

INTERACTIVE THERMODYNAMICS EXPERIMENTS SUPPORTED BY ARDUINO TECHNOLOGY

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OVERVIEW

- Students of the 21st century. Why do we need to teach differently?
- Sokoloff – method. What is, and why is it useful?
- Experimental setup for studying thermal equilibrium
- Interesting worksheet for studying thermal equilibrium
- Results
- Possibilities for further improvement

**Rapidly changing
word**

**Generation Z and
alpha**

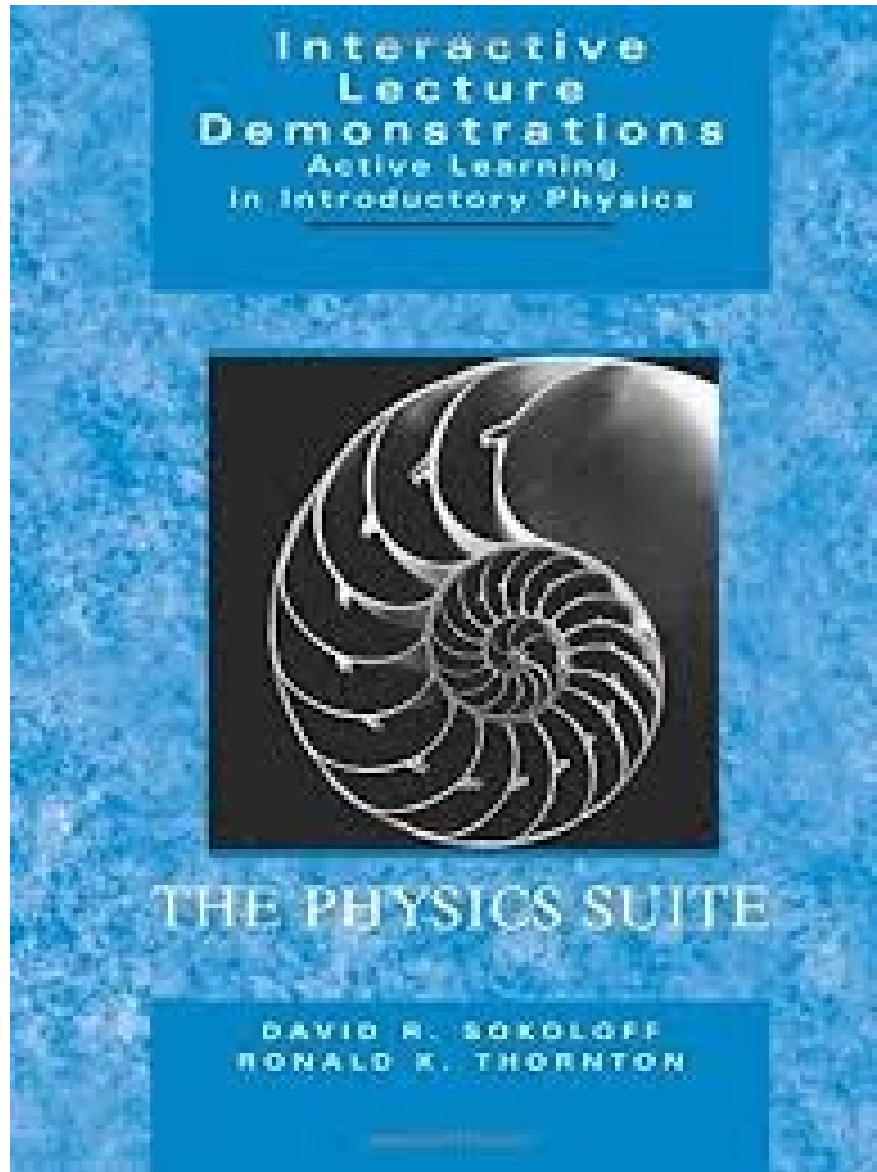
**Active
learning**



**Student –
centered
education**

**Competency – based physics
education**

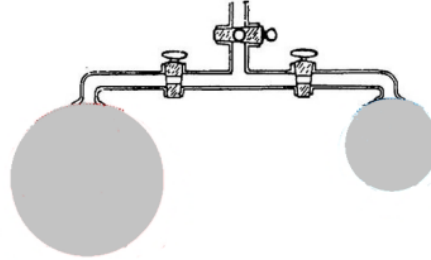
**Activity – based
education**



David R. Sokoloff: Interactive Lecture Demonstrations

Worksheet for the “Two Bubbles” Experiment

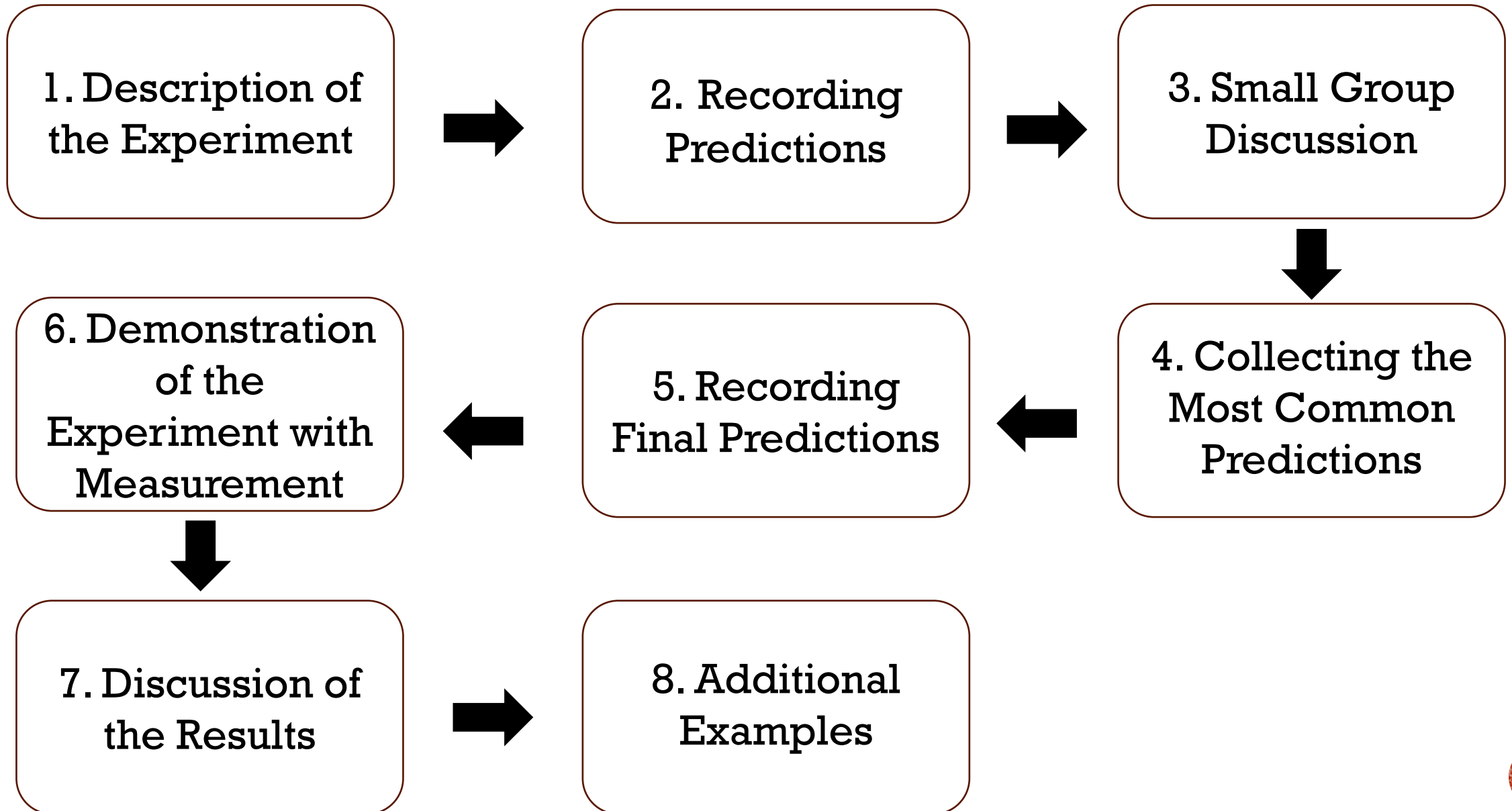
Experiment: A tube with three outlets is used. A smaller and a larger bubble are blown at each end of the tube, with a closed valve between them. The valves connecting the bubbles to the external air are then closed, and the valve between the two bubbles is opened. Observe what happens next.



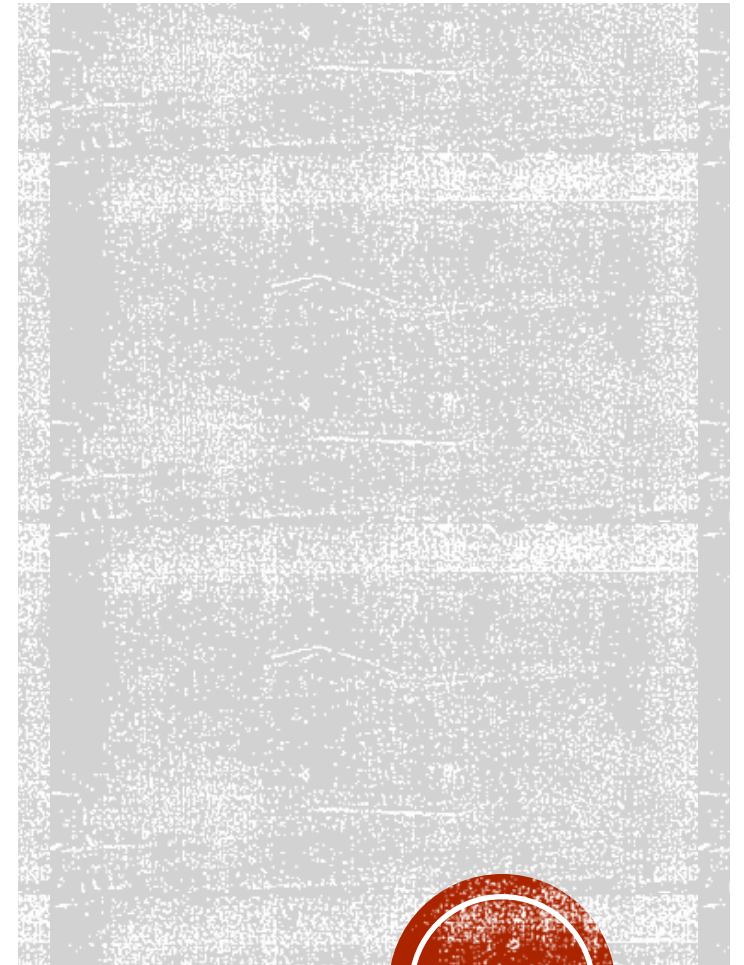
What do you think will happen to the size of the bubbles? Which bubble will grow, and which one will shrink?

Demonstration 7: A massive (heavy) cart (called Truck) is pushed toward a light cart (called Car) that isn't moving. Describe in words how $\vec{F}_{T \rightarrow C}$ (the force of Truck on the Car) compares to $\vec{F}_{C \rightarrow T}$ (the force of the Car on the Truck) during the collision. Make a rough graph of the forces over time.

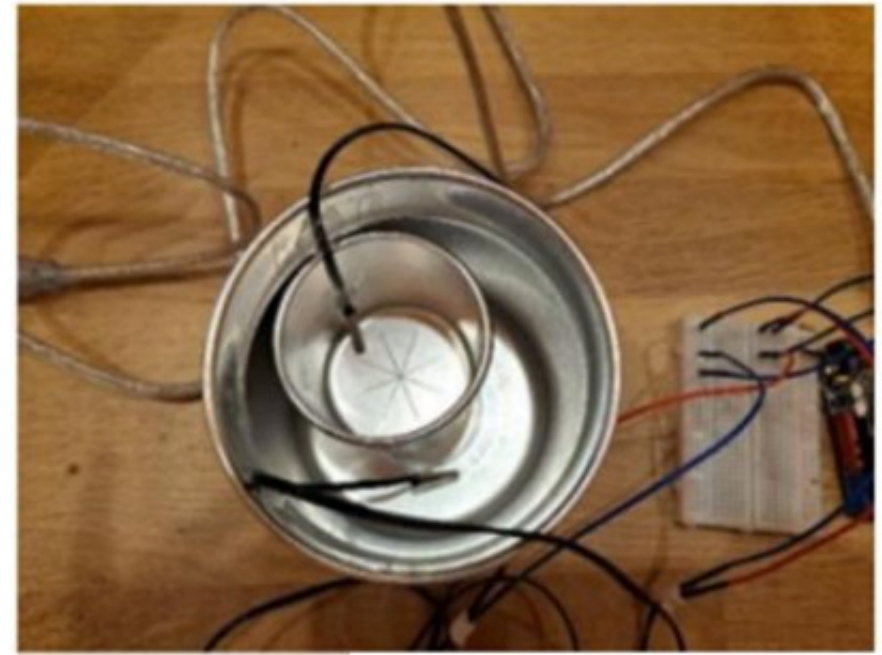
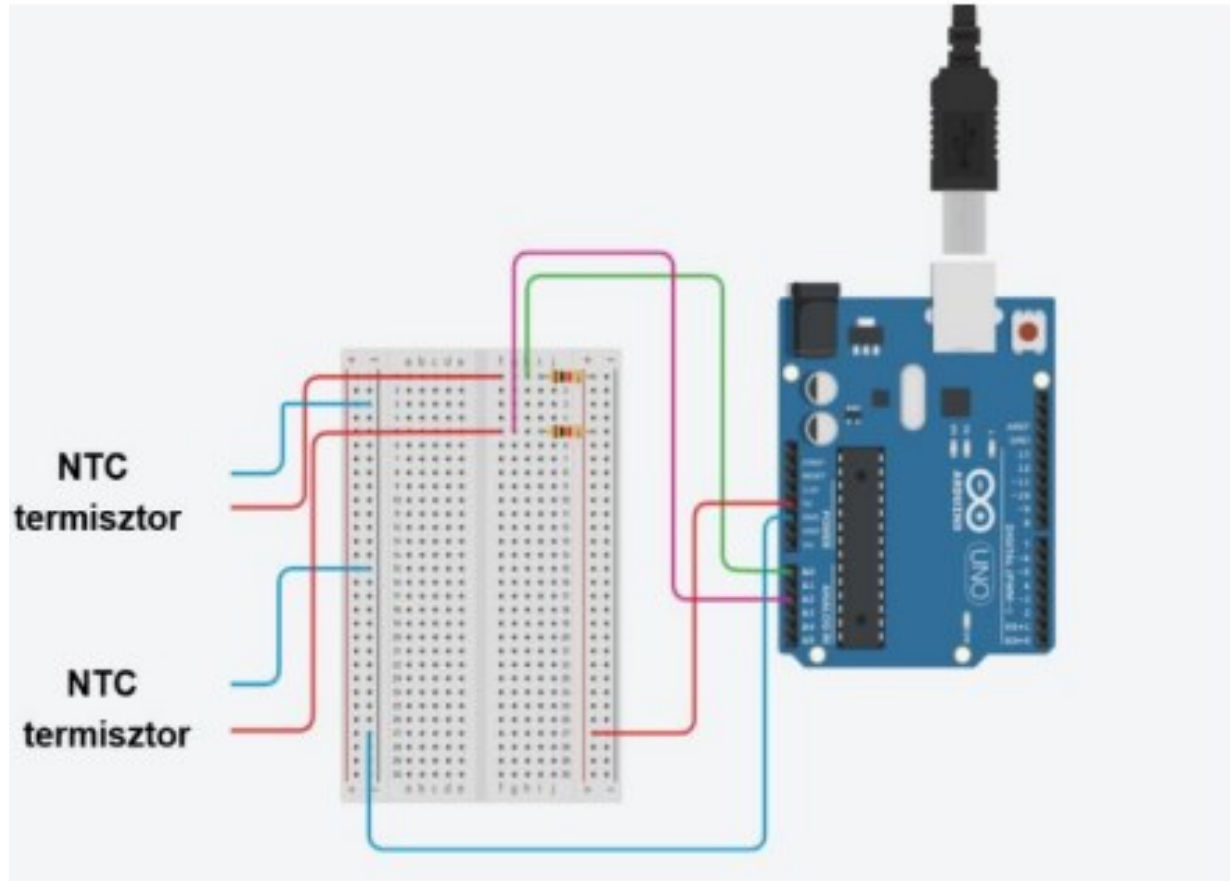
Sokoloff - method



INVESTIGATION OF THERMAL EQUILIBRIUM



Experimental setup



Make a guess! 😊

- *A cup of hot tea is placed into cold water in order to cool it down more quickly to a drinkable temperature. How do the temperatures of the water and the tea change during their interaction?*
- *The temperature of the water and the tea after some time. How do you think the final temperature will be?*
- *Plot the temperature of the water and the tea as a function of time.*
- *Is it possible for the final temperature to be less than 291 K?*
- *Is it possible for the final temperature to be greater than 291 K?*

Fill-in-the-blank text:

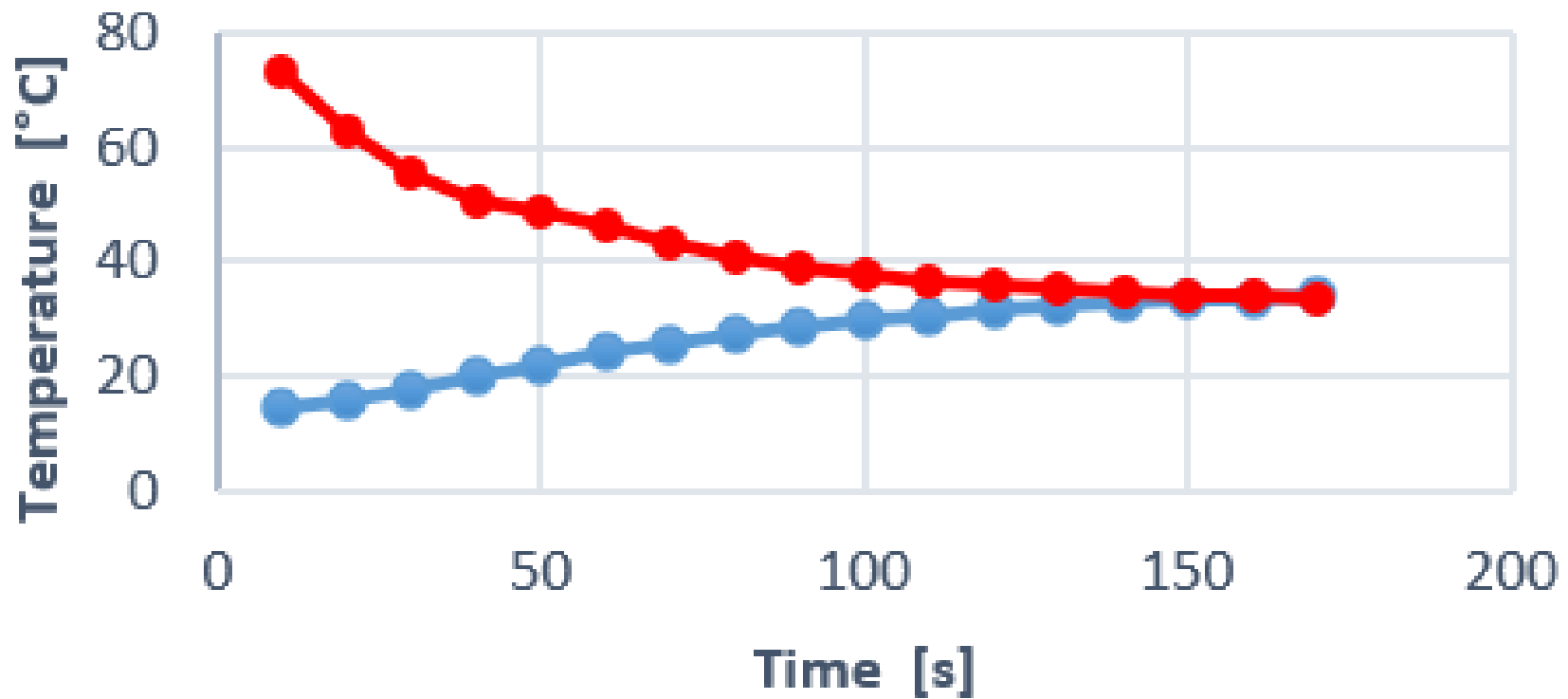
Particle Structure Interpretation

The hot water **transfers** heat to the wall of the container it is in contact with. The container then causes the adjacent, colder water particles on the other side to move **faster**. During **collisions** between the fluid particles, they transfer energy to neighbouring particles, until all the fluid particles start moving **faster**, and the **energy** and **temperature** of the fluid increase.



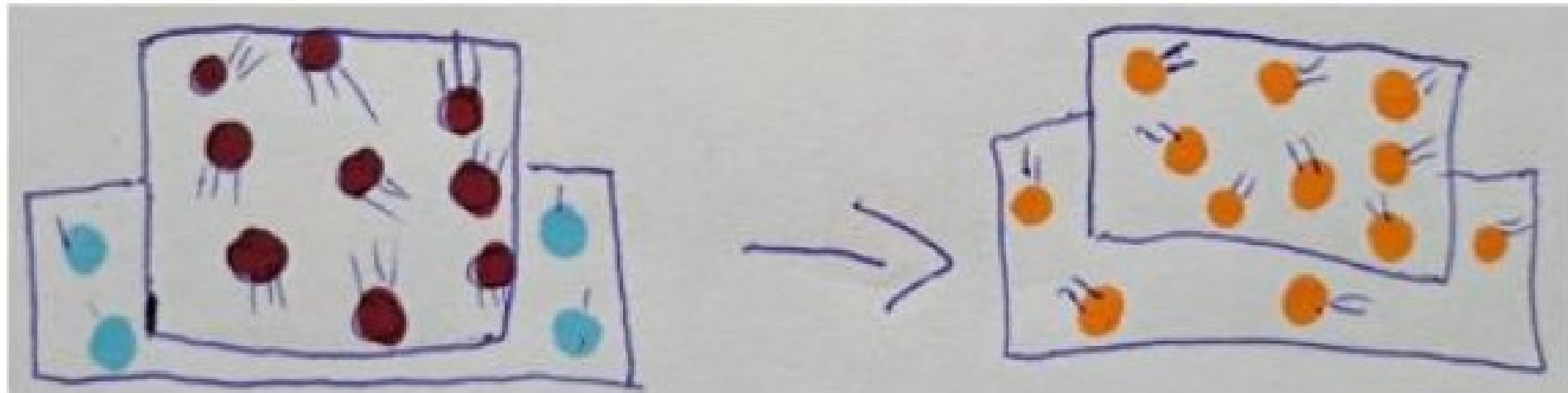
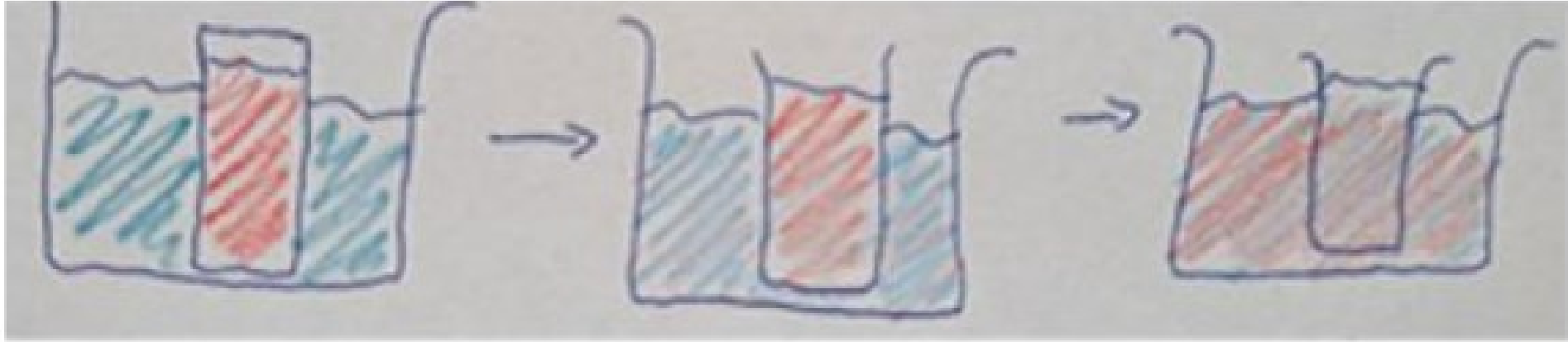
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Thermal equilibrium



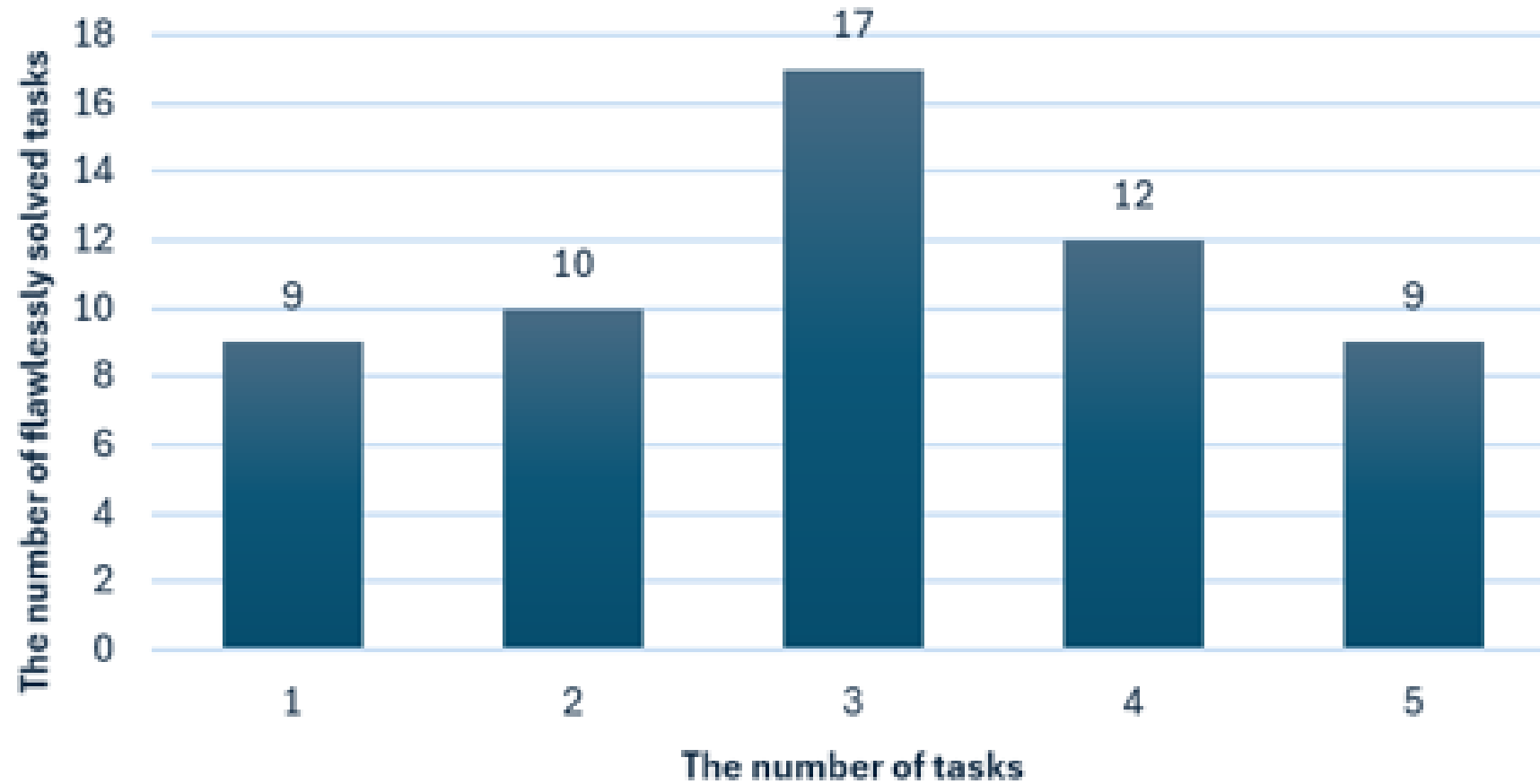
Analyzing the answers from submission sheet

1. What characterizes thermal equilibrium?
2. Determine what possible common temperature can develop during the thermal interaction between $80\text{ }^{\circ}\text{C}$ tea and $20\text{ }^{\circ}\text{C}$ water. Justify your answer.
3. Plot the temperature of the two liquids as a function of time on the same graph.
4. Explain what determines which liquid undergoes a greater change in temperature.
5. Create an explanatory particle-structure diagram to interpret the thermal interaction (putting a cup of hot tea into cold water)



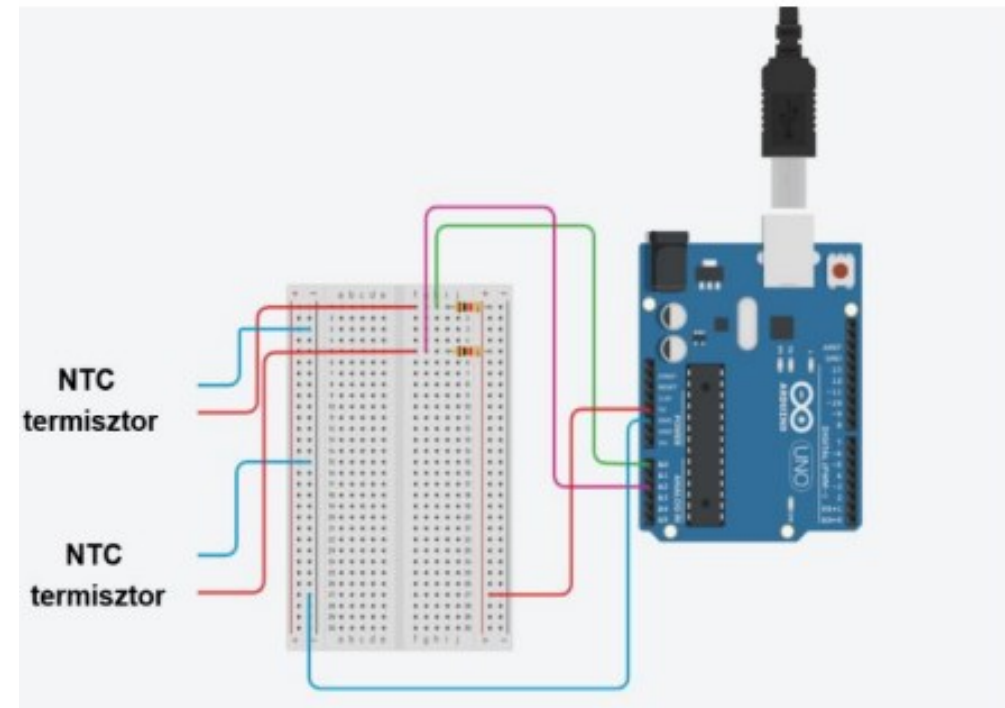
Explanatory particle-structure figures showing the formation of thermal equilibrium — students' work.

Overall results of the tasks



Possibilities for further improvement

- Discuss the circuit diagram
- Built the circuit themselves
- log transformation





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