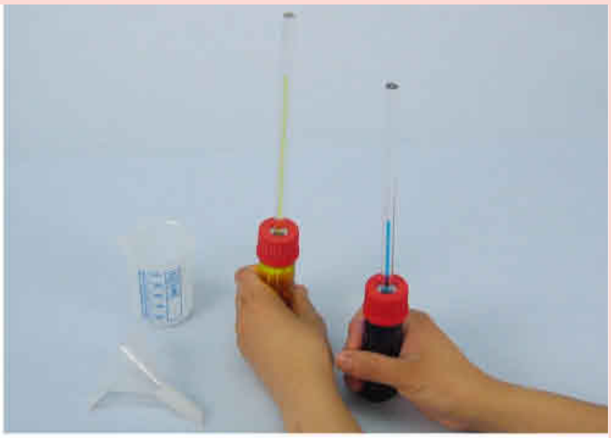
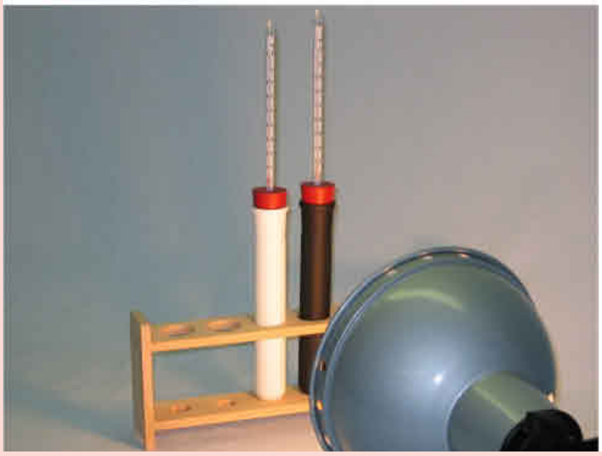
Student and Demonstration Experiments

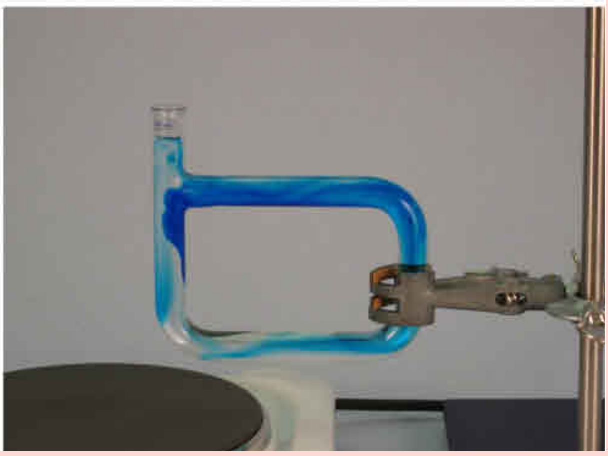
TESS beginner

PHYWE

Heat







01160-52

TESS beginner Student and Demonstration experiments

Heat

Order No. 01160-52

PHYWE series of publications
TESS beginner Student and Demonstration experiments: Heat
Order No. 01160-52

Author of experimental literature: Regina Butt

1st edition

Contents

Student experiments:

Demonstration experiments:

Equipment and Storage

Student Set, Heat 13235-88

	Description	No.	Quantity
(1)	Felt sheet 100 x 100 mm	04404-20	3
(2)	Beaker, 100 ml, low form, plastic	36011-01	1
(3)	Funnel, plastic, dia.50mm	36890-00	1
(4)	Rubber bands, 50 pieces	03920-00	1
(5)	Holder for fixing tape	170454	1
(6)	Adhesive tape, 19 mm	170455	1
(7)	Screw cap jar, 40 ml	170462	2
(8)	Gasket for GL 25-8	162405	2
(9)	Screw caps, red	162407	2
(10)	Capillary tube, straight, l 250mm	36709-00	2
(11)	Stirring thermometer non-graduat.	38003-00	1
(12)	Lab thermometer,-10..+100C	38056-00	2

Demonstration Set, Heat 13236-88

	Description	No.	Quantity
(1)	Filament lamp,220V/120W,w.refl.	06759-93	1
(2)	Ceramic lamp socket E27 with reflector, switch, safety plug	06751-01	1
(3)	Rubber stopper 26/32, 1 hole 7 mm	39258-01	2
(4)	Test tube rack, wood, for 6 tubes d= 30 mm	40569-10	1
(5)	Test tube, d 30mm, l 200mm, black	36294-06	1
(6)	Test tube, d = 30 mm, l = 200 mm, white	36294-05	1
(7)	Stainless Steel pot 3,2 l	05934-00	1
(8)	Heating + cooking hotplate,230V	04025-93	1
(9)	Graduated vessel, 1 l, with handle	36640-00	1
(10)	Glass beaker DURAN®, tall, 600 ml	36006-00	1
(11)	Retort stand, 210 mm × 130 mm, h = 500 mm	37692-00	1
(12)	Glass tube holder with tape measure clamp	05961-00	1
(13)	Right angle clamp	37697-00	2
(14)	Support rod, stainless steel, l = 250 mm, d = 10 mm	02031-00	1
(15)	Universal clamp	37715-00	1
(16)	Convection of liquids tube, small	04510-01	1
(17)	Circular filter,d 70 mm,100 pcs	32977-02	1
(18)	Glass rod,U-shaped	05911-00	1
(19)	Aluminium rod,U-shaped	05910-00	1
(20)	Copper rod, U-shaped	05910-01	1
(21)	Heat sensitive paper	04260-00	2
(22)	Lab thermometer,-10..+100C	38056-00	2
	Storage tray		

Hot or cold?

Task

Test the temperature sensitivity of your skin by touching bottles filled with water at different temperatures.

Material

2 Screw cap jars
1 Beaker
1 Funnel

Fig. 1

Set-up and procedure

- Hot water and icy water are available on the teacher's table.
- Use the funnel to fill one of the bottles with hot water and the other one with icy water.
- Fill cold tap water (20°C) into the beaker.
- Hold the bottle containing icy water in your left hand and the one containing hot water in your right hand (Fig. 1).
- Keep holding the bottles for about 1 minute.
- Now simultaneously dip a left hand finger and a right hand finger into the beaker containing tap water and move both fingers about in the water (Fig. 2).

Fig. 2

Observations

1. What do your fingers feel? Is the water in the beaker hot or cold?

....

....

....

Evaluation

1. Can you use your fingers to differentiate between hot and cold?

....

....

....

2. Give further examples which show that you can feel a difference between hot and cold.

....

....

....

(Hot or cold?)

Material from the Heat Demo-Set

1	Heating + cooking hotplate,230V	04025-93
1	Stainless Steel pot 3,2 l	05934-00
1	Graduated vessel, 1 l, with handle	36640-00
1	Glass beaker DURAN®, tall, 600 ml	36006-00
1	Lab thermometer,-10..+100C	38056-00

Additional material

1 Hammer
1 Towel
Ice cubes

Preparation

Icy water (0°C) and hot water (approx. 50°C) must be made available. Each group of students requires about 40 ml of each.

Ice cubes can be best broken down by wrapping them in a towel and hitting them with a hammer. The small fragments of ice which are left in the towel can now be used.

The students would enjoy breaking up the ice cubes if you consider this to be appropriate.

There should still be ice cubes in the water so that it remains cold for as long as possible.

Notes on set-up and procedure

Make sure that the fingers of the students in particular touch the bottles, as these are more sensitive to temperature than the palm of the hand.

Students could also dip fingers directly into the water in the bottles when the hot water is not too hot for this.

Observations

1. The water in the beaker feels warm to the finger of the left hand which held the bottle with ice cold water, but cool to the finger of the right hand which held the bottle containing hot water. Sensitivity to temperature depends on whether the finger was previously hot or cold.

Evaluation

1. The two fingers sense different temperatures for the water in the beaker. The water feels hot to the left hand finger (previously cold) but colder to the right hand finger (previously hot).
2. Example: The hall feels warmer than outside when you come home from school but when you go on into the living room, the hall seems to have been cooler.Tipps und Tricks, die vielleicht nicht ganz offensichtlich sind, vielleicht als Aufzählung

Room for notes

Thermal expansion of air and water

How do the volumes of air and water change when they are heated?

Task

Compare the effects of heating a water-filled bottle and an air-filled bottle.

Material

2 Screw cap jars
2 Caps
2 Gaskets
2 Capillary tubes
1 Funnel
1 Beaker

Distilled water
Absorbent paper
Ruler

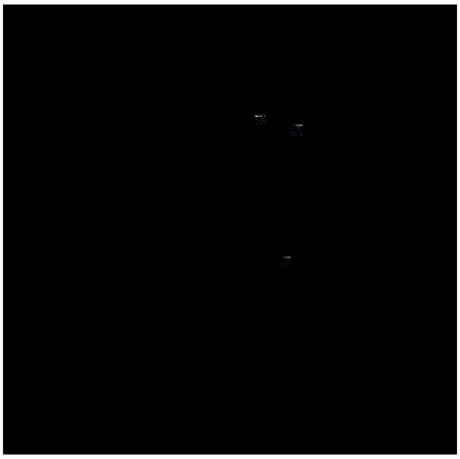


Fig. 1

Set-up and procedure

- Fetch distilled water from the teacher's table.
- Use the beaker and funnel to fill water into one of the bottles to a height of about 2 cm.
- Fill the other bottle almost completely with water.
- Slide a sealing ring so far on one capillary tube that the tube protrudes out by about 4 cm on one side and fit a cap on (Fig. 2). Repeat this procedure with the second capillary tube.
- Dip the prepared tubes into the bottles and screw the caps tight on the bottles.
  Caution: The water level in the water-filled tube rises up immediately, so water could overflow or spurt out!
- Push the tube in the air-filled bottle down so far that is dips into the water, which now rises up in the tube.
- Before the start of measurement, ensure that both tubes are slid down so far that approx. 1 cm of liquid is to be seen above their cap (Fig. 1).
- Re-tighten the caps.
- Heat the bottles with your hands and observe the water levels in the tubes.
  When doing this, take care not to cause the caps or tubes to wobble or shake (Fig. 3).
- Measure the heights to which the water ascends in the tubes of the air-filled and water-filled bottles.

Fig. 2

Fig. 3

Observations

1.

....

....

....

Evaluation

2. Describe the behaviour of the water in the tubing?

....

....

....

3. Compare the heights of ascent in the air-filled bottle and the water-filled bottle?

....

....

....

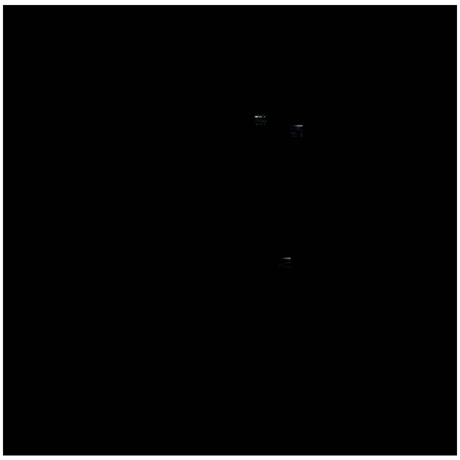
Additional experiment

Place the two bottles in a water bath containing water at about 30 °C (available at the teacher's table). Wait about 30 s before you read the heights of ascent.

....

....

....



(How do the volumes of air and water change when they are heated?)

Material from the Heat Demo-Set

1	Heating + cooking hotplate,230V	04025-93
1	Stainless Steel pot 3,2 l	05934-00
1	Lab thermometer,-10..+100C	38056-00

Additional material
Absorbent paper or towel
Distilled water

Preparation

The objective of this experiment is to take a qualitative look at thermal expansion and to compare that of water and air. It is therefore first intended that the students simply heat the bottles with their hands.

It could be that their hand-heat is not sufficient to cause the water level in the water-filled bottle to rise.

This is predominately because water has a high heat capacity. The hands are cooled and their warmth is then insufficient to heat the water up by several degrees. In addition, the thermal expansion of water is less than that of air.

A satisfactory qualitative comparison therefore requires that a pot containing about 27°C warm water is available for the students to warm their bottles.

Heating the air up much more than 6 degrees in this experiment could cause water to overflow out of the capillary tube of the air-filled bottle!

Notes on set-up and procedure

Distilled water is to be used in this experiment, as otherwise lime deposits in the capillaries when the tubes are dried.

Caution

Water spurts out like a fountain when capillary tubes are quickly pushed into water-filled bottles instead of carefully easing them in. The students would naturally enjoy this! This effect has nothing to do with thermal expansion, however, but results from the displacement of water through the capillary tubes.

Each screwing action at the screw-caps and wobbling of the tubes influences the water level in the tubes. The students should try this out prior to measurement. They then realize that only the bottles are to be touched during the measurement procedure. Any other action falsifies their results.

Observations

1. Water rises in each of the tubes. It rises very quickly in the tube of the air-filled bottle. In the water-filled bottle, however, it takes about 1 min before it starts to rise and then does so only very slowly.
   Typical values for heights of ascent (dependent on the room temperature and the warmth of hands)
   Air: approx. 11 cm
   Water: approx. 4 cm

Evaluation

1. The water level of the air-filled bottle rises immediately. That of the water-filled bottle only changes very slowly.
2. The height of ascent (expansion) is much greater for air.
   Air: approx. 11 cm
   Water: approx. 4 cm

Room for notes

How does heating change the volumes of water and methylated spirit?

Task

Fill one bottle with water and a second one with methylated spirit. Fit capillary tubes in each of the bottles and keep a watch the bottles while they are heated.

Material

2 Screw cap jars
2 Caps
2 Gaskets
2 Capillary tubes
1 Beaker
1 Funnel

Methylated spirit
Distilled water
Food colouring
Ruler
Absorbent paper

[redacted]

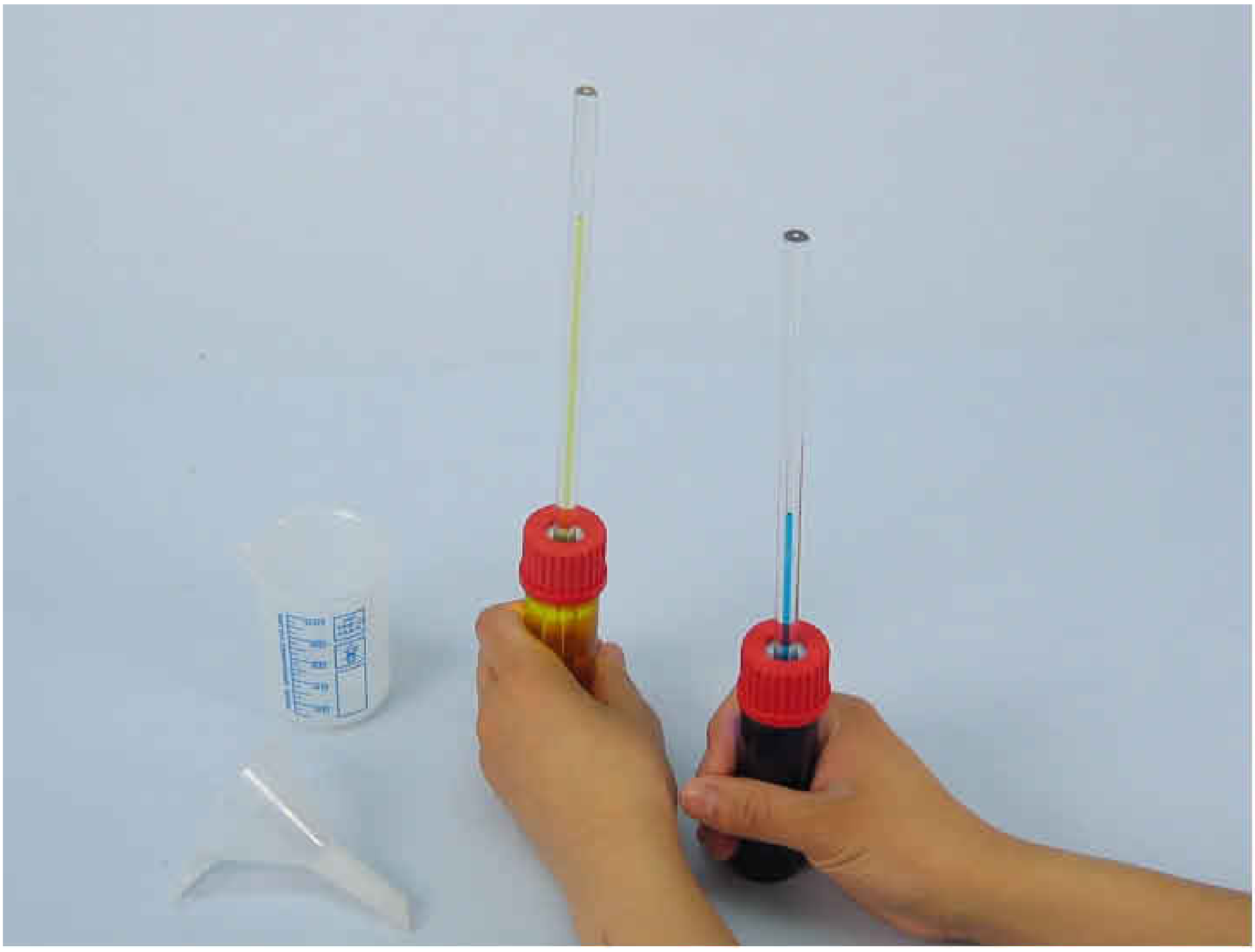


Fig. 1

Set-up and procedure

- Methylated spirit and coloured distilled water are available at the teacher's table.
- Use the beaker to fetch approx. 40 ml of coloured water and use the funnel to fill this water into a screw-cap bottle up the lower thread edge.
- Using the beaker again to fetch approx. 40 ml of spirit and fill this into the second bottle in the same way as with water.
- Push sealing rings on both capillary tubes so that they protrude out by about 4 cm. Fit caps on (Fig. 2).
- Fit the tubes so carefully in the bottles that no liquid flows out and screw the caps tight. The liquids rise up in the capillary tubes.
- Before starting measurement, position the tubes so that the both liquid levels are approx. 1 cm above the caps.
- Heat the bottles with your hands and observe the water levels in the two tubes.
  Do not cause the caps or tubes to wobble or shake while doing this.
- Measure the heights to which water and spirit acend.

Fig. 2

Observations

1. How have the liquid levels changed?

   ....

   ....

2. Measured values:

   Water.................................

   Spirit.................................

Evaluation

1. Compare the behaviour of water with that of spirit.

   ....

   ....

   ....

2. Which of the two liquids would you choose for a self-made thermometer when you want to use it to also measure small temperature changes?

   ....

   ....

   ....

Additional experiment

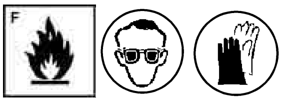
Place the two bottles in a water bath containing water at about 30 °C (available at the teacher's table). Wait about 30 s before you read the heights of ascent.

....

....

....

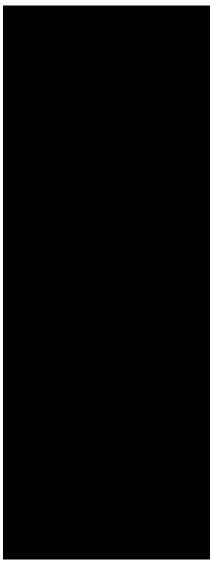
Safety precautions for methylated spirits



Methylated spirit is a highly flammable liquid. When handling it, extinguish all naked flames which are in the vicinity and keep it away from all other sources of ignition (lighters etc.).

Do not swallow it (do not drink it!). Avoid contact with skin. Do not breathe vapours. Wear eye protection.

Bring the methylated spirit back to your teacher at the end of the experiment for it to be suitably disposed of.



(How does heating change the volumes of water and methylated spirit?)

Material from the Heat Demo-Set

1	Heating + cooking hotplate,230V	04025-93
1	Stainless Steel pot 3,2 l	05934-00
1	Graduated vessel, 1 l, with handle	36640-00
1	Glass beaker DURAN®, tall, 600 ml	36006-00
1	Lab thermometer,-10..+100C	38056-00
	Additional material	
1	Denaturated alcohol (spirit for burning), 1000 ml	31150-70
1	Water, distilled, 5 l	31246-81
1	Spatula, double blade, 150 mm	33460-00
1	Patent Blue V (sodium salt), 25 g	48376-04

Preparation

Distilled water must be used for this experiment! Tap water dirties capillary tubes by leaving a lime deposit in the capillary when it dries. They then gradually become unusable.

A comparison is made of the thermal expansions of water and methylated spirits. Coloured water is used so that they can be distinguished from each other. The least dangerous way for this is to use food colouring, whereby only a spatula tip amount of this is required.

Water and methylated spirit are best made available to the students in a 1 litre graduated jug or a 600 ml beaker. The students are to fetch the liquids from the teacher's table with their 100 ml beakers. Each group of students needs 40 ml of each.

A litre of water heated to 30°C allows an improved comparison of the thermal expansions of water and methylated spirit.

Notes on set-up and procedure

Caution:

When a capillary tube had been dipped into a filled bottle and must be pushed further into it, water or methylated spirit could flow out. Capillary tubes are only to be very carefully moved after caps have been screwed tight. Rapid movement could cause liquid to spurt out of the capillaries. This must be avoided, particularly with methylated spirit!

Each screwing action at the screw-caps and wobbling of the tubes influences the water level in the tubes. The students should try this out prior to measurement. They then realize that the bottles only are to be touched during the measurement process. Any other action falsifies the result.

Observations

1. Liquid rises up in both tubes.
2. Methylated spirit rises higher than water.

Evaluation

1. The heights of both liquids only slowly increase, water slower than methylated spirit. Ascent heights after 1 to 2 min: Typical examples of heights of ascent (dependent on room temperature and hand-warmth)
   Water: approx. 4 cm
   Methylated spirit: approx. 8 cm

2. With the same heating, methylated spirit showed a greater ascent height. It would therefore allow greater spacing between marks for 1°C and be more suitable than water for small changes.

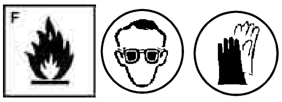
Additional experiment

Heights of ascent in a water bath of approx. 30°C (typical values):

Water: approx. 5 cm

Methylated spirit: approx. 13 cm

Safety precautions for methylated spirit



Methylated spirit consists of approx. 92-96% of ethanol which has been made unfit for human consumption by denaturing.

Ethanol is a highly flammable, colourless liquid with a characteristic pleasant odour. It can be mixed with water and almost all organic solvents in all proportions. Vapour may form explosive mixtures with air.

Risks:

Ethanol is highly flammable.

Safety precautions:

Keep container tightly closed. Keep away from sources of ignition – do not smoke.

First aid:

On contact with skin, eyes with eyelids open, wash immediately with plenty of water.

In the case of eye injury, seek medical advice immediately. In case of accident or if you feel unwell seek medical advice immediately. If inhaled: Fresh air, keep respiratory tract free. On respiratory distress: Transport to doctor in half-sitting position.

Waste disposal:

Collect combustible, halogen-free organic solvents and solutions in a correspondingly labelled container and pass to safe waste disposal.

How is the Celsius temperature scale defined?

Task

Label a thermometer with a scale which enables you to measure temperature values in degrees Celsius.

Material

1 Beaker
1 Thermometer without a scale
1 Adhesive tape dispenser

Ruler
Soft pencil
Ice fragments

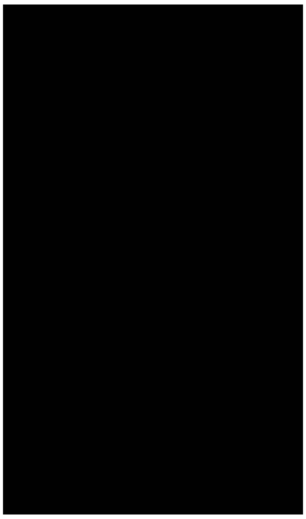


Fig. 1

Set-up and procedure

- Boiling water is available on a heating plate at the teacher's table.
- Tear an approx. 20 cm long piece of adhesive tape off from the dispenser.
- Carefully stick it along the whole length of the front of the thermometer stem (Fig. 2).
- Tear off another such length and stick this on the back of the stem.
- Fill the beaker with fragments of ice and pour cold water on them up to the 50 ml mark.
- Carefully stir the icy water and keep a watch on both the icy water and the thermometer.
- Wait until the reading no longer changes.
- Use the pencil to mark the position of the red liquid (Fig. 1).
- Go to the boiling water pot at the teacher's table, taking your thermometer with you.

Danger: Steam is hot! Keep your hands at the edge of the pot. Never reach in low to the middle of it!

- Put your thermometer in the pot so that it lies at an angle and keep a watch on it.
- Mark the tube at the position which the liquid in the thermometer reaches.

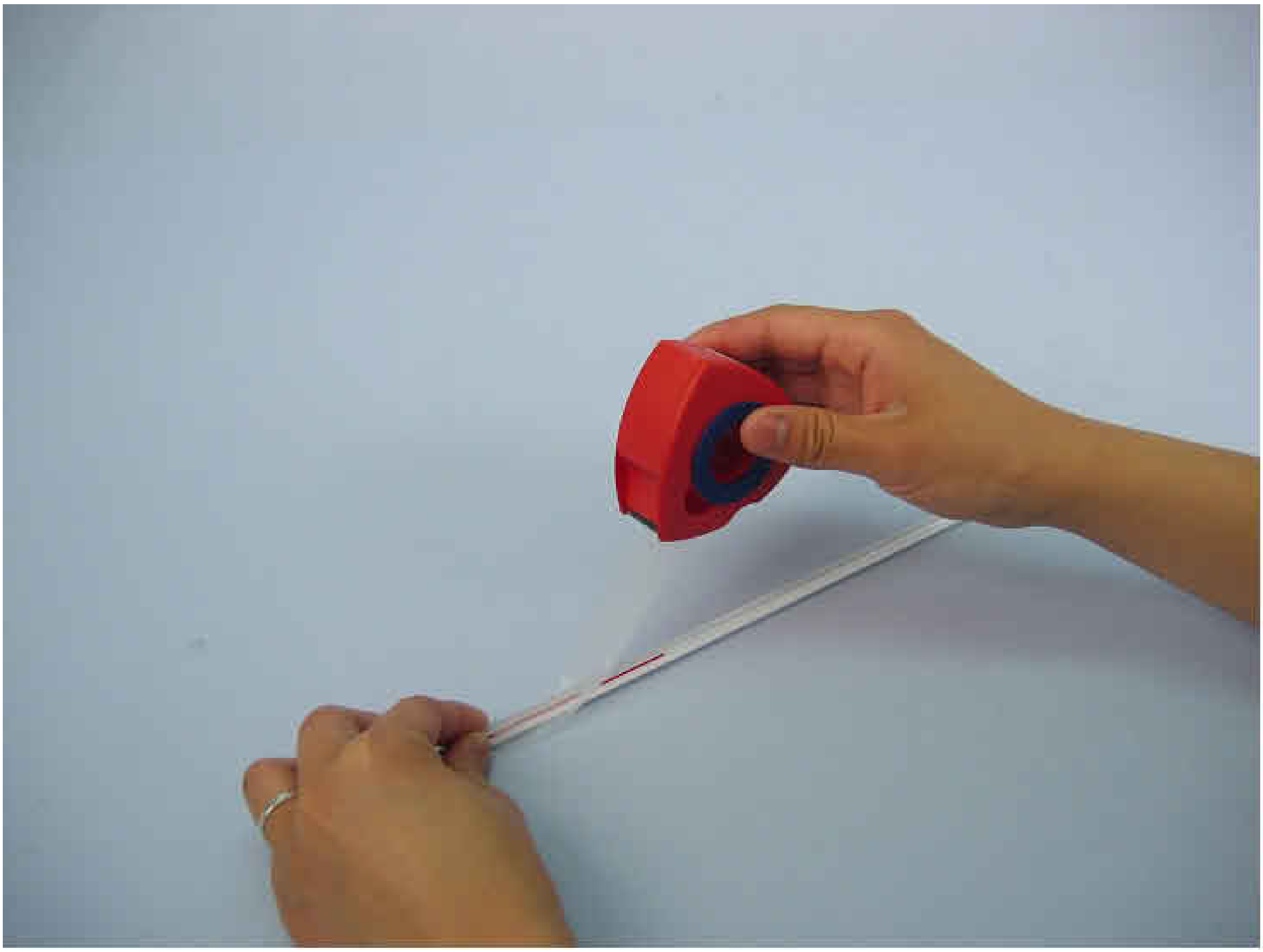


Fig. 2

Observations

1. Thermometer in icy water

   ....

   ....

2. Thermometer in boiling water

   ....

   ....

Evaluation

1. Write in the following values at the positions you have marked:
   0°C for the freezing point of water and
   100°C for the boiling point of water.
   Make further marks which divide the space between the two marks into 10 equal sections. Label these marks.

   Make further but smaller marks in each section so that it has 10 divisions (Fig. 3).Give further examples which show that you can feel a difference between hot and cold.

Fig. 3

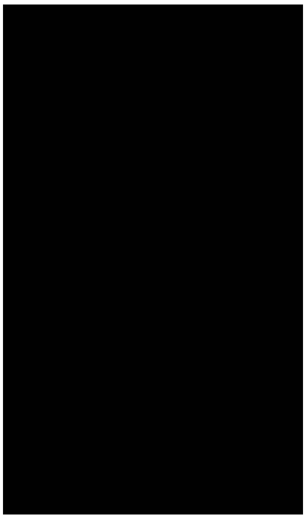
2. Use your thermometer to measure various temperatures, e.g.: tap water, hot water, room temperature, finger temperature, and record them here.

   ....

   ....

   ....

3. Compare the readings which your group has made with those of other groups.



(How is the Celsius temperature scale defined?)

Material from the Heat Demo-Set

1	Heating + cooking hotplate,230V	04025-93
1	Stainless Steel pot 3,2 l	05934-00
1	Graduated vessel, 1 l, with handle	36640-00

Additional material

1 Hammer
1 Towel
Ice cubes

Preparation

Quite a lot of ice fragments are required for the beakers of the students. Ice cubes can be best broken down by wrapping them in a towel and hitting them with a hammer. The small fragments of ice which are then in the towel among the remains are required. The graduated jug could be used to distribute them.

Notes on set-up and procedure

The Celsius temperature scale is defined by the boiling point and freezing point of water. The students are to mark such a scale on a non-graduated thermometer and carry out various measurements with their graduated thermometer. The students must stir the icy water well before applying the mark for 0°C and the beaker should still contain some pieces of ice, as otherwise the water could already be above zero degrees. They are not to take the thermometer out of the water to take the reading.

The students must be supervised while they establish the 100°C mark. A litre of water is required. The water is to be boiling gently with merely a few bubbles rising up.

The adhesive of the adhesive tape which contacts the glass of the thermometer dissolves in boiling water, whereas adhesive between two tapes does not dissolve. This is why tape is to be additionally stuck on the back of the stem. It could be necessary to also stick adhesive tape around some parts of the thermometer stem.

Caution:

The boiling water is only to generate a little steam!

The students are to lay their thermometers in the pot at a slope, wait until the liquid level no longer rises and then mark this position. They must try not to allow their hands to go further than the rim of the pot during this procedure.

The teacher can carry out this part of the experiment if this is found to be appropriate.

Observations

1. The ice partly dissolves during stirring. The liquid in the thermometer drops and then slowly comes to a standstill.
2. When the thermometer is in the boiling water pot, the liquid in the thermometer rises very quickly to start with, then slower until it reaches an end point.

Evaluation

1. The fixed points of the Celsius scale are labelled 0°C and 100°C. The space between these is first divided into 10 equal sections and the marks labelled 10°C, 20°C and on.
   The small marks for individual °C are then added in between.

Remarks

When a thermometer which contains alcohol is used to check the boiling point of water, attention must be paid to the immersion depth and/or column temperature which is given on the thermometer.

The thermometers from the set which are used have these values on the back of the stem: An immersion depth of approx. 5 cm, an average column temperature (for the upper part of the thermometer) of 35°C.

The upper part of the thermometer should theoretically not be in the hot steam when the measurement in boiling water is being carried out,!

When thermometers with alcohol filling are use to measure the temperature of boiling water, they therefore always give a slightly higher temperature than 100°C (e.g. 103°C). The deviation is correspondingly larger with vigorously boiling water and exposure of the thermometer to more steam.

How must you read a thermometer to obtain the correct temperature value?

Task

Examine on what the correct reading of a thermometer is dependent (Fig. 1).

Material

2 Thermometers
1 Beaker
1 Screw cap jar
1 Funnel

Dry cloth
Watch

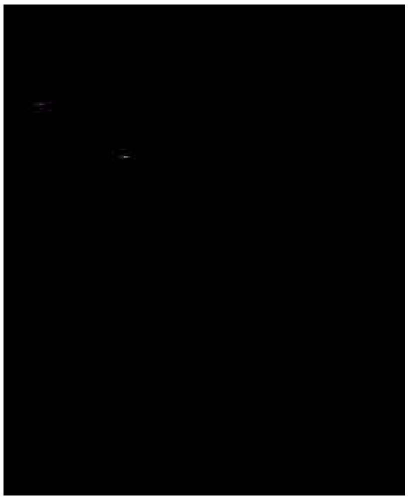


Fig. 1

Set-up and procedure

- Hot water is available at the teacher's table.
- Fill the beaker with cold water and carefully stir the water with the thermometer.
- Hold the thermometer at an angle. Look at the scale vertically and read the temperature.
- Hold the thermometer upright. Look at it sideways from above so that you can still just recognize the scale and read the temperature.
- Hold an additional thermometer in the beaker and stir carefully with both of them. Wait a moment, look exactly sideways at the scales and read their temperatures (Fig. 2).
- Fill the bottle with cold water and the beaker with hot water.
- First hold both thermometers in the hot water, carefully stir, read their temperatures and enter them in the Table at time = 0 s.
- Wipe drops of water from the thermometers, stand one thermometer in the bottle with cold water and lay the other on the table (Fig. 3).
- Read the temperatures at 30 s intervals and enter them in the Table.

Fig. 2

Fig. 3

Observations

1. One thermometer, direction of sight:

   Vertically to the scale..

   From above ....
2. Read two thermometers:

   First ....

   Second ....
3. Temperature variation

Time in s	Thermometer in water Temp. in °C	Thermometer in air Temp in °C
0		
30		
60		
90		
120		
150		
180		

Evaluation

1. From which direction must you look at the scale?

   ....

   ....

   ....

2. How exactly can the scale be read?

   ....

   ....

   ....

3. How can you find the “right” temperature value when two thermometers show different values or several people read different values for one temperature?

   ....

   ....

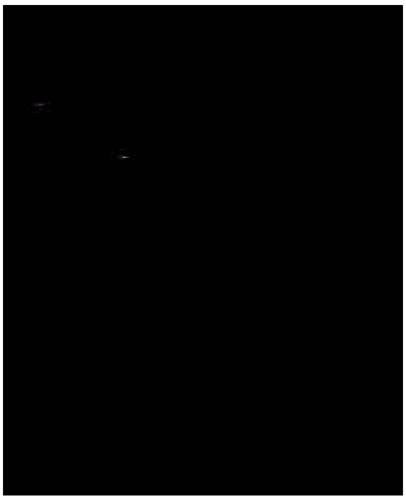
   ....

4. It took a while for the thermometers to correctly show the temperatures of cold water or cold air when they were hot. What importance does this have for reading temperatures from thermometers?

   ....

   ....

   ....



(How must you read a thermometer to obtain the correct temperature value?)

Material from the Heat Demo-Set

1	Heating + cooking hotplate,230V	04025-93
1	Stainless Steel pot 3,2 l	05934-00
1	Graduated vessel, 1 l, with handle	36640-00
1	Lab thermometer,-10..+100C	38056-00

Preparation

60°C hot water must be made available for this experiment.

Notes on set-up and procedure

In the fourth part of the experiment, drops of water should be quickly wiped off of the hot thermometer so that measurements during cooling are accurate.

When the thermometer is exposed to air without previous wiping, any water drop would evaporate off and so additionally cool the thermometer.

When the thermometer dipped in water, falsification of the measurement by a hot drop of water is unnecessary.

The last part of the experiment is the most important one for an understanding of how to correctly take readings of temperature. The students come to realize that temperature equalization between the thermometer and the surroundings must be complete before a reading is made. In other words, sufficient patience and a long enough wait, or possibly careful stirring, are always necessary.

Observations

1. Read one thermometer:
   Vertically from above e.g. 24.0 °C
   From above e.g. 23.5 °C
2. Read two thermometers:
   First e.g. 24.0 °C
   Second e.g. 24.5 °C
3. Temperature variation:
   (Water and room temperature: 22°C

Time in s	Thermometer in water Temp. in °C	Thermometer in air Temp in °C
0	57,0	57,0
30	24,0	40,0
60	23,0	36,0
90	22,5	32,5
120	22,5	30,5
150	20,0	29,0
180	22,0	28,0

Evaluation

1. One must always look vertically towards the scale to take a reading.
2. A value between two small marks on the scale can be approximated to 0.5°C.
3. Take the average of all readings (of all thermometers or all students who take readings). Round off this average value up or down.
   Notes: There is no sense in giving the “correct” value to more than one decimal place. The example in this experiment shows that temperature displays of two thermometers can also differ slightly.
4. With water (or other liquids) one should wait one minute before taking a reading. Stirring can accelerate temperature equalization.
   Notes: The heat contact to the surroundings is much less in air (or other gases), which is why heat exchange takes longer. Here also, movement can accelerate temperature equalization.

The measured times are valid for glass thermometers with alcohol filling, thermoelements etc. react much quicker.

How can you bring hot bath water to the temperature you need?

Task

Examine which temperature is reached when hot and cold water are mixed.

Material

2 Screw cap jars
2 Thermometer
1 Beaker
1 Funnel

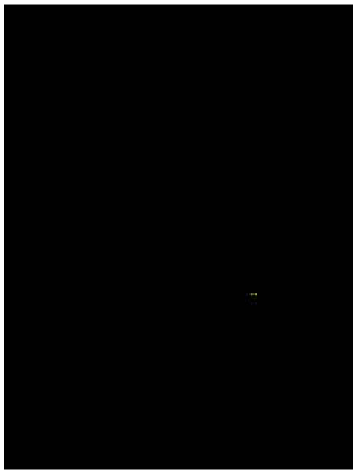


Fig. 1

Set-up and procedure

- Hot water is available at the teacher's table

Experiment 1

- Completely fill a screw-top bottle with cold water.
- Pour 40 ml of hot water into the beaker.
- Measure the temperatures of the cold water and the hot water (Fig. 1).
- Pour the cold water out of the bottle and into the beaker (Fig. 2).
- Use the thermometer to carefully stir the mixture and measure the temperature of it (mixed temperature)

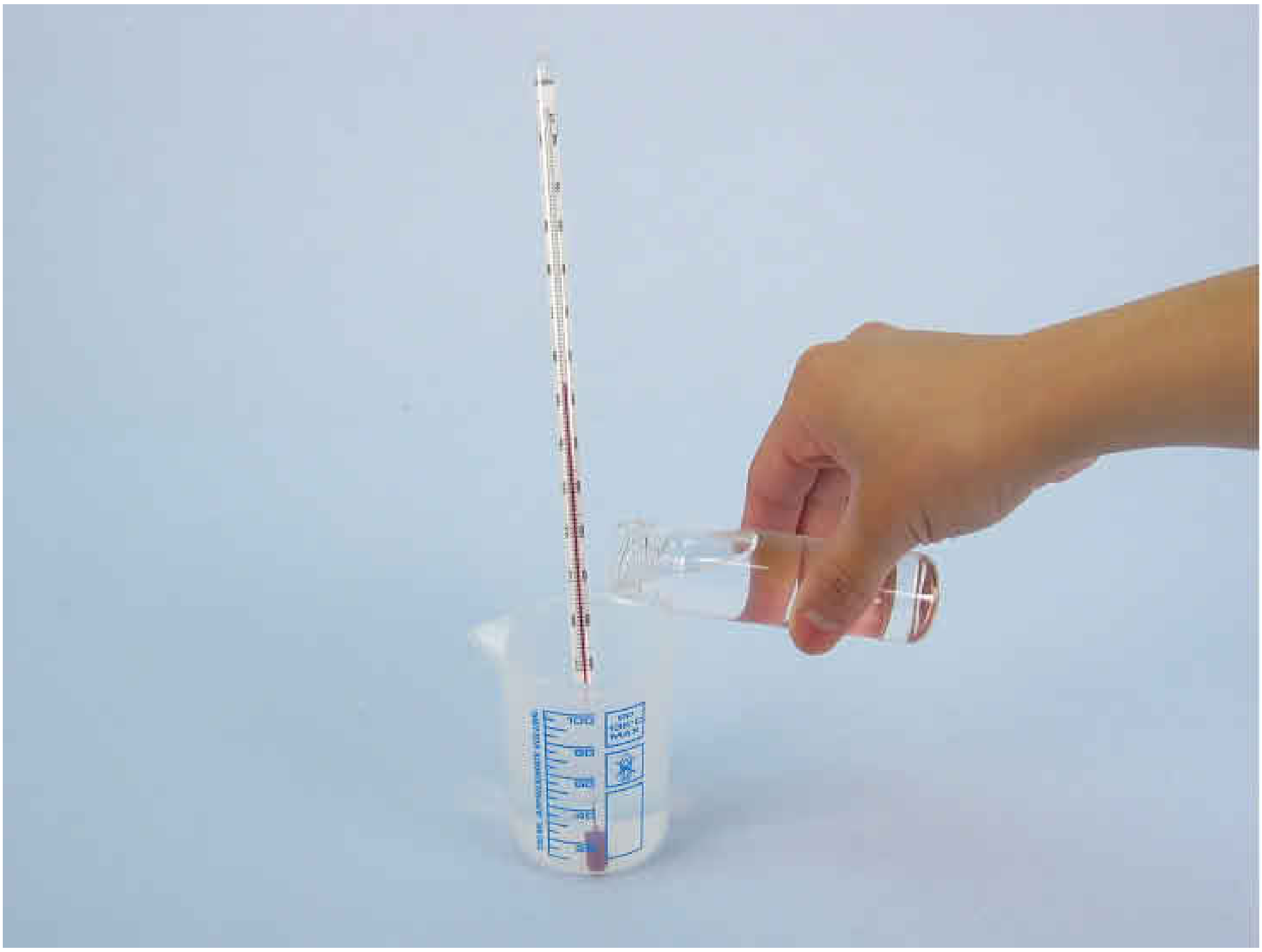


Fig. 2

In the experiment which follows, you are to use different amounts of hot and cold water for each measurement and read the temperatures of each mixture.

Experiment 2

- Rinse the beaker with cold water and dry it.
- Use the beaker and funnel to fill cold water into two bottles, each to a total volume of 60 ml.
- Pour 40 ml of hot water into the beaker.
- Measure cold water and hot water temperatures.
- Pour the cold water from both bottles into the beaker
- Carefully stir the mixture with the thermometer and measure the mixed temperature.

Experiment 3

- Use the following amounts of water in this experiment:
  80 ml of cold water (2 full bottles)
  20 ml of hot water

Experiment 4

- Use the following amounts of water in this experiment:
  40 ml of cold water (1 full bottle)
  60 ml of hot water

Observations

Experiment 1

	Volume	Temperature	Temperature of mixture
Cold water	40 ml		
Hot water	40 ml		

Experiment 2

	Volume	Temperature	Temperature of mixture
Cold water	60 ml		
Hot water	40 ml		

Experiment 3

	Volume	Temperature	Temperature of mixture
Cold water	20 ml		
Hot water	80 ml		

Experiment 4

	Volume	Temperature	Temperature of mixture
Cold water	40 ml		
Hot water	60 ml		

Evaluation

1. How high is the mixed temperature with equal amounts of cold and hot water?

   ....

   ....

   ....

2. How does the mixed temperature change when the beaker contains more hot than cold water?

   ....

   ....

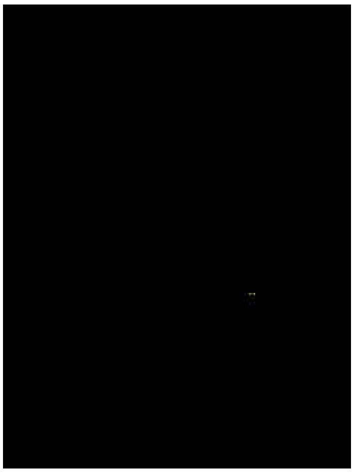
   ....

3. Which temperature is reached when the amounts of hot and cold water are exactly reversed?

   ....

   ....

   ....



(How can you bring hot bath water to the temperature you need?)

Material from the Heat Demo-Set

1	Heating + cooking hotplate,230V	04025-93
1	Stainless Steel pot 3,2 l	05934-00
1	Graduated vessel, 1 l, with handle	36640-00
1	Lab thermometer,-10..+100C	38056-00

Preparation

About 2.5 litres of 60°C hot water must be made available for this experiment. Each student group requires about 250 ml.

Notes on set-up and procedure

The students are to compare the results of individual experiments with each other. The hot and cold water must therefore always have the same temperature at the beginning of the experiment. The 50 ml beaker need not be used for filling cold water into the screw-top bottles, as it would then subject to cooling. The bottles have a volume of 40 ml, so they can be filled directly from the water tap.

Observations

Experiment 1

	Volume	Temperature	Temperature of mixture
Cold water	40 ml	22°C	42°C
Hot water	40 ml	62°C	

Experiment 2

	Volume	Temperature	Temperature of mixture
Cold water	60 ml	22°C	45°C
Hot water	40 ml	62°C	

Experiment 3

	Volume	Temperature	Temperature of mixture
Cold water	20 ml	23°C	52°C
Hot water	80 ml	60°C	

Experiment 4

	Volume	Temperature	Temperature of mixture
Cold water	40 ml	22°C	38°C
Hot water	60 ml	60°C	

Evaluation

1. When equal amounts of cold and hot water are mixed with each other, the temperature of the mix is in the middle of their original temperatures. The mixed temperature is the average of the temperatures of the hot water and the cold water which were used.
2. When there is more hot water than cold water in the beaker, the mixed temperature is higher than the average of the two original temperatures.
3. When there is more cold water than hot water in the beaker, the mixed temperature is lower than the average of the two original temperatures. A comparison between experiments 2 and 4 shows the same deviation from the average value in each of these two experiments.

Wool keeps us warm!

Task

Follow the cooling of hot water as it cools in two bottles, one of which is insulated with several felt sheets (Fig.1).

Material

2 Screw cap jars
2 Caps
2 Gaskets
2 Thermometers
1 Beaker
1 Funnel
3 Felt sheets
Rubber bands

Watch

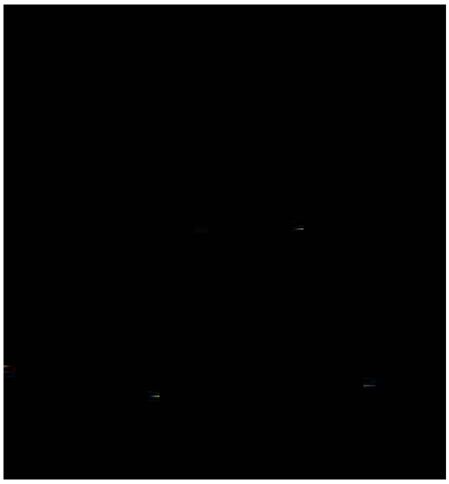


Fig. 1

Set-up and procedure

- Use felt sheets and elastic bands to make a felt “jacket” for one of the bottles. This jacket must have two characteristics (Fig. 2):
    a. It must insulator the bottle particularly well.
    b. It must be possible to take the bottle out of it for filling hot water into the bottle and then to replace the bottle.
- Take the bottle out of the jacket and place both on the table.
- Place the bottle without insulation next to it on the table.
- Have about 80 ml of hot water (approx. 60°C) poured into the beaker.
- Use the funnel to fill each bottle with hot water.
- Screw sealing rings on both thermometers to the 0°C marking and fit caps on each (Fig. 3).
- Insert the thermometers in the bottles and screw the caps on tight.
- Put one bottle back in the felt jacket.
- Read the initial temperature (time = 0 min) in each of the bottles.
- Watch how the temperatures change.
- Read the temperature for 30 minutes.

Fig. 2

Fig. 3

Observations

1.

....

....

....

Time in min	Jar without felt Temp. in °C	Jar with felt jacket Temp in °C
0		
5		
10		
15		
20		
25		
30		

Evaluation

1. Compare the temperature in the bottle with felt jacket and that without?

....

....

....

2. When is fleece sheared from sheep?

....

....

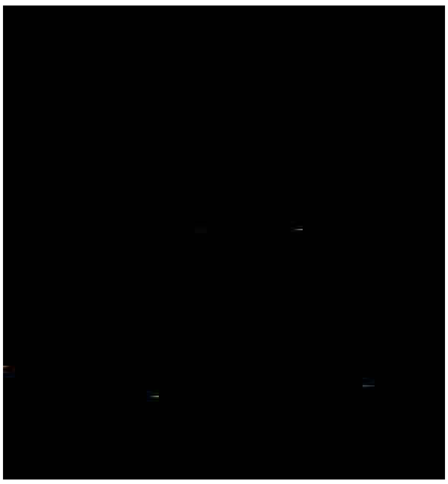
....

3. How can you protect yourself against cold?

....

....

....



(Wool keeps us warm!)

Material from the Heat Demo-Set

1	Heating + cooking hotplate,230V	04025-93
1	Stainless Steel pot 3,2 l	05934-00
1	Graduated vessel, 1 l, with handle	36640-00
1	Lab thermometer,-10..+100C	38056-00

Additional material
Distilled water

Comment

Felt is made up of animal hair, just as is wool. Felt is put to technical use, however, as it has a much denser structure than wool and is more resistant to tear. The students have no doubt experienced how matted a pullover is when it has been washed at too high a temperature.

Preparation

The use of distilled water is recommended to avoid the need to clean the narrow screw-cap bottles.

The thermal insulation property of wool (felt sheets) is shown by a comparison of the cooling of hot water in an insulated bottle and in one without insulation. Hot water must be available, 100 ml for each group. When the hot water is at a high temperature, the effect can be well and quickly shown. The temperature should not be higher than 60°C though, as the students could then possibly suffer scalding. The students should come to your table to have their beakers filled.

Notes on set-up and procedure

The construction of the felt jacket is not described in detail here, as the students should be allowed to prepare it themselves. The same result will be obtained whether 2 felt sheets are used for the jacket and one as underlay on the table, or all three sheets are used for the jacket. It is very important, however, that the bottle is fitted in the jacket as quickly as possible. A competition on who makes the best jacket could be interesting here!

Observations

1. The temperature does not go down as quickly in the felt jacketed bottle as in the non-insulated one. The temperature drops relatively quickly in the first few minutes but then more slowly.

Time in min	Jar without felt Temp. in °C	Jar with felt jacket Temp in °C
0	54	54
5	50	51
10	45	49
15	42	47
20	39	45
25	37	44
30	35	43

Evaluation

1. The temperature in the non-insulated bottle already went down by 10 degrees within 10 min, that in the insulated one only 6 degrees. After 30 min the difference was 19 degrees against 11 degrees.
2. Sheep are sheared in early summer so that the fleece has time to grow thick again and be a very good insulator in winter.
3. We wear warm pullovers and jackets when we go outdoors. Pullovers used to be predominately made of wool, but nowadays there are new micro-fabrics made from polyester fibres (but also called fleece) and these are also good insulators against the cold.

Notes

Theoretically, the thickness of the insulating layer and the K value of an insulating layer, i.e. the insulation effect, are dependent on each other, but this can only be recognized after 30 min at the earliest with these simple means. A higher initial temperature would be better, but then the students could not carry out the experiment themselves.

Time in min	Without felt Temp. in °C	1 x Felt Temp. in °C	2 x Felt Temp. in °C	3 x Felt Temp in °C
0	59	59	59	59
5	53	55	55,5	56
10	47,5	51	52	52,5
15	44	50	51	51,5
20	40	46	47,5	48
30	35	42	44	45

How does feathering protect a bird from the cold?

Task

Insulate a bottle with an air layer in the form of scraps of paper (feathers). Watch how hot water in this bottle cools and compare it with the cooling of hot water in a non-insulated bottle (Fig. 1).

Material

2 Screw cap jars
2 Caps
2 Gaskets
2 Thermometers
1 Beaker
1 Funnel
1 Adhesive tape dispenser

Paper
Watch

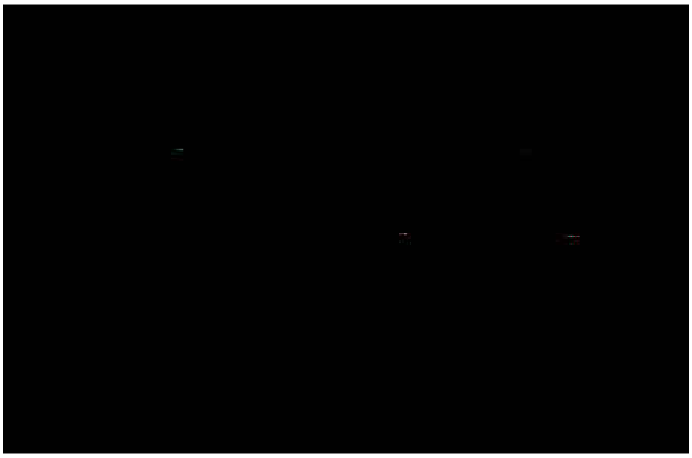


Fig. 1

Set-up and procedure

- A bottle is to be given a “mantle of air” (Fig. 2):
- Crumple paper strips which are to be used to fill the space between the bottle and the wall of the beaker. Also cut out a smooth cover for the beaker (e.g. from a circular filter).
- Fit a bottle in the beaker and try out which amount of crumpled paper will be required and how the set-up should be so that the bottle can be properly stood in the beaker.
- Take the bottle out of the insulated vessel, so that the paper will not get wetted when you now fill hot water into the bottle. Empty the paper out on the table.
- Have both bottles almost filled with hot water (approx. 60°C) from the 1 litre beaker.

Fig. 2

- Push sealing rings on each of the thermometers to the 0°C mark, then the caps (Fig. 3).
- Insert the thermometers in the bottles and screw the caps tight.
- Put one of the bottles back in the beaker and insulate it with crumpled paper. Stick adhesive tape over the paper to keep everything in place.
- Read the initial temperatures (time = 0 min) in the two bottles.
- Watch the change in temperature.
- Take temperature readings for 30 minutes.

Fig. 3

Observations

1.

....

....

Time in min	Jar only Temp. in °C	Jar in the beaker Temp in °C
0		
5		
10		
15		
20		
25		
30		

Evaluation

1. Compare the temperature changes in the two bottles.

....

....

....

2. How do birds behave to protect themselves from the cold?

....

....

....

3. Do you know of any other examples in which air is used for thermal insulation?

....

....

....

(How does feathering protect a bird from the cold?)

Material from the Heat Demo-Set

1	Heating + cooking hotplate,230V	04025-93
1	Stainless Steel pot 3,2 l	05934-00
1	Glass beaker DURAN®, tall, 600 ml	36006-00
1	Lab thermometer,-10..+100C	38056-00
1	Circular filter, d = 70 mm	32977-02

Additional material
Distilled water

Preparation

The use of distilled water is recommended because then the narrow screw-cap bottles need not be cleaned afterwards.

The thermal insulation provided by air (between scraps of paper or genuine feathers) in one bottle is determined by comparison with a non-insulated bottle.

Hot water must be made available for this, approx. 100 ml for each group.

As the students need their beaker as part of the insulated vessel, the hot water is to be distributed directly from the 1 litre beaker to the students. It is to be carefully filled in the bottles through the funnel until the bottles are almost full.

Notes on set-up and procedure

The insulated vessel should be ready assembled before the actual experiment is started, so that the students know how to proceed as soon as they obtain hot water is obtained. This is important as the next steps are to be taken as rapidly as possible.

The covering of the insulated vessel is to prevent air from escaping out from below. A 70 mm diameter circular filter fits exactly after the middle has been cut and forms a “collar” around the bottle (Fig. 2).

The taking apart of the insulated vessel when hot water is to be poured in the bottle is necessary, as insulation would be lost if the paper was wetted or there was water in the beaker.

Observations

1. The temperature in the non-insulated bottle drops quicker than that in the insulated bottle. It drops more quickly to start with than later.

Time in min	Jar only Temp. in °C	Jar in the beaker Temp in °C
0	53	53
5	50	51
10	44	47
15	42	45
20	38	43
30	34	40

The good thermal insulation of air can already be recognised after watching the temperatures for 10 minutes. The difference after 30 minutes is naturally more impressive.

Evaluation

1. In the first 10 minutes the non-insulated bottle temperature dropped by 9 degrees, the insulated bottle temperature by only 6 degrees. After 30 minutes the total drops were 19 and 13 degrees.
2. The birds fluff their feathers out when it is cold and so increase their surrounding air layer.
3. Warm clothing contains air, e.g. thick pullovers made of wool or modern micro-fabrics consisting of micro-fibres. Further examples are insulating materials such as polystyrene foam or mineral wool, new building materials which contain air.

Note

This experiment shows that: Air is a good protection against heat loss!

Why are scraps of paper filled into the air-filled space between the bottle and the beaker?

Small air spaces are mostly used In nature (plumage of birds, animal hair) and in engineering (insulating materials). Larger spaces, such as insulating glass panels, are evacuated, i.e. emptied of air.

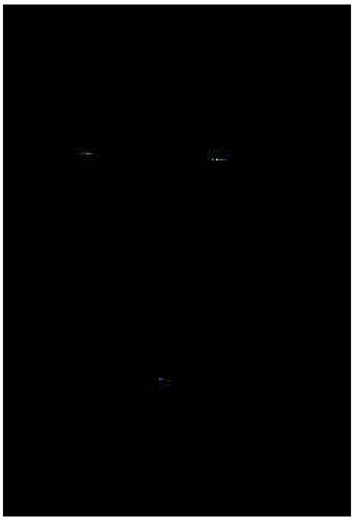
The reason is as follows: A wide air space enables circulation of the air to take place. There would be a greater heat exchange between the bottle and the wall of the beaker in our insulating vessel when used without the crumpled paper. The paper hinders this circulation and effects improved insulation. This is, however, only detectable using higher temperatures and longer measurement.

Save heating costs with thermal insulation.

Task

Measure the cooling rate of hot water in two bottles, one of which stands in a polystyrene box. (Fig.1).

Material



2 Screw cap jars
2 Caps
2 Gaskets
2 Thermometers
1 Beaker
1 Funnel
1 Heat-Set experimental box

Watch

Fig. 1

Set-up and procedure

- Have about 80 ml of hot water (approx. 60°C) poured into the beaker.
- Use the funnel to fill the hot water in the bottles.
- First push sealing rings on the thermometers to the 0°C marking, then add caps (Fig. 2).
- Insert the thermometers in the bottles and tighten the caps to hold them tight.
- Place one of the bottles in the appropriate opening in the polystyrene foam box (Fig. 1) and stand the other bottle next to the box.
- Read the initial temperatures (time = 0 min) in each of the bottles.
- Watch and describe the course of the temperatures.
- Take temperature readings over a time period of 30 min.

Fig. 2

Observations

1.

....

....

....

Time in min	Jar only Temp. in °C	Jar in foam box Temp in °C
0		
5		
10		
15		
20		
25		
30		

Evaluation

1. Compare the temperatures in the two bottles.

....

....

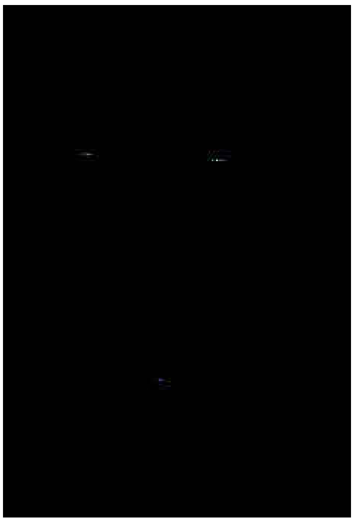
....

2. Can you think of any other thermally insulating materials?

....

....

....



(Save heating costs with thermal insulation.)

Material from the Heat Demo-Set

1	Heating + cooking hotplate,230V	04025-93
1	Stainless Steel pot 3,2 l	05934-00
1	Graduated vessel, 1 l, with handle	36640-00
1	Lab thermometer,-10..+100C	38056-00

Additional material
Distilled water

Preparation

The use of distilled water is recommended as this avoids the need to clean the narrow bottles.

The thermal insulation of polystyrene foam is to be examined by comparing the rate of cooling of hot water in a bottle surrounded by such foam with that of hot water in a non-insulated bottle. The hot water which is required for this must be made available, whereby each group needs about 100 ml. A high water temperature would lead to a good and rapid effect but could result in scalding of students. The water should therefore not be hotter than 60°C and the students are to fill it into their beakers at your table.

Notes on set-up and procedure

The student need of hot water is approx. 40 ml of hot water for each bottle.

The polystyrene foam box should be emptied before the start of this experiment.

The bottle caps must be screwed tightly on, so that students can grip the cap of a bottle to fit it in the opening in the polystyrene box.

Observations

1. The water temperature goes down more quickly in the non-insulated bottle than in the insulated bottle. It drops most quickly to start with and then slows down.

Time in min	Jar only Temp. in °C	Jar in foam box Temp in °C
0	54	54
5	50	52
10	45	49
15	42	48
20	39	46
25	37	45
30	35	44

It takes only a 10 minute temperature watch to see that polystyrene foam is a good heat insulating material. The difference after 30 minutes is naturally more impressive.

Evaluation

1. The non-insulated bottle temperature dropped by 9 degrees in the first 10 minutes, that in the insulated bottle only by 5 degrees. After 30 minutes the total drops were 19 and 10 degrees.
2. Further insulating materials are mineral wool, building materials such as aerated concrete and plastic fibre fabrics for the free-time area, sport clothing, insulating mats etc.

It could be that the students are not very technically versed but can find better examples from everyday life.

Note

The three experiments, this one, “Thermal insulation with wool” one and “Thermal insulation with air (feathers)” are all on the same topic. The objective is always to reduce the loss of heat.

The structures of the insulating materials used have the similarity that they all contain small air spaces. The understanding is so brought that these small spaces contribute to the heat loss reducing effect of each of the materials, although to different extents.

Why do we sweat?

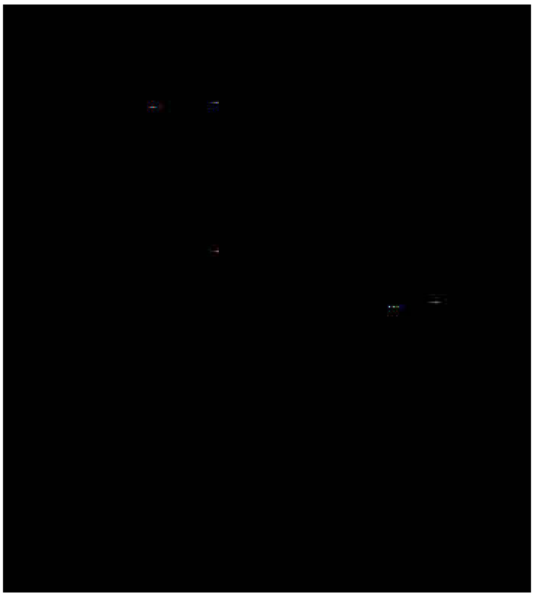
Task

Examine the temperature shown by a wetted thermometer when it is moved to and fro in the air.

Material

2 Thermometers
1 Beaker
Rubber band

Absorbent paper
Watch



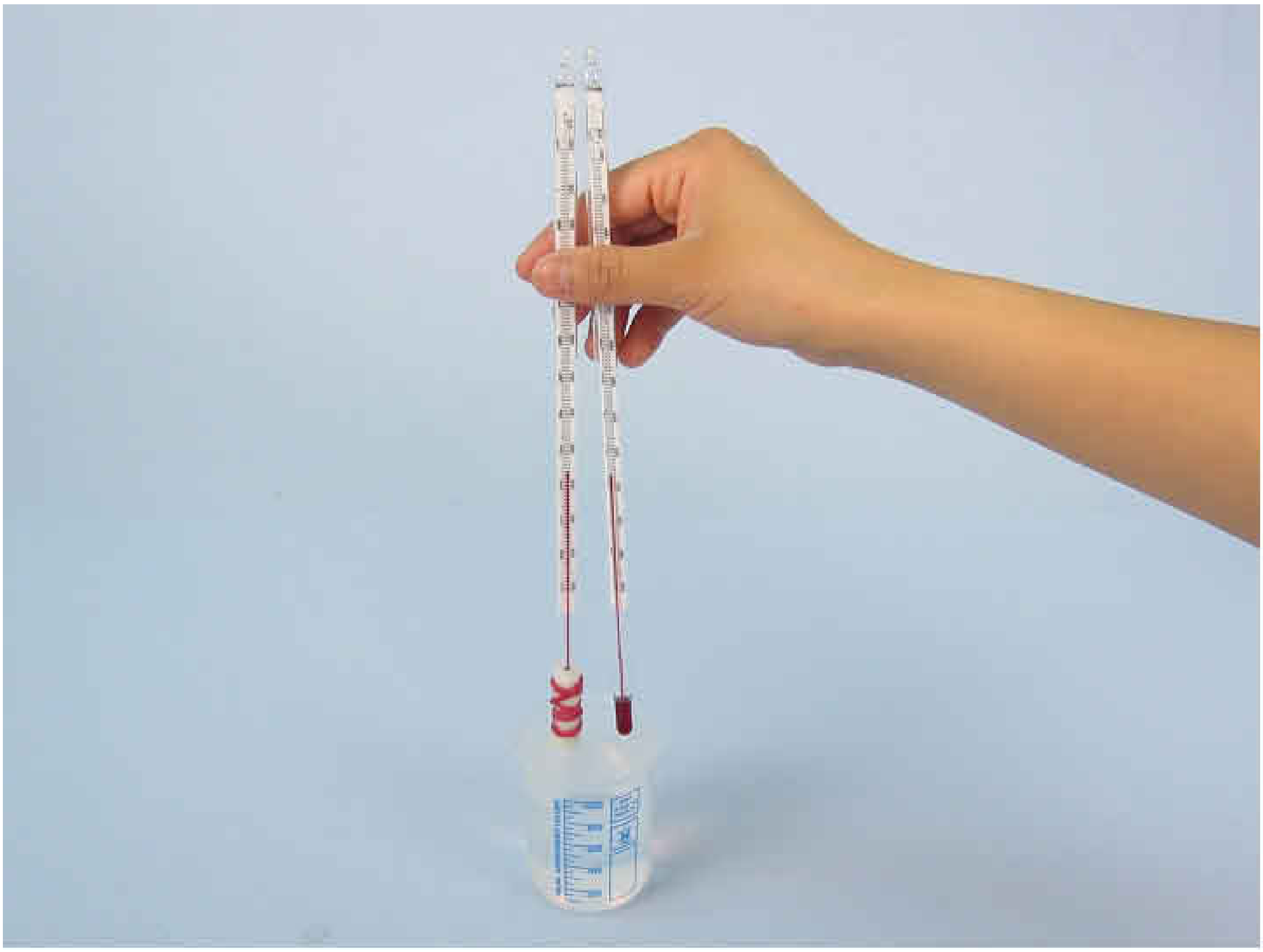


Fig. 1

Set-up and procedure

- Fill approx. 40 ml of cold water into the beaker.
- Hold a thermometer in the water, stir the water with it and read the temperature it shows.
- Take the thermometer out of the water, move it slowly back and forth and keep a watch on the temperature.
- Note what you observe.
- Take a second thermometer, wind filter paper around the lower end of it and use an elastic band to hold the paper in position (Fig. 2).
- Now hold the two thermometers in the water in the beaker and stir with them both until they show the same temperature (Fig. 1).
- Enter this temperature for time = 0 min in the Table.
- Take the thermometers out of the water and move them slowly to and fro.
- Read the values shown by the two thermometers every one minute.
- Touch the thermometers briefly between readings. Are they still wetted or have they dried?
- Complete the Table.

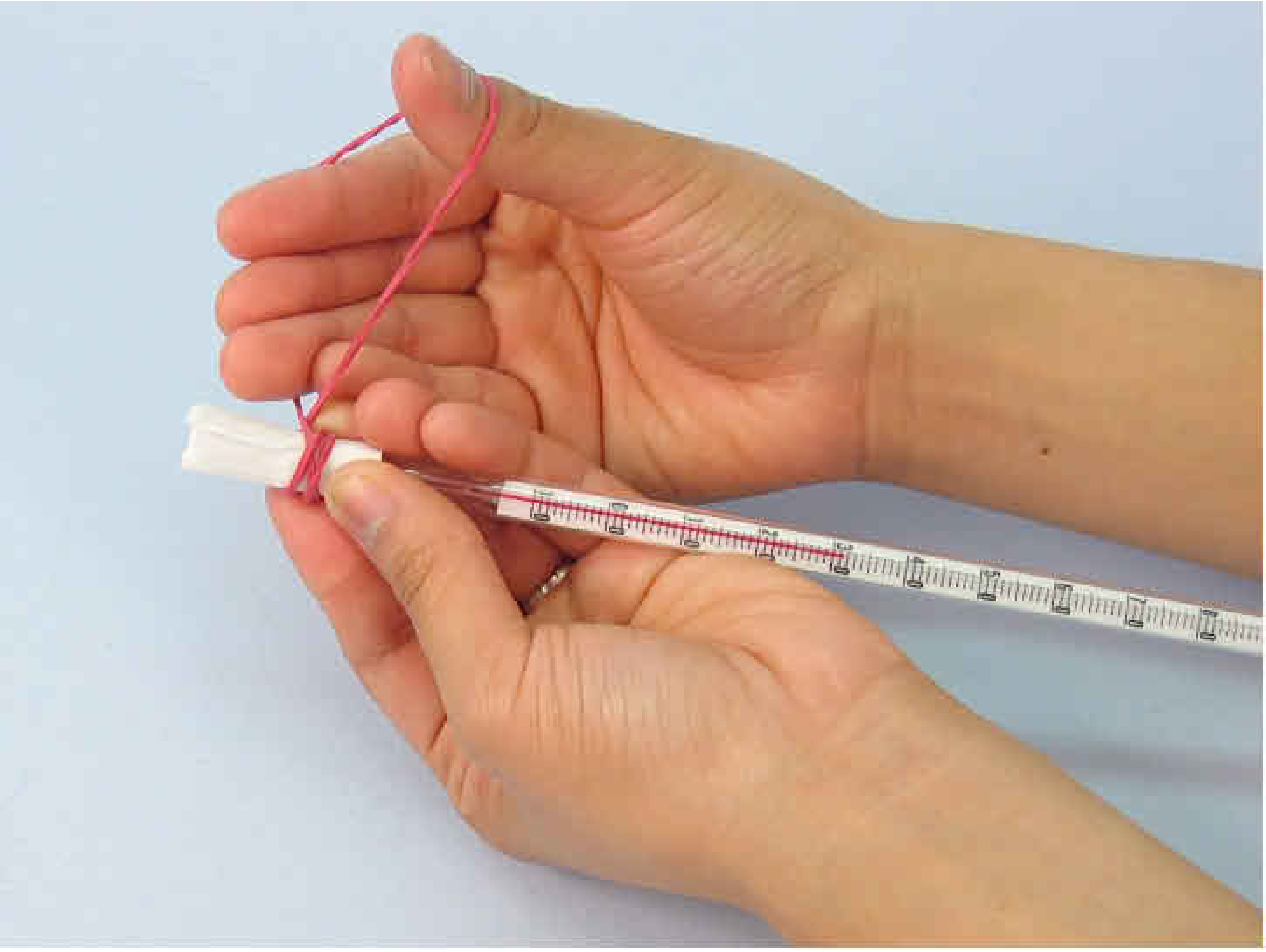


Fig. 2

Observations

1. Experiment with one thermometer:

....

....

....

2. Experiment with two thermometers:

Time in min	Without paper Temp. in °C	With paper Temp in °C
0		
1		
2		
3		
4		
5		
6		

3. Do the thermometers feel wetted or dry when felt between readings?

....

....

....

Evaluation

1. Compare the readings for the thermometers with and without filter paper.

....

....

....

2. You have additionally tested if the thermometers are wetted or dry. Can you find a connection between the measured values and the wetness of the thermometers?

....

....

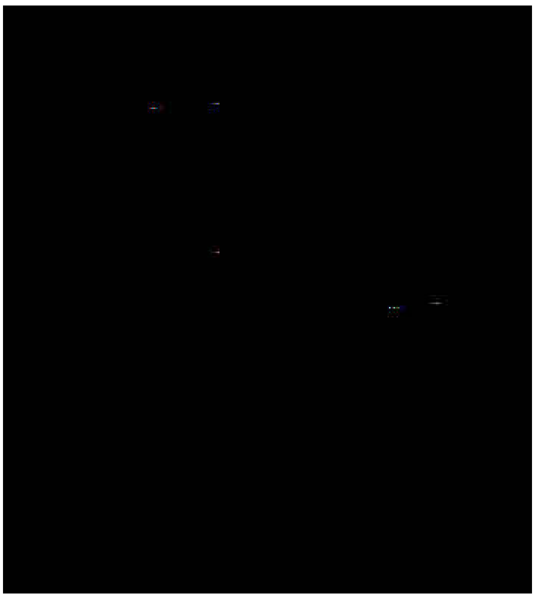
....

3. Why do we sweat?

....

....

....



(Why do we sweat?)

Material from the Heat Demo-Set

1 Circular filter, d = 70 mm 32977-02

Preparation

The circular filters are very suitable for use as absorbent paper for wrapping the thermometers. Each group requires one of these filters.

Notes on set-up and procedure

Thermometers warm up during the wrapping of them because of finger contact.

It is therefore recommended that the first readings be taken after a wait of approx. 30 seconds from the time they are dipped in the water.

Observations

1. The temperature drops when the thermometer is taken out of the water.
2.

Time in min	Without paper Temp. in °C	With paper Temp in °C
0	21	21
1	19	20
2	18	18
3	18	16
4	19	15
5	20	14
6	20	13,5

3. The thermometer without paper is dry after approx. 3 min and the temperature then again increases. The thermometer with paper is still somewhat moist even after 6 min.

Evaluation

1. The temperature of the thermometer without filter paper drops from 21°C to 18°C in approx. 2 min, remains briefly at this value and then slowly increases. The temperature of the thermometer with filter paper continuously decreases and has reached 13.5°C after 6 min.
2. The thermometer without filter paper is dry within approx. 3 min and clearly does not cool any more, whereas the thermometer with filter paper is still wet, or moist.
3. We sweat from exertion or in hot weather because sweat on the skin has a cooling effect.

Room for notes

Are there liquids which cool more than water when they evaporate?

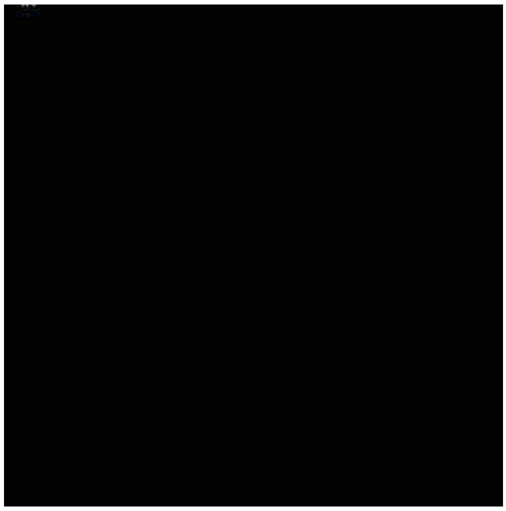
Task

Wind absorbent paper around each of two thermometers, soak one of then with spirit and the other with water, then follow the course of the temperatures.

Material

2 Screw cap jars
2 Thermometers
1 Beaker
1 Funnel
Rubber bands

Filter paper
Spirit



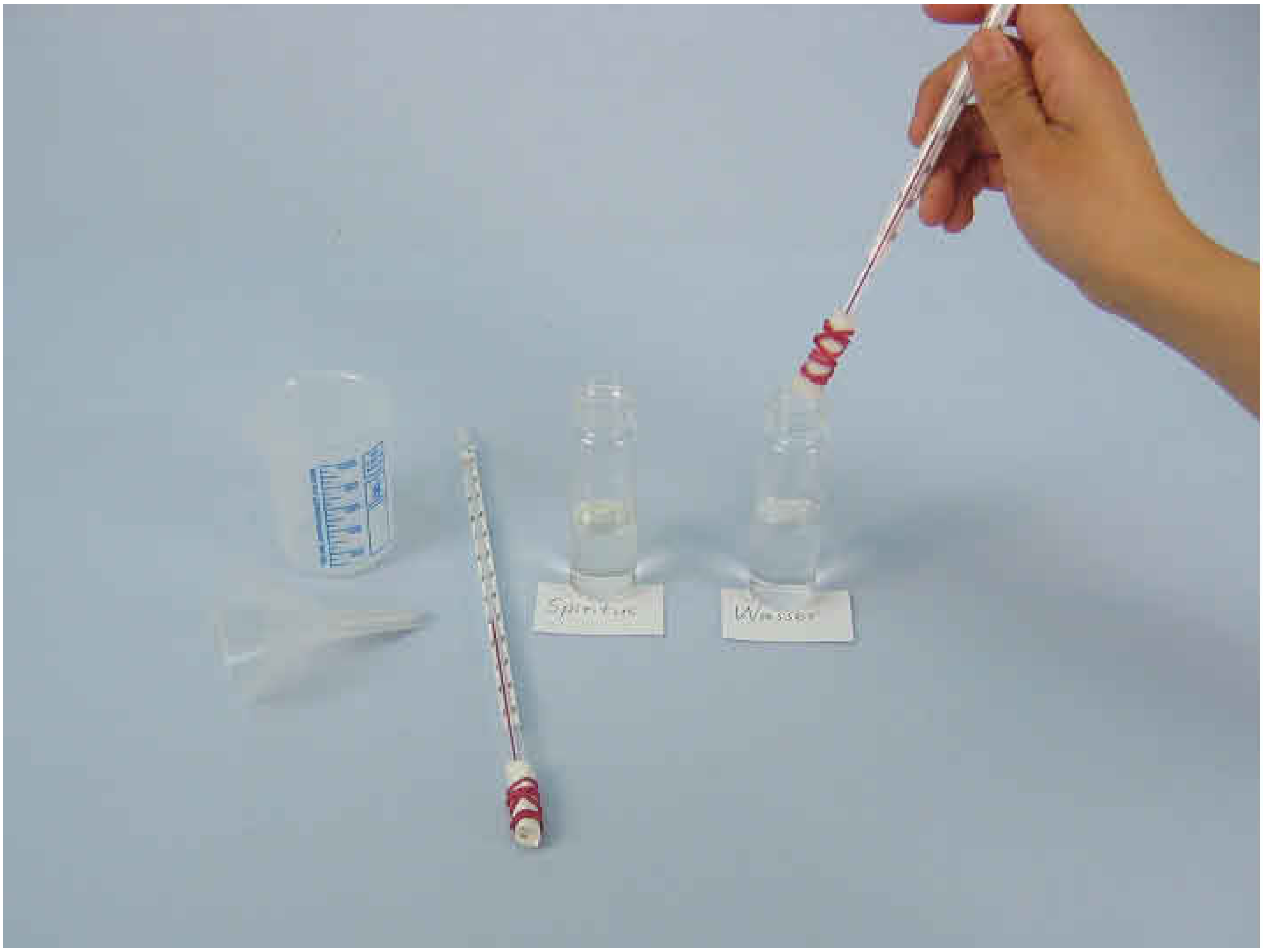


Fig. 1

Set-up and procedure

- Fill e approx. 20 ml of water into one screw-cap bottle.
- Have approx. 20 ml of spirit poured in your beaker.
- Use the funnel to fill the spirit in the second bottle (Fig. 2).
- Measure the room temperature and the initial temperatures of water and spirit. All three temperatures should be the same!
- Wind pieces of absorbent paper (filter paper) around the ends of each thermometer and hold them in place with elastic bands (Fig. 3).
- Dip thermometers into each bottle. Wait about 30 seconds until they again show the initial temperature. Enter the readings at time = 0 min in the Table.
- Take the thermometers out of the bottles. Move them slowly back and forth while keeping a watch on the temperatures.
- Read the values shown by the two thermometers.
- Complete the Table.

Fig. 2

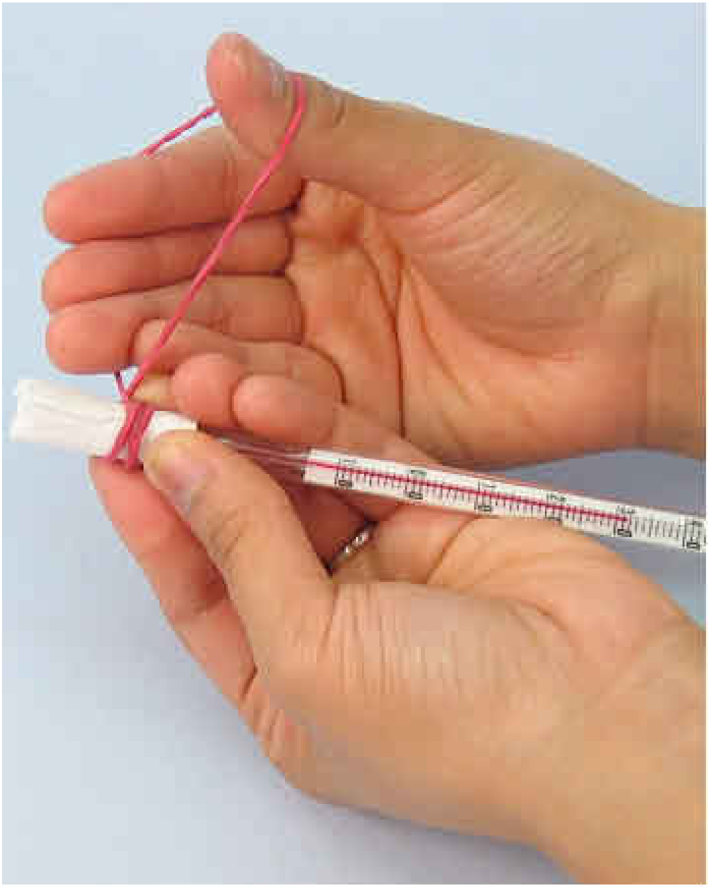


Fig. 3

Observations

1.

	Water	Spirit
Time in min	Temp. in °C	Temp in °C
0		
1		
2		
3		
4		
5		
6		

Evaluation

1. Compare the results for water and spirit.

   ....

   ....

   ....

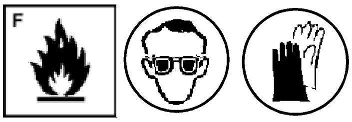
2. Do you know of any applications which require rapid cooling?

   ....

   ....

   ....

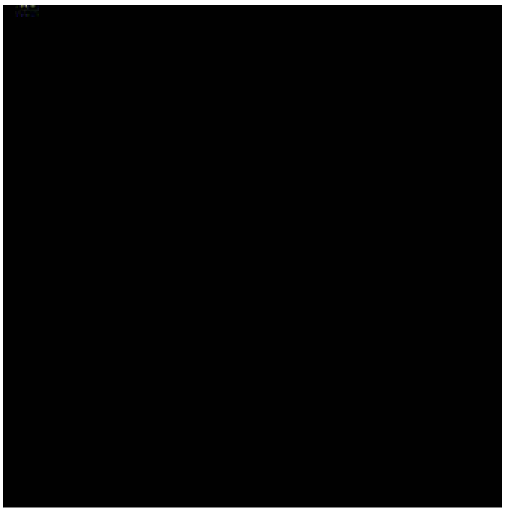
Safety precautions, methylated spirit



Methylated spirit is a highly flammable liquid. When handling it, extinguish all naked flames and keep it away from all other sources of ignition (e.g. cigarette lighters etc.)

Do not swallow the liquid (do not drink it!). Avoid skin contact. Do not inhale vapour. Wear eye protection.

At the end of the experiment, bring the methylated spirit back to the teacher for safe waste disposal.



(Are there liquids which cool more than water when they evaporate?)

Material from the Heat Demo-Set

1 Circular filter, d = 70 mm 32977-02

Additional material

1 Denaturated alcohol (spirit for burning), 1000 ml 31150-70

Preparation

The circular filters are very suitable as wrapping for the thermometer. Each group needs two of them.

Each group needs 20 ml of spirit.

The water and the spirit must have the same temperature otherwise the comparison will be very inaccurate. It is therefore necessary to allow the liquids to stand in the classroom for several hours before they are to be used.

Notes on set-up and procedure

The thermometers warm up while they are being wrapped because of finger contact.

It is therefore recommended that the first readings be first taken after a wait of approx. 30 seconds after they are dipped in the water.

Observations

1.

	Water	Spirit
Time in min	Temp. in °C	Temp in °C
0	21	21
1	20	18
2	17	13
3	16	10
4	15	9
5	14	9
6	14	8

Evaluation

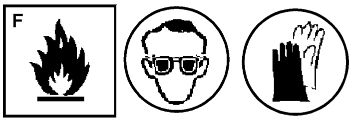
1. The thermometer with spirit-soaked paper cools more quickly than the one with water-soaked paper. The former goes down to a temperature of approx. 8°C in 6 minutes, the latter only to about 14°C.
2. Sport injuries without open wounds, such as bruises, sprains and hematoma, are treated by spraying ether on them.

Notes

The energy required for the evaporation of liquids is taken from the liquid and causes it to cool.

The amount evaporated and so also the cooling are dependent on the boiling point of the liquid and the ambient temperature.

Safety precautions, methylated spirit



Methylated spirit consists of approx. 92-96% of ethanol which is denatured to make it unfit for human consumption.

Ethanol is a highly flammable, colourless liquid with a characteristic pleasant smell. It mixes with water and almost all organic solvents in all proportions. Vapour can form explosive mixtures with air.

Risks**:** Methylated spirit is highly flammable.

Safety precautions*:* Keep container tightly closed. Keep away from sources of ignition – do not smoke.

First aid: In case of contact with skin, eyes with wide open eyelids, wash immediately with plenty of water. In case of eye injury, seek medical advice immediately. In case of accident or feeling unwell, seek medical advice immediately. **If inhaled:** Fresh air, keep respiratory tract open. **On respiratory distress:** Transport to medical aid in a half-sitting position.

Waste disposal*:* Collect combustible halogen-free organic solvents and solutions in an appropriately labelled container and pass to safe waste disposal.

Can water still be in the liquid state below 0°C?

Task

A beaker is to be filled with plenty of ice and just a little water. Salt is then to be added and you are to try to reach the lowest possible temperature (Fig. 1).

Material

1 Beaker
1 Thermometer

1 Teaspoon
Ice fragments
Common salt

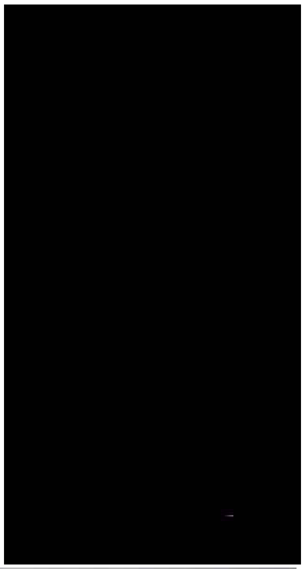


Fig. 1

Set-up and procedure

- Fragments of ice and salt are available at the teacher's table.
- Fill the beaker with ice fragments.
- Add water which is as cold as possible to bring the water level to the 50 ml mark.
- Stir carefully and read the temperature.
- Describe how much ice is still in the beaker and roughly at which mark the water level is.
- Fill further water in to make up to the 100 ml mark.
- Add a heaped teaspoonful of salt (corresponds to approx. 7 g of salt) to the beaker (Fig. 2).
- Stir carefully and observe the ice.
- Measure the temperature.
- Add a further spoonful of salt to the beaker.
- Stir, observe the ice and read the temperature.

Fig. 2

Observations

1. Temperature of icy water:

   ....

   ....

   ....

2. What happens after the addition of a teaspoonful of salt?

   ....

   ....

   ....

3. What changes occur when more salt is added?

   ....

   ....

   ....

Evaluation

1. Can you think of a use for what occurs in this experiment?

   ....

   ....

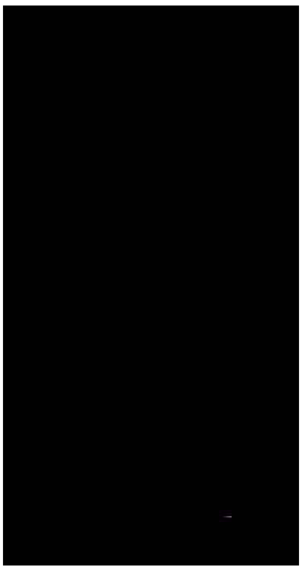
   ....

2. Is there a connection between the amount of salt added and the temperature?

   ....

   ....

   ....



(Can water still be in the liquid state below 0°C?)

Material from the Heat Demo-Set

1	Stainless Steel pot 3,2 l	05934-00
1	Graduated vessel, 1 l, with handle	36640-00
1	Glass beaker DURAN®, tall, 600 ml	36006-00

Additional material

1 Hammer
1 Towel
1 Teaspoon
Ice cubes
Common salt

Preparation

Numerous fragments of ice are required for this experiment. It is best to break up the ice cubes by wrapping them in a towel and then hitting them with a hammer. The ice fragments which are in the towel are required.

These small pieces can be collected either in the pot or in the graduated jug. The salt can be made available in the 600 ml beaker.

The colder the water used for filling into the beakers is, the lower the temperature that can be reached. It is therefore practical to also utilize the water from the melting ice. In an experiment in which approx. 40 ml of such water was used, for example, a temperature of – 10°C was reached.

Careful stirring and slow carrying out of the experiment also assist in getting good results. A competition on who can reach the lowest temperature could possibly be interesting!

Notes on set-up and procedure

In this experiment in particular, the result is dependent on many factors, one of which is how carefully the students carry it out.

The amount of ice that the students use, how warm the water which is added is and how long and carefully the students stir before the next step is made, are all important.

Observations

Two measurement examples are given here:

a. *Using tap water*
b. *Using water from melting ice (40 ml) and tap water*

1. The temperature of ice with water was in both cases first 0°C to 1°C, but the amount of ice present was greater when water from melting ice was used!

a. *When the beaker was only half-filled with ice when water was filled in.*

1. A spoonful of salt was added: The ice melted to a layer of approx. 1 cm thickness, temperature -3.5°C.
2. After a second spoonful of salt: The ice had all melted, temperature -4.5°C.

b. When the beaker was full of ice after adding water from melting ice (40 ml) and tap water:

1. A spoonful was salt is added: The beaker was ¾ full with ice, temperature -6°C.
2. After a second spoonful of salt: Still an ice layer of approx. 1 cm on top, temperature -10°C

Evaluation

1. Thawing ice on roads, cooling food, for example.
2. The more salt added, the lower the temperature.

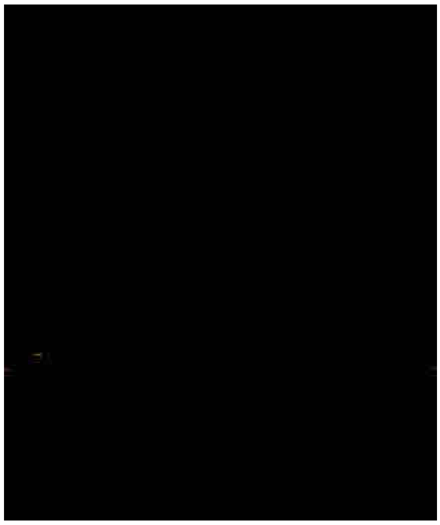
(This connection is only valid when the ice has not completely melted and the solution is not yet saturated with salt.)

Which temperature does water which is under the ice have?

Task

You are to measure the temperatures in a beaker of water on which ice is floating.

Material



1 Beaker
1 Screw cap jar
2 Thermometers

Ice fragments

Fig. 1

Set-up and procedure

- Ice fragments are available at the teacher's table.
- Half-fill the beaker with pieces of ice and add about a screw-cap bottleful of cold water.
- Stir the icy water for about 1 minute, keeping a watch on the ice and the thermometer.
- What is the temperature of the icy water?
- How much ice is still in it?
- Dip the thermometer to the bottom of the beaker, wait approx. 5 min, then read the temperature (Fig. 1).
- Hold the second thermometer up top in the ice layer and read the temperature there (Fig. 2).

Fig. 2

Observations

1. Temperature of icy water:

   ....

   ....

2. How much ice?

   ....

   ....

3. Temperature at the bottom of the beaker:

   ....

   ....

4. Temperature of the ice layer:

   ....

   ....

Evaluation

1. Did you already know what you have found in the experiment from something that you have seen in nature?

   ....

   ....

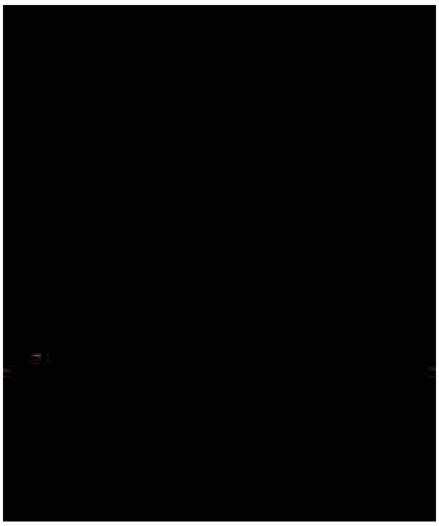
   ....

2. Which advantage is there in nature that there is still water beneath the ice?

   ....

   ....

   ....



(Which temperature does water which is under the ice have?)

Material from the Heat Demo-Set

1 Graduated vessel, 1 l, with handle 36640-00

Additional material

1 Hammer
1 Towel
Ice cubes

Preparation

The students require numerous small pieces of ice are required for this experiment. Ice cubes can be best broken up by wrapping them in a towel and then hitting them with a hammer. The ice fragments which are in the towel are required for the experiment.

These fragments can be distributed using the graduated jug, for example.

Notes on set-up and procedure

The contents of the beaker must be well stirred after water is filled in! After this, ice fragments should only float in the upper third of the beaker and the beaker should be completely filled with water, so that depth of the water is sufficiently large. It could be necessary to add further ice or water.

The result can be demonstrated well after a wait of 3 to 5 minutes under the conditions described,. The temperatures are then 4°C at the bottom and 1°C at the top. Deviations of 1°C must hereby be accepted.

Observations

1. The water has a temperature of approx. 0°C to 1°C.
2. The ice melts until there is only a layer floating at the top
3. After 5 min: 4°C
4. After 5 min: approx. 1°C

Notes

This experiment could also be carried out as a demonstration experiment. Use of the 600 ml beaker would then result in a water height of approx. 11 cm. This would provide a better spatial resolution of the course of temperature.

Only part of the thermometer dips in the water when the temperature of the ice layer is read. Proper immersion is not reached here and the value displayed is therefore too high. It could even possibly be 2°C.

Evaluation

1. When a lake freezes over, the ice layer is formed on the water and thickens downwards.
2. Fish which are in the lake can still swim in water. Only severe frost will result in a living space that is too small or too little exchange of oxygen.

Room for notes

How much a body heats up when it is exposed to sunlight is dependent on its colour. A black and a white test tube are to be heated here by a 120 W reflector lamp (Fig. 1).

Measurements of the temperatures of the air in the test tubes over time show that it takes only a few minutes for a distinct difference in the heating of them to result.

Material

1	Test tube, d 30mm, l 200mm, black	36294-06
1	Test tube, d = 30 mm, l = 200 mm, white	36294-05
2	Lab thermometer, -10..+100C	38056-00
2	Rubber stopper 26/32, 1 hole 7 mm	39258-01
1	Ceramic lamp socket E27 with reflector, switch, safety plug	06751-01
1	Filament lamp, 220V/120W,w.refl.	06759-93
1	Support rod, stainless steel, l = 250 mm, d = 10 mm	02031-00
1	Retort stand, 210 mm × 130 mm, h = 500 mm	37692-00
2	Right angle clamp	37697-00
1	Test tube rack, wood, for 6 tubes	40569-00

Additional material

1 Watch

Measuring tape

Glycerol

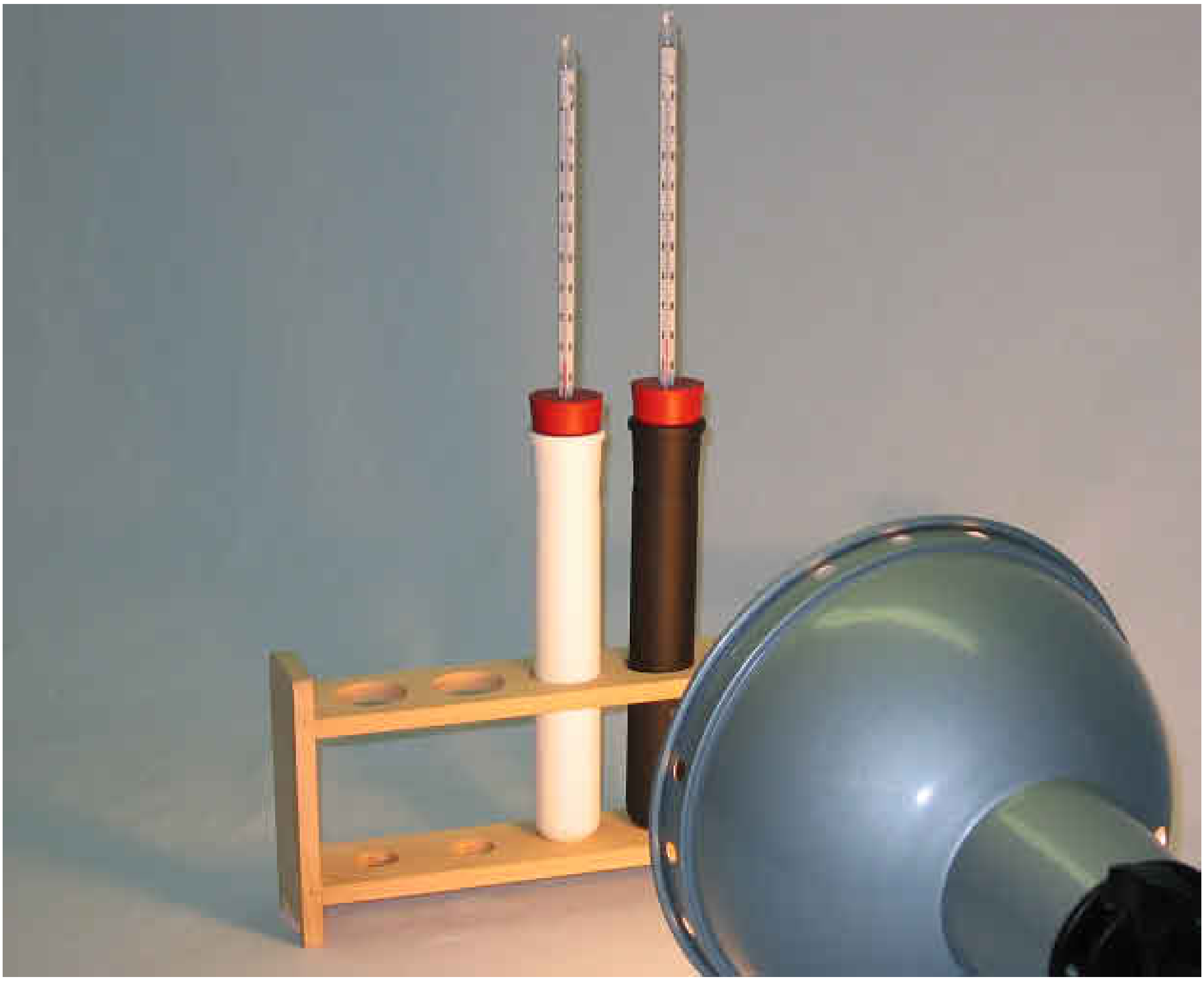


Fig. 1

Set up and procedure

- Rub glycerol (or water) on the lower parts of the thermometers and insert them in the stoppers to the 5°C mark.
- Close the test tubes with the stoppers and stand them in the middle of the test tube rack.
- Fix the lamp holder with fitted-in reflector lamp to the retort stand.
- Switch the lamp on briefly to so adjust the position of it that the centre of the light cone which illuminates the test tubes is a little above the test tube rack and that the lamp at the same distance (20 to 25 cm) from each tube. Ensure that the two tubes are evenly illuminated (Fig. 1).
- Switch the lamp off and measure the initial temperatures.
- (Table: Time t = 0 min)
- Switch the lamp on again and measure the temperatures in the black and white tubes at intervals of 1 minute, later at greater intervals.
- At the end of the experiment, switch the lamp off, ease the thermometers out of the stoppers and wipe them dry (they stick tight when left longer in the stoppers and can then only be removed with difficulty or even break during removal).

Notes on set-up and procedure

To obtain an impressive difference in the heating up, the distance between the test tubes and the glass of the lamp should not be too great (approx. 25 cm). The illuminating cone is then quite small, however, so care must be taken that both test tubes are equally illuminated.

Observations

Time in min	Black Temperature in °C	White Temperature in °C
0	25	25
1	26	26
2	28	27
3	30	28
4	33	29
5	35	30
10	42	32
15	45	34
20	47	35
25	48	36

Evaluation

On illumination by the light from a 120 W reflector lamp, the air in the black test tube warms up much quicker than that in the white one. Measurement should last for at least 5 minutes under the given conditions. In this example, the difference was then 5°C and increased to 10°C after 10 minutes.

Note

The experiment is particularly impressive when the test tubes can be heated in direct sunlight. In this case, the test tube rack should be appropriately inclined. Water could now be warmed in the test tubes instead of air.

Heating water in a closed tube at one position causes the water to flow, because warm water rises to the top and cold water sinks to the bottom. A circular liquid convection tube is used in this experiment and the flow of water is made visible with a food colouring substance (Fig. 1).

Material

1	Heating + cooking hotplate,230V	04025-93
1	Convection of liquids tube, small	04510-01
1	Glass beaker DURAN®, tall, 600 ml	36006-00
1	Graduated vessel, 1 l, with handle	36640-00
1	Retort stand, 210 mm × 130 mm, h = 500 mm	37692-00
1	Right angle clamp	37697-00
1	Universal clamp	37715-00

Additional material

1	Patent Blue V (sodium salt), 25 g	48376-04
1	Microspoon, steel	33393-00

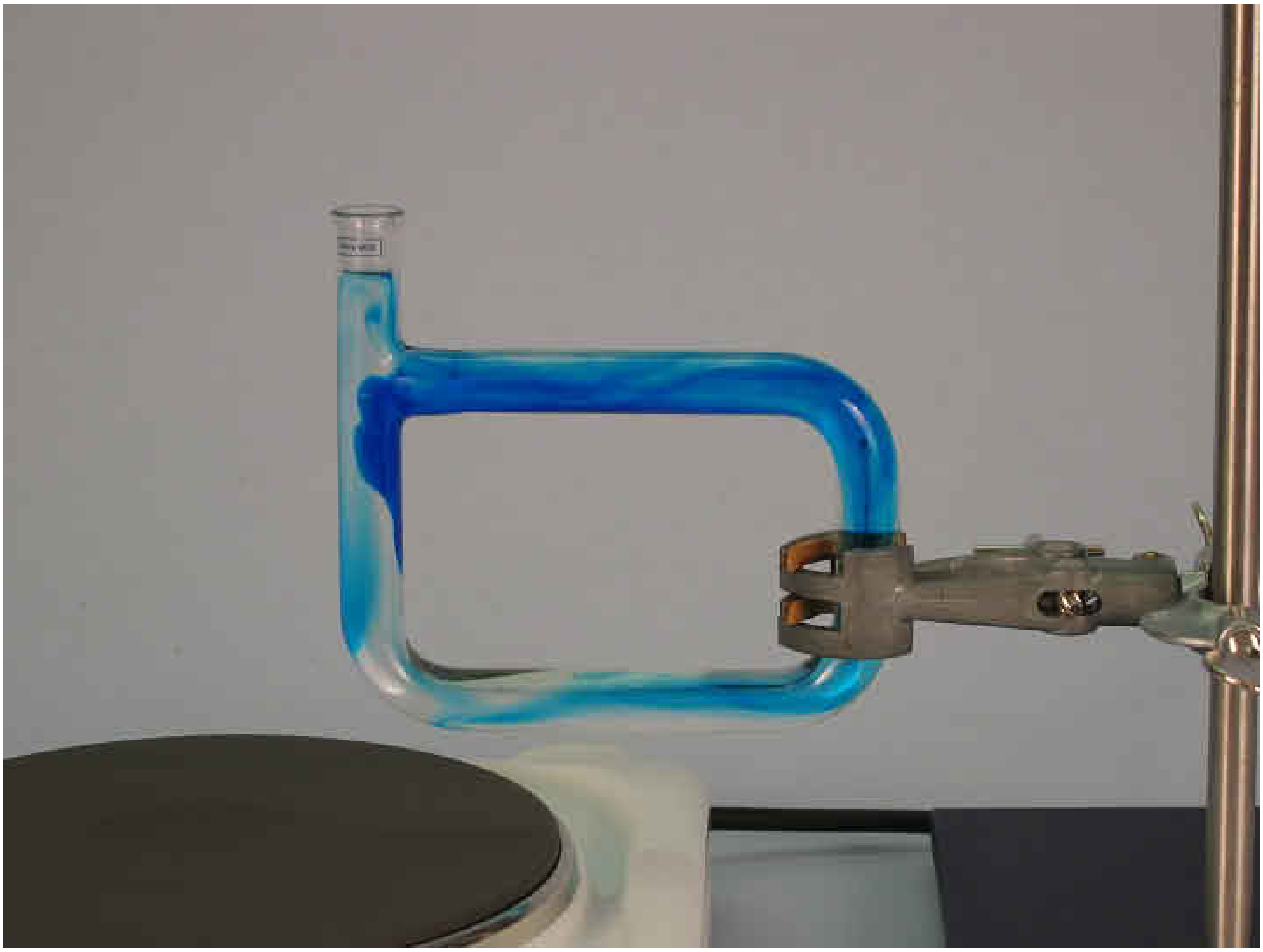


Fig. 1

Set up and procedure

- Make up a highly concentrated dye solution in the 600 ml beaker by dissolving a spatula-tip of patent blue in approx. 50 ml of water.
- Use the retort stand, universal clamp and right angle clamp to hold the liquid convection tube (Fig. 1).
- Fill the liquid convection tube with water to the level of the upper horizontal limb.
- Push the set-up so above the heating plate that one vertical limb is positioned about 5 cm above the plate (Fig. 1).
- Set the heating plate to step 3 and switch it off as soon as it is hot.
- Slowly pour about 5 ml of the prepared dye solution in the liquid convection tube and observe how the colour is distributed

Notes on set-up and procedure

It is best to carry this experiment several times to determine the conditions under which the movement of the coloured drop is best visible:

- How hot must the heating plate be?
- How long should you wait before pouring the dye solution in?

The amount of dye solution which you have prepared is sufficient for about 10 experiments.

Observations

Part of the dye solution sinks in the vertical limb below the filling opening but another part simultaneously migrates into the horizontal limb. The part in the vertical limb ascends again. The more strongly coloured part moves through the upper limb to the cold vertical limb and descends there in striations (also called schlieren). The coloured striations move along the bottom to the heated limb and rise up again there.

Evaluation

Warm water rises up because the density of it has been lowered. Cold water from below must therefore follow it and be warmed again. The result is circulatory flow.

Note

The Gulf Stream which brings us in Central Europe a temperate climate is part of a huge circulatory flow in the North Atlantic. Warm water from the Gulf of Mexico flows north-east to the European west coast, cools hereby and sinks in deeper water off of the coast of Greenland, from where it flows back to the Golf of Mexico in the west part of the Atlantic.

Thermal conduction in glass and metal

Temperature indicator strips are wrapped around copper, aluminium and glass rods for this experiment. These strips change colour from orange to red at a temperature of about 40°C and this change in colour enables differences in the heat conduction of the three materials to be followed.

Material

1	Heating + cooking hotplate,230V	04025-93
1	Stainless Steel pot 3,2 l	05934-00
2	Heat sensitive paper	04260-00
1	Glass tube holder with tape measure clamp	05961-00
1	Aluminium rod,U-shaped	05910-00
1	Copper rod, U-shaped	05910-01
1	Glass rod,U-shaped	05911-00
1	Lab thermometer, -10..+100C	38056-00
1	Support rod, stainless steel, l = 250 mm, d = 10 mm	02031-00
1	Retort stand, 210 mm × 130 mm, h = 500 mm	37692-00
1	Right angle clamp	37697-00
1	Graduated vessel, 1 l, with handle	36640-00

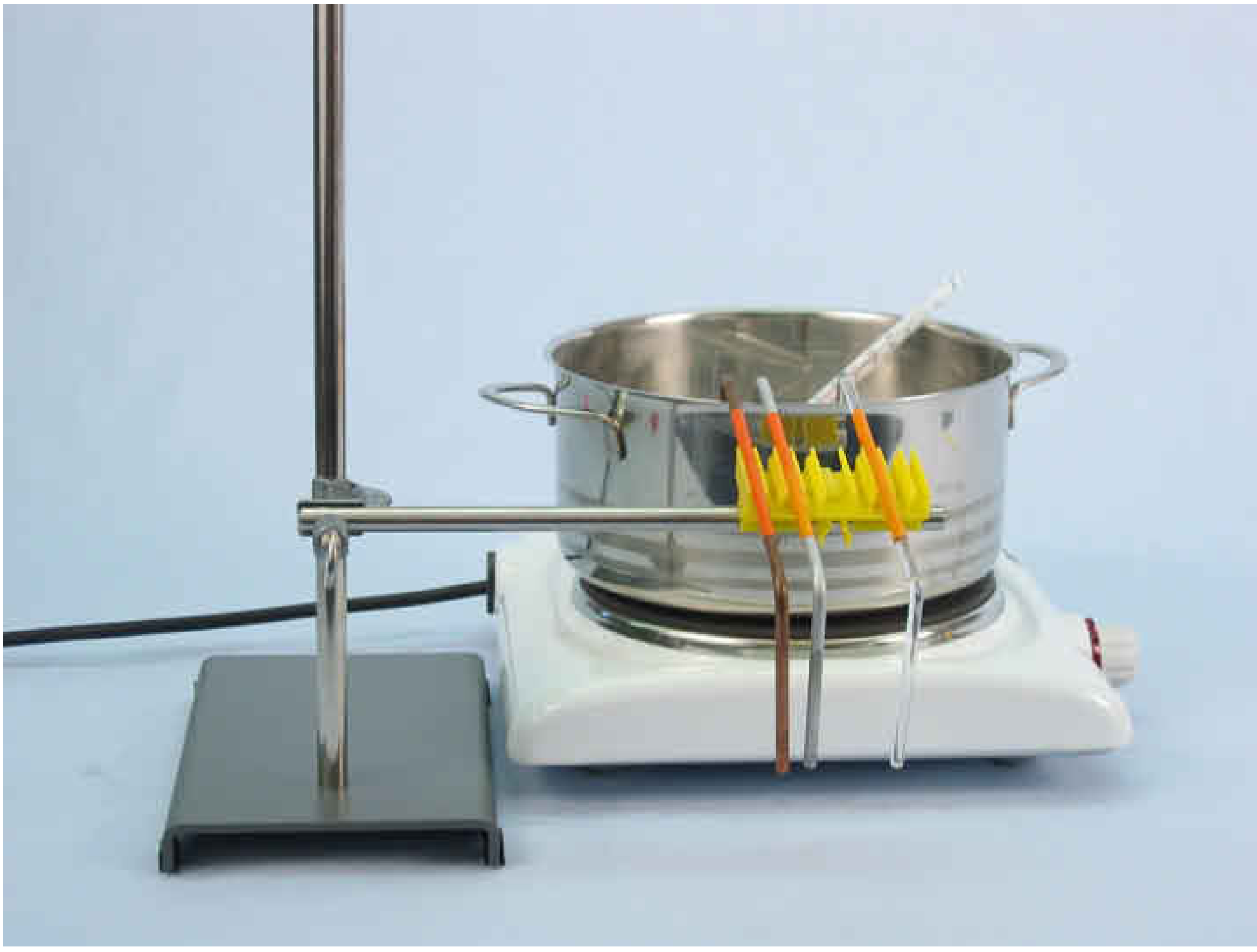


Fig. 1

Set up and procedure

- Fill about 2.5 litres of water in the pot.
- Bring the retort stand alongside the heating plate and attach the stainless steel support rod to it.
- Stick 10 to 12 cm long temperature indicator strips to the three rods, leaving about the first 3 cm free so that strips do not hang over the pot (see Fig. 1).
- Press the glass rod and the two metal rods in the thin grooves of the glass tube holder (Fig. 2).
- Now attach the glass tube holder to the support rod and adjust this rod to such a height that one side of each test rod dips about 5 cm into the water but none of them lie on the edge of the pot.
- Remove the glass tube holder complete with rods from the water. Heat the water in the pot to 90°C and then set the heating plate to setting 1.
- Replace the glass tube holder with rods in the set-up so that all three rods are immersed to the same extent and that no paper is within the area of the pot.
- Keep a watch on the temperature indicator strips on the rods for some minutes.

Fig. 2

Notes on set-up and procedure

Some students should come to the front and describe what they observe to the rest of the class. Change in colour of the temperature indicator strips ceases after some minutes. The support rod can then be raised up and the glass tube holder so adjusted that the rods hang vertically.

The students should then be given the opportunity to touch the rods with their fingers to estimate their temperatures.

Observations

Copper:

First red colouration after 0.5 to 1 min; the dark red colouration reached the end of the strip.

Aluminium:

First red colouration came a little later than with copper; the dark red colouration almost reached the end If the strip; flowing transitions from red-light red-orange occur.

Glass:

The strip stayed orange.

On touching the rods at the ends which were not in water:

- Copper rod hot
- Aluminium rod warm
- Glass rod cold

Evaluation

Metals conduct heat better than glass (and plastics). The two metals used here conduct heat to different extents. Copper is a very good conductor of heat. Aluminium is not such a good conductor of heat as copper.

Basically, thermal insulation and heat conduction have similar physical principles. Good thermal insulation of a house possibly results in a low conduction of heat by the materials of the wall. The thermal insulation of a wall is, however, also dependent on further technical parameters, such as their surface condition.

The temperature in the pot is checked with an alcohol-filled thermometer. This has an immersion depth of 5 cm and the given “column temperature” (for the upper part of the thermometer) is 35°C. During measurement, however, it is completely immersed in hot water or steam. A temperature of 106°C instead of 100°C is therefore shown for the boiling temperature!

Room for notes

Temperature indicator strips are wrapped around copper, aluminium and glass rods for this experiment. These strips change colour from orange to red at a temperature of about 40°C and this change in colour enables differences in the heat conduction of the three materials to be followed.

Material

1	Glass tube holder with tape measure clamp	05961-00
1	Glass beaker DURAN®, tall, 600 ml	36006-00
2	Lab thermometer, -10..+100C	38056-00
1	Ceramic lamp socket E27 with reflector, switch, safety plug	06751-01
1	Filament lamp, 220V/120W,w.refl.	06759-93
1	Support rod, stainless steel, l = 250 mm, d = 10 mm	02031-00
1	Retort stand, 210 mm × 130 mm, h = 500 mm	37692-00
2	Right angle clamp	37697-00
1	Universal clamp	37715-00

Additional material

1	Patent Blue V (sodium salt), 25 g	48376-04
1	Microspoon, steel	33393-00

Fig. 1

Set up and procedure

- Fill 500 ml of water into the 600 ml beaker and place the beaker on the retort stand.
- Use a universal clamp to fix the reflector lamp at the upper end of the retort stand and position it as vertically as possible over the beaker.
- The distance of the lamp bulb from the water surface should be about 15 cm.
- The beaker is to be illuminated with the reflector lamp for approx. 15 min (Fig. 1), but after approx. 10 min exposure time, use a spatula to place a very small amount of food colouring on the water surface.
- Observe the behaviour of the coloured striations.
- Switch the reflector lamp off after 15 min and carefully remove it from the stand.
- Use the right angle clamp to connect the support rod and clamp the glass tube holder on.
- Position the glass tube holder over the beaker and fit two thermometers on it (Fig. 2). The thermometers are now to be so carefully eased in the water from above that there is no mixing of the water.
- Measure the temperature directly below the water surface with the first thermometer. Ease the second thermometer down to the bottom of the beaker to take the temperature here. Note these values.
- Now draw the second thermometer up until it is about 5 cm below the water surface (Fig. 3) and again read the temperatures of the two thermometers.
- At the end of the experiment, observe and note the colour of the water again.

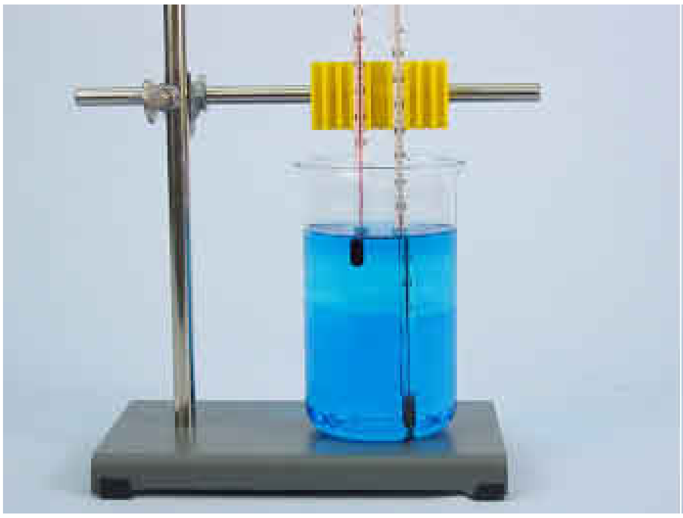


Fig. 2

Fig. 3

Observations

Temperature measurement

Height in the beaker	Above	5 cm	Below
1. Measurement	36°C	---	28°C
2. Measurement	34°C	29°C	---

Appearance of colouring

The appearance of colouring described here is dependent on when the food colouring substance was added and to which amount. The description here applies to Figs. 1, 2 and 3, other possibilities are described in the evaluation.

1. At the points on the surface where the food colouring was scattered, striations are drawn down which gradually completely colour the water).
2. A lighter layer of some cm can be observed in the upper part of the beaker (see Figs. 2 and 3).

Evaluation

Temperature measurement shows that the water temperature in the lower region remains practically constant (here 28 °C or 29 °C). The first change is in a layer which is 4 to 5 cm beneath the water surface. The temperature here is about 5 to 7 degrees. The colour distribution also shows this temperature layering. The coloured particles which first fell downwards because of their density remain in this area and do not migrate into the warmer layer. There is no exchange here. If the powder is added very late and in too small an amount, it could possibly mainly collect in the upper layer. It will also be seen here that two layers are formed.

The experiment shows that the heat conductivity of water is very low, otherwise deeper warm layers would be formed.

Energy transport always occurs in water by means of flow of heat: Hot water rises up.

Room for notes

Ice floats – Maximum density of water is 4°C

A beaker is filled with pieces of ice and water. After careful stirring the water cools to about 0 °C and a major part of the ice has melted. The remaining ice floats on the water surface. Temperature equilibrium is attained below the ice and this is to be measured.

Material

1	Glass beaker DURAN®, tall, 600 ml	36006-00
1	Graduated vessel, 1 l, with handle	36640-00
2	Lab thermometer, -10..+100C	38056-00
1	Support rod, stainless steel, l = 250 mm, d = 10 mm	02031-00
1	Glass tube holder with tape measure clamp	05961-00
1	Retort stand, 210 mm × 130 mm, h = 500 mm	37692-00
1	Right angle clamp	37697-00

Additional material

Hammer
Towel
Ice cubes
Teaspoon

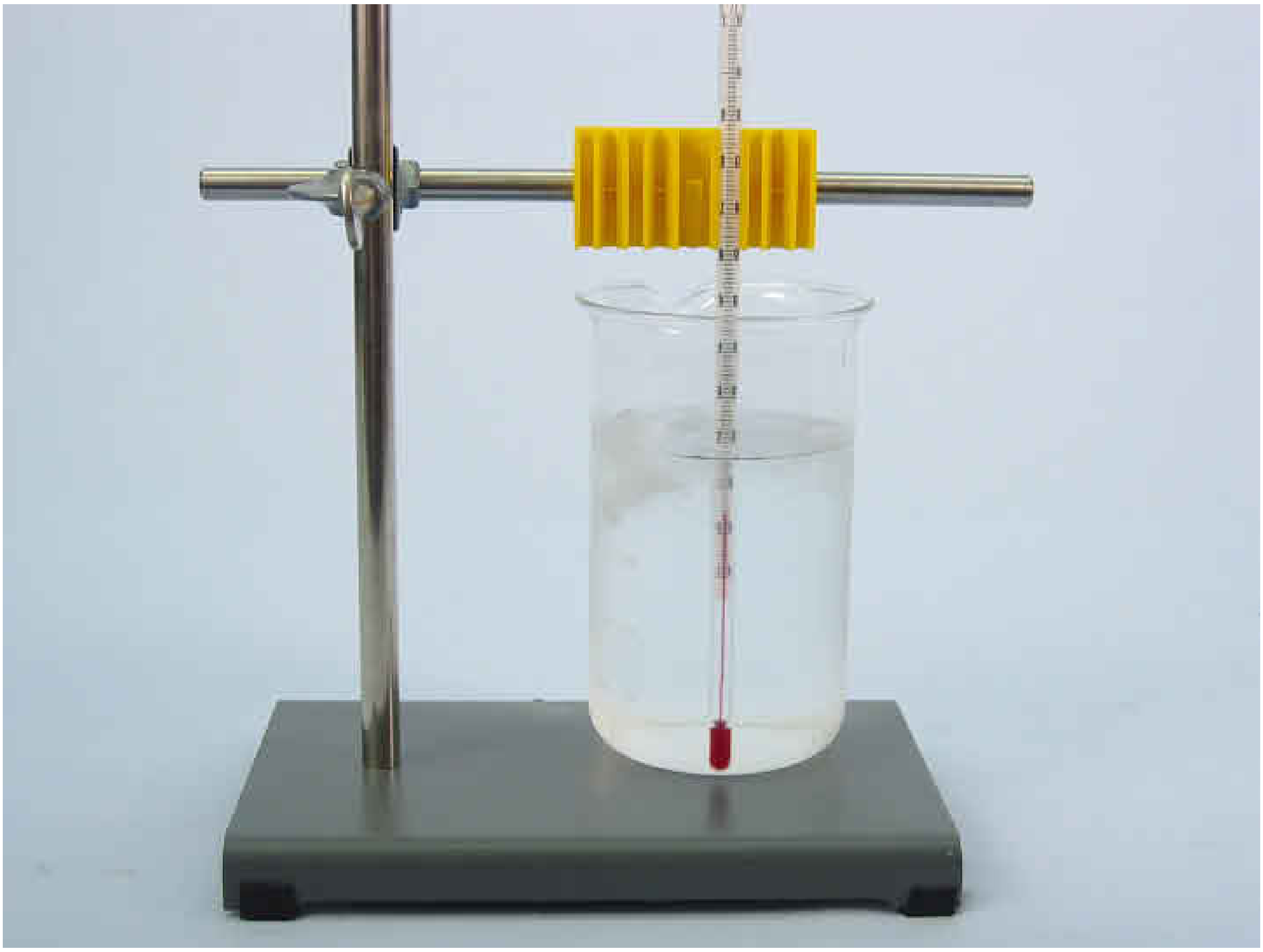


Fig. 1

Set up and procedure

- Wrap the ice cubes in a cloth and break them down with a hammer to pieces of different sizes.
- Fill the beaker to about a third with pieces of ice and add 300 ml of cold water.
- Stir the icy water well for one minute and observe the amount of ice and the temperature while doing so. Note the temperature after stirring.
  How much ice remains after stirring depends on the original amount of it, the size of the pieces of ice and the temperature of the cold water which was used. Good conditions are given for the continuation of the experiment when the beaker now contains about 500 ml of icy water and the ice layer is about 2 cm thick. Ice or water must possibly be added to, or removed from, the beaker.
- Fix a support rod with glass tube holder to the retort stand.
- Fit a thermometer in the glass tube holder, ease it down so that it is just above the bottom of the beaker (Fig. 1) and observe the temperature for about 3 to 5 minutes during which time you carefully wipe off condensed water from the beaker.
- Hold a second thermometer in the ice layer but do not stir with it! Instead of this, wait for temperature equalization before you measure the temperature here (Fig. 2).
- Now ease the thermometer slowly down while keeping a watch on the temperature.

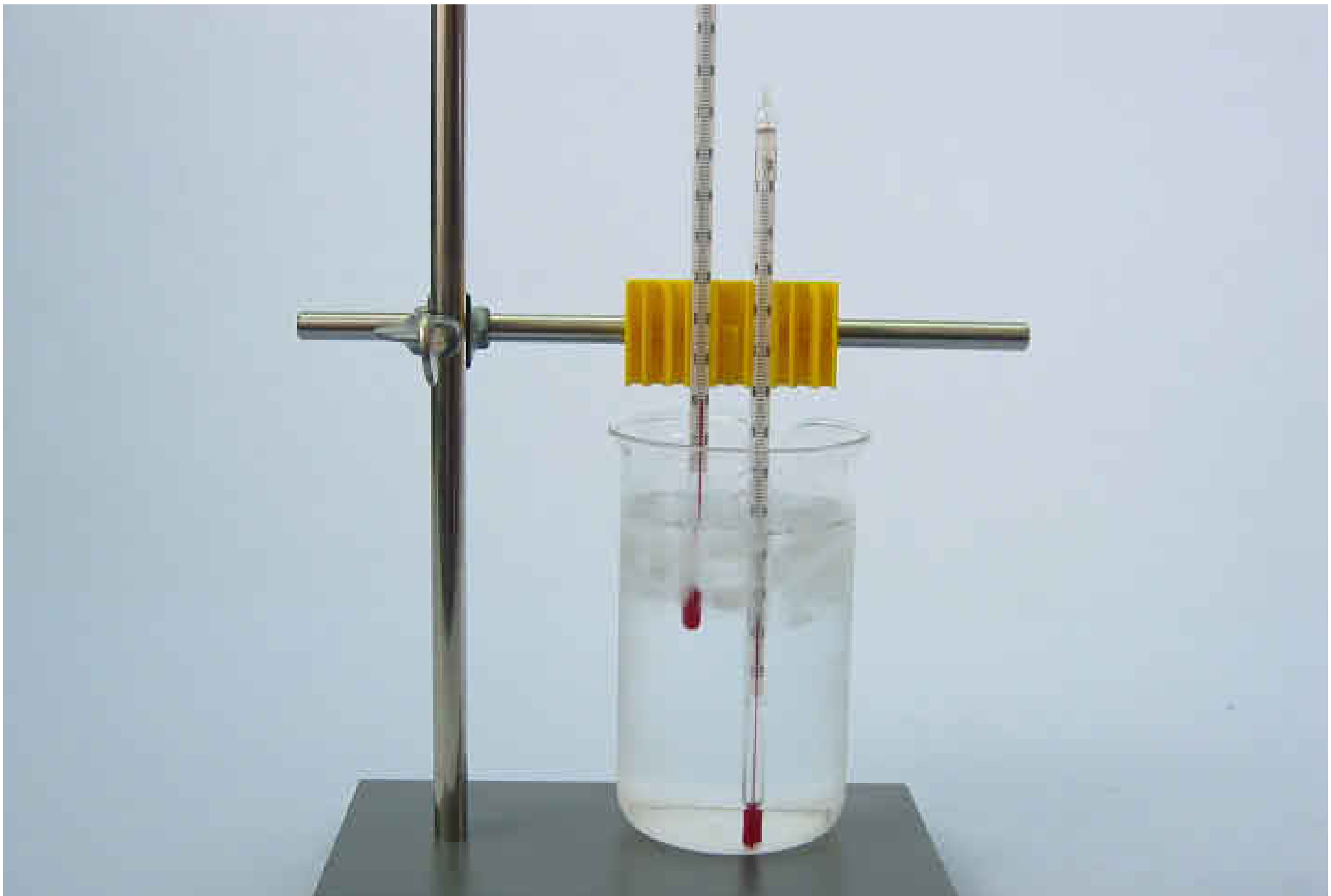


Fig. 2

Observations

1. After stirring, the temperature of the icy water was 0 °C to 1 °C.
2. The temperature at the bottom of the beaker slowly increased and reached a value of about 4 °C. (According to the thickness of the ice layer, the temperature at the bottom could be between 3 °C and 5 °C.)
3. The temperature in the ice layer was 0 °C to 1 °C.
4. The further down the thermometer is eased the higher the temperature until it reached 4 °C.

Evaluation

The melting point of ice is 0 °C. Ice and water are evenly mixed by the stirring so that the temperature is the same throughout.

Ice and water separate when the beaker is allowed to stand. Ice floats up, the warmer water sinks down. The temperature at the bottom slowly increases until 4 °C is measured. This shows that the density of ice is lower than that of 4 °C water.

Other experiments i.e. S2 “Thermal expansion of air and water” and D2 “Thermal convection in water” have however shown that the density of a liquid decreases with temperature. The behaviour of water between 0 °C and 4 °C does not follow this general law. This is called the anomaly of water:

Water has the highest density at 4 °C. This characteristic of water has the following effect in nature: Bodies of water freeze from the top. This enables aquatic life (animals and plants) to survive in the water and the earth.

Room for notes