly within the mass of water.
Place the two cups in the respective glass basins, allowing the two quantities of water having different temperatures to interact.

Execution of the experiment
Start timing the experiment. Observe and record the change of temperature in each cup.

FILL IN THE FOLLOWING TABLE 1, RECORDING THE TEMPERATURE IN EACH CUP EVERY 0.5 MINUTES:

TIME	WATER TEMPERATURE IN GLASS CUP (°C)	WATER TEMPERATURE IN PLASTIC CUP (°C)
Initial		
0.5 min		
1 min		
1.5 min		
2 min		
2.5 min		
3 min		
3.5 min		
4 min		
4.5 min		
5 min		
5.5 min		
6 min		
6.5 min		
7 min		

TABLE 1

Initial and final temperature in each cup

- What is the initial temperature in each cup?

  glass cup: …… °C   plastic cup: …… °C

- What is the final temperature after 7 min in each cup?

  glass cup: …… °C   plastic cup: …… °C

Temperature differences in each cup

- What is the difference between the initial temperature and the temperature after 7 min in each cup?

  glass cup: …… °C   plastic cup: …… °C

- The water in the ………………… cup has cooled down faster than the water in the ……………… cup.

Comparison of your predictions to the results of the experiment
Compare the experimental results with your prediction

In case your prediction does not agree with the experimental results, how do you explain the differences you observed?

1.2.3. ACTIVITY: Classification of cups' materials

The water in the .... cup has reached after 7 min a lower temperature than the water in the

.... cup

We will say that the ………………. cup conduct heat faster than the ……………….. cup

Please make available the data of Table 1 to your teacher, who will proceed to compare them with the data from the other groups. After discussing with each other and with your teacher the data from all groups, write down which cup conducts heat better.

Which of the two cups conducts heat better?

1.2.4. ACTIVITY: "A day at school" revisited

Does your prediction on which cup containing hot chocolate will **cool down faster** agree with the experimental results? Why?

Does your prediction on which cup containing hot chocolate is better **to hold on** agree with the results of the experiment? Why?

1.3 CUPS FILLED WITH LIQUID (METAL & GLASS)

Here you will consider first a situation that may occur to you at the school buffet and then you will perform an experiment where

a) you will study the thermal interaction between 2 equal quantities of water, having the same temperature, during their cooling down in cups made of different materials,
b) you will investigate in which cup the temperature drop is greater.

1.3.1. PREDICTION: "A day at school"

In a cold winter day, you went with your friends to the school buffet and ordered hot chocolates to drink. The drinks had the same temperature and were served in different cups.

Which cup of hot chocolate would you choose, in order to be able to hold it without getting burned?

Glass cup ☐ *Metal cup* ☐ *Plastic cup* ☐

Provide a brief explanation of your choice:

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After a while, in which cup would the chocolate cool down faster?

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Experiment to test prediction: Measuring temperature values

Put a thermometer in each cup and write down the temperature values:

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In each small glass basin there are 120 ml of water at room temperature.
You will now put each cup, together with its thermometer, in the respective basin, allowing these two quantities of water having different temperatures to interact.

Prediction of water temperature drop
In which cup do you think the water temperature will drop faster?
In the metal cup: .... In the glass cup: ....

Experiment to test prediction: measure of water temperature drop in time
Preparation of the experimental setup

Make sure that the thermometers do not get in contact with the cups' inner walls. They should remain constantly within the mass of water.
Place the two cups in the respective glass basins, allowing the two quantities of water having different temperatures to interact.

Execution of the experiment
Start timing the experiment. Observe and record the change of temperature in each cup.

FILL IN THE FOLLOWING TABLE 1, RECORDING THE TEMPERATURE IN EACH CUP EVERY 0.5 MINUTES:

TIME	WATER TEMPERATURE IN METAL CUP (°C)	WATER TEMPERATURE IN GLASS CUP (°C)
Initial		
0.5 min		
1 min		
1.5 min		
2 min		
2.5 min		
3 min		
3.5 min		
4 min		
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6 min		
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Initial and final temperature in each cup

- What is the initial temperature in each cup?

  metal cup: …… °C glass cup: …… °C

- What is the final temperature after 7 min in each cup?

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Temperature differences in each cup

- What is the difference between the initial temperature and the temperature after 7 min in each cup?

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- The water in the ………………… cup has cooled down faster than the water in the …………….. cup.

Comparison of your predictions to the results of the experiment
Compare the experimental results with your prediction

In case your prediction does not agree with the experimental results, how do you explain the differences you observed?

1.3.3. ACTIVITY: Classification of cups' materials

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We will say that the ……………… cup conduct heat faster than the ……………….. cup

Please make available the data of Table 1 to your teacher, who will proceed to compare them with the data from the other groups. After discussing with each other and with your teacher the data from all groups, write down which cup conducts heat better.

Which of the two cups conducts heat better?

1.3.4. ACTIVITY: “A day at school” revisited

Does your prediction on which cup containing hot chocolate will **cool down faster** agree with the experimental results? Why?

Does your prediction on which cup containing hot chocolate is better **to hold on** agree with the results of the experiment? Why?

1.4 CUPS FILLED WITH LIQUID (METAL & PLASTIC)

Here you will consider first a situation that may occur to you at the school buffet and then you will perform an experiment where

a) you will study the thermal interaction between 2 equal quantities of water, having the same temperature, during their cooling down in cups made of different materials,
b) you will investigate in which cup the temperature drop is greater.

1.4.1. PREDICTION: "A day at school"

In a cold winter day, you went with your friends to the school buffet and ordered hot chocolates to drink. The drinks had the same temperature and were served in different cups.

Which cup of hot chocolate would you choose, in order to be able to hold it without getting burned?

Glass cup ☐ *Metal cup* ☐ *Plastic cup* ☐

Provide a brief explanation of your choice:

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After a while, in which cup would the chocolate cool down faster?

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Give a brief explanation describing your point of view:

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Experiment to test prediction: Measuring temperature values

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You will now put each cup, together with its thermometer, in the respective basin, allowing these two quantities of water having different temperatures to interact.

Prediction of water temperature drop
In which cup do you think the water temperature will drop faster?
In the metal cup: .... In the plastic cup: ....

Experiment to test prediction: measure of water temperature drop in time
Preparation of the experimental setup

Make sure that the thermometers do not get in contact with the cups' inner walls. They should remain constantly within the mass of water.
Place the two cups in the respective glass basins, allowing the two quantities of water having different temperatures to interact.

Execution of the experiment
Start timing the experiment. Observe and record the change of temperature in each cup.

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TIME	WATER TEMPERATURE IN METAL CUP (°C)	WATER TEMPERATURE IN PLASTIC CUP (°C)
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3 min		
3.5 min		
4 min		
4.5 min		
5 min		
5.5 min		
6 min		
6.5 min		
7 min		

Initial and final temperature in each cup

- What is the initial temperature in each cup?

  metal cup: …… °C   plastic cup: …… °C

- What is the final temperature after 7 min in each cup?

  metal cup: …… °C   plastic cup: …… °C

Temperature differences in each cup

- What is the difference between the initial temperature and the temperature after 7 min in each cup?

  metal cup: …… °C   plastic cup: …… °C

- The water in the ………………… cup has cooled down faster than the water in the ……………… cup.

Comparison of your predictions to the results of the experiment
Compare the experimental results with your prediction

In case your prediction does not agree with the experimental results, how do you explain the differences you observed?

1.4.3. ACTIVITY: Classification of cups' materials

The water in the .... cup has reached after 7 min a lower temperature than the water in the

.... cup

We will say that the ………………. cup conduct heat faster than the ……………….. cup

Please make available the data of Table 1 to your teacher, who will proceed to compare them with the data from the other groups. After discussing with each other and with your teacher the data from all groups, write down which cup conducts heat better.

Which of the two cups conducts heat better?

1.4.4. ACTIVITY: “A day at school” revisited

Does your prediction on which cup containing hot chocolate will **cool down faster** agree with the experimental results? Why?

Does your prediction on which cup containing hot chocolate is better **to hold on** agree with the results of the experiment? Why?

UNIT 2: MICROSCOPIC MODELS FOR THERMAL PHENOMENA

In this Unit you will visualize how scientists describe the inner microscopic structure of different materials. The microscopic model allows to link particles' motions both to temperature values and to heat conduction.

2.1 TEMPERATURE AND THE MICROWORLD

In this part we will study a microscopic model for temperature both for ceramics and metals

Student's point of view

In the previous lab, we observed that the temperature of hot water in the metal cup was falling sooner than in the plastic one. Thus, we concluded that metals conduct heat better than plastic.

Why this is this so? What do you think happens?

....

....

....

2.1.1. COMPUTER ACTIVITY: Ceramics

Figures below show how scientists imagine the lattice of two ceramic materials, an amorphous and a crystalline one. These images are a model of the lattice, which in reality is much smaller and more complex.

Observe carefully the patterns formed by the particles in their lattice and discuss in class their differences.

Which material is the crystalline and which the amorphous one?

Complete the figure captions using the terms CRYSTALLINE and AMORPHOUS.

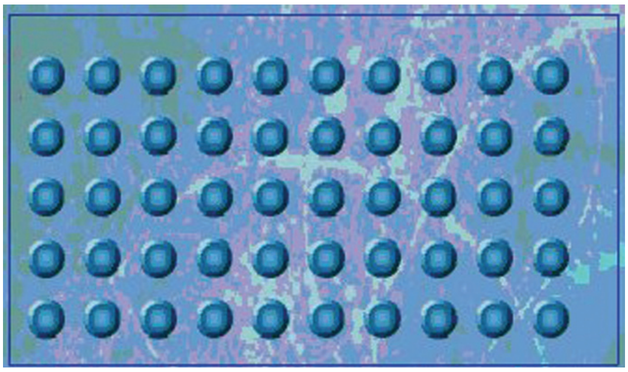

FIG.W3 ....MATERIAL

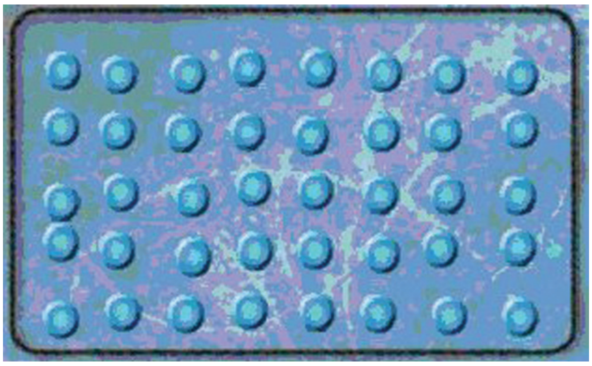

FIG.W4 ....MATERIAL

Exploring the model
Now run the simulation titled "**Microscopic Model**" and then "**Lab1**".

Press "Step A1" to start. You will see how the particles in a ceramic material vibrate, at a low temperature. *By the term "vibration" we mean the continuous motion of particles around a fixed position.*

Use the yellow arrow on the right to proceed to the next animation and observe how the movement of the particles changes when temperature increases. What do you observe?

....

....

....

Describe the motion of the particles, as the material gets hotter and the particles move

Finally, use the right arrow to proceed to the next animation, where you can increase or decrease the temperature at will. Now, decrease the temperature to the lowest value allowed by the simulation. What do you observe?

2.1.2. ACTIVITY: What would happen if…

Can you completely stop the vibration of the particles? ……………………………………

Is there a temperature at which this can be achieved? ……………………………………

Which is this temperature? ………………………………………………………………

2.1.3. ACTIVITY: Temperature and particles' motion

Which is the relationship between the temperature of the materials and the particles' vibrations?

What happens to the kinetic energy of particles when the temperature is increased?

If we consider ALL the particles of the material (in our case all 50 particles), do you think that their TOTAL KINETIC energy is changing while the material's temperature rises or falls?

Explain what happens inside a material, according to scientists, when we measure "*a rise of temperature*".

2.1.4. COMPUTER ACTIVITY: Metals

Now, let's use another simulation to see what happens inside the metals. The first picture we will encounter in the simulation represents how scientists imagine the lattice in metals. This picture is a model of the lattice, which in reality is much smaller and more complex.

Observing the model

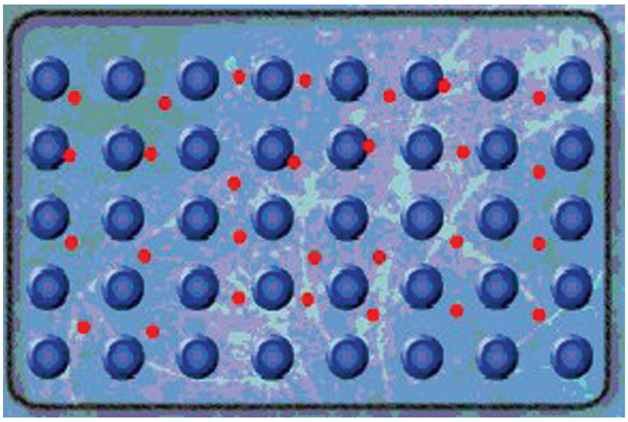

FIGURE W5

In this picture we notice that:
1. Metals also have a crystalline structure.
2. There are free electrons moving around the particles of the metal (depicted as red balls).

In metals, the electrons that are furthest from the nucleus are free to wander around within the material's structure. These electrons are called "**free electrons**".

Exploring the model

Now, let's proceed to simulation "Step A2".

Observe how particles vibrate and the free electrons move in a metallic material, at low temperature.

First focus on the particles' vibration. What do you observe?

....

....

....

Then focus on the motion of free electrons. What do you observe?

....

....

....

Focus on the electrons of the first and the last rows.

Do they move in the same way? ....

Do they follow similar paths during their motion? ....

Using the right arrow you can proceed to the next animations and observe the vibration of particles and the motion of the free electrons at moderate and high temperatures.

What happens now…

to the vibration of the lattice particles?

to the motion of free electrons?

2.1.5. ACTIVITY: Temperature and particles' motion

In ceramic materials, if the temperature raises the lattice particles move

In metals, if the temperature raises the lattice particles move

and the free electrons

2.2 THERMAL CONDUCTION AND THE MICRO WORLD

We will now observe first what happens in an experiment of heat conduction of two different bars and then we will visualize a microscopic model for temperature variations versus time both for ceramics and metals

Student's point of view

In the previous lab, we observed that the temperature of hot water in the metal cup was falling faster than in the glass one. Thus, we concluded that metal CONDUCTS heat better than glass.

Why this is the case? What do you think happens?

2.2.1. EXPERIMENT: Two bars heated at one end

You will now watch a demonstration experiment, where your teacher will heat up, with two small candles the end part of two rods, one made of glass and one made of metal.

On top of both rods, and at the same distance from the end that is heated up, there are four small blobs of wax, placed at equal distances.

The wax, when heated up, will start melting.

Prediction

In which rod will the wax melt first?

Justify your answer

Experiment and comparison

Your teacher performs the experiment

Compare your prediction with the results of the experiment

2.2.2. COMPUTER ACTIVITY: The microscopic model of temperature increase in two bars

We will now use a computer simulation which depicts how the temperature raises in different parts of two rods, one of a ceramic material, heated at one end.

Then you will visualize what is the microscopic model for the observed differences.

Observing the virtual experiment

Run simulation "**Microscopic Model**" and then "**Lab4**".

Press "**Step B**" to start and select "**Graph**"

Press "play" and observe how the various parts of the two rods gradually get hotter. Observe the thermometers that indicate the temperature at various positions on the rod.

What happens?

....

....

....

Fill in the following table as you watch the simulation.

	CERAMIC MATERIAL	METAL
Time needed to heat up the whole rod		
Final temperature at the left end of the rod		
Final temperature at the right end of the rod		
Temperature difference between the two ends of the rod		

Observing the microscopic model

We will now observe a simulation of the microscopic model, which in reality is much more complex

Bring the simulation to its initial state, by pressing

Activate "Microscopic" at the lower left corner of the menu Γράφημα Μικροσκοπικό and restart the simulation. What do you observe?

....

....

....

Focus on the particles in the first and in last columns. Do they vibrate in the same way?

Focus on the free electrons in the first and in last columns. Do they move in the same way?

2.2.3. ACTIVITY: Heat conduction in ceramics and in metals

Describe how heat is transferred in ceramics and metals

1. In ceramics, heat is transferred

2. In metals, heat is transferred

2.2.4. ACTIVITY: … some more explorative questions

i. Report some examples of real situations in which you have heat conduction

ii. In which ways were the simulations helpful for you?

UNIT 3: FROM MATERIALS TO CATEGORIES OF MATERIALS

In this Unit you will examine the thermal behavior of different metals and other materials as ceramics, plastics and textiles, and classify them in broad categories

3.1 THERMAL CONDUCTION IN METALS

In this part you will study heat conduction in metals and rank various metals and alloys. You will reflect first about the experiment performed in the last session and perform a new one.

3.1.1. ACTIVITY: Experiment with the bars and wax revisited

Describe which was the role of the wax

If the metal is changed, what will change?

How could you test your prediction? Design and discuss a possible experiment

3.1.2. EXPERIMENT: Rank 5 metallic materials according to their thermal conductivity

Each group will perform the following experiment

In front of you there is a set of 5 rods of equal length and thickness, but different materials. Each of the rods is numbered. In the following table, some features of the rods are listed.

	WHAT IS IT?	WHAT'S ITS COLOUR?	DOES IT GET ATTRACTED BY A MAGNET?	NUMBER
Aluminium	Metal	Light grey	NO	
INOX	Alloy	Dark grey	NO	
Brass	Alloy	Yellowish	NO	
Iron	Metal	Dark grey	YES	
Copper	Metal	Reddish	NO	

In the last column, write down the number of the material you have identified.

Let's make some measurements

- Your teacher will hand you a piece of thermal paper. Thermal paper becomes dark when heated. (Perhaps you have noticed that the receipts from your bakery cashier become dark when they are in contact with hot bread. Thermal paper is used for cashier receipts and for some types of fax machines).
- Lay the piece of thermal paper on one of your books (about 2 cm thick). Put the 5 metal rods parallel to each other on the thermal paper, and stabilise them using erasers or pencil sharpeners so that they don't roll off. The rods should protrude from the book about 5 cm.

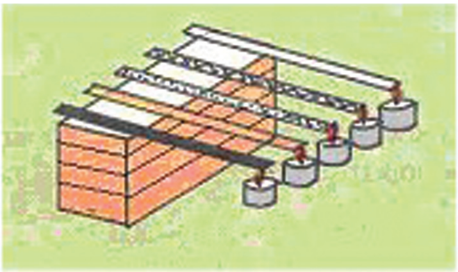

FIGURE W6

- Using your ball pen, mark the position of each rod on the thermal paper.
- Under the protruding end of each rod, you are going to place one lit candle provided by your teacher.
  TAKE CARE to place all 5 candles under the rods simultaneously.
  TAKE CARE each candle's flame touches the end of the respective rod.
- After placing the candles under the rod ends, wait for 10 minutes, without moving the rods or putting out or moving the candles.
  TAKE CARE to not breathe near the candles. Breathing will affect the flame and the rods will not get heated uniformly.
- After the 10 minutes, put out the candles and ask your teacher to remove the rods.
  CAUTION: Some of the rods will be very hot and might burn you!!
  DO NOT TOUCH the rods with your hands, especially the end that was heated by the candles!
  Now observe the thermal paper. You will notice dark traces of different length.

Measure the length of the traces using the ruler. Rank the 5 rods, starting with the one that left the longest trace on the thermal paper.

1st (longest trace)	
2nd	
3rd	
4th	
5th (shortest trace)	

3.1.3. ACTIVITY: Heat conduction and the microscopic interpretation

Which of the metals conducts heat better?

Now try to interpret the experimental result by using the microscopic model we have already studied. Discuss the result and the interpretation in your group and in class.

3.2 THERMAL CONDUCTION IN CERAMICS, PLASTICS, TEXTILES

In this part you will perform in a virtual environment an experiment about thermal conductivity in ceramics, which is similar to the first experiment with the three cups

3.2.1. COMPUTER ACTIVITY: Cooling water in different ceramic materials' cups

Now, run «Simulated Experiments» and select simulation «**Cooling**» and then explore the simulations «**Lab3**» «**Lab4**» and «**Lab5**».

In this virtual lab we will compare the cooling of two quantities of water having equal volumes (50 ml), the same temperature (80 °C) but contained in two different vessels. The big vessel is always made of **glass, but the small** one can be made of **different** materials. We will cool down the water contained in the small vessel by putting it into the larger vessels containing again the same quantities of water (50 ml) but at a lower temperature (20 °C). We assume that the outer vessel is not affected by the environment.

In the various simulations you can select the material of the small vessel. In particular:

In Lab 3: **glass and plexiglas**

In Lab 4: **glass and rubber**

In Lab 5: **glass and bakelite**

You can observe some objects made of the materials at hand in the simulations.

For all simulations you can proceed as follows:

- Select the material of the small vessel (click on the right icon on top). Select first **glass** (click on the left on the icon)
- Place the small vessel into the big one and insert the thermometer.
- Let the water cool down and observe the graph.
- Focus on the thermometer in the small window. When the chronometer marks 10 min press «pause». What is the value of the temperature? Water has reached the equilibrium temperature?

....

....

....

If yes, why? If no, why? Explain

....

....

....

- Press "continue". The chronometer resumes operation. How much time will it take until thermal equilibrium is reached?

....

....

....

What will be the temperature at equilibrium?? ....

- Repeat the experiment but select the other material (click on the icon on top) What happens now to the graph?

....

....

....

What is different?

....

....

....

- How much time will it take until thermal equilibrium is reached?

....

....

What will be the temperature at equilibrium?? ....

After you performed all the experiment fill in the Table 1 below.

TABLE 1:

	Initial Temperature	Final Temperature	Time to reach thermal equilibrium
Lab 3: Glass vessel	80 °C		
Perspex vessel	80 °C		
Lab4. Glass vessel	80 °C		
Bakelite vessel	80 °C		
Lab5. Glass vessel	80 °C		
Rubber vessel	80 °C		

3.2.2. ACTIVITY: Classification of ceramics' thermal conductivity

Classify the materials from more conductive to less conductive

....

....

....

3.2.3. ACTIVITY: Plastics and their use

Polymers constitute a large class of ceramics. Plastics belong to the class of polymers.

DISCUSS WITH THE OTHER MEMBERS OF YOUR GROUP AND WRITE DOWN 3 CASES IN WHICH WE USE PLASTICS

....

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In table 2, you may see the recycling symbol and the typical use of some recyclable plastics. After studying their properties, rank the materials from the more heat-conductive to the more heat-insulating.

TABLE 2: RECYCLABLE POLYMERS

Recycling category	Recycling symbol	Abbreviation	Name	Usage
1	♳	PET	Polyethylene	Beverage, water and other soft drink bottles
2	♴	HDPE	High Density Polyethylene	Milk, shampoo, laundry detergent bottles
3	♵	PVC	Polyvinyl chloride	Insulation of electric wires, sanitary pipes. NOT SUITED FOR FOOD CONTAINERS
4	♶	LDPE	Low Density Polyethylene	Plastic bags
5	♷	PP	Polypropylene	Plastic folders, straws
6	♸	PS	Polystyrene	CD & DVD cases, toys

Put the 6 abbreviations of polymers into the 6 places of the axis:

more heat-conductive material .... *more heat-insulating*

1)...... 2)...... 3)...... 4)...... 5)...... 6)......

3.2.4. ACTIVITY: Using different textiles for thermal insulation

If, during the winter, you want to keep warm and you have: a wool sweater, a dawn jacket, a cotton shirt, a silk shirt

Which would you choose?

Explain

And during the summer?

Explain

3.2.5. ACTIVITY: Factors affecting textiles' thermal conduction

What can have an influence on the conductivity of the different textiles?

UNIT 4: FACTORS AFFECTING THERMAL CONDUCTION

In this Unit you will investigate about all the factors that influence materials' thermal conduction

4.1 MATERIALS' CONDUCTIVITY

In the first place we consider again the initial situation of house insulation.

4.1.1. ACTIVITY: Reading thermal photography

The picture below shows a house with two different types of thermal insulation.

FIGURE W7

Which part of the house is insulated? Which is not? Why?

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How would you reduce the heat losses in your house? How could you save energy?

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Suppose you want to thermally insulate two parts of the house: the windows and the walls.

4.1.2. ACTIVITY: Choosing appropriate glass panes for the windows

What glass panes would you choose for the windows?
(Use the data of the technical characteristics (thermal insulation) for single and double glass windows panes reported in Table 1 and 2 below).

Justify your choice.

....

....

....

TABLE 1. SINGLE GLASS PANES DIFFERENT WIDTH
(Note: more insulating materials have lower K)

Glass Type	K (W/m^2K)
single 4mm	5.8
single 6mm	5.7
single 10mm	5.6
single12mm	5.5

TABLE 2. DOUBLE GLASS PANES DIFFERENT WIDTH
(Note: 4-12-4 means that between the two 4mm panes there is a 12 mm interface)

Glass Type	K (W/m^2K)
double 4 -12-4	2,9
double 6-12-6	2,8
double 10-12-6	2,7
double 12-12-6	2,6

How do you think is a double pane made? What is in between the two panes?

....

....

....

4.1.3. ACTIVITY: Choosing appropriate bricks

What kind of bricks would you choose for the house walls?

(Use the data of the technical characteristics (thermal insulation) of an external wall 38 cm thick, with added thermal insulating material of different width).

Justify your choice.

....

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TABLE 3 (Note: more insulating materials have lower k)

Kind of brick	Insulator's width	k (with thermal insulator of different width) (W/m2.K)
38 cm of simple bricks	0 cm	1.45
	6 cm	0.45
	8 cm	0.37
	10 cm	0.31
	12 cm	0.27
	14 cm	0.24
38 cm of cored bricks	0 cm	0.36
	6 cm	0.23
	8 cm	0,21
	10 cm	0,19
	12 cm	0,17
	14 cm	0,16

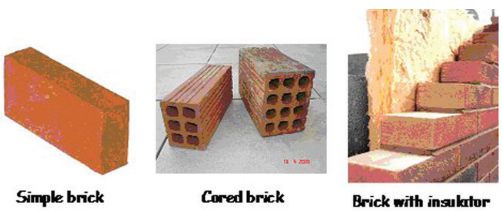

FIGURE W8

4.2 SURFACE AREA

In this part we shall consider what is the effect of the surface area dimension on thermal conduction.

4.2.1. PREDICTION: One day in the house

Your mother left on the stove a little more the milk she was preparing for you. In order to cool it down quickly, she poured it from the initial glass into a larger one having the same wall thickness. She believed that this way the milk should cool down faster.

Do you agree or disagree with her? Why?

....

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How could you verify your prediction?

DISCUSS WITH THE OTHER MEMBERS OF YOUR GROUP HOW TO VERIFY YOUR PREDICTION AND WRITE IT DOWN:

....

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....

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4.2.2. COMPUTER ACTIVITY: Vessels of different surface area

Now run “Simulated Experiments”, choose “**Cooling**” and then “**Lab6**”.

In this virtual lab we will cool down 100 ml of water, of initial temperature 80 °C, by putting the small vessel in a larger basin containing 100 ml of water, of initial temperature 20 °C . You may choose a small or large surface area for the base of the vessel containing the hot water.

Follow this procedure:

1. Choose the surface area for the base of the vessel,
2. Put the small vessel (with hot water) into the larger basin (clicking the small vessel will automatically place it into the basin),
3. Put the thermometer into the vessel (clicking the thermometer will automatically place it into the small vessel),
4. Press «start» to start the virtual experiment.

Carry out the experiment, observe the track of the line drawn on the graph and answer the following questions:

4.2.3. ACTIVITY: Equilibrium temperature in the two vessels

What will be the temperature when the water in the two vessels will reach thermal equilibrium?

4.2.4. ACTIVITY: Time to reach equilibrium in the two vessels

How much time will it take until thermal equilibrium is reached?

Repeat the whole procedure while carefully observing the **time icon** and the **temperature icon**,
Repeat the above process by choosing a different surface area for the vessel base.

4.2.5. ACTIVITY: Comparing initial and final temperatures with time intervals

Fill in the following table:

	Small base surface area	**Large base surface area**
Initial temperature of the water in the small (inner) vessel		
Initial temperature of the water in the large (outer) basin		
Final temperature of the water in the small (inner) vessel		
Time until thermal equilibrium is reached		

4.2.6. ACTIVITY: Influence of surface area on cooling time interval

Describe how the cooling down time interval of the water in the small vessel depends on the surface area of the vessel
Larger area implies less time
Smaller area implies more time

4.2.7. ACTIVITY: "One day in the house" revisited

What do you think about your mothers' way to cool down your milk?

REPORT TO YOUR CLASS THE CONCLUSIONS OF YOUR TEAM.

4.2.8. ACTIVITY: More factors?

Have another team reported other factors affecting the heat flow from and to the vessel?

If yes, write them down:

4.3 THICKNESS

In this part we shall consider what is the effect of thickness on thermal conduction.

4.3.1. PREDICTION: One day in the house

Your mother left on the stove a little more the milk she was preparing for you. In order to cool it down quickly, she poured it from the initial glass into another one with thicker wall. She believed that this way the milk should cool down faster.

Do you agree or disagree with her? Why?

How could you verify your prediction?

DISCUSS WITH THE OTHER MEMBERS OF YOUR GROUP HOW TO VERIFY YOUR PREDICTION AND WRITE IT DOWN:

4.3.2. COMPUTER ACTIVITY: Vessels of different thickness

Now run "Simulated Experiments", choose "**Cooling**" and then "**Lab1**" and "**Lab2**"

In this virtual lab we will cool down 100 ml of water, of initial temperature 80 °C, by putting the small vessel in a larger basin containing 100 ml of water, of initial temperature 20 °C . You may choose two values of the vessel's wall thikness of the vessel containing the hot water.

Follow this procedure:

1. Choose the thickness of the vessel,
2. Put the small vessel (with hot water) into the larger basin (clicking the small vessel will automatically place it into the basin),
3. Put the thermometer into the vessel (clicking the thermometer will automatically place it into the small vessel),
4. Press «start» to start the virtual experiment.

Carry out the experiment, observe the track of the line drawn on the graph and answer the following questions:

4.3.3. ACTIVITY: Equilibrium temperature in the two vessels

What will be the temperature when the water in the two vessels will reach thermal equilibrium?

4.3.4. ACTIVITY: Time to reach equilibrium in the two vessels

How much time will it take until thermal equilibrium is reached?

4.3.5. ACTIVITY: Comparing initial and final temperatures with time interval

Repeat the whole procedure while carefully observing the **time icon** and the **temperature icon**,
Fill in the following table for the two wall thicknesses

	2.5 mm	5 mm
Initial temperature of the water in the small (inner) vessel		
Initial temperature of the water in the large (outer) basin		
Final temperature of the water in the small (inner) vessel		
Time until thermal equilibrium is reached		

4.3.6. ACTIVITY: Influence of surface area on cooling time interval

Describe how the cooling down time interval of the water in the small vessel depends on the surface area of the vessel

More thick implies less time

More thick implies more time

4.3.7. ACTIVITY: "One day in the house" revisited

What do you think about your mothers' way to cool down your milk?

REPORT TO YOUR CLASS THE CONCLUSIONS OF YOUR TEAM.

4.2.8. ACTIVITY: More factors?

Have another team reported other factors affecting the heat flow from and to the vessel?

If yes, write them down:

MATERIALS
SCIENCE PROJECT

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