Experiment: Heat Transfer

Purpose :

a. to compare the effectiveness of 3 heat transfer mechanisms
b. to experimentally verify the relationship between the rate of the heat transfer and temperature difference

Materials:

- LabPro interface
- LoggerPro software
- Styrofoam Cups
- Electric immersion heater
- Heat lamp
- Black and shiny identical containers
- 2 temperature probes

Preliminary Questions:

1) During the spring, the outside temperature is (in average) 15 degrees Celsius, and during the winter it is 5 degrees Celsius. Compare the energy costs to maintain an inside temperature of 25 degrees Celsius, assuming that the price of energy does not change.

2) Consider 2 identical cups containing the same amount of water at the same temperature of 45 degrees Celsius, one of them covered and the other one not. After 5 minutes, would you expect the temperature to be the same in the 2 cups? Why?

3) 2 identical closed metallic cups containing water are exposed to light from a lamp. One of the cups is painted black, the other one is white.

a) Will the temperature of the water change? Why?

b) Which cup will have a higher temperature after 5 minutes?

c) If the 2 cups contain hot water (at 85 degrees Celsius) which one will cool down first? Why?

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The transfer of heat energy from a cup containing hot water to its surroundings takes place through several different mechanisms. There is **conduction** through the cup into the table and the surrounding air. There is **convection** from the air flow that results when the air is heated by the water and cup. Finally, there is **radiation** the electromagnetic waves (mostly infrared) emitted from the hot surfaces of the cup.

The rate of the heat transfer by conduction depends on the transfer surface, the length and the temperature difference between the cup and the surroundings:

Equation 1: $Q/t = (kA\Delta T)/L$

The rate of the heat transfer by radiation depends on the temperature, surface area and the emissive properties of the cup:

Equation 2: $Q/t = \varepsilon\sigma AT^4$

The heat absorbed/released can be directly calculated from temperature change:

Equation 3: $Q = cm\Delta T$

The temperature change and the mass will be measured during the experiment

Experiment:

Part I: Heat transfer through convection

1) Plug two temperature sensors into the LabPro interface (CH1 and 2, respectively).
2) Start up the LoggerPro software then open the experiment file:

Additional Physics/Real Time Physics/Heat and Thermodynamics/L3A2-1(Cooling Down).cmbl

3) Record the room air temperature
4) Using an immersion heater, warm ~200 mL water in a beaker to 90 degrees Celsius. Quickly but carefully, pour a 75 ml water sample into two separate Styrofoam cups. Place a temperature sensor into each cup. Cover one of the cups but leave the other uncovered. Read the initial temperature of the water (around 85 degrees). Push “Collect” to start graphing.
5) Store this run.
6) Using the Examine/Analyze feature, record the initial and the final temperature for each graph. Record data in Table 1.
7) Cut and Paste the graphs into Word.

QUESTION 1: What is the heat transfer mechanism(s) for the covered cup? For the uncovered cup?

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1) Record room air temperature
2) Heat water in a beaker to 70 degrees Celsius. Quickly pour 75 ml water into a Styrofoam cup. Put the temperature sensor in the cup and cover the cup. Read the initial temperature of the water (around 65 degrees). Push Collect to start graphing.
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4) Using an immersion heater, warm ~200 mL water in a beaker to 90 degrees Celsius. Quickly but carefully, pour a 75 ml water sample into two separate Styrofoam cups. Place a temperature sensor into each cup. Cover one of the cups but leave the other uncovered. Read the initial temperature of the water (around 85 degrees). Push "Collect" to start graphing.
5) Store this run.
6) Using the Examine/Analyze feature, record the initial and the final temperature for each graph. Record data in Table 1.
7) Cut and Paste the graphs into Word.

QUESTION 1: What is the heat transfer mechanism(s) for the covered cup? For the uncovered cup?

QUESTION 2: Calculate the heat lost by the covered and uncovered cup, respectively. What is the rate of heat transfer for the 2 cases?

Part II: Heat transfer through conduction

1) Record room air temperature
2) Heat water in a beaker to 70 degrees Celsius. Quickly pour 75 ml water into a Styrofoam cup. Put the temperature sensor in the cup and cover the cup. Read the initial temperature of the water (around 65 degrees). Push Collect to start graphing.
3) Store this run.
4) Repeat steps 1-3 with water at the initial temperature of 45 degrees Celsius.
5) Cut and Paste the graphs into Word.
6) Calculate for each case the heat energy transferred and the rate of the heat energy transfer.

QUESTION 3: Does your data agree or disagree with equation 1? Explain.

QUESTION 4: Based on your data, how does the effectiveness of convection vs. conduction compare, as mechanisms of heat transfer?

Mass of water =__________ *{should be the same for each of these trials}*

Table 1	**Initial temp**	**Final temp**	**Temp change**	**Q lost**	**Q/time**	**Heat transfer mechanism**
Cup covered						
Cup uncovered						
Cup covered						
Cup covered						

Part III: Heat transfer through radiation

1) Open the experiment file: *L3A3-2(Radiation).cmbl*
2) Set a heat lamp 35 cm in front of a can, at the same height; the face of the lamp and the can should be directly across.
3) Pour 75 ml of water (room temperature) into a black can. Place the cover tight on the can. Insert the temperature sensor through the cover. Place a piece of paper on the temperature sensor, so that it prevents radiation from lamp from reaching the temperature sensor directly.
4) Record the initial temperature of the water in Table 2. Begin graphing and turn on the lamp. Gently stir the can while collecting data.

5) When the graphing is over, record the final temperature. Store the run. Turn off the lamp.
6) Repeat steps 2-5 with a white shiny cup PLACED IN THE SAME EXACT PLACE AS THE BLACK CAN. Record the temperatures.
7) Cut and Paste the graphs into Word then print all graphs.

Table 2	**Initial temperature**	**Final temperature**	**Change in temperature**	Q_{gained}
Black can				
Shiny can				

QUESTION 5: Which cup received more heat? Calculate the ratio Q_{black}/Q_{shiny}.

QUESTION 6: Based on your results in Table 2, which can will lose heat by radiation faster?

8) To test your prediction (question 6) pour 75 ml hot water (80 degrees) in the black can. Record the initial temperature. Collect data for 5 min. Record the final temperature. Repeat the step 7 with the shiny can.

Table 3	**Initial temperature**	**Final temperature**	**Change in temperature**	Q_{lost}
Black can				
Shiny can				

QUESTION 7: Which of the cans lost more heat?

Experiment: Heat Transfer

Purpose :

a. to compare the effectiveness of 3 heat transfer mechanisms
b. to experimentally verify the relationship between the rate of the heat transfer and temperature difference

Materials:

- LabPro interface
- LoggerPro software
- Styrofoam Cups
- Electric immersion heater
- Heat lamp
- Black and shiny identical containers
- 2 temperature probes

Preliminary Questions:

1) During the spring, the outside temperature is (in average) 15 degrees Celsius, and during the winter it is 5 degrees Celsius. Compare the energy costs to maintain an inside temperature of 25 degrees Celsius, assuming that the price of energy does not change.

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Purpose :

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Materials:

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QUESTION 7: Which of the cans lost more heat?

Experiment: Heat Transfer

Purpose :

a. to compare the effectiveness of 3 heat transfer mechanisms
b. to experimentally verify the relationship between the rate of the heat transfer and temperature difference

Materials:

- LabPro interface
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- Electric immersion heater
- Heat lamp
- Black and shiny identical containers
- 2 temperature probes

Preliminary Questions:

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a) Will the temperature of the water change? Why?

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1) Record room air temperature
2) Heat water in a beaker to 70 degrees Celsius. Quickly pour 75 ml water into a Styrofoam cup. Put the temperature sensor in the cup and cover the cup. Read the initial temperature of the water (around 65 degrees). Push Collect to start graphing.
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Table 1	Initial temp	Final temp	Temp change	Q lost	Q/time	Heat transfer mechanism
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Cup uncovered						
Cup covered						
Cup covered						

Part III: Heat transfer through radiation

1) Open the experiment file: *L3A3-2(Radiation).cmbl*
2) Set a heat lamp 35 cm in front of a can, at the same height; the face of the lamp and the can should be directly across.
3) Pour 75 ml of water (room temperature) into a black can. Place the cover tight on the can. Insert the temperature sensor through the cover. Place a piece of paper on the temperature sensor, so that it prevents radiation from lamp from reaching the temperature sensor directly.
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Table 3	**Initial temperature**	**Final temperature**	**Change in temperature**	$\mathbf{Q_{lost}}$
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QUESTION 7: Which of the cans lost more heat?

Experiment: Heat Transfer

Purpose :

a. to compare the effectiveness of 3 heat transfer mechanisms
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Materials:

- LabPro interface
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- Heat lamp
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Preliminary Questions:

1) During the spring, the outside temperature is (in average) 15 degrees Celsius, and during the winter it is 5 degrees Celsius. Compare the energy costs to maintain an inside temperature of 25 degrees Celsius, assuming that the price of energy does not change.

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5) When the graphing is over, record the final temperature. Store the run. Turn off the lamp.
6) Repeat steps 2-5 with a white shiny cup PLACED IN THE SAME EXACT PLACE AS THE BLACK CAN. Record the temperatures.
7) Cut and Paste the graphs into Word then print all graphs.

Table 2	**Initial temperature**	**Final temperature**	**Change in temperature**	Q_{gained}
Black can				
Shiny can				

QUESTION 5: Which cup received more heat? Calculate the ratio Q_{black}/Q_{shiny}.

QUESTION 6: Based on your results in Table 2, which can will lose heat by radiation faster?

8) To test your prediction (question 6) pour 75 ml hot water (80 degrees) in the black can. Record the initial temperature. Collect data for 5 min. Record the final temperature. Repeat the step 7 with the shiny can.

Table 3	**Initial temperature**	**Final temperature**	**Change in temperature**	Q_{lost}
Black can				
Shiny can				

QUESTION 7: Which of the cans lost more heat?

Experiment: Heat Transfer

Purpose :

a. to compare the effectiveness of 3 heat transfer mechanisms
b. to experimentally verify the relationship between the rate of the heat transfer and temperature difference

Materials:

- LabPro interface
- LoggerPro software
- Styrofoam Cups
- Electric immersion heater
- Heat lamp
- Black and shiny identical containers
- 2 temperature probes

Preliminary Questions:

1) During the spring, the outside temperature is (in average) 15 degrees Celsius, and during the winter it is 5 degrees Celsius. Compare the energy costs to maintain an inside temperature of 25 degrees Celsius, assuming that the price of energy does not change.

2) Consider 2 identical cups containing the same amount of water at the same temperature of 45 degrees Celsius, one of them covered and the other one not. After 5 minutes, would you expect the temperature to be the same in the 2 cups? Why?

3) 2 identical closed metallic cups containing water are exposed to light from a lamp. One of the cups is painted black, the other one is white.

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c) If the 2 cups contain hot water (at 85 degrees Celsius) which one will cool down first? Why?

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The rate of the heat transfer by radiation depends on the temperature, surface area and the emissive properties of the cup:

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The heat absorbed/released can be directly calculated from temperature change:

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The temperature change and the mass will be measured during the experiment

Experiment:

Part I: Heat transfer through convection

1) Plug two temperature sensors into the LabPro interface (CH1 and 2, respectively).
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QUESTION 1: What is the heat transfer mechanism(s) for the covered cup? For the uncovered cup?

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1) Record room air temperature
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1) Record room air temperature
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Table 1	**Initial temp**	**Final temp**	**Temp change**	**Q lost**	**Q/time**	**Heat transfer mechanism**
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Cup uncovered						
Cup covered						
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Part III: Heat transfer through radiation

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3) Pour 75 ml of water (room temperature) into a black can. Place the cover tight on the can. Insert the temperature sensor through the cover. Place a piece of paper on the temperature sensor, so that it prevents radiation from lamp from reaching the temperature sensor directly.
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Table 2	**Initial temperature**	**Final temperature**	**Change in temperature**	**Q_{gained}**
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QUESTION 7: Which of the cans lost more heat?

Experiment: Heat Transfer

Purpose :

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Materials:

- LabPro interface
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Preliminary Questions:

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Experiment:

Part I: Heat transfer through convection

1) Plug two temperature sensors into the LabPro interface (CH1 and 2, respectively).
2) Start up the LoggerPro software then open the experiment file:

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3) Record the room air temperature
4) Using an immersion heater, warm ~200 mL water in a beaker to 90 degrees Celsius. Quickly but carefully, pour a 75 ml water sample into two separate Styrofoam cups. Place a temperature sensor into each cup. Cover one of the cups but leave the other uncovered. Read the initial temperature of the water (around 85 degrees). Push "Collect" to start graphing.
5) Store this run.
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QUESTION 1: What is the heat transfer mechanism(s) for the covered cup? For the uncovered cup?

QUESTION 2: Calculate the heat lost by the covered and uncovered cup, respectively. What is the rate of heat transfer for the 2 cases?

Part II: Heat transfer through conduction

1) Record room air temperature
2) Heat water in a beaker to 70 degrees Celsius. Quickly pour 75 ml water into a Styrofoam cup. Put the temperature sensor in the cup and cover the cup. Read the initial temperature of the water (around 65 degrees). Push Collect to start graphing.
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Mass of water =__________ *{should be the same for each of these trials}*

Table 1	**Initial temp**	**Final temp**	**Temp change**	**Q lost**	**Q/time**	**Heat transfer mechanism**
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2) Set a heat lamp 35 cm in front of a can, at the same height; the face of the lamp and the can should be directly across.
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QUESTION 7: Which of the cans lost more heat?

Experiment: Heat Transfer

Purpose :

a. to compare the effectiveness of 3 heat transfer mechanisms
b. to experimentally verify the relationship between the rate of the heat transfer and temperature difference

Materials:

- LabPro interface
- LoggerPro software
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- Electric immersion heater
- Heat lamp
- Black and shiny identical containers
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Purpose :

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Purpose :

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6) Calculate for each case the heat energy transferred and the rate of the heat energy transfer.

QUESTION 3: Does your data agree or disagree with equation 1? Explain.

QUESTION 4: Based on your data, how does the effectiveness of convection vs. conduction compare, as mechanisms of heat transfer?

Mass of water =__________ *{should be the same for each of these trials}*

Table 1	**Initial temp**	**Final temp**	**Temp change**	**Q lost**	**Q/time**	**Heat transfer mechanism**
Cup covered						
Cup uncovered						
Cup covered						
Cup covered						

Part III: Heat transfer through radiation

1) Open the experiment file: *L3A3-2(Radiation).cmbl*
2) Set a heat lamp 35 cm in front of a can, at the same height; the face of the lamp and the can should be directly across.
3) Pour 75 ml of water (room temperature) into a black can. Place the cover tight on the can. Insert the temperature sensor through the cover. Place a piece of paper on the temperature sensor, so that it prevents radiation from lamp from reaching the temperature sensor directly.
4) Record the initial temperature of the water in Table 2. Begin graphing and turn on the lamp. Gently stir the can while collecting data.

5) When the graphing is over, record the final temperature. Store the run. Turn off the lamp.
6) Repeat steps 2-5 with a white shiny cup PLACED IN THE SAME EXACT PLACE AS THE BLACK CAN. Record the temperatures.
7) Cut and Paste the graphs into Word then print all graphs.

Table 2	**Initial temperature**	**Final temperature**	**Change in temperature**	Q_{gained}
Black can				
Shiny can				

QUESTION 5: Which cup received more heat? Calculate the ratio Q_{black}/Q_{shiny}.

QUESTION 6: Based on your results in Table 2, which can will lose heat by radiation faster?

8) To test your prediction (question 6) pour 75 ml hot water (80 degrees) in the black can. Record the initial temperature. Collect data for 5 min. Record the final temperature. Repeat the step 7 with the shiny can.

Table 3	**Initial temperature**	**Final temperature**	**Change in temperature**	Q_{lost}
Black can				
Shiny can				

QUESTION 7: Which of the cans lost more heat?

Experiment: Heat Transfer

Purpose :

a. to compare the effectiveness of 3 heat transfer mechanisms
b. to experimentally verify the relationship between the rate of the heat transfer and temperature difference

Materials:

- LabPro interface
- LoggerPro software
- Styrofoam Cups
- Electric immersion heater
- Heat lamp
- Black and shiny identical containers
- 2 temperature probes

Preliminary Questions:

1) During the spring, the outside temperature is (in average) 15 degrees Celsius, and during the winter it is 5 degrees Celsius. Compare the energy costs to maintain an inside temperature of 25 degrees Celsius, assuming that the price of energy does not change.

2) Consider 2 identical cups containing the same amount of water at the same temperature of 45 degrees Celsius, one of them covered and the other one not. After 5 minutes, would you expect the temperature to be the same in the 2 cups? Why?

3) 2 identical closed metallic cups containing water are exposed to light from a lamp. One of the cups is painted black, the other one is white.

a) Will the temperature of the water change? Why?

b) Which cup will have a higher temperature after 5 minutes?

c) If the 2 cups contain hot water (at 85 degrees Celsius) which one will cool down first? Why?

Introduction:

The transfer of heat energy from a cup containing hot water to its surroundings takes place through several different mechanisms. There is **conduction** through the cup into the table and the surrounding air. There is **convection** from the air flow that results when the air is heated by the water and cup. Finally, there is **radiation** the electromagnetic waves (mostly infrared) emitted from the hot surfaces of the cup.

The rate of the heat transfer by conduction depends on the transfer surface, the length and the temperature difference between the cup and the surroundings:

Equation 1: $Q/t = (kA\Delta T)/L$

The rate of the heat transfer by radiation depends on the temperature, surface area and the emissive properties of the cup:

Equation 2: $Q/t = \varepsilon\sigma A T^4$

The heat absorbed/released can be directly calculated from temperature change:

Equation 3: $Q = cm\Delta T$

The temperature change and the mass will be measured during the experiment

Experiment:

Part I: Heat transfer through convection

1) Plug two temperature sensors into the LabPro interface (CH1 and 2, respectively).
2) Start up the LoggerPro software then open the experiment file:

Additional Physics/Real Time Physics/Heat and Thermodynamics/L3A2-1(Cooling Down).cmbl

3) Record the room air temperature
4) Using an immersion heater, warm ~200 mL water in a beaker to 90 degrees Celsius. Quickly but carefully, pour a 75 ml water sample into two separate Styrofoam cups. Place a temperature sensor into each cup. Cover one of the cups but leave the other uncovered. Read the initial temperature of the water (around 85 degrees). Push "Collect" to start graphing.
5) Store this run.
6) Using the Examine/Analyze feature, record the initial and the final temperature for each graph. Record data in Table 1.
7) Cut and Paste the graphs into Word.

QUESTION 1: What is the heat transfer mechanism(s) for the covered cup? For the uncovered cup?

QUESTION 2: Calculate the heat lost by the covered and uncovered cup, respectively. What is the rate of heat transfer for the 2 cases?

Part II: Heat transfer through conduction

1) Record room air temperature
2) Heat water in a beaker to 70 degrees Celsius. Quickly pour 75 ml water into a Styrofoam cup. Put the temperature sensor in the cup and cover the cup. Read the initial temperature of the water (around 65 degrees). Push Collect to start graphing.
3) Store this run.
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6) Calculate for each case the heat energy transferred and the rate of the heat energy transfer.

QUESTION 3: Does your data agree or disagree with equation 1? Explain.

QUESTION 4: Based on your data, how does the effectiveness of convection vs. conduction compare, as mechanisms of heat transfer?

Mass of water =__________ *{should be the same for each of these trials}*

Table 1	**Initial temp**	**Final temp**	**Temp change**	**Q lost**	**Q/time**	**Heat transfer mechanism**
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Cup covered						
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Part III: Heat transfer through radiation

1) Open the experiment file: *L3A3-2(Radiation).cmbl*
2) Set a heat lamp 35 cm in front of a can, at the same height; the face of the lamp and the can should be directly across.
3) Pour 75 ml of water (room temperature) into a black can. Place the cover tight on the can. Insert the temperature sensor through the cover. Place a piece of paper on the temperature sensor, so that it prevents radiation from lamp from reaching the temperature sensor directly.
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Table 2	**Initial temperature**	**Final temperature**	**Change in temperature**	$\mathbf{Q_{gained}}$
Black can				
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QUESTION 5: Which cup received more heat? Calculate the ratio Q_{black}/Q_{shiny}.

QUESTION 6: Based on your results in Table 2, which can will lose heat by radiation faster?

8) To test your prediction (question 6) pour 75 ml hot water (80 degrees) in the black can. Record the initial temperature. Collect data for 5 min. Record the final temperature. Repeat the step 7 with the shiny can.

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QUESTION 7: Which of the cans lost more heat?

Experiment: Heat Transfer

Purpose :

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b. to experimentally verify the relationship between the rate of the heat transfer and temperature difference

Materials:

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