If two bodies with different temperatures are brought together their temperatures will gradually be equalized. In the case of liquids this equalization process can be accelerated by stirring. Water of different temperatures is used in this experiment. The mixing temperature which is reached depends on the amounts of water and their initial temperatures.

Material

1	Demo physics board	02150.00
1	Clamping holder, *d* = 0 ... 13 mm, fixing magnet	02151.07
1	Holder for hand-held meters	02161.00
1	Burner-holder on fixing magnet	02162.00
1	Wire gauze holder on fix. magnet.	02163.00
1	Wire gauze 160 mm x 160 mm, ceramic cen.	33287.01
1	Glass beaker DURAN®, tall, 600 ml	36006.00
1	Beaker, 250 ml, low plastic	36013.01
1	Graduated cylinder 100 ml, BORO 3.3	36629.00
1	Glass rod, l=200mm, d=6mm	40485.04
1	Temp. meter 2xNiCr-Ni, hand-held	07140.00
2	Immersion probe NiCr-Ni, stainl. steel	13615.03
1	Large-scale display, digital, RS-232 port	07157.93
1	Data cable RS 232, SUB-D/USB	07157.01
1	Butane burner, Labogaz 206 type	32178.00
1	Butane cartridge without valve, 190 g	47535.00

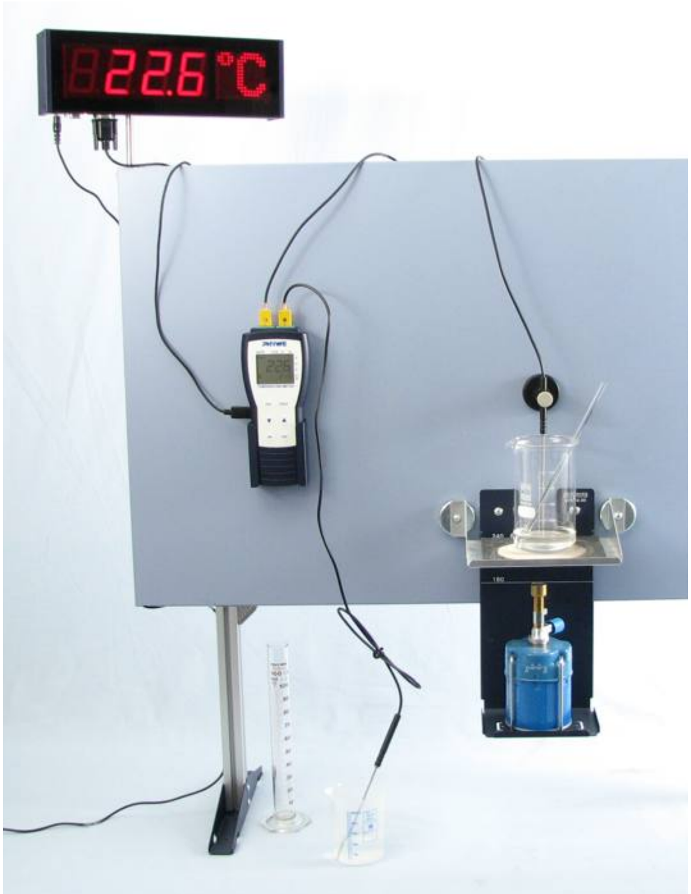

Fig. 1

Setup

- Place the holder for the burner at the bottom of the board (Fig. 1)
- If using the butane burner place the holder for the wire gauze upon the board at the marked height of 240 and put the wire gauze on top of it
- Place the 600 ml glass beaker upon the wire gauze
- Place the ring-shaped clamp upon the board in such a way that it is positioned about half way up the glass beaker
- Place the hand-held meter into the magnetic holder on the board and connect it to the large-display unit
- Connect both temperature sensors with the hand-held meter
- Place the clamping holder above the glass beaker on the board, attach the temperature sensor within it and attach its cable to the meter in such a way that it does not sag (above the board edge)

Implementation

Experiment 1

- Measure out 100 ml of water in the graduated cylinder and fill it into the 600 ml glass beaker
- Shift the clamping holder until the temperature sensor is immersed approx. 1 cm deep into the water in the glass beaker
- Fill the graduated cylinder with 100 ml of cold water once more, measure the water temperature ϑ_c and make a note of it (table 1)

- Light the butane burner and heat up the water in the 600 ml glass beaker until it reaches a temperature of approx. 83°C, regularly stirring as you do so.
- Switch off the burner and remove it
- Continue to stir the water and monitor the temperature (1)
- Once the water temperature in the glass beaker reaches ϑ_w = 80°C pour in the contents of the graduated cylinder, carefully stir it and monitor the temperature (2)
- If the temperature remains roughly constant measure the mixing temperature ϑ_m and make a note

Experiment 2
- Perform the experiment with 100 ml of hot and 200 ml of cold water
- Place the cold water in readiness in the 250 ml beaker, measure out 100 ml of water twice in the graduated cylinder to do this
- The temperatures ϑ_w and ϑ_c should be precisely the same as in the first experiment if possible.

Experiment 3
- Perform the experiment with 100 ml of hot and 50 ml of cold water

Observation and measurement results
(1) The temperature slowly drops if the burner is turned off.
(2) If cold water is poured into the hot water then the temperature will initially drop very rapidly and then slowly reaches a constant value.

Table 1: Measured values for the volumes and temperatures

	Volumes	Temperature	Mixing temperature measured	Mixing temperature calculated
Experiment 1 Hot water Cold water	 100 ml 100 ml	 ϑ_w = 80.1°C ϑ_c = 20.5°C	ϑ_m = 51.0℃	ϑ_m = 50.3
Experiment 2 Hot water Cold water	 100 ml 200 ml	 ϑ_w = 80.0°C ϑ_c = 20.1°C	ϑ_m = 40.8℃	ϑ_m = 40.1
Experiment 3 Hot water Cold water	 100 ml 50 ml	 ϑ_w = 80.0°C ϑ_c = 20.4°C	ϑ_m = 59.7℃	ϑ_m = 60.1

Evaluation
To begin with the hot water in the glass beaker is surrounded by colder air, it only cools down slowly. If cold water is added both amounts of water are mixed through, the water in the glass beaker cools down quickly until it reaches the mixing temperature. The amounts of water are selected in such a way that the values for the mixing temperatures can also be explained without calculations.

Experiment 1
If equally large amounts of hot and cold water are poured together the mixing temperature will be at the midway point of both temperatures.
The mixing temperature is the average value of the temperature of the hot water and the cold water. The calculated value is stated in Table 1.

$$\vartheta_m = \vartheta_c + \frac{1}{2}(\vartheta_w - \vartheta_c) = \frac{\vartheta_c + \vartheta_w}{2}$$

Experiment 2 and 3
If the quantity of hot water is smaller than the quantity of cold water the mixing temperature will also be lower than the average value and vice versa.
The volume shares of the entire volume amount to 1/3 and 2/3. It is therefore obvious that the temperature interval between ϑ_w and ϑ_c should be divided accordingly or the temperatures are to be taken into account at the same ratio as the amounts of water to determine the mixing temperature. The mixing temperatures calculated are entered in Table 1.

$$\vartheta_m = \vartheta_c + \frac{1}{3}(\vartheta_w - \vartheta_c) = \frac{2}{3}\vartheta_c + \frac{1}{3}\vartheta_w$$

or

$$\vartheta_m = \vartheta_c + \frac{2}{3}(\vartheta_w - \vartheta_c) = \frac{1}{3}\vartheta_c + \frac{2}{3}\vartheta_w$$

Remarks

1. The measuring accuracy for the absolute value in the case of the NiCr-Nr temperature sensors is +/-1.5°C. The temperature meter and the two sensors must therefore be calibrated to the same temperature in a vessel with water (refer to the operating instructions of the temperature meter). We recommend that you calibrate it before the lesson.
   The last digit of a digital meter can always vary by 1 digit. For this reason short-term differences of 0.1°C or 0.2°C between the sensors are normal following calibration.

2. The water quantity in the glass must always be measured out with the graduated cylinder as the 100 ml mark of the glass beaker is too imprecise for this experiment.

3. When heating the water you can save time if warm water from the previous experiment is used.

4. The temperatures ϑ_w and ϑ_c should be precisely the same in all the individual experiments if possible so the mixing temperatures can be easily compared in qualitative terms.

5. General calculation of the mixing temperatures
   If any amounts of cold and hot water are poured together the mixing temperature can be calculated using the energy balance whereby m = Mass and V = Volume of the cold or hot water, c = specific effective heat capacity and ρ = density of water. The energy that the water absorbs when heating or emits when cooling is

$$\Delta E = c \cdot m \cdot \Delta\vartheta$$

   The cold water is heated to the mixing temperature the hot water cools down to the mixing temperature. These two energy amounts are equal.

$$c \cdot m_c \cdot (\vartheta_m - \vartheta_c) = c \cdot m_w \cdot (\vartheta_w - \vartheta_m)$$

$$m_c \cdot \vartheta_m - m_c \cdot \vartheta_c = m_w \cdot \vartheta_w - m_w \cdot \vartheta_m$$

$$m_c \cdot \vartheta_m + m_w \cdot \vartheta_m = m_w \cdot \vartheta_w - m_c \cdot \vartheta_c$$

$$(m_c + m_w) \cdot \vartheta_m = m_w \cdot \vartheta_w - m_c \cdot \vartheta_c$$

$$\vartheta_m = \frac{m_w \cdot \vartheta_w + m_c \cdot \vartheta_c}{m_c + m_w}$$

The mass of water can be converted to the volume with the aid of the density. Due to the fact that mass and volume are proportional to another,

$$m = \rho \cdot V$$

the mixing temperature can also be calculated in accordance with the corresponding formula dependent on the amounts of water (volumes) used.

$$\vartheta_m = \frac{V_w \cdot \vartheta_w + V_c \cdot \vartheta_c}{V_c + V_w}$$

