Student Experiments

Manual

HEAT 2

P9160-5C

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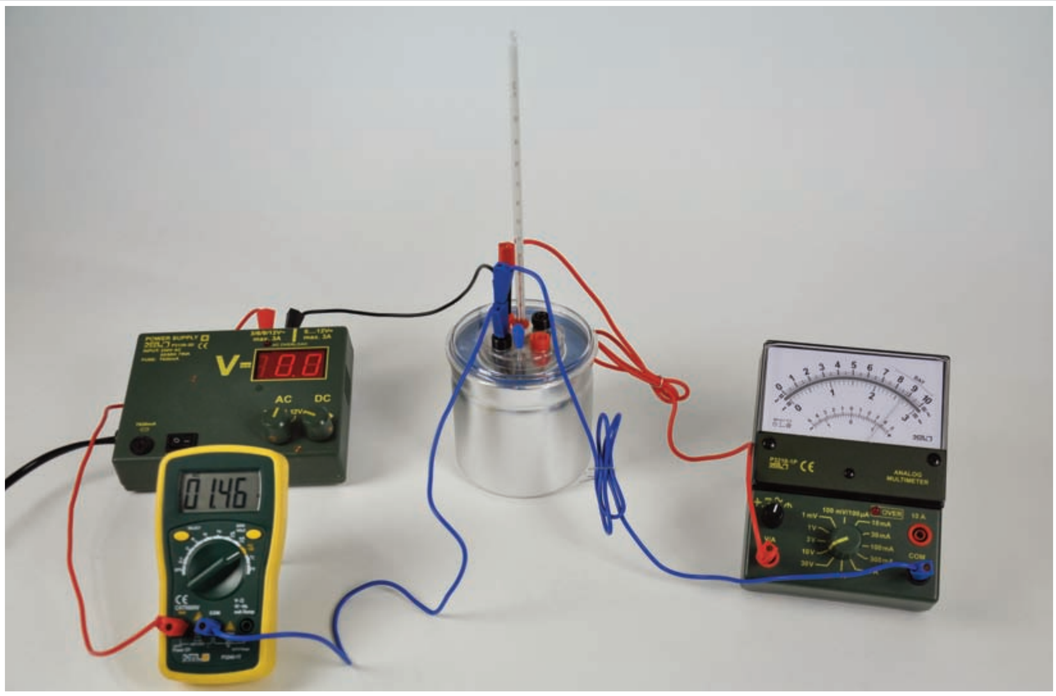
INDEX

SPECIFIC HEAT OF WATER

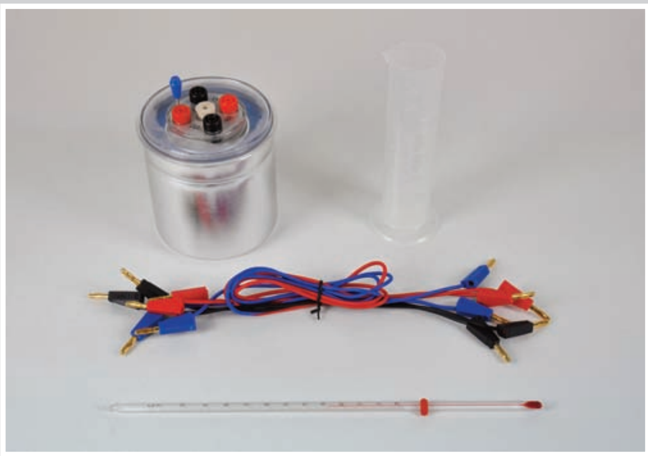
TDS 2.2

Required Kit:
P9902-5C Heat 2



Material:
1x Joule's calorimeter universal
1x Thermometer graduated

Additionally required:
1x Measuring cylinder
2x Measuring instruments, connecting cables
and power supply



SPECIFIC HEAT OF WATER

TDS 2.2

If the costs of a bath-tub are to be calculated, the amount of energy that is required to heat 1kg of water by 1 degree has to be known.

Preparation:
Arrange according to the illustration. 100 ml of water gets filled into the calorimeter (measured by means of the measuring cylinder!). The heating spiral gets inserted in the calorimeter and an A.C. of 9V is applied. The electric power supply is not switched on yet. An ammeter (measuring range of 10A) gets connected in series with the heating spiral in order to measure the electric current. The applied voltage gets measured by means of a voltmeter at the plug-in connection of the heating spiral. The thermometer is pushed through the cover of the calorimeter. The water temperature in the calorimeter gets measured and recorded.

Experiment:

The electric power supply gets switched on and the time gets recorded (set stopwatch or check time on a wrist-watch). The current intensity and the voltage get measured and recorded. The heating lasts for exactly 20 minutes. Then the eletric power supply gets switched off, the water in the calorimeter gets mixed (up and down movement of the twirling stick) and the temperature of the water gets read off.

Evaluation:
Electric energy = voltage x current intensity x time
(Joule) (Volt) (Ampere) (seconds)

$$W = U \times I \times t$$

Mass of water m = 0,1 kg

Time t = 200 s

Current intensity I = ...A

Voltage U = ...V

Electric Energy W = ...J

Initial temperature T_1 = ...°C

Final temperature T_2 = ...°C

Rise in temperature: ....°C

Supplied energy: ....J

Now the energy which is required for a specific rise in temperature of 0,1 kg of water is known. Based on this the energy which is required to heat 0,1 kg of water by 1°C can be calculated easily:

Energy required: ….. J

In order to heat 1 kg of water by 1°C, we require ten times more energy, meaning .... J.

The value of specific heat indicated in the manual is 4186 J/kg °C

In this experiment numerous errors may occur. Consider what kind of errors they are.

Conclusion:
The specific heat of water is equal to the amount of heat (amount of energy) that is required to heat 1 kg of water by 1°C.

QUANTITATIVE HEAT EXPANSION OF GASES - GAY LUSSAC LAW (ABSOLUTE ZERO POINT)

TDS 3.1

Required Kit:
P9902-5C Heat 2

Material:
1x Joule's calorimeter universal
1x Lid with stoppers
1x Sphere for Gay Lussac
1x Manometer for Gay Lussac
1x Thermometer graduated

QUANTITATIVE HEAT EXPANSION OF GASES - GAY LUSSAC LAW (ABSOLUTE ZERO POINT)

TDS 3.1

Theory:
The thermal state of a gas is defined through the parameters pressure, volume, temperature and amount of substance.

$p \cdot V = n \cdot R \cdot T$	p….pressure V….volume n….amount of Mol R….gas constante; $R = 8{,}3\ J\ mol^{-1}\ K^{-1}$ T….absolute temperature

If V and n are constant, p and T are directly proportional to each other due the thermal equation of state. This conclusion is known as the "Gay Lussac law". The goal of this experiment is to prove the direct proportionality of p and T (if V and n are constant) and to estimate the value of the absolute zero point.

Experiment:

The thread of the manometer gets sticked in the holes of the lid from above. Then it gets screwed with the hollow metal sphere from below. The manometer is now indicating the pressure of the air inside the sphere. Now the beaker of the calorimeter gets filled with water (the sphere should be completely covered by the water). The temperature of the water is measured by the thermometer which is secured by a silicone stopper.

The air inside the hollow metal sphere (approx. 2 minutes, watch the manometer) adjusts to the temperature of the water within a short time. If there are no changes at the display of the manometer anymore, the temperature of the air (inside the hollow metal sphere) can be read off from the thermometer and the air pressure from the manometer. Transmit the values into the chart. Now we are going to change the temperature of the water to generate more pairs of value.

Advices for teachers:
To ensure a quick performance of the experiment for several groups, it is recommended to prepare enough water with different temperatures (ice water, cold water, warm water, hot water) for students and pupils.

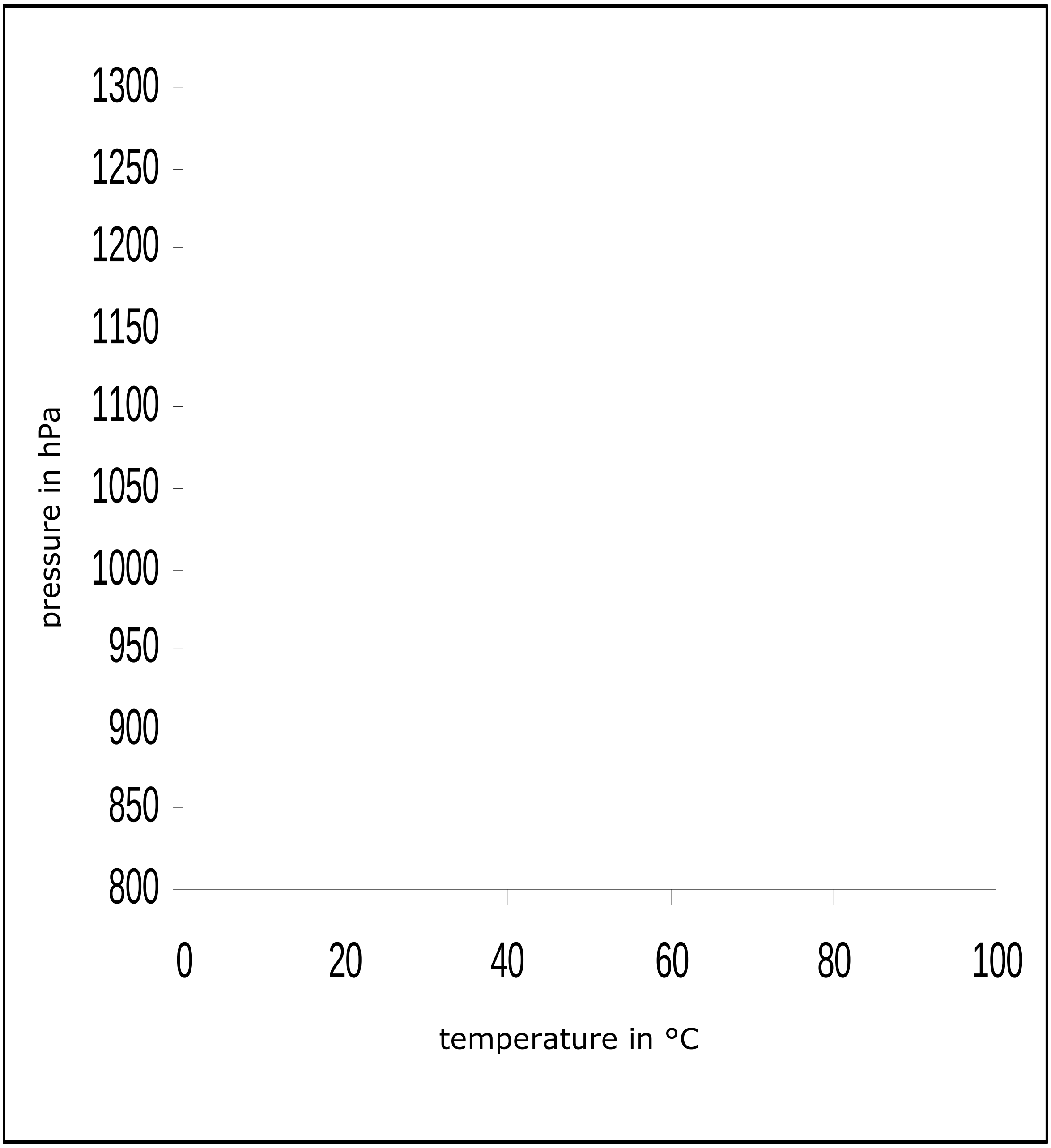
QUANTITATIVE HEAT EXPANSION OF GASES - GAY LUSSAC LAW (ABSOLUTE ZERO POINT)

TDS 3.1

We change the water in the beaker several times to change the air temperature inside the sphere and tarnsmit the generated value paris into the chart:

T/°C					
p/hPa					

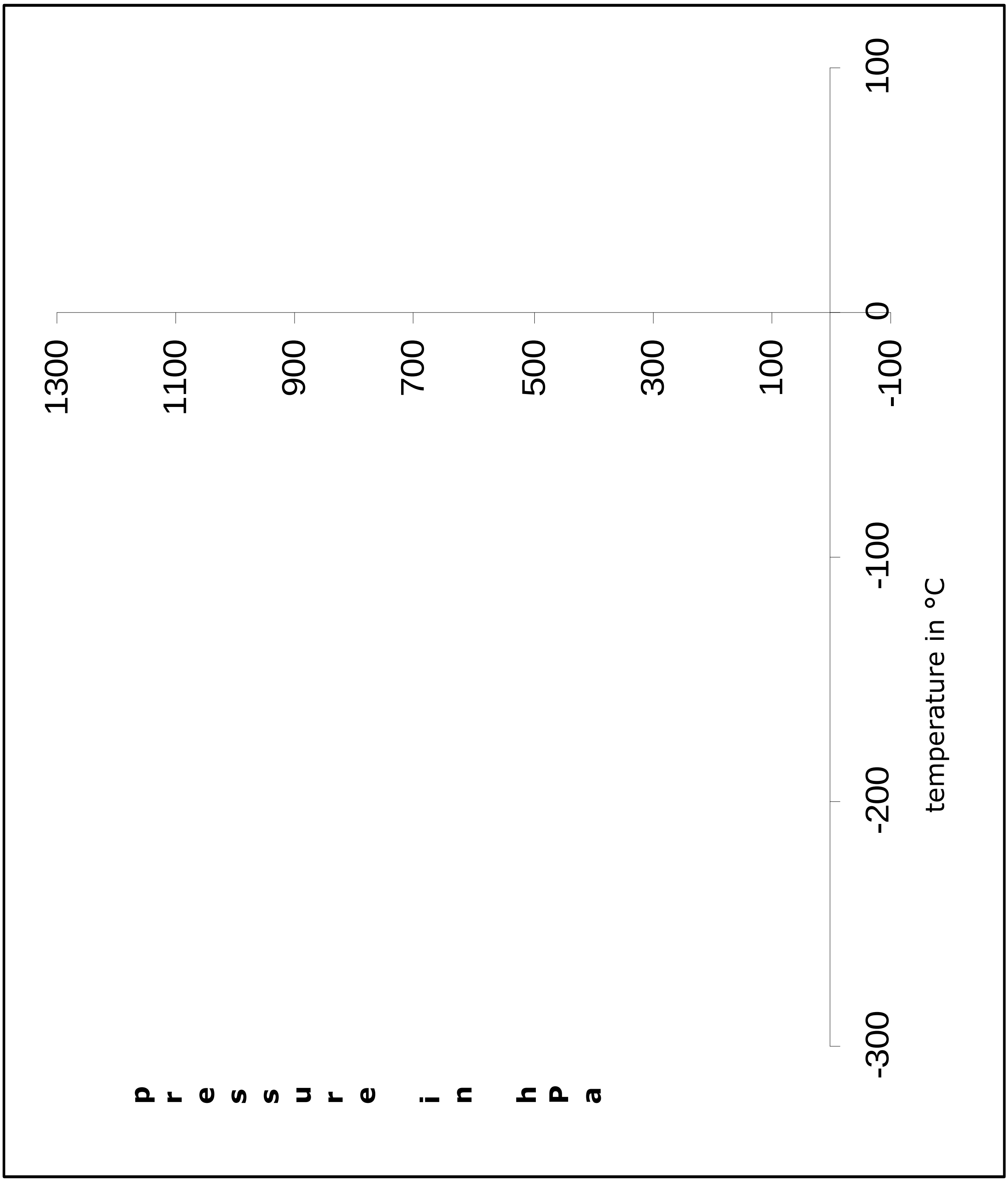
Now the generated values can be transmitted into a diagram.



QUANTITATIVE HEAT EXPANSION OF GASES - GAY LUSSAC LAW (ABSOLUTE ZERO POINT)

TDS 3.1

To estimate the absolute zero point, we transmit the value pairs of our chart into a bigger diagram:



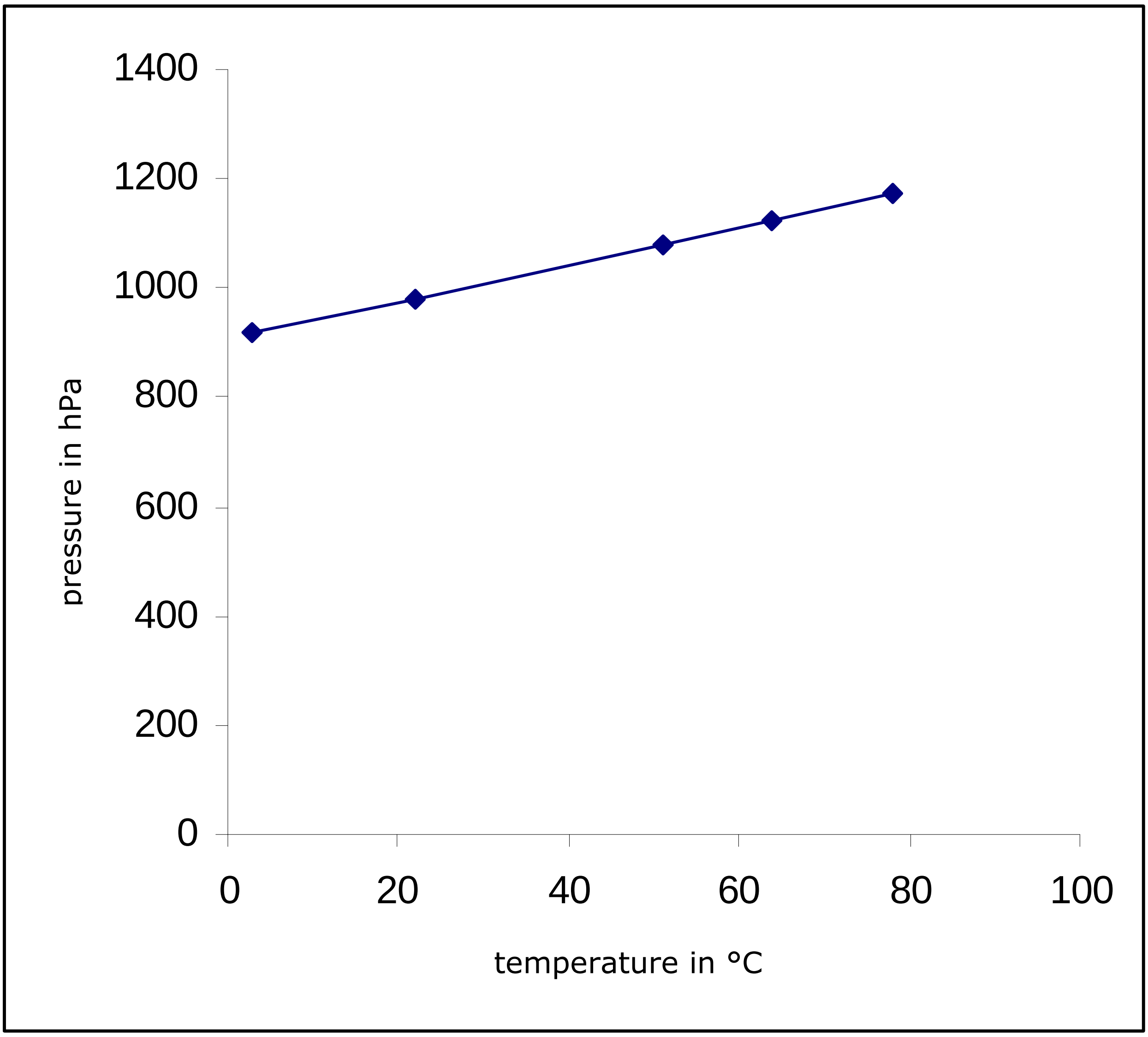
QUANTITATIVE HEAT EXPANSION OF GASES - GAY LUSSAC LAW (ABSOLUTE ZERO POINT)

TDS 3.1

Example:
The following values have been measured:

T/°C	3	22	51	64	78
p/hPa	920	980	1080	1125	1175

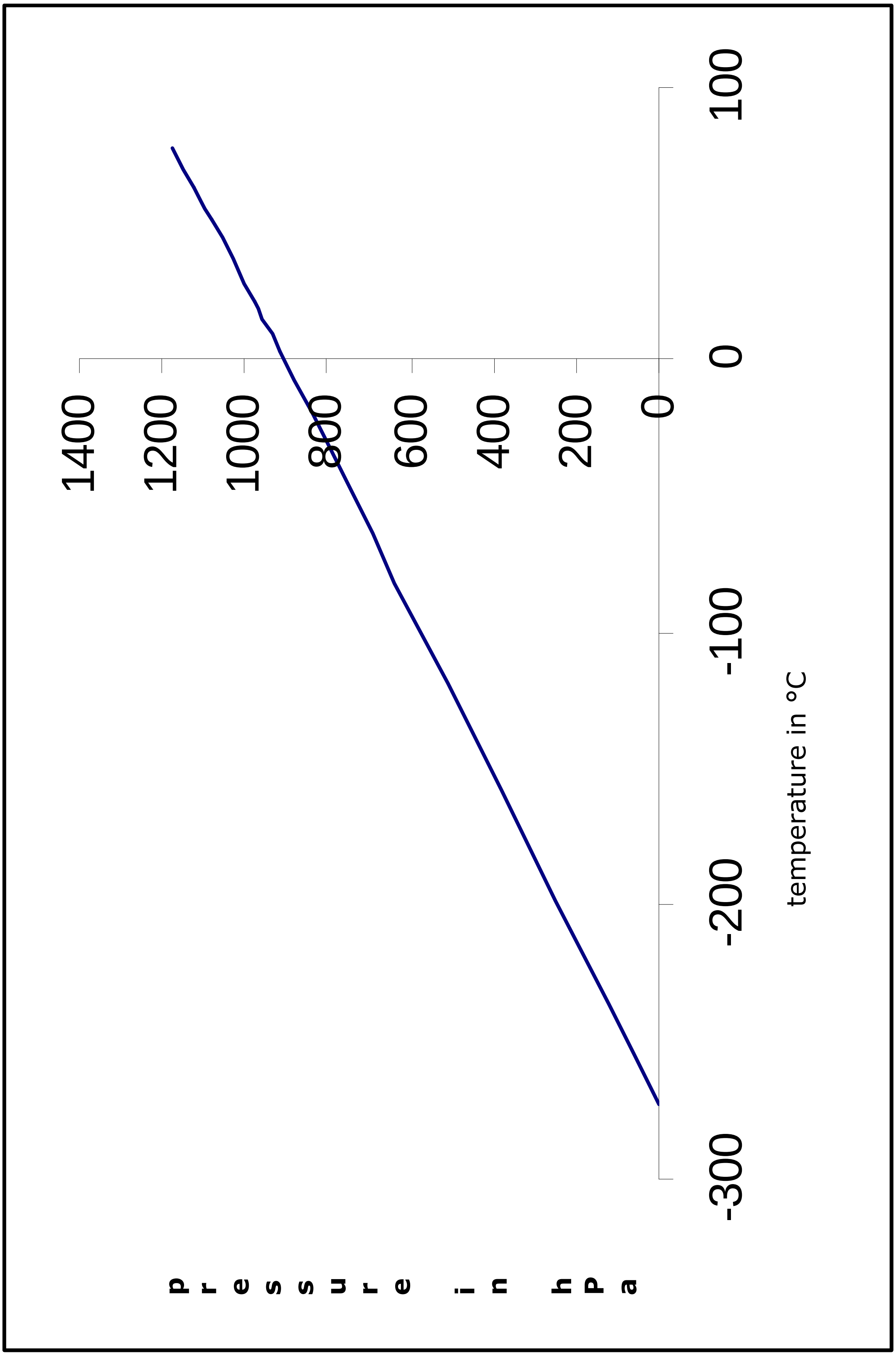
This results in the following diagram:



QUANTITATIVE HEAT EXPANSION OF GASES - GAY LUSSAC LAW (ABSOLUTE ZERO POINT)

TDS 3.1

When we extrapolate into the negative temperature range, the function of the t-axis intersects the absolute zero point.



QUANTITATIVE HEAT CONDUCTION OF SOLIDS

TDS 3.2

Required Kit:
P9902-5C Heat 2

Material:
1x Joule's calorimeter universal
1x Lid with stoppers
1x Rods for heat-conduction
1x Thermometer graduated

Aditionally required:
Hot water
Warm water

QUANTITATIVE HEAT CONDUCTION OF SOLIDS

TDS 3.2

In this experiment we want to demonstrate that heat conduction depends on the individual material. Different materials conduct heat in different intensive ways. The warmer a material is, the stronger the molecules (or atoms) are vibrating around their resting position. The intensity of the transmission of these vibrations is dependent on the heat conduction of the material.

An application in practice can be found e.g. when building a house.
To avoid too much heat emission from inside to outside in winter, we isolate the house with thermal insulation materials - e.g. bad or non-conducting materials

Experiment:

The rods for heat-conduction get sticked into the drillings of the acrylic glas lid through the silicone stoppers. It is important to make sure that the slots for fixing the thermometers are positioned upwards. The beaker of the calorimeter gets filled with water (perfect temperature is approx. 80 degrees). The slots of the rods for heat-conduction get also filled with water (tepid). After the lid got placed on the beaker, please check again whether the four rods for heat conduction are placed in the same depth in the water.
To observe how the different materials conduct heat, read off the temperature at the upper end of the rods in certain time intervalls (e.g. every 15 to 20 seconds).

The measured values get recorded in the chart:

time	temperature in °C of			
	glas	steel	aluminium	copper

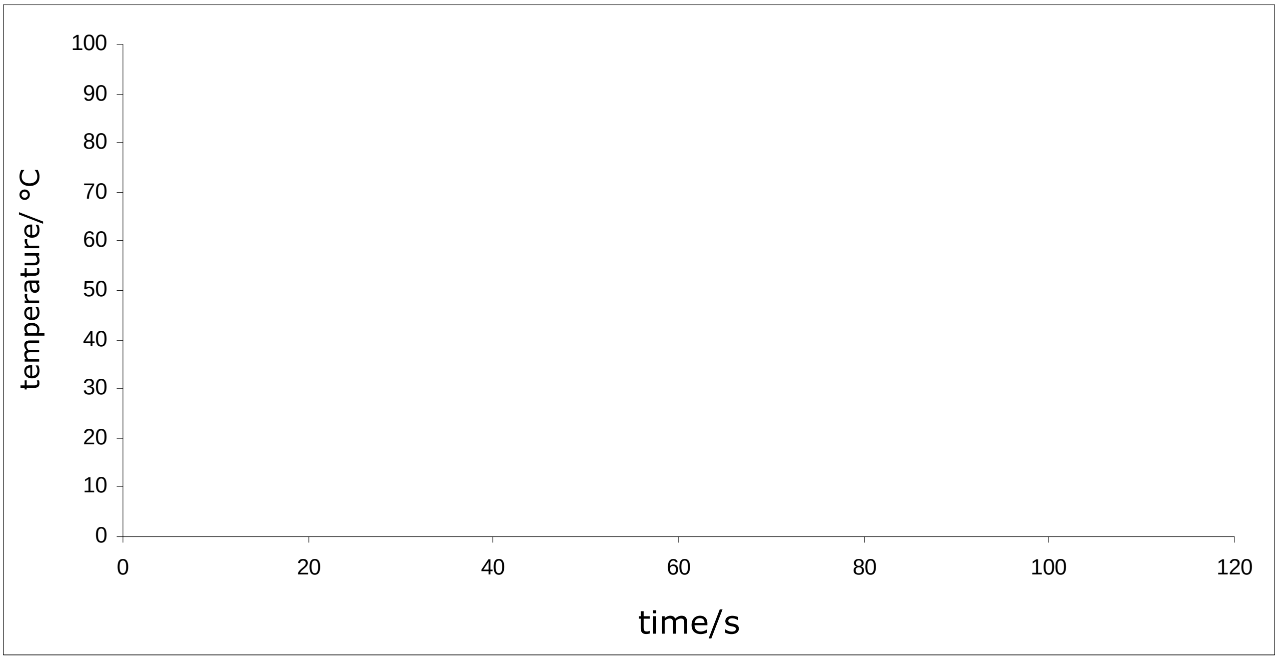
Our experiment has shown: ………………………………………………… is the best,

……………………………………… is the worst heat-conductor.

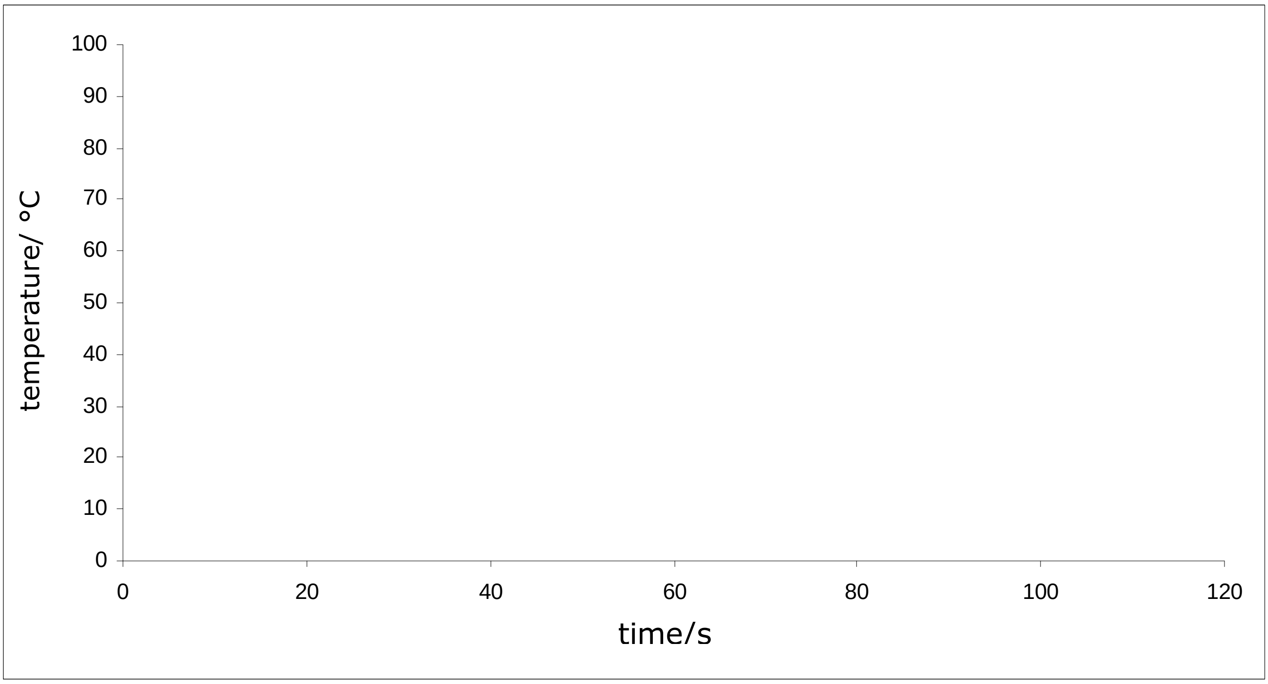
QUANTITATIVE HEAT CONDUCTION OF SOLIDS

TDS 3.2

t – T diagram for copper:



t – T diagramm for aluminium:

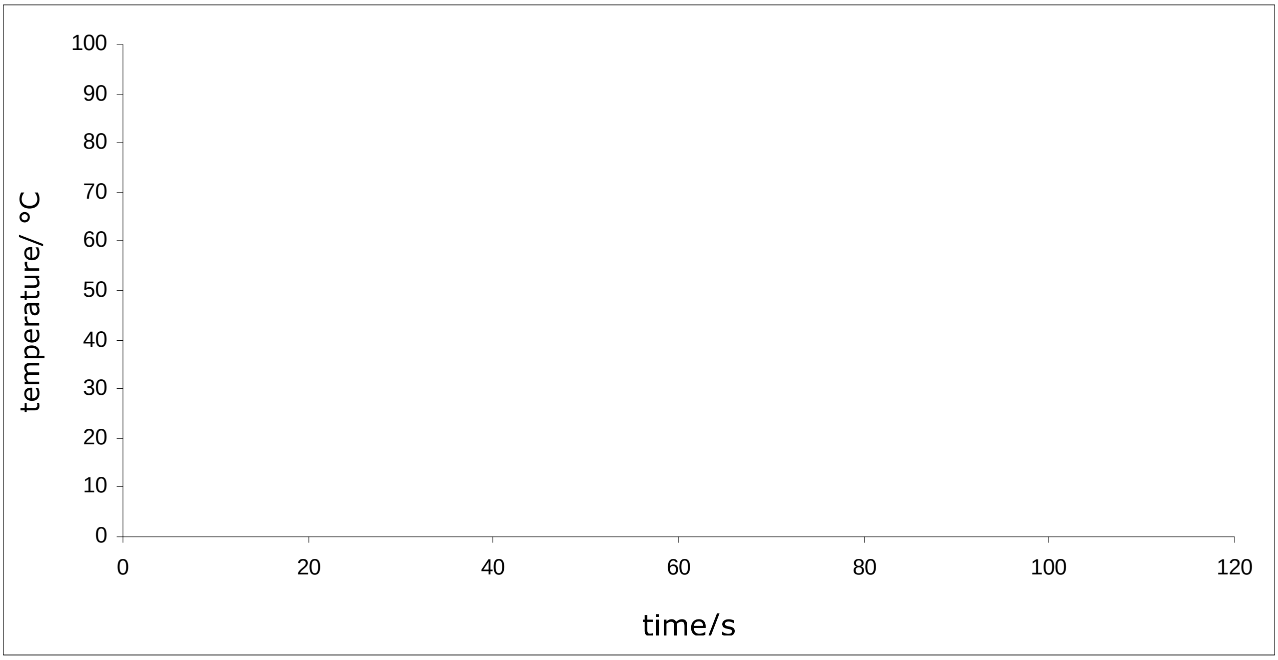


e

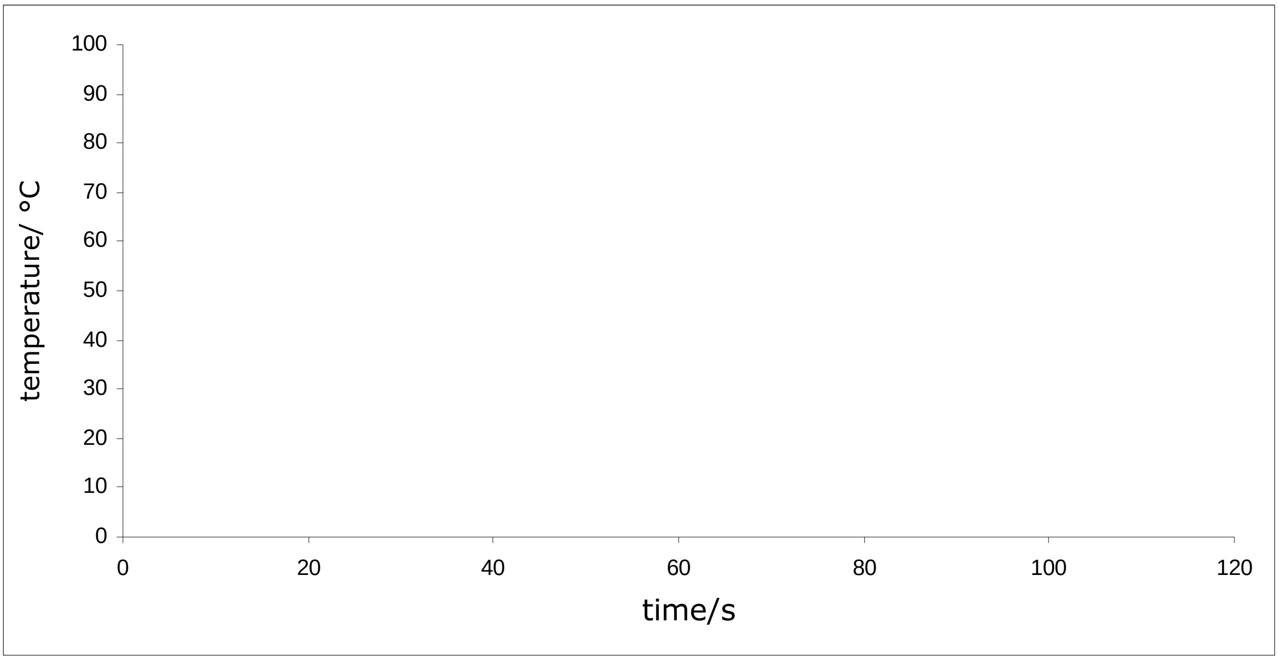
QUANTITATIVE HEAT CONDUCTION OF SOLIDS

TDS 3.2

t – T diagram for steel:



t – T diagram for glas:

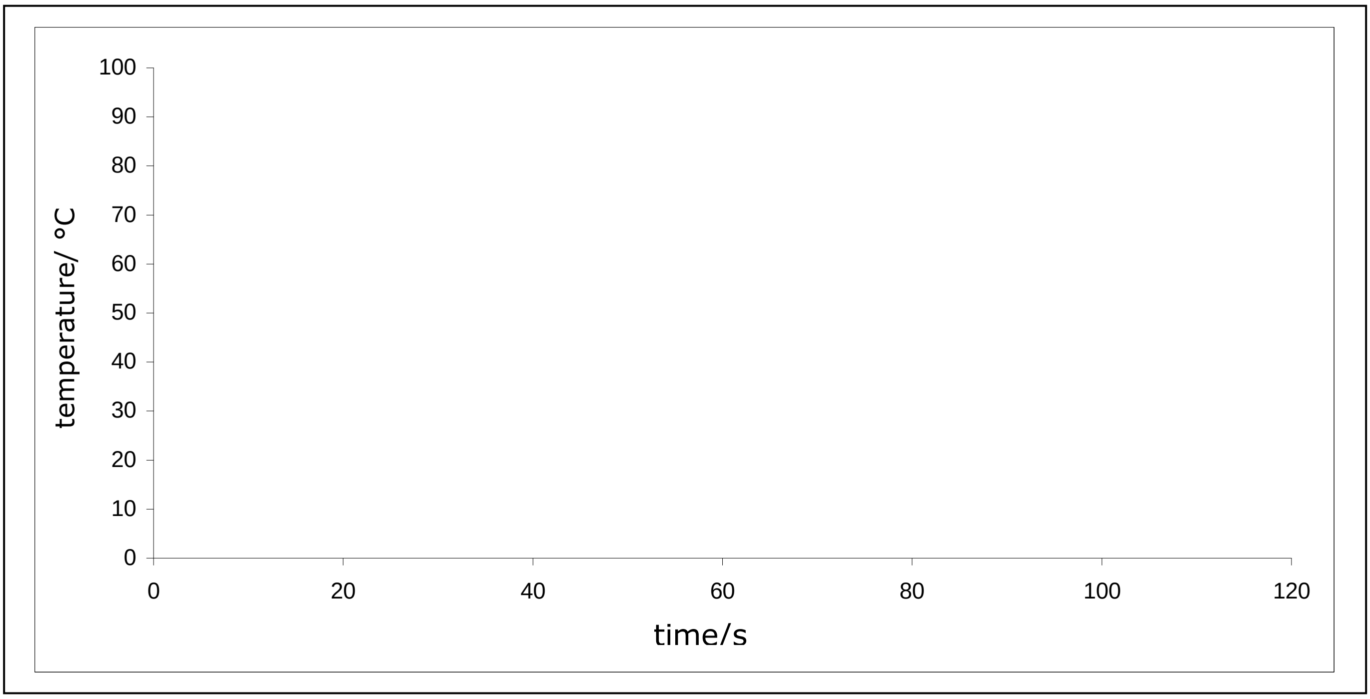


QUANTITATIVE HEAT CONDUCTION OF SOLIDS

TDS 3.2

We transmit the measured values of the 4 charts into the following diagram.
Afterwards, the graphs are named after their materials.

t – T Diagramm for all 4 materials:

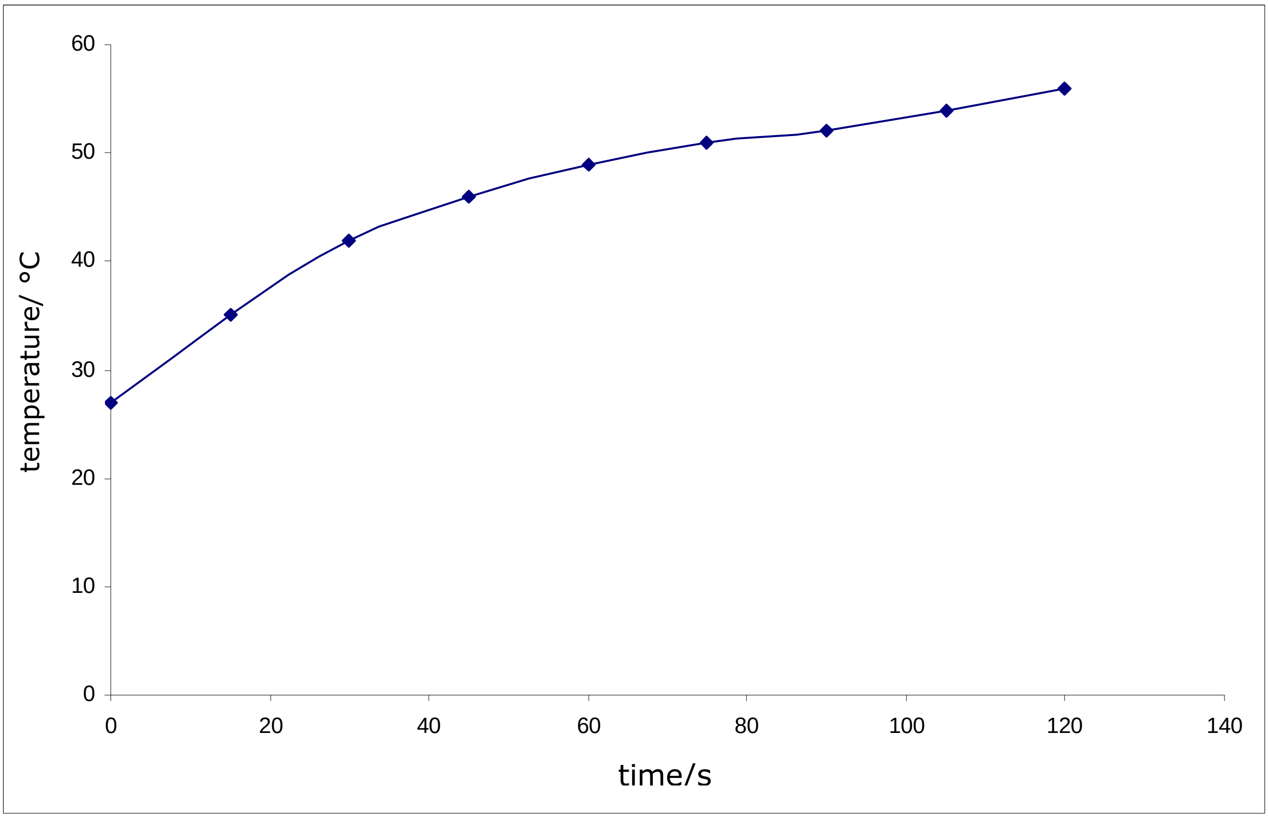


QUANTITATIVE HEAT CONDUCTION OF SOLIDS

TDS 3.2

Advice for teachers:
The experiment is working very properly when it gets done in groups of 5 students. One student is observing the time, whereas the other ones are observing the thermometers. If the time periods among the measurements get recorded accurately in a column, a very clean time - temperature graph of the different materials can be drawn.

Here is an example for copper:



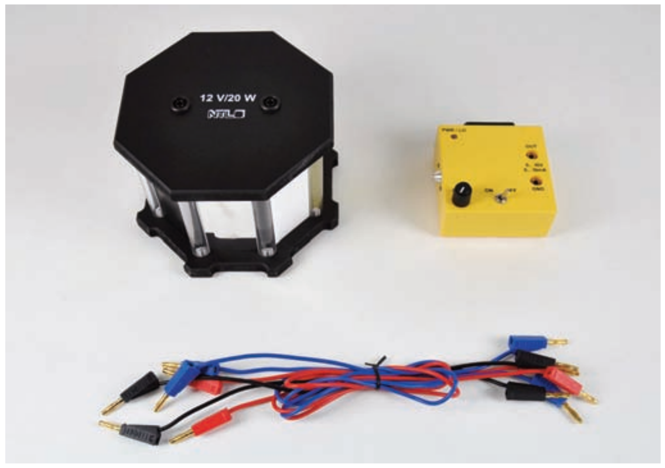
QUANTITATIVE HEAT RADIATION

TDS 3.3

Required Kit:
P9902-5C Heat 2

Material:
1x Thermo-octagon
1x Thermopile „compact“

Additionally required:
1x Measuring cylinder
2x Measuring instruments, connecting cables
and power supply



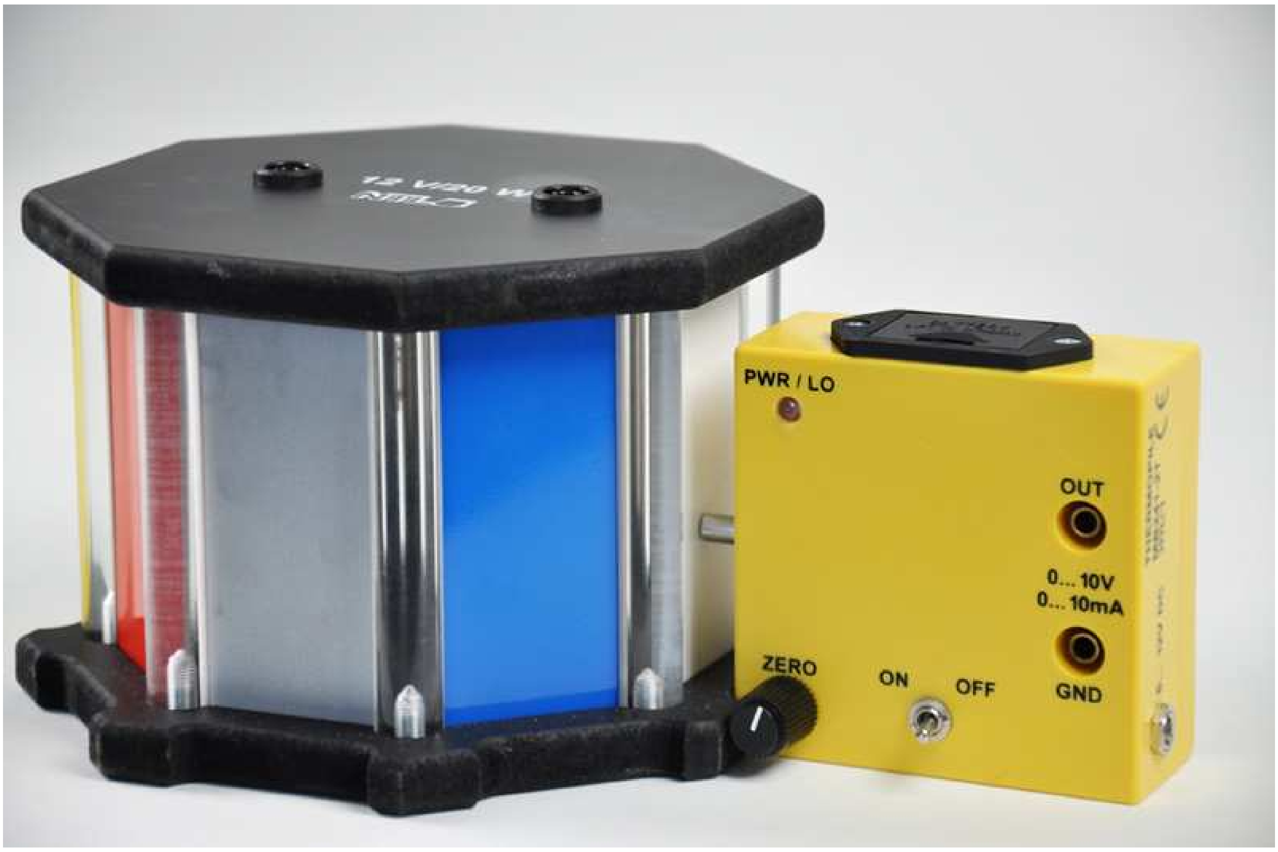
QUANTITATIVE HEAT RADIATION

TDS 3.3

A solid body which is exposed to heat radiation, is absorbing parts of this radiation and also do radiate parts of this energy. In this experiment, we examine in which amount the emitted radiation (emission) is dependent on the surface texture and the color of the body.

Experiment:
The colored metal plates of the thermo-octogon get turned outside and get then irradiated with a halogen lamp from inside. As it takes a little bit longer to generate a constantly emitted radiation (approx. 20 minutes), the lamp should be already switched on at the beginning of the lesson (with a power suppy, 12V A.C.). The thermopile gets connected to the multimeter (an analog multimeter is recommended) and set to 1V D.C. Because all plates have the same inner texture, differences in the emission-behavior can only appear at the outer surfaces of the plates.
The thermopile converts the generated heat radiation into voltage that can be read off from the multimeter.

After 20 minutes we start our measurement. The thermopile gets placed directly in front of one of the plates of the thermo-octogon (it should be positioned in the mould of the base of the octogon). At first we start with the plate "nature polished". We make sure that the thermopile is turned on and adjust the amplifier to an indicated value of 0,5 V. The octogon gets moved circularly and we do the same measurement at the other 7 surfaces. The values get transferred then into the chart. In the line "ranking" we appoint a ranking of the surfaces according to their emission-behavior, the first place gets appointed to the surface with the strongest emission.



QUANTITATIVE HEAT RADIATION

TDS 3.3

surface	nature polished	white	red	yellow	black	nature - matt finished	blue	white - matt finished
U/V								
ranking								
U/V								
ranking								

Conclusion:
Heat radiation depends on surface texture and color.

To double-check the first measurements, we start a secound round of measuring. It is important to do these measurements in a quick way. Of course, it is also possible that diferrent values get generated in the second round than in the first round (the constant state has not reached 100% yet), but the ranking should stay the same as in the first round.

QUANTITATIVE HEAT RADIATION

TDS 3.3

Advices for teachers:

The use of an analogue multimeter is recommended for following reasons. The emission values of the surfaces red, yellow, black and blue are nearly identical.
With an analog multimeter it is easier for the student to rank these colors as "equal".

Interpretation of the result:

A rough surface radiates more energy than a smooth one (this can be observed clearly at "nature" and "white"). For the colors red, yellow, black and blue we get values with small gaps between.

There is no real coherence between the brightness of the color and the emission-behavior because the chemical structure of the color also influences the emission-behavior.

It is recommended to ask the students to turn on the thermo-octogon at the beginning. Then, they should continue with other preparations. If it is not possible to wait 20 minutes until the first measurements get done, an earlier start-up is also possible.

In this case the ranking is likely to be different in comparison to the second round of measuring. These differences might only occur at the above-listed colors red, yellow, black and blue (with the use of an analogue multimeter, the values for these 4 colors can be rated as "nearly the same").

Required Kit:
P9902-5C Heat 2

Material:
1x Thermo-octagon
1x Thermopile „compact“

Additionally required:
1x Measuring instruments, connecting cables
and power supply

QUANTITATIVE HEAT ABSORPTION TDS 3.4

Solid bodies, that are exposed to a heat radiation, absorb parts of this radiation (this process is called absorption). In this experiment we will observe on which characteristics of the solid body the amount of absorbed radiation is dependent on.

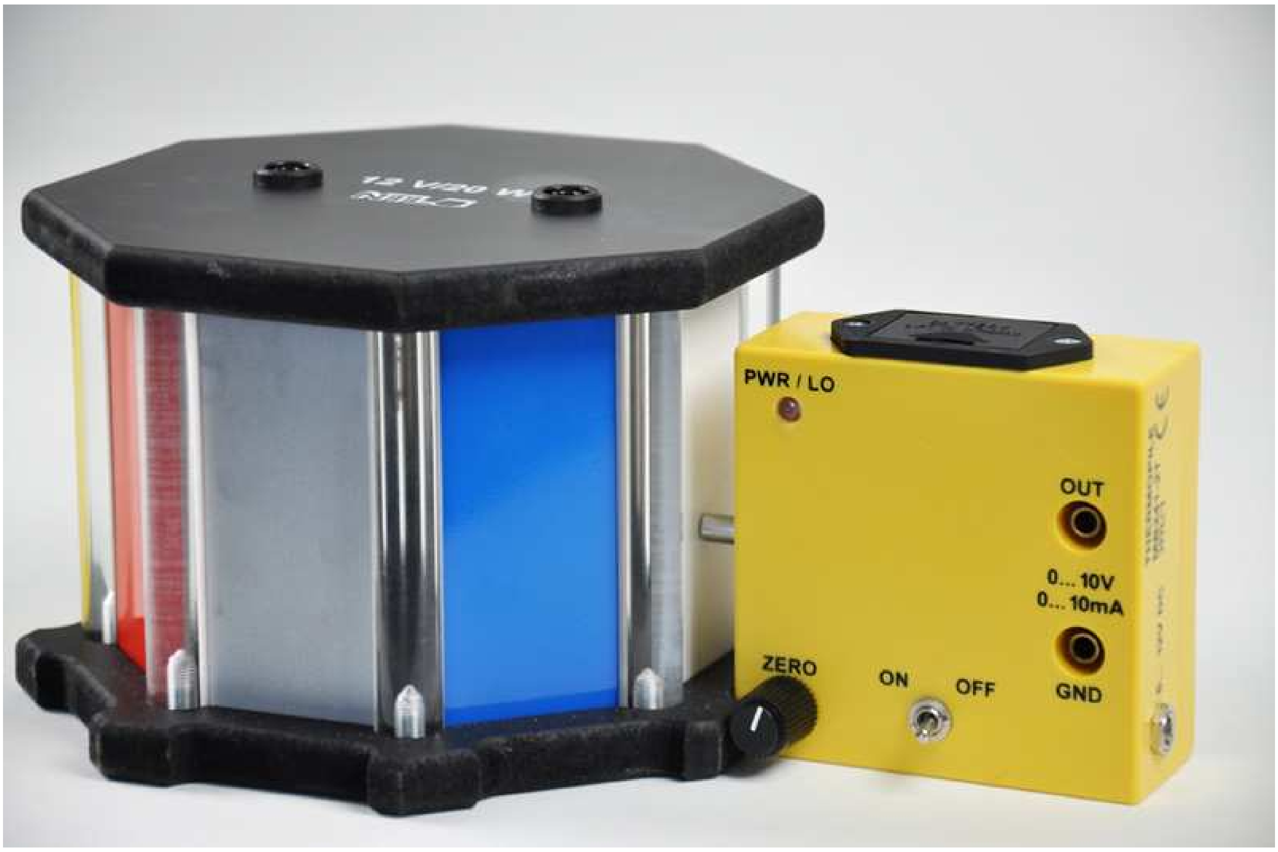
Set-up:

The metal plates of the heat-octogon get placed with the untreated sides of the aluminum plates outwards in the gauges. Then, they get radiated with a halogen lamp as heat source from inside.

The thermopile gets connected with the multimeter (the use of an analogue multimeter is recommended) and we set a range of 100mV A.C. . The thermopile is converting the received heat radiation into voltage that can be read off from the multimeter accordingly. Since all plates have equal outer surfaces, the measured differences of the emission behavior can only occur through different absorption behaviors inside the octogon.

After 20 minutes we start our measurement. The thermopile gets placed directly in front of one of the plates of the thermo-octogon (it should be positioned in the mould of the base of the octogon). At first we start with the plate "nature polished".

We make sure that the thermopile is turned on and adjust the amplifier to a voltage of approx. 20 mV. The octogon gets moved circularly and we do the same measurement at the other 7 surfaces. The values get transferred then into the chart.



QUANTITATIVE HEAT ABSORPTION

TDS 3.4

surface	nature polished	white	red	yellow	black	nature - matt finished	blue	nature - white finished
U/V								
ranking								
U/V								
ranking								

In the line "ranking" we appoint a ranking of the surfaces according to their emission-behavior. The first place gets appointed to the surface with the strongest emission.

Conclusion:
The absorption of heat radiation depends on the surface texture and the color.

QUANTITATIVE HEAT ABSORPTION

Advices for teachers

The use of an analogue multimeter is recommended for following reasons: The emission values of the surfaces red, yellow, black and blue are nearly identical.
With an analogue multimeter it is easier for the student to rank these colors as "equal".

Evaluation of the result:
A rough surface absorbs more energy than a smooth one (this can be observed clearly at "nature" and "white"). For the colors red, yellow, black and blue we get values with small gaps between.

There is no real coherence between the brightness of the color and the absorption-behavior because the chemical structure of the color also influences the absorption-behavior.

It is recommended to ask the students to turn on the thermo-octogon at the beginning. Then, they should continue with other preparations. If it is not possible to wait 20 minutes until the first measurements get done, an earlier start-up is also possible.

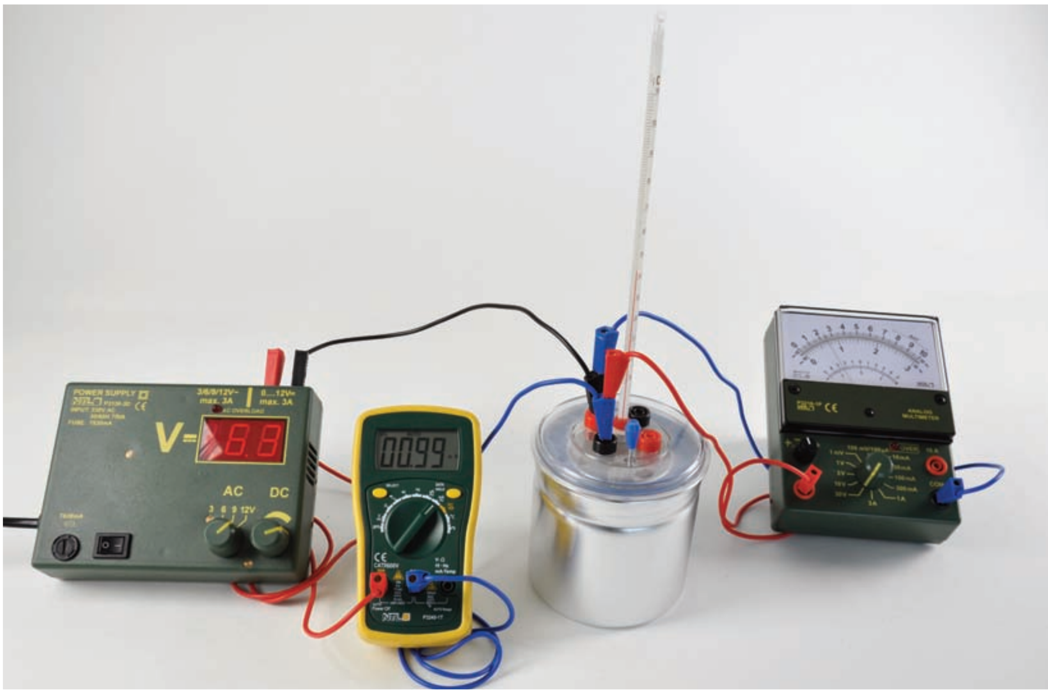
In this case the ranking is likely to be different in comparison to the second round of measuring. These differences might only occur at the above-listed colors red, yellow, black and blue (with the use of an analog multimeter, the values for these 4 colors can be rated as "nearly the same").

This waiting time of 20 minutes should even be considered after performing the experiment TDS 3.3 (quantitative heat radiation).

HEAT EMISSION AND AMPERAGE

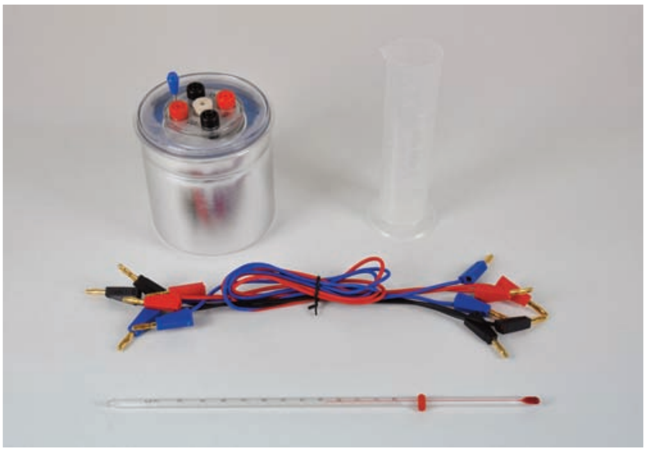
ELS 4.2.1

Required Kit:
P9902-5C Heat 2



Material:
1x Joule's calorimeter universal
1x Thermometer graduated

Additionally required:
1x Measuring cylinder
2x Measuring instruments, connecting cables
and power supply



HEAT EMISSION AND AMPERAGE

ELS 4.2.1

We want to measure the heat output of electric current in an immersion heater.

Set-up: We fill 100 ml of water into the calorimeter (measured with the measuring cylinder). The immersion heater of the calorimeter is connected to a variable power source. The power supply still remains switched off. To measure the current, we connect an amperemeter (measuring range 10A ~) in series with the immersion heater. The voltage gets measured at the connections of the immersion heater with a voltmeter (measuring range 30V ~). The thermometer gets sticked in the calorimeter through the rubber stopper.

Experiment:

We measure the water temperature in the calorimeter and keep a record of the same.

Observation: Initial temperature of the water: δ_1=_______°C

We turn on the power supply and adjust the direct current to an amperage of 1A. The voltage at the immersion heater gets measured and recorded.

Observation: Voltage at the immersion heater: U=_____V

We heat up for exactly 300 seconds (stopwatch). Then we switch off the power supply, mix (moving the stirrer up an down) the water in the calorimeter, read off the temperature of the water and calculate the rise of the temperature.

Observation: Final temperature: δ_2=_______°C
Temperature difference: e$\Delta\delta=\delta_2-\delta_1$=_______°C

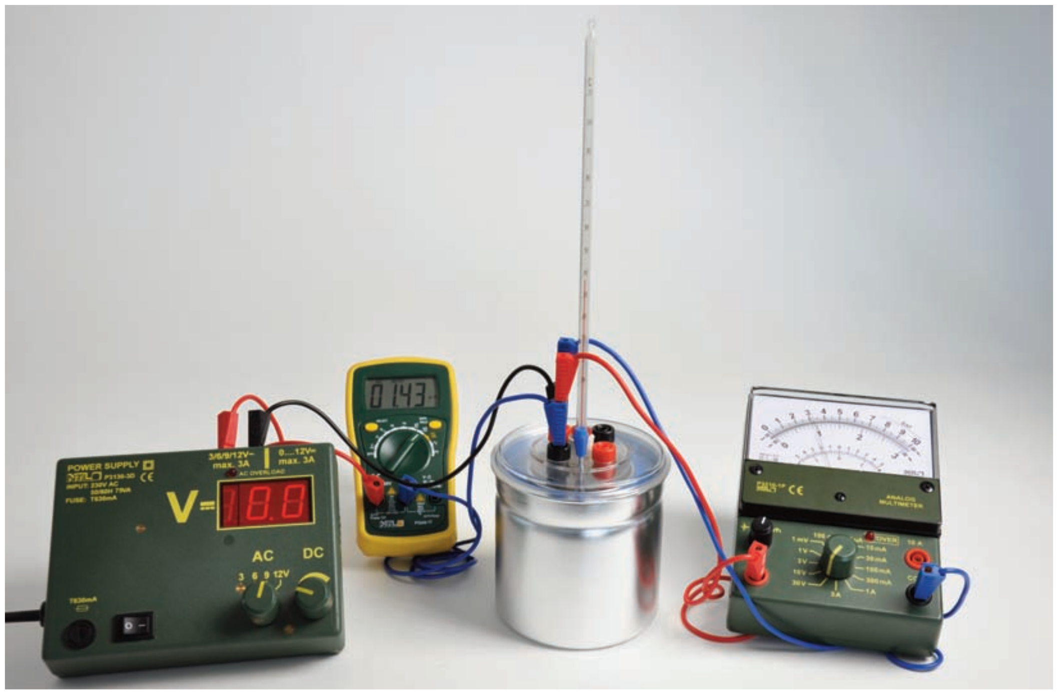
We turn on the power supply again and set the amperage to 2A. After 300 seconds we switch off the power supply, stir and measure the temperature of the water.

Oberservation: Final temperature: δ_3=_______°C
Temperature difference: $\Delta\delta=\delta_3-\delta_1$=_______°C

Conclusion:
The amount of emitted heat increases with the square of the current. The reason is the dependence of eletrical work on the current intensity according to the formula $W = I^2 * R * t$.

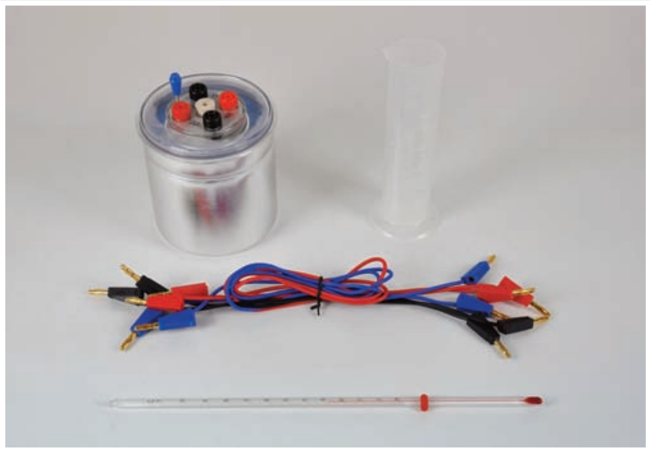
ELETRICAL THERMAL EQUIVALENT

Required Kit:
P9902-5C Heat 2



Material:
1x Joule’s calorimeter universal
1x Thermometer graduated

Additionally required:
1x Measuring cylinder
2x Measuring instruments, connecting cables
and power supply



ELECTRICAL THERMAL EQUIVALENT

ELS 4.2.2

We want to calculate, how much electrical energy is required to heat up 1 kg of water by 1°C.

Set-up: 100 ml of water get filed into the calorimeter (measured by means of the measuring cylidner). The immersion heater is connected to 9V A.C. . The power supply remains switched off. The amperemeter (measuring range of 10 A) gets connected in series with the immersion heater. The applied voltage gets measured by means of a voltmeter at the connection with the immersion heater (measuring range of 30 V ~). The thermometer gets sticked in the calorimeter through the rubber stopper.

Experiment:

We measure the temperature of the water in the calorimeter and record it.

Observation: Initial temperature of the water: δ_1=_______°C

We turn on the power supply and record the time (turn on the stopwatch or read off the time from your wrist-watch) .The amperage and voltage get measured and recorded. Afterwards, we switch off the power supply, stir the water in the calorimeter and read off the temperature of the water.

Observation:

	Voltage:	U=______V
	Amperage:	I=____A
	Final temperature:	δ_2=_______°C
	Temperature difference:	$\Delta\delta=\delta_2-\delta_1$=_______°C

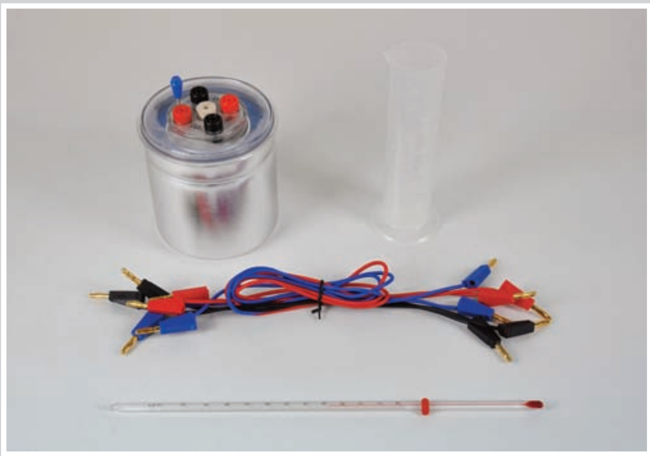
WATER EQUIVALENT

ELS 4.3

Required Kit:
P9902-5C Heat 2

Material:
1x Joule's calorimeter universal
1x Thermometer graduated

Additionally required:
1x Measuring cylinder
2x Measuring instruments, connecting cables
and power supply



WATER EQUIVALENT

ELS 4.3

When a liquid gets heated, the vessel must be heated as well. The vessel itself then behaves like water that has to be heated. The water equivalent of the calorimeter is to be found out.

Set-up: 200 ml of water are poured into the calorimeter. The immersion heater gets immersed in the calorimeter and an 9 Volt A.C. get applied. The electrical power supply is not switched on yet. An ammeter (measuring range of 10 A ~) gets connected in series with the immersion heater in order to be able to measure the eletrical current. The thermometer gets inserted in the calorimeter through the rubber stopper. The temperature of the water in the calorimeter is measured and recorded.

Experiment:

We measure the water temperature in the calorimeter and record it.

Observation: Initial temperature of the water: δ_1=_______°C
The electrical power supply gets switched on and the time gets recorded (use a stopwatch or read the time from your wrist-watch). The current intensity and the voltage get measured and recorded. Heat up for exactly 400 seconds. Then the electrical power supply gets switched off. Stir the water in the calorimeter (move twirling-stick up and down) and read off the temperature of the water.

Observation:	Voltage	U=______V
	Current intensity:	I=____A
	Final temperature:	δ_2=_______°C
	Temperature difference:	$\Delta\delta=\delta_2-\delta_1$=_______°C
	Specific heat of water :	c_w=4186j/kg°C

The water equivalent w gets determined by following equation.

$$(m+w)*\Delta\delta*c_w=U*I*t$$

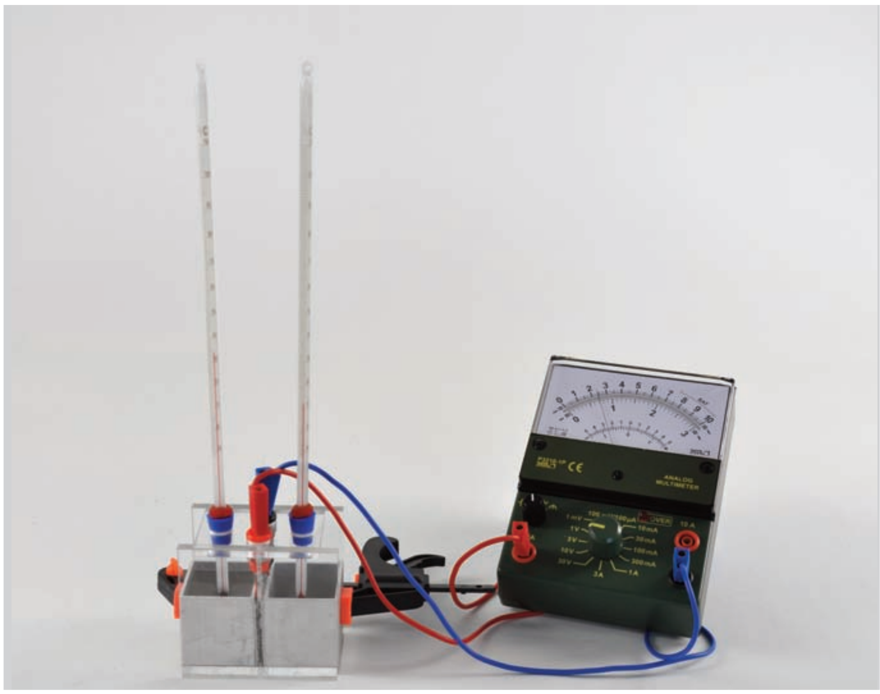
w = ______ kg

Conclusion:
The water equivalent of a vessel corresponds to water which has to be heated.

TEMPERATURE DIFFERENCES CAUSES TENSION

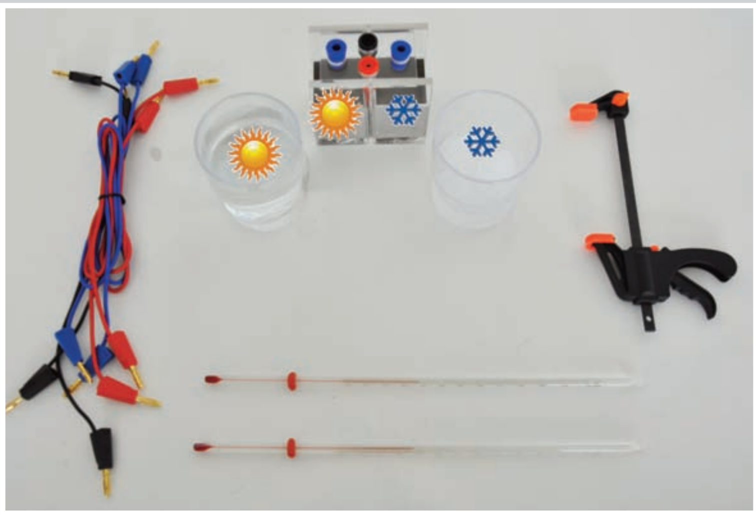
TDS 5.1

Required Kit:
P9902-5C Heat 2



Material:
1x Thermal generator with clamp
2x Thermometer graduated

Additionally required:
1x Measuring instruments
Connecting cables
Power supply
Hot water
Cold water (ice cubes)



TEMPERATURE DIFFERENCE CAUSES TENSION

TDS 5.1

Two wires of different materials are soldered together at their endings. If the two solder-joints are at different temperature-leves an electric tension, named thermal voltage, gets generated between these solder-joints (This effect can be found in literature as the "Seebeck"-effect). The amount of tension depends on the temperature difference between the solder-joints. We will examine this thermocouple in the next two experiments.

The first experiment demonstrates the appearance of thermal voltage because of temperature differences.

In the second experiment (TDS 5.2) we will cause a temperature difference by an external applied voltage (this means that we can raise the temperature in one of the thermo-elements and lower it in another).

Experiment:

Due to a temperature difference a thermal tension appears.

Set-up:

One of the beakers of the thermo generator gets filled with hot water, the other one with cold water (small ice cubes recommended). The beakers get placed in the thermo generator and strongly pressed against the peltier-element (located in the partition between the tanks) with the help of a clamp. The peltier-element gets connected to the multimeter via two cables. The water temperature in both beakers get measured with the two thermometers, fixed by silicone stoppers.

Due to a fast temperature adjustment, many values can be measured. In the first line the temperature difference between the beakers gets recorded, in the second line the associated values of the thermal tension.

ΔT/°C				
U/V				

We observe:

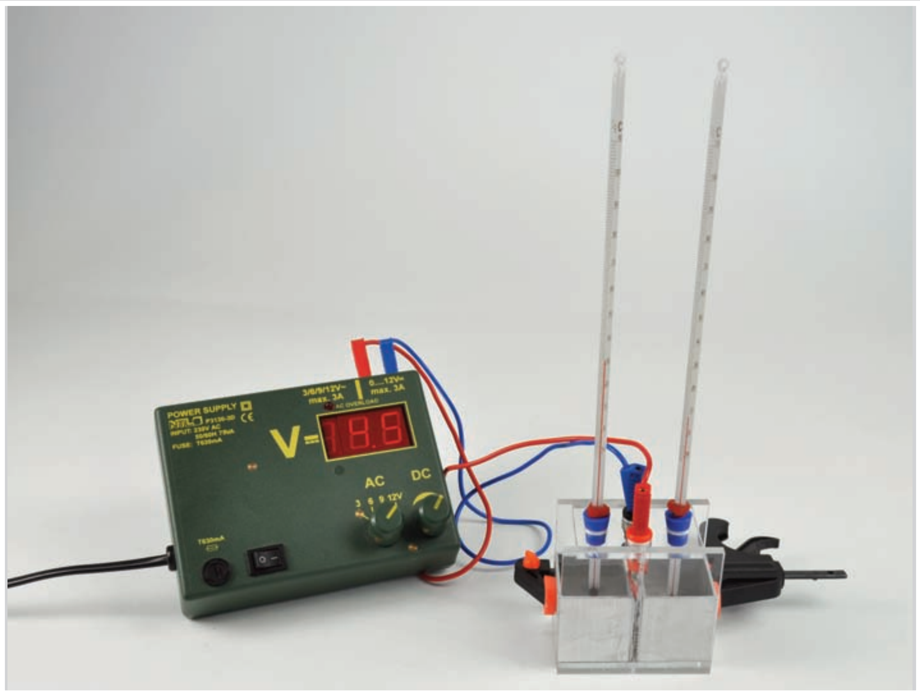
The ……………………… the temperature difference in the two beakers is,

the ……………………… is the appearing thermal tension.

THERMOELETRICAL COOLING - “PELTIER-EFFECT“

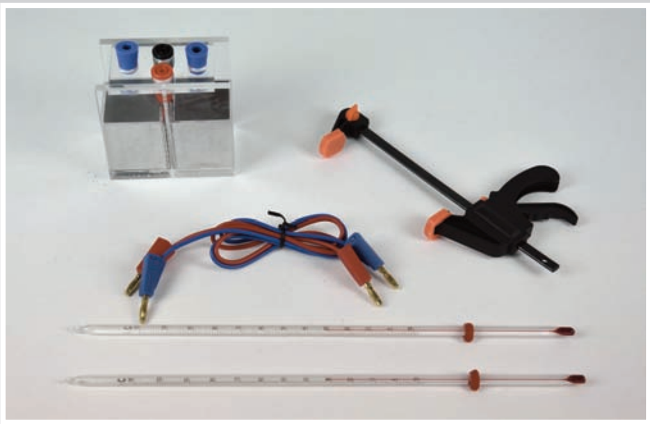
TDS 5.2

Required Kit:
P9902-5C Heat 2



Material:
1x Thermal generator with clamp
2x Thermometer graduated

Additionally required:
1x Connecting cables
and power supply



THERMOELECTRICAL COOLING - "PELTIER-EFFECT"

TDS 5.2

Experiment:

A temperature difference appears due to an applied voltage.

Set-up:
The alu-beakers of the thermogenerator get filled with water of the same temperature. The beakers get strongly clamped to the peltier-element. We connect the peltier-element with the power supply via two cables and set D.C. The temperature inside the beaker gets displayed by the two thermometers, fixed by the silicone stoppers.

The measured values can be recorded in the chart.
There, the following parametes can be modified in this experiment:

We use the same applied voltage and measure the temperature in different time intervalls. e.g. 4.5V and measure every two minutes (3 values). Afterwards we measure again 3 values in two minutes.

voltage/V	time/min	t_1	t_2

We realize:
The temperature difference is increasing move, the ……………………….. the thermo generator is active.
The temperature difference is increasing move, the ……………………….. the applied voltage is.

Application:
Refrigerators operating by this principle can be build very small and have no moving parts. They are used as mobile freezing boxes, e.g. for medicine or freezing cases in cars.

Student Experiments

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