THE BEST WAITRESS: COOLING LIQUIDS

Núria is a college student who works as a part-time waiter at the university cafeteria. She has observed that customers have diverse opinions on what a perfect coffee is. She is faced with the following dilemma: One of her customers is not going to drink her hot coffee with milk for ten minutes, but wants it to still be as hot as possible. Núria asks herself the question: Is it better to immediately add the room-temperature milk, stir the coffee, and let it sit for ten minutes, or is better to let the coffee sit for ten minutes and then add and stir in the milk?

Your tasks in this activity will lead you to help the waitress to find the answer to this demand.

Before going on, write down your prediction, explain your reasoning and how you could design an experiment to help the waitress!

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A. Preparation

1) The number in the table on the right represent data collected from an experiment: A distinct amount of hot water with an initial temperature of 80°C is cooling down in a room with an air temperature of 24°C.

Time (min)	Temperature (°C)
0	80
2,5	70
6	60
10,5	50
17	40
30	30
54	25
90	24

2) Find out how long it takes the water to cool down by 5°C. Specifically, look at the following temperature intervals: from 80°C to 70°C, from 70°C to 60°C, from 60°C to 50°C, from 50°C to 40°C, from 40°C to 30°C, and from 30°C to 25°C. Fill in the table on the right below.

3) Make a prediction and show your reasoning concerning the temperature the water will show after a time period oft wo hours.

Temperature interval	Time (min)	Temperature difference (°C)
[80°C; 70°C]	2,5	10
[70°C; 60°C]		
[60°C; 50°C]		
[50°C; 40°C]		
[40°C; 30°C]		
[30°C; 25°C]		
[25°C; 24°C]		

Explain what you found out:

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B. Modeling the situation in the laboratory

Hint: To complete this experiment in a short time, you will use a small quantity of hot water at least about 30°C above room temperature. Record the water's temperature as it cools with a temperature sensor connected to a calculator.

1) Use your temperature sensor to find out the room temperature: T_{Room} = ….. °C
2) Set up the calculator and interface for data collection. Use 10 minutes for data collection time and set the data collection rate to one sample per minute. Then, collect your cooling data for ten minutes and inspect you graph.
3) Complete the table below by filling in your collected data to find out the relationship between the change in the water temperature and the temperature difference $T_{difference}$ between Liquid and room ($T_{Difference} = T_{Water} - T_{Room}$). Use the specified time intervals: [0min; 1min], [1min; 2min], ..., [9min; 10min].

Time t (min)	Water temperature T_{Water} (°C)	$T_{Difference}$ (°C)	Change of T_{Water} per minute ($=\frac{\Delta T}{\Delta t}$)	$\frac{\Delta T}{\Delta t}$ divided by $T_{Difference}$
0				
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

C. Show your results:

Explore if your data support the following statement: **The amount of thermal energy which moves from one body to another is proportional (by a constant k) to the difference in temperature between the two bodies** ($T_{Difference}$). What value did you get for k? k = ……

F1) Explain once more the relationship described in the statement above. Possibly, try to also introduce a formula for describing the relationship?

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F2) Explain in your own words what you learned from the experiment at all.

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D. Further considerations:

1) When the time for data collection t is very large, for example, two hours, what value of temperature difference do you expect? What is the corresponding temperature of the water at that time? Please, also show your reasoning.

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2) How can you influence the time which the water needs for cooling down?

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E. Summary:

Please, complete the following sentences:

If a specified amount of water with room temperature is added early to a cup of hot water and not after a time period of ten minutes then, ……

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Therefore, I recommend Núria:

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F3) Can you explain why the point in time for adding the milk makes a difference?

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Further questions:

a) It was easy for our group to design our own experiment and find an appropriate solution to the given task. Tick a number 1, 2, 3, 4 or 5 (1: strongly agree 5: strongly disagree).

Please explain your answer:

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b) The guidance in the worksheet helped us to perform the experiment and analyze the data in order to understand the physics behind and apply physics concepts to everyday life situations. Please, tick a number 1, 2, 3, 4 or 5 (1: strongly agree 5: strongly disagree).

Please explain your answer:

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