Task 203
Thermometers gauging

Preliminary requirements

Before reading this instruction and carrying out the experiment find information about:

1. The state of thermodynamical equilibrium – what does it mean that two thermodynamical systems are in equilibrium?
2. What does say the 0-th law of thermodynamics? Explain the concept of temperature.
3. International Practical Scale of Temperature. Absolute scale of temperature.
4. The phenomenon of temperature expansion of liquids and solids.
5. Devices to measure temperature: thermometers, thermopairs, .
6. Scaling of thermometers.

Literature

- R. Resnick, D. Halliday: *Physics*, part 1 , John Wiley and Sons, Inc., New York 1973
- H.D. Young, R.A. Freedman, *University Physics: with modern physics*, Addison-Wesley Publ. Co, San Francisco 2000.
- E. Hecht, *Physics: Calculus*, Brooks/Cole Thomson Learning 2000.

The aim of a task

The aim of this task is to gauge (scale) two thermometers.

Description of the method of measurements

Liquid thermometer consist of a container filled with liquid joined to a capillary closed tube. The capillary tube is equipped with tape measure. The liquid usually used is alcohol or mercury. When temperature grows, volume of liquid increases i.e. its level in capillary tube raises.

Scaling thermometers means to assign the value of temperature to the scale of tape measure. It can be done in two ways. First way is to compare our thermometer with a model one. Second way, which is used in this task, is to determine the level of liquid, at least, at two known temperatures - named model (constant) points. Here in this task those model points are:

- freezing point (273,15 K),
- boiling point (373,15 K).

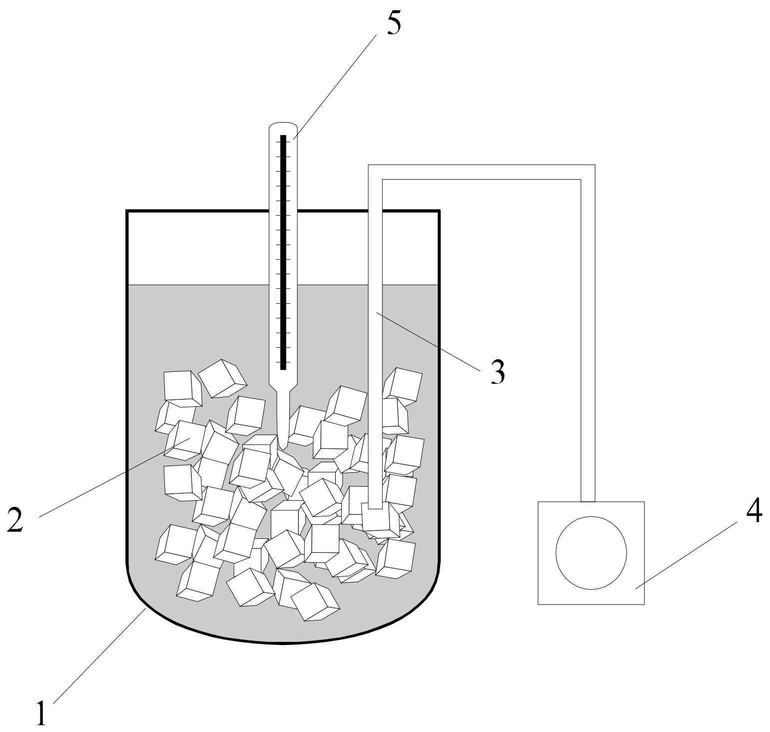
The scale of temperature based on those model points (at normal pressure 1,013 105 Pa) is known as Celsius scale of temperature (centigrade) i.e. freezing point is t_{C1}= 0ºC, boiling point is t_{C2}= 100ºC .

Description of apparatus

Apparatus consist of two separate systems:

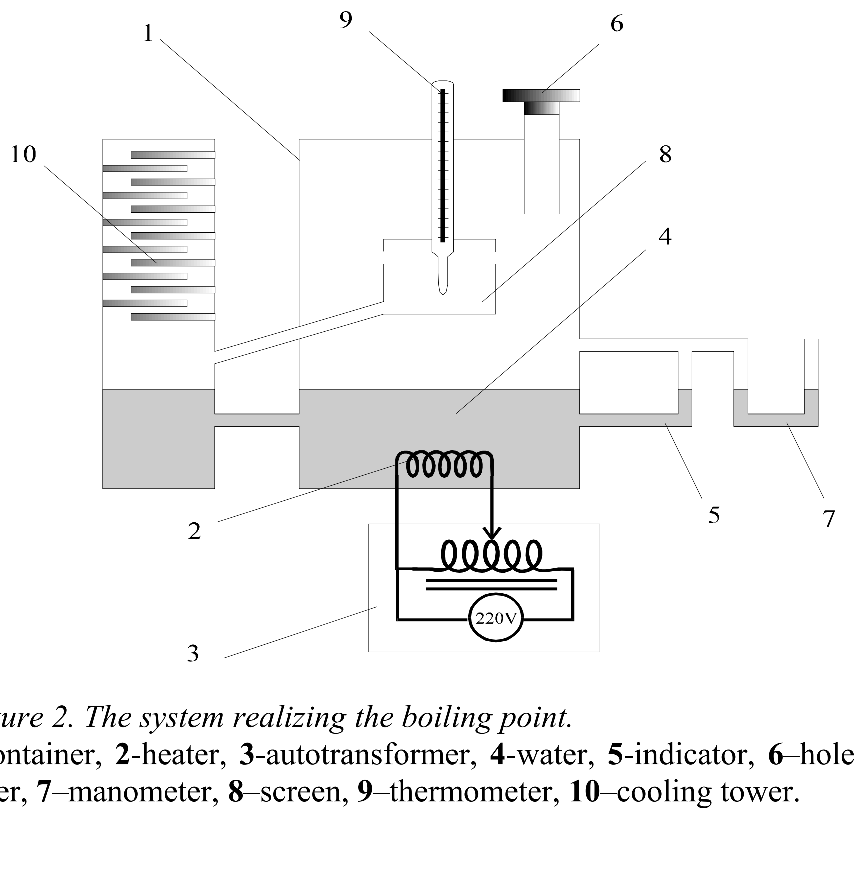
- one to realize the freezing point,
- one to realize the boiling point

and katetometer which is used to determine the level of liquid in thermometers.



Picture 1. The system realizing the freezing point.
1-container, **2**-mixture of water and ice, **3**-tube to air the mixture, **4**-pump, **5**-thermometer.

System realizing the freezing point consist of a container (thermos™ flask, vacuum flask) filled with a mixture of distilled water and ice. This mixture should be constantly mixed in order to remain in a state of equilibrium. This is ensured by a tube joined to pump which air the water.
By a hole in a cover a handle with thermometers can be installed.



Picture 2. The system realizing the boiling point.
1-container, **2**-heater, **3**-autotransformer, **4**-water, **5**-indicator, **6**–hole in a cover, **7**–manometer, **8**–screen, **9**–thermometer, **10**–cooling tower.

The system realizing the boiling point consist of a metal container equipped with electric heater. The power of a heater is adjustable. The container is filled with distilled water. The level of water can be controlled by looking at the indicator. The pressure of a steam is controlled by a manometer, which is also at the same time a safety valve. While water boils steam is gathering on a screen. It condenses there so inside the screen one achieves a state of equilibrium between condensed steam and water. The measured thermometers can be installed inside a screen by a hole in a cover. Condensed steam as a water flows down to a cooling part of the container.

Katetometer built with a vertical column on which one can move a small telescope. The telescope among other things is equipped with an eye-piece with screw. By this screw one can adjust the cross on an eye-piece precisely eg. at the end of a mercury column in order to determine its level.

The course of measurements

Before starting the measurement process the system should be prepared.
In order to prepare the system to achieve a freezing point:

a) fill the container with distilled water and ice to ¾ its volume and cover it,
b) insert a tube to air the mixture and turn on the pump,
c) into a hole in a cover insert a handle with thermometers.

Wait until water, ice and liquid in thermometers become in equilibrium. In the meanwhile, prepare the system to achieve a point of boiling water.

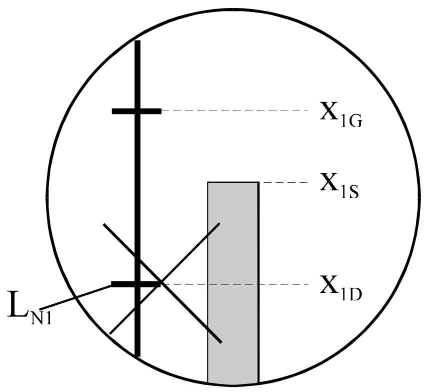
In order to prepare the system of boiling water point:

(**Caution! Do not try to remove the cover of a container**)

a) check level of water in a container. It should be between scratches on an indicator tube (compare the *Picture* 2),
b) if needed fill the container with distilled water,
c) turn on the heater and also a radiator. Adjust voltage of the heater on 150V,
d) wait about 10 minutes until water boils. Then decrease voltage of a heater to 100V.

Measurements:

The measurements can be carried out when water, ice and thermometers are in a state of equilibrium i.e. when the level of liquid in thermometers is constant in time.



Picture 3. Method of determining level of liquid.

1. Place microscope in such a way that you can see the end of a mercury column in thermometer.
2. Read, without any apparatus, on a tape measure the level L_{N1} of a mercury column.
3. Turn the screw of a katetometer in order to put the cross of en eye-piece onto a line which is below the level of mercury column.
4. Notice the position x_{1D} of a screw of a katetometer (compare the Picture 3).
5. Next turn the screw of a katetometer in order to put the cross of an eye-piece onto a line which is above the level of mercury column and take down the position x_{1G} of a screw. Take notice

whether the screw was being rotated more than once. In such a case to the number x_{1G} it should be added 100.
6. Finally, put the cross on the end of the column and notice x_{1S} .
7. Repeat the points 1 ÷ 6 for the other liquid thermometer and write down L_{N2}, x_{2D}, x_{2G}, x_{2S}.
8. Change the system i.e. insert the handle with thermometers into the container with boiling water.
9. Wait a few minutes until saturated steam and thermometers achieve a state of equilibrium.
10. Repeat actions described in points 1 ÷ 6 for the mercury thermometer and determine the quantities L_{W1}, y_{1D}, y_{1G}, y_{1S} (in temperature 100ºC) which are analogous to L_{N1}, x_{1D}, x_{1G}, x_{1S} (determined in temperature 0ºC).
11. Again repeat actions described in points 1 ÷ 6 but for the other thermometer in order to find the quantities L_{W2}, y_{2D}, y_{2G}, y_{2S} .
12. Results write down in a table

temperature	*Mercury thermometer*				*Liquid thermometer*			
273,15 K	L_{N1}	x_{1D}	x_{1G}	x_{1S}	L_{N2}	x_{2D}	x_{2G}	x_{2S}
373,15 K	L_{W1}	y_{1D}	y_{1G}	y_{1S}	L_{W2}	y_{2D}	y_{2G}	y_{2S}

Report preparation

Report should include:

1. Short description of the idea of the method of measurements.
2. Table consisting results of measurements.
3. Calculations:

a) the height of a column of mercury $L_1(0ºC)$ in the temperature of 273,15 K (0ºC)

$$L_1(0^o C)=L_{N1}+\frac{x_{1S}-x_{1D}}{x_{1G}-x_{1D}}$$

b) the height of a column of mercury $L_1(100ºC)$ in the temperature of 373,15 K (100ºC)

$$L_1(100^o C)=L_{W1}+\frac{y_{1S}-y_{1D}}{y_{1G}-y_{1D}}$$

c) the height of a column of liquid $L_2(0ºC)$ in the temperature of 273,15 K (0ºC) for liquid thermometer

$$L_2(0^o C)=L_{N2}+\frac{x_{2S}-x_{2D}}{x_{2G}-x_{2D}}$$

d) the height of a column of mercury $L_1(100ºC)$ in the temperature of 373,15 K (100ºC)

$$L_2(100^o C)=L_{W2}+\frac{y_{2S}-y_{2D}}{y_{2G}-y_{2D}}$$

e) the sensitivity of mercury thermometer Γ_1

$$\Gamma_1=\frac{L_1(100^o C)-L_1(0^o C)}{100}$$

f) the sensitivity of mercury thermometer Γ_2

$$\Gamma_2=\frac{L_2(100^o C)-L_2(0^o C)}{100}$$

4. Insert calculated quantities into a table

Mercury thermometer		
Position of a mercury column at 0ºC, $L_1(0ºC)$	Position of a mercury column at 100ºC, $L_1(100ºC)$	sensitivity Γ_1

Mercury thermometer		

Liquid thermometer		
Position of a liquid column at 0ºC, $L_2(0ºC)$	Position of a liquid column at 100ºC, $L_2(100ºC)$	sensitivity Γ_2

5. Conclusions

The last but not least point of a report. You are asked to comment:

- the used method,
- your results,
- their precision, accuracy.