

VANDERBILT STUDENT VOLUNTEERS FOR SCIENCE

<http://studentorgs.vanderbilt.edu/vsvs>

# Conduction, Convection and Radiation

2018-2019 VINSE/VSVS Rural

Goal: To introduce students to conduction, convection and radiation.

**TN Curriculum Alignment:**

Conduct experiments on the transfer of heat energy through conduction, convection and radiation

VSVSer Lesson Outline

\_\_\_\_\_ **1. Introduction – What is Temperature? What is Heat?**

Students discuss the difference between temperature and heat.

\_\_\_\_\_ **2. Introducing Liquid Crystal Thermometers**

Liquid crystal sensors are introduced.

**A. Experiment.** Students observe the color changes when they put their fingers on the sensor.

**B. How Do Liquid Crystals work?**

\_\_\_\_\_ **3. How is Energy Transferred?**

Tell students they are going to “see” conduction, convection and radiation by using the liquid crystal sensors.

\_\_\_\_\_ **A. Radiation:** A liquid crystal sensor is exposed to a lamp and/or sunlight and the color changes noted.

\_\_\_\_\_ **B. Convection:** A heat pack is activated and a liquid crystal sensor held above it and the color changes noted.

\_\_\_\_\_ **C. Conduction:**

1. Students visualize conduction in copper, iron and wood strips, using a heat pack as the heat source.

2. Students observe that ice melts faster on one of two black squares.

3. Students measure the temperatures of 3 materials, using liquid crystal temperature strips, and discover that it is the same for all. VSVS members put a piece of ice on the 3 materials.

Students will observe that the ice on the aluminum melts faster than on the wood or Styrofoam.

\_\_\_\_\_ **D. Results and Discussion**

Students conclude that the aluminum metal square is a good conductor and that the Styrofoam would be a good insulator.

**LOOK AT THE VIDEO BEFORE YOU GO OUT TO YOUR CLASSROOM**

<https://studentorg.vanderbilt.edu/vsvs/lessons/>

**USE THE PPT AND VIDEO TO VISUALIZE THE MATERIALS USED IN EACH SECTION.**

**2. During the Lesson:**

**Here are some Fun Facts**

- When sunrays hit an object, more rays will be absorbed by darker colors than lighter ones. As a result, they are better at absorbing radiation. This is why black pavement is so hot during the summer.
- People actually build computers in fish tanks filled with water to keep them cool

- Earthquakes are actually caused by convection! The hot mantle in Earth has many convection currents that move the Earth's crust in separate plates.
- Conduction works better in metals than other solid materials because metal atoms are more "flexible" and can more easily transfer heat energy from one molecule to the next. That's why your metal pots and pans have wooden or plastic handles. The heat can very easily move from the bottom of the pan to the handle if it was all metal.

### Materials

- 10 Plastic bags containing:
  - 1 aluminum metal square
  - 1 small Styrofoam square
  - 1 wood square
- 10 white foam board rectangles
- 10 pairs of black ice melting blocks
- 10 thermometer strips
- 10 plates
- 10 liquid crystal sensors, 25-30° C
- 10 heat packs (recyclable)
- 1 work light
- 1 large laminated liquid crystal sensor, 30-35° C
- 1 large Styrofoam cup with ice
- 10 thermal conductivity foam blocks with a strip of copper, iron and wood attached
- Paper towels
- 1 infrared thermometer

### **Unpacking the Kit – What you will need for each section:**

VSVSers do this while 1 person is giving the Introduction. Note that students are put into **10 groups (or 3 per group)**

Write the following vocabulary words on the board:

**Temperature, heat, liquid crystals, conduction, convection, radiation**

#### **For Part 2. Introducing Liquid Crystal Thermometers**

- 10 liquid crystal sensors, 25-30° C. 1 per group of 3

#### **For Part 3. How is Energy Transferred?**

- A. Radiation:** 1 work light, 1 large laminated liquid crystal sensor, 30-35° C, 1 infrared thermometer
- B. Convection:** 10 white foam board rectangles, 10 heat packs (recyclable) plus 10 liquid crystal sensors from Part 2
- C. Conduction:**
  - a. **Experiment 1 - Visualizing Conduction**
    - 10 thermal conductivity foam blocks with a strip of copper, iron and wood attached, plus 10 liquid crystal sensors from Part 2
  - b. **Experiment 2. Observing ice melt on 2 black squares**
    - 10 sets of 2 identical looking black squares (1 is aluminum and the other plastic), Ice, 10 paper towels

**Your Notes:**

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### c. Experiment 3. Ice melting on 3 different materials

10 plastic bags containing: 1 aluminum metal square, 1 styrofoam square, 1 wood square, 1 Thermometer strips, 10 foam board rectangles (students should already have), Ice

#### 1. What is Temperature? What is Heat?

**Learning Goal:** Students understand that adding heat energy to a medium causes an increase in temperature

Ask students: what is temperature?

Temperature is the scientific measure of how hot or cold something is.

It is measured with a thermometer.

It is a measure of the average kinetic energy of the molecules in a substance.

- Hot tea has more average kinetic energy than ice tea. The temperature of hot tea is higher than ice tea.

Ask students: what happens when we add ice to hot tea?

- The ice melts – its temperature becomes warmer. Energy from the hot tea is transferred to the ice cube. This transfer of energy is called **heat**. Thus the temperature of the ice tea is cooler since kinetic energy is lost during the transfer

#### 2. Introducing Liquid Crystal Temperature Sensors

**Learning Goal:** Students identify different tools that can be used to measure the transfer of energy

- Ask students if they have ever seen anything that changes color with temperature?  
Answers may include mood rings, strip thermometers.

Hand out a laminated liquid crystal temperature sensor to each group of students.

Tell students that they will be using these to visualize temperature changes and how heat flows.

**Note:** The temperature of the classroom determines which sensor is more effective. The laminated sensor changes color between 25-30° C. The sensors attached to the metal strips used in Part 3C of the lesson sense changes between 30-35° C. The sensors should be black at the lowest temperature they measure, so if the classroom temperature is above 25°C, it will have already turned green or red-orange without being touched.

Give the students the following rules for using the sensors:

1. The sensor must not be placed in the sun or near a heat source such as room heater, computer, hot drinks etc, since this will skew the results of the experiments.
2. Always hold the strips using the clear laminated part (show students how to do this).
3. Do NOT touch the liquid crystal unless instructed to do so.

#### A. Experiment

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1. Tell students to look at the liquid crystal sensor and note the temperatures written on the colored tab. Explain that different sensors have different temperature ranges.
2. Tell students to hold the liquid crystal temperature sensor by the clear plastic part. Tell students to note the color of the sensor. Turn the sensor over and note that it is covered with white paper.
3. Tell students place the sensor on the white foam pad, black side facing up.
4. Tell one student in each pair to place the pad of a fingertip on the liquid crystal sensor for 15 seconds and then remove it. Record what happens, and note the pattern of colors produced. Some observations will include:
  - the color of the sensor changes.
  - color changes spread out from the center of the finger and changes color as it spreads.
5. Ask students:
  - What color is in the center of the finger print? At the outer edge? What color fades first? Last?
  - What color indicates the coolest temperature? – Black
  - What color indicates the warmest temperature? – Blue
  - What is the order of temperature colors from cooler to warmer? Black, yellow, red, green, blue.

**Explanation:** Blue represents the warmest area because that was the area in direct contact with the finger. The surrounding area's colors were not directly touched by the fingertips, but were produced as a result of **conduction** of heat through the crystal.

6. Place the strip back on the desk top and watch it return to room temperature.

## B. How do Liquid Crystals work?

**Information for VSVS team** – use it if you feel the class can grasp the topics. (This information is from NanoDays Exploring Materials – Liquid Crystals.)

**The way a material behaves on the macroscale is affected by its structure on the nanoscale.** Changes to a material's molecular structure are too small to see directly, but we can sometimes observe corresponding changes in a material's properties. The liquid crystals change color as a result of nanoscale shifts in the arrangement of their molecules.

**Nanotechnology** takes advantage of special properties at the nanoscale to create new materials and devices. Liquid crystals are used in cell phone displays, laptop computer screens, and strip thermometers. They're also being used to create nanosensors—tiny, super-sensitive devices that react to changes in their environment.

1. Liquid crystals represent a phase in between liquid and solid. The molecules can move independently, as in a liquid, but remain somewhat organized, as in a crystal (solid).
2. The liquid crystals are *thermotropic*, which means that they respond to changes in temperature by changing color. As the temperature increases, the color of the liquid crystal changes from red to orange, yellow, green, blue, and purple.
3. The liquid crystals are made of mixtures of long, thin molecules stacked in rotating layers, like a spiral staircase (helix).
4. When light strikes a liquid crystal, some of the light is reflected. The color of the reflected light depends on how tightly twisted the helix is.
5. More tightly twisted helices reflect wavelengths on the blue end of the spectrum.
6. More loosely twisted helices reflect wavelengths on the red end.
7. As the temperature of the liquid crystal changes, the spacing of the helix changes. This changes the wavelength of light that is reflected and the color that you see.

- Explain to students that liquid crystals are sensitive to temperature, and will change colors according to the temperature of the crystal. Black is the coolest color. (Note: it only appears

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black because of the black background glued onto the back side of the sensor. The lowest temperature is actually clear!) Changes are from red to orange, yellow, green, blue, and purple. Liquid crystals are used in displays for cell phones, laptop computers, and other electronics.

- Where does the thermal energy come from to change the liquid crystal color?  
Answer: your skin temperature is about 10 degrees C higher than room temperature. When you touch something at room temperature, heat flows from your fingers into the object.
- Where does the energy go when the color changes back to its colder temperature?  
Answer: it is transferred to the desk or Styrofoam pad, which is at room temperature. Heat flows from the warmer sensor to the colder desk.

### 3. How is Energy Transferred?

#### Learning Goals:

- Students explain that energy is transferred through a solid during conduction, a liquid/gas during convection, and any medium during radiation.
- Students identify different tools that can be used to measure the transfer of energy

- Thermal energy is transferred by heat.
- Heat always flows from a hotter object to one that is cooler. In this case, your body is warmer than room temperature and heat flows from your finger to the sensor.
- Ask students if they know the different ways thermal energy is transferred?  
Energy can be transferred by conduction, convection, or radiation.
- Tell students we are going to “see” conduction, convection and radiation by using the liquid crystal sensors.

#### A. Radiation

- Radiation is the transfer of energy by electromagnetic waves, such as light, UV, Infrared, X-Rays.
- Ask students if they can name some sources that transfer heat by radiation?  
*The sun, a fire, bar heater, incandescent light bulb ....*
- Radiation is a method of heat transfer that does not rely upon any contact between the heat source and the heated object. Radiation can even be transferred through space where there is a vacuum (where there are no particles in air to carry heat). We can feel heat from the sun even though we are not touching it, AND there is no air in space.

**Note:** Make sure that the large crystal sensor being used in this demonstration has been kept out of sunlight and has not been exposed to heat. The color needs to be black before starting.

#### **Demonstration - Visualizing Radiation**

- A VSVS member holds the large liquid crystal sensor up so that all students can see it. Note the color.
- Hold the lamp in a vertical position, turn it on and hold the large sensor vertically, about 5 inches away.
- Wait for a few minutes until the sensor changes color, then remove the light and let students observe the changes.

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**Demonstration: Visualizing Sun Radiation** (if the sun is shining into the classroom)

Now hold the sensor in the sunlight and note the color changes.

Point out that there is no contact between the lamp and the sensor.

Other experiments with the sensor and sunlight are at the end of this lesson and can be done if there is time, after convection and conduction experiments are finished.

**Demonstration: Infrared Thermometer**

The IR thermometer uses a sensor to measure the surface temperature of an object.

- To use the thermometer press (do not hold down) the “Meas” button while the sensor is pointed at a surface.
- Hold the sensor in place while the thermometer takes a reading.
- Use this thermometer to measure the surface temperature of the lamp.
- Compare the temperature of the light bulb to the temperatures of various surfaces around the classroom. You should find that objects directly exposed to light have significantly higher surface temperatures than objects that receive less light.

**B. Convection**

- Convection is the transfer of thermal energy by the movement of liquids or gases.
- Ask students if they can name some sources that transfer heat by convection?  
Heating water, fans, hot air balloons...

**Experiment – Visualizing Convection**

- Show students how to activate the hot pack and place it on the white foam board.
- Tell students to hold their hands above it to feel the transfer of heat through convection through the air. Hold a hand to the side and below it. The air will feel warmer above the hot pack.
- Hold the liquid crystal sensor (by the clear plastic part) about 10 cm above the heat pack and note the color changes

**Explanation:** When the heat pack warms up it begins to warm the air next to it (through conduction). The warm air molecules move more quickly, which forces them to spread out. This causes the air to become less dense, so the warmer air rises. The sensor changes color.

**Note:** Do not spend too much time in discussions. The heat pack needs to be used with the next experiment while it is still hot.

**C. Conduction**

**Learning Goal: Students use evidence to demonstrate that metal is a better conductor than wood**

- Conduction is the transfer of thermal energy between objects that are **touching**. Thermal conduction is slow – it moves from one side of an object to the other.
- Remind students that they have already “seen” conduction when they put a finger on the sensor.
- Tell students that some materials are better conductors than others.  
Ask students if they can name a good thermal conductor and poor thermal conductor?

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Metals are usually good conductors (which is why most cooking pots are made of metal).

### Experiment 1 - Visualizing Conduction

- Hand out the thermal conductivity boards. Explain that the 3 different materials have been covered with a liquid crystal sensor, mounted on a Styrofoam board and covered with plastic.
- Ask students if they can identify the 3 different materials? (They are copper, wood and iron.)
- Tell students to place the heat pack on top of **the bottom edges** of the 3 exposed prongs, being careful to keep the heat pack from contacting the sensor.
- Watch the liquid crystal change colors (or not). Students will need to wait a few minutes before they see any changes.
- Ask students to describe what they see.  
Answers should include: The color change starts nearest the heat pad.  
The color change travels up the materials.  
The rate that the color change travels is different for the 3 materials.  
Therefore heat is travelling up the materials at different rates.
- Which material had the fastest changing temperature sensor? **Copper**
- Which material had the slowest changing temperature sensor? **Wood**
- Ask students which material is the best conductor of heat? **Copper**
- Tell students that copper and iron are both good conductors of heat and have high thermal conductivity. Wood is a poor conductor and has a low thermal conductivity.
- Tell students to remove the sensor and watch which metal loses energy faster.  
The sensor on the copper strip returns to its original color faster.
- Collect the liquid crystal sensors, heat packs and thermal conducting blocks.

### Experiment 2. Observing ice melt on 2 black squares

Materials

10 sets of 2 identical looking black squares (1 is aluminum and the other plastic), Ice

Important: do not tell the students that the identical-looking black blocks are actually made of different materials. They will be asked to come to that conclusion after the experiment.

- Distribute the pairs of black blocks at student's tables so that all can see the next experiment.
- Do not explain that the 2 blocks are made from different materials.
- Place some ice in the middle of each block and tell students to watch what happens.
- Ask students if they can explain this. Tell them that it has something to do with **conduction of heat**. Do not spend more than a few minutes on discussion.

### Experiment 3. Ice melting on 3 different materials

Materials

10 plastic bags containing:

1 aluminum metal square, 1 styrofoam square, 1 wood square, 1 Thermometer strips

10 foam board rectangles (students should already have)

- Pass out the plastic bags containing the wood, styrofoam and metal squares and thermometer strips to groups. Spread the materials on the long piece of foam board.
- Tell the students they must not touch the blocks being handed out until they are told.
- Tell the students to:

**Your Notes:**

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1. Briefly place a palm on top of each block (for no more than 1 second).
2. Decide, as a group, and put the blocks in order from coolest to warmest.
3. Report the order to VSVS members who will record the results on the board.  
Results may vary, but make sure that students in each group all agree which one feels colder (the aluminum square should feel coldest, the foam board will feel warmer, and the wood may be in between, but definitely warmer than the aluminum ).
4. Set aside the squares so that they can return to room temperature (ie. do not touch while the next demonstration is done.)

- Show the students the strip thermometer and the degree markings (in F and C) on it. Explain that the thermometer strips are made of the same liquid crystal material, with a temperature scale added.
- Note the temperature where the **dark blue** color is. Explain that this is room temperature, and all measurements will be compared to this number. Explain that these thermometers are not highly accurate but are good enough measure changes in temperature.
- Tell them to place a thermometer strip in the middle of the wood block and record its temperature. Repeat with the Styrofoam and metal blocks.
- Ask students if the temperatures of the blocks are different?  
There should be no significant difference within a group. Temperature readings will differ from one group to another.
- Ask students what they think will happen to ice if it is placed on the blocks?  
Will the ice melt faster on one?  
Tell students to place a small piece of ice in the middle of each block and to record the results. The ice on the metal will melt in just a few seconds.  
Wipe the ice off the metal block and measure its temperature again.  
The temperature will have dropped significantly.
- Ask the students why the ice on the metal melted faster?  
Since the metal is a good conductor, it transfers heat from it to the ice faster than the other 2 materials.
- Based on these results, what materials are the 2 black squares made from?

#### 4. Results and Discussion

Learning Goal: Students use evidence to demonstrate that metal is a better conductor than wood

- Ask students why the metal square felt cooler than the others, when the actual temperature is the same? *The square that felt colder is CONDUCTING heat away from your hand so it is actually your hand that is cooling. Your hand is not a thermometer!*
- Ask students which object is the best conductor? *This metal square is the best conductor.*
- Ask students which object would be a good insulator? *Styrofoam.*

**Clean-up:** Place all materials back in kit. Wipe off wet surfaces.  
Discard leftover ice at the school if possible. Return kit immediately to SC 5233

**Your Notes:**

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**Radiation extension:**

A VSVS member can cast a shadow on the sensor by blocking the radiation reaching half the sensor with a book.

Students will see that the sun's radiation does not travel through the book.

Ask students how this could relate to weather on a cloudy day? (Clouds prevent or block radiation.)

The sensor can also be held at an angle to the lamp's or sun's rays rather than facing it directly, and note the sensor warms up slower.

Ask students how this can relate to the seasons. *As Earth orbits the sun, its tilted axis always points in the same direction. So, throughout the year, different parts of Earth get the sun's direct rays.*

Lesson written by:

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**Your Notes:**

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## Conduction, Convection and Radiation Observation Sheet

### 2. Introducing Liquid Crystal Temperature Sensors

Record what happens when you put your finger on the liquid crystal sensor. Note the pattern of colors produced.

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Circle the color indicating the coolest temperature

Black Red Orange Yellow Green Blue Purple

Circle the color indicating the warmest temperature

Black Red Orange Yellow Green Blue Purple

### 3. How is Energy Transferred?

#### A. Radiation

What color does the sensor change to when the lamp is shone on to it? \_\_\_\_\_

What does this show? \_\_\_\_\_

#### B. Convection

What color does the sensor change to when it is held above the heat pack? \_\_\_\_\_

What does this show? \_\_\_\_\_

#### C. Conduction

##### 1. Using the Thermal Conductivity boards

Circle the material that had the fastest changing temperature sensor. Copper iron wood

Circle the material had the slowest changing temperature sensor. Copper iron wood

Circle the material that is the best conductor of heat. Copper iron wood

##### 1. Ice melting on the 2 black squares.

What do you observe? \_\_\_\_\_

##### 2. Ice melting on 3 different materials

Which block feels the coldest? \_\_\_\_\_

Which block feels the warmest? \_\_\_\_\_

What are the temperatures of the 3 blocks? \_\_\_\_\_

Which block melts ice the fastest? \_\_\_\_\_

What do you think the black squares (in #2 above) are made of?

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## Conduction, Convection and Radiation Answer Sheet

### 2. Introducing Liquid Crystal Temperature Sensors

Record what happens when you put your fingers on the liquid crystal sensor. Note the pattern of colors produced.

*color changes spread out from the center of the finger (blue/green) and changes color as it spreads*

What color indicates the coolest temperature? *Black*

What color indicates the warmest temperature? *Blue*

### 3. How is Energy Transferred?

#### A. Radiation

What color does the sensor change to when the lamp is shone on to it? *From black to yellow/red/green/blue*

What does this show? *Heat is being transferred from the lamp to the sensor via electromagnetic radiation*

#### B. Convection

What color does the sensor change to when it is held above the heat pack? *From black to yellow/red/green/blue*

What does this show? *Thermal energy is being transferred from the heat pack to the sensor by convection currents.*

#### C. Conduction

##### 1. Using the Thermal Conductivity boards

Which material had the fastest changing temperature sensor? *Copper (orange metal)*

Which material had the slowest changing temperature sensor? *Wood*

Which material is the best conductor of heat? *Copper*

##### 1. Ice melting on the 2 black squares.

What do you observe? *Ice melts very fast on one of the blocks, and does not melt on the other. Both blocks look the same. One is heavier to hold.*

##### 2. Ice melting on 3 different materials

Which block feels the coldest? *Aluminum (silver colored)*

What are the temperatures of the 3 blocks? *The temperatures of the 3 blocks are nearly the same within each group. The thermometers are not accurate and can differ from one group to another.*

Which block melts ice the fastest? *The aluminum metal.*

What do you think the black squares (in C2 above) are made of? *One is aluminum and the other is a material similar to Styrofoam.*

## Conduction Convection and Radiation Instruction sheet

### 5. What is Temperature? What is Heat?

Discuss temperature and heat.

### 6. Introducing Liquid Crystal Temperature Sensors

Follow the rules below for using the sensors:

4. The sensor must not be placed in the sun or near a heat source such as room heater, computer, hot drinks etc, since this will skew the results of the experiments.
5. Always hold the strips using the clear laminated part.
6. Do NOT touch the liquid crystal unless instructed to do so.

### Experiment

7. Look at the liquid crystal sensor and note the temperatures written on the colored tab. Different sensors have different temperature ranges.
8. Hold the liquid crystal temperature sensor by the clear plastic part. Note the color of the sensor. Turn the sensor over and note that it is covered with white paper.
9. Place the sensor on the white foam pad, black side facing up.
10. One student in each pair places 3 fingertips on the liquid crystal sensor for 15 seconds and then removes them. Record what happens, and note the pattern of colors produced
11. Answer the questions on your observation sheet.
12. Place the strip back on the desk top and watch it return to room temperature

### 3. How is Energy Transferred?

#### A. Radiation

Observe the color change when the lamp is shone on to the sensor.

#### B. Convection

1. Activate the hot pack and place it on the white foam board.
2. Hold your hand above it to feel the transfer of heat through convection through the air. Hold a hand to the side and below it.
3. Hold the liquid crystal sensor (by the clear plastic part) about 10 cm above the heat pack and note the color changes.
4. Answer the questions on your observation sheet.

#### C. Conduction

Can you identify the 3 different materials on the thermal conductivity board?

- Place the heat pack on top of **the bottom edges** of the 3 exposed prongs, being careful to keep the heat pack from contacting the sensor.
- Watch the liquid crystal change colors (or not). You need to wait a few minutes before you see any changes.
- Describe what you see.
- Which material is the best conductor of heat?

### Observing ice melt on 2 black squares

Place some ice in the middle of each block. Watch what happens.

### **Experiment: Ice melting on 3 different materials**

1. Place the wood, styrofoam and metal squares on the long piece of foam board.
2. Do not touch the blocks until you are told to.
3. Briefly place a palm on top of each block (for no more than 1 second).
4. Decide, as a group, and put the blocks in order from coolest to warmest. Record the results.
5. Set aside the squares so that they can return to room temperature (ie. do not touch while the next demonstration is done.)
6. Examine the thermometer strips and determine the temperature reading.
7. Place a thermometer strip in the middle of the wood block and record its temperature. Repeat with the Styrofoam and metal blocks.

**Are the temperatures of the blocks different?**

**Predict if ice will melt at different rates on the blocks**

8. Place a small piece of ice in the middle of each block. Which block melts ice the fastest?

**Based on these results, what materials are the 2 black squares made from?**

What block is the best conductor? What material would be the best insulator?