Leybold Physik Physics Physique

Kalorik
Heat
Chaleur

Expansion and propagation of heat – Heat energy and states of matter

588 152
Students' work sheets
(Masters for copying)

Schülerversuche Naturwissenschaften

SVN
STM

Science Teaching Modules

STM-Physics
Heat
Expansion and Propagation of Heat –
Heat Energy and States of Matter

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General instructions on the use of STM work folders

The need for complete editorial revision of the literature in the STM series (Science Teaching Modules) containing descriptions of experiments for schools was an ideal opportunity to give the series a fresh, practical orientation:

The student's worksheets form the main focus of each work folder. These are laid out as a series of reference sheets, loose-leaf pages designed for use as master copies and capable of meeting the demands of a modern educational environment.

The associated teacher's workbook is an exact replica of the worksheets. In addition to defining the actual assignments, however, it also describes the object of each experiment and includes special hints and tips on each working step in the experiment, as well as additional information, calculated sample measurements and the answers to questions asked in the students' worksheets.

How the experiments are laid out:

The structure of the worksheets is essentially the same for all experimental topics. The basic information, such as the nature of the assignment itself, the list of apparatus required, setup diagrams etc. always appear in the same place and in the same order. For additional convenience, however, the experiments are also divided up into a series of consecutively numbered working steps. Diagrams and illustrations are also numbered consecutively. Any supplementary illustrations which appear in the teacher's notes are numbered according to the decimal classification system.

Symbols used:

The following symbols are used in the students' worksheets:

⚠ Caution! hazardous for the experimenter or experimental apparatus.
Follow working instructions exactly.

▶ Refer to another point.

About the apparatus:

To familiarise students with the equipment they will be using, the worksheets are preceded by a detailed section describing the various pieces of apparatus.

In addition to the list of apparatus and other aids which appears before each experiment (complete with catalogue numbers in the teacher's workbook), you will also find a complete list of all the apparatus used at the end of the book (after the reference sheets), showing all the apparatus and other equipment required for the particular subject area under examination.

Each folder also contains a constantly updated list of the entire range of STM literature.

Preface

This textbook is part of the literary series describing experiments associated with the Leybold STM Physics system of apparatus.

In this book, we describe experiments dealing with heat (thermodynamics), covering the following subject areas in particular:

- Thermal expansion and thermometry
- Heat transfer
- Heat capacity
- Thermal energy and states of aggregation.

All experiments can be performed with apparatus from STM sets of apparatus **BMC1**, **BMC2** and **CAL1**, combined with a few additional items of apparatus (e.g. sources of heat).

Student's Sheet 1

About the apparatus

Setting up the stand

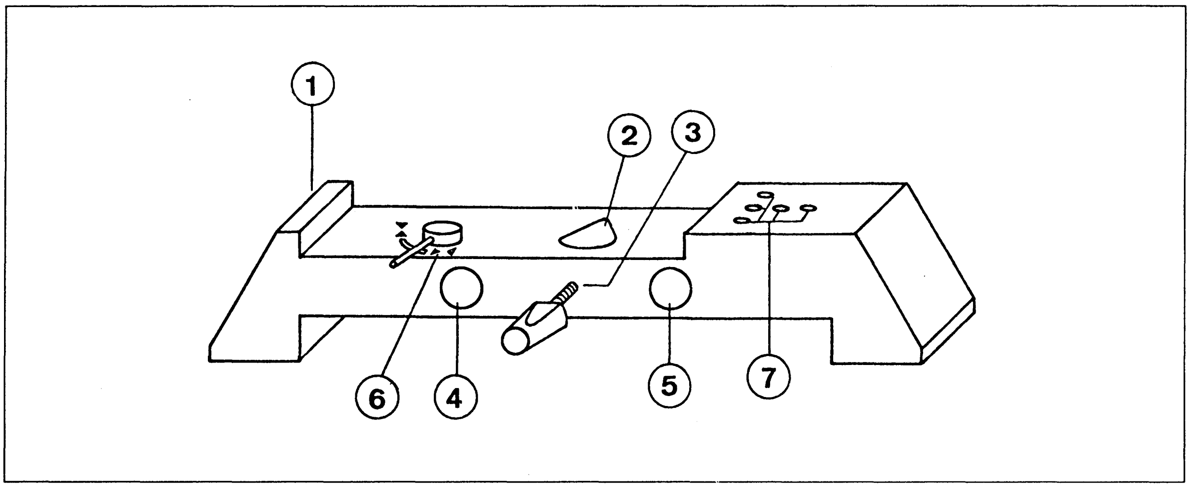

Fig. 1 Stand base (301 21)

Together with two 50 cm stand rods and one 25 cm stand rod, two stand bases **(1)** are the most important components in the various stand set-ups required for experiments covering mechanics and heat. A stand rod can be clamped firmly in the central socket **(2)** using a screw **(3)**. Two horizontal sockets **(4)** and **(5)** also accept stand rods, meaning that it is easy to create a stable base. Socket **(4)** has a quick-fastening clamp **(6)** with a toggle (fig. 2). The five other sockets **(7)** are used for holding or mounting various items of apparatus with the aid of 4 mm plug pins.

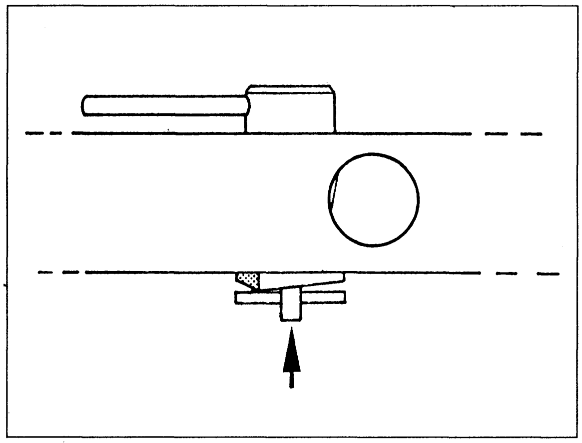

Fig. 2 Quick-fastening clamp on the stand base
▶ Arrow

Note on (6)

Socket **(4)**'s quick-fastening clamp with toggle may fit rather tightly at first. In this case, you will have to push the cone up slightly from underneath when you are inserting the stand rod.

The undersides of the stand bases are non-slip.

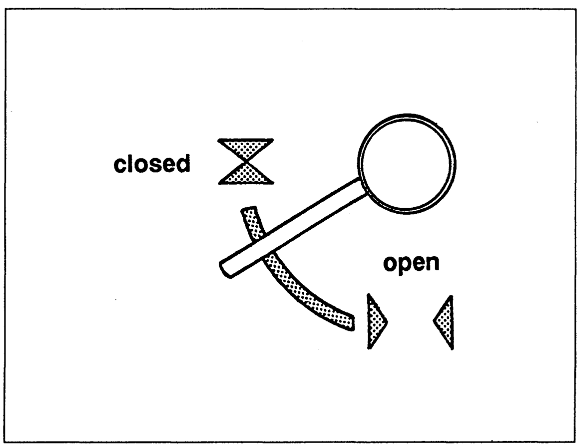

Fig. 3 Clamp positions

Student's Sheet 2

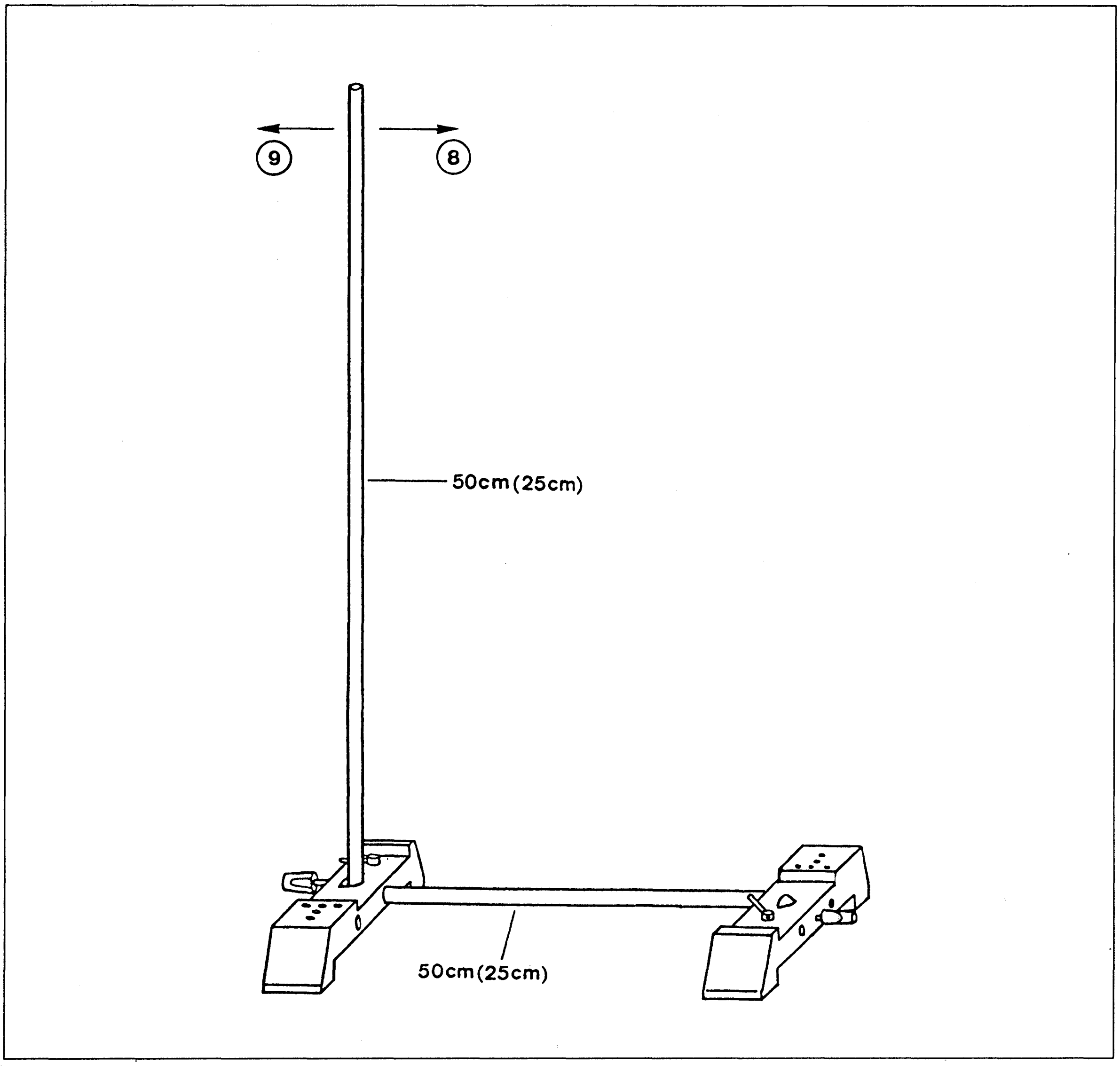

Fig. 4 Frequently used stand arrangement

Fig. 4 shows a popular way of setting up a stand
In which direction is the stand

a) most stable? ______________________

b) least stable? ______________________

Student's Sheet 3

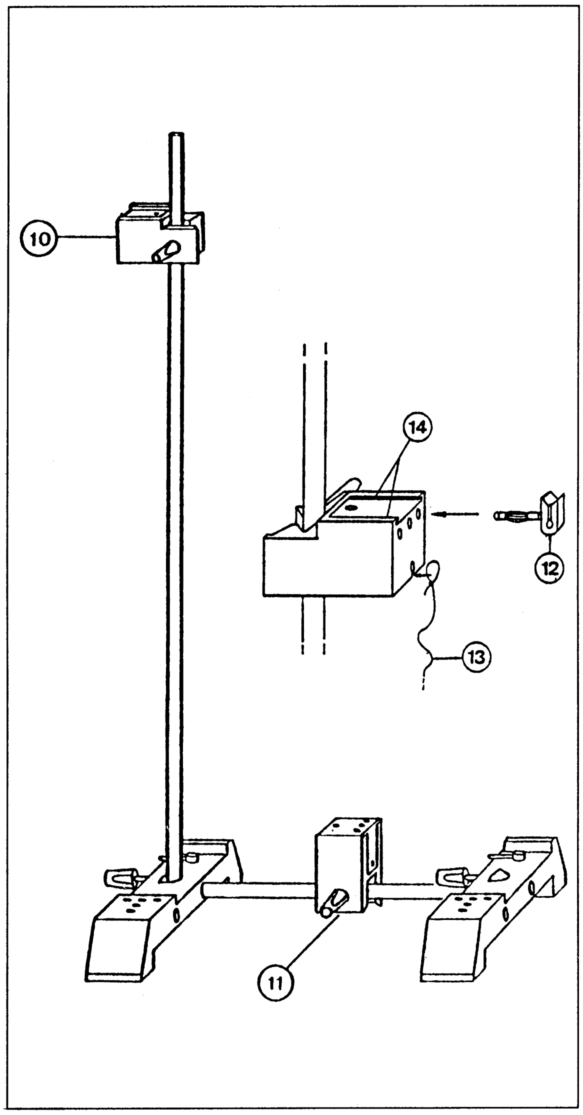

Fig. 5 Sleeve block

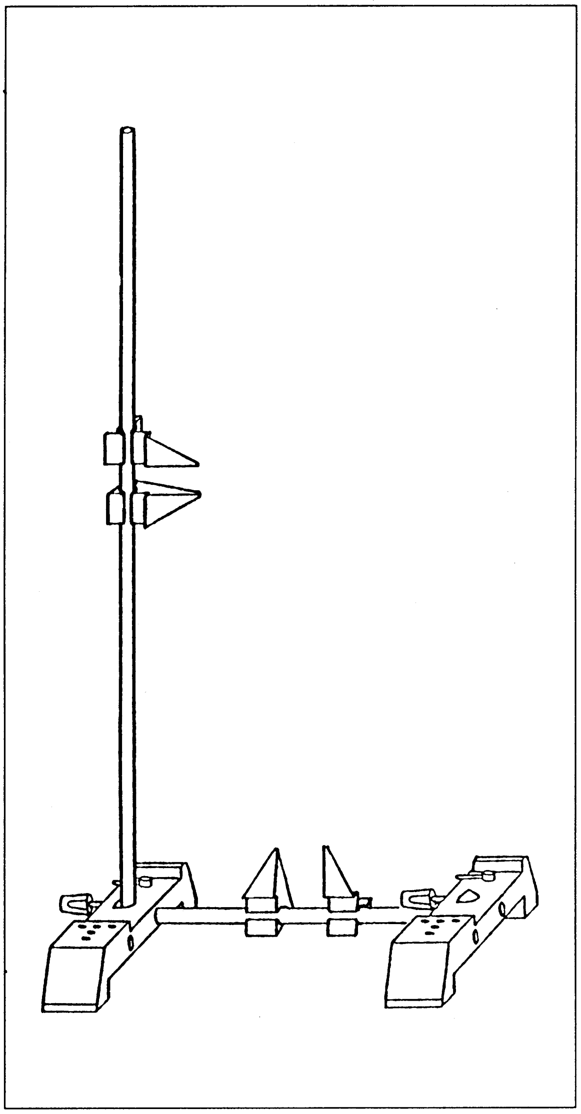

Fig. 6 Pair of pointers

Sleeve block

You can attach the sleeve block to vertical **(10)** or horizontal **(11)** stand rods using the clamping screw.

The sleeve block has a total of eight sockets for holding plug-in experimental apparatus **(12)**, together with a cord holder **(13)** and a leaf spring holder **(14)**.

Pair of pointers

Pointers for marking starting positions, intermediate positions and final positions when you are comparing or measuring lengths can be clamped to the stand rods. You can then rotate them or slide them along the rods.

Note:

You will find it easier to slide the pointers into place on the rods than to fix them directly to the rods.

Student's Sheet 4

Double socket (example of double socket in use with universal clamp)

You can use the double socket to connect rods and tubes at right angles to one another. The coupling should be attached to the vertical rod as shown in fig. 4. By undoing the screw at the front **(15)**, you can move the experimental setup to the level you want.

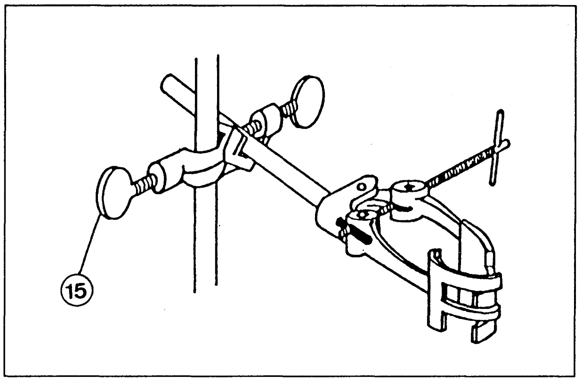

Fig. 7

Universal coupling (example of universal coupling used to lengthen stand rods)

Using the universal coupling, rods and tubes can be connected to one another at right angles and in straight lines (extensions). The coupling can be fitted over one end of each of the stand rods.

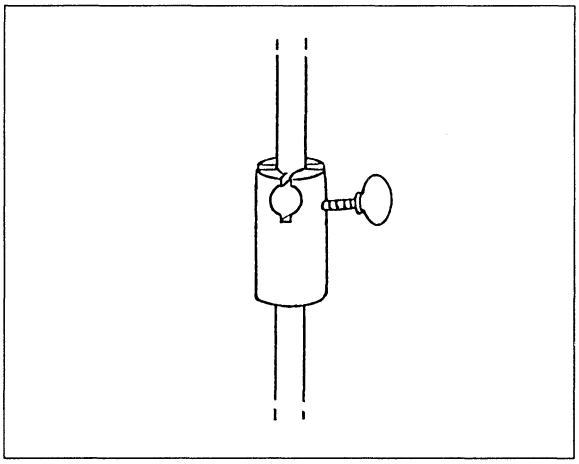

Fig. 8

Sources of heat

The **alcohol burner** has a supply vessel **(16)** which holds ca. 60 ml of alcohol. It also has a knurled thumb screw **(17)** for feeding out the wick **(18)** and a closing cap **(19)** to put out the flame.

⚠ Only your teacher is allowed to fill the burner with alcohol! Make quite sure that the lower part of the wick **(20)** is firmly screwed into place before you light the burner. Make sure there is no alcohol in the overflow gutter **(21)**.

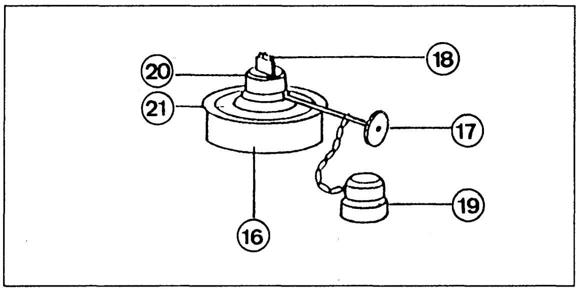

Fig. 9

Student's Sheet 5

The **bunsen burner** is supplied with gas via a rubber hose. The amount of gas is regulated by a gas tap **(22)**. You use the locking ring **(23)** to set the size of the air admission hole **(24)**. Gas and air are mixed in the mixing tube **(25)**, emerging from the burner's nozzle **(26)**.

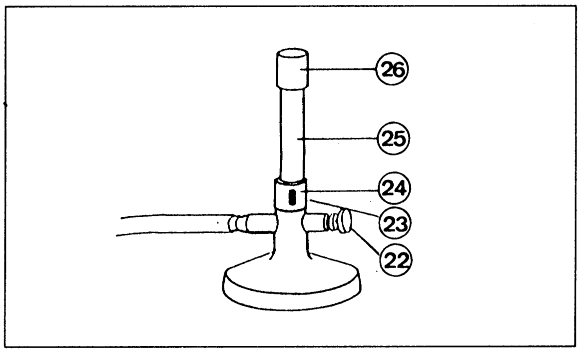

Fig. 10

The **butane gas burner** consists of a burner head **(27)**, a sheet steel hood **(28)**, a cartridge **(29)** and a base **(30)**. The gas supply is controlled using a knob **(31)**, the supply of air by the ring **(32)**.

⚠ Only your teacher is allowed to replace the gas cartridge!

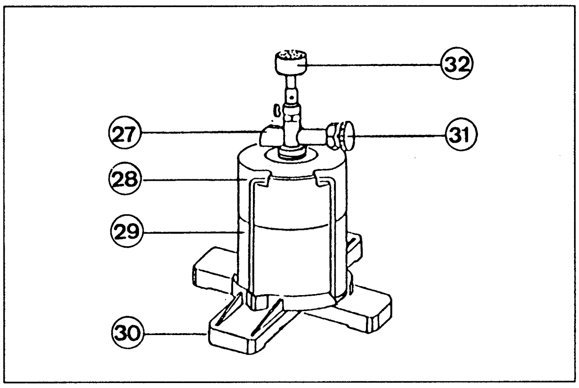

Fig. 11

⚠ You should always light bunsen burners with the air admission hole **closed.** The resulting "luminous flame" has a low temperature.

Opening up the air supply causes the flame to burn more quickly. The temperature of this "non-luminous flame" is higher.

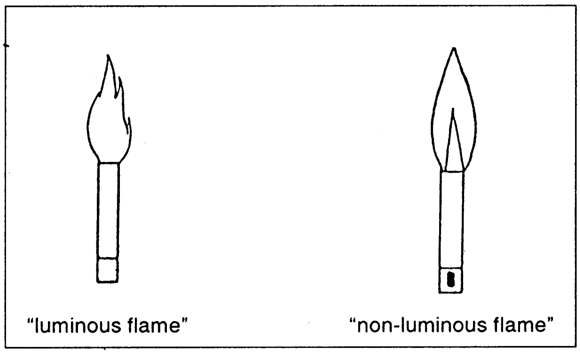

Fig. 12

Student's Sheet 1

Thermal properties of water

Assignment: To observe water heating up and cooling down.

Apparatus:

2 stand bases
2 stand rods, 50 cm
1 double socket
1 universal clamp
1 conical flask, 50 ml
1 stopper with hole
1 riser tube
1 universal marker
1 glass beaker

in addition:
1 source of heat, e.g. alcohol burner
1 colouring agent
Ice
Water

Student's Sheet 2

Setup:

1. Set up the stand as shown in fig. 1. Attach the double socket and apparatus clamp as shown.

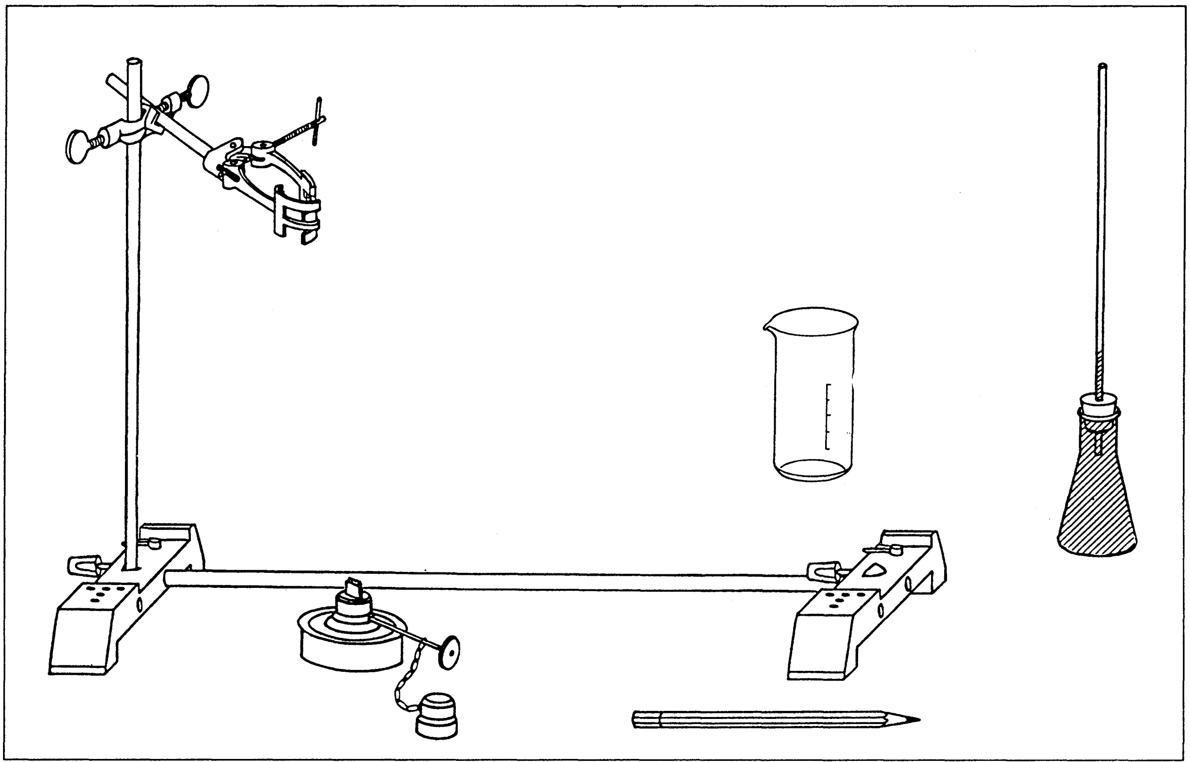

Fig. 1 Setup for heating water

2. Insert the riser tube into the hole in the rubber stopper.

3. Fill the flask up to the brim with coloured water and insert the stopper. Make sure that no air bubbles are trapped under the stopper.

4. Fill the beaker up to about halfway with a mixture of ice and water.

Performing the experiment:

5. Use the universal marker to mark the position of the water level in the riser tube.
6. Place the conical flask in the beaker containing the ice water.
7. After some time has passed (the teacher will tell you when), make a mark next to the water level.

8. Dry off the flask and clamp it in the universal clamp.
9. Light the burner.

Student's Sheet 3

10. Make a mark next to the water level after the period of time indicated by your teacher.

11. Turn off the burner.

Observations and measurements:

12. Remove the conical flask from the experimental setup and observe the water's meniscus.

Evaluation:

13. Draw in the water levels at each stage of the experiment on the diagram in fig. 2.

14. The water ________________ when it is cooled.

15. The water ________________ when it is heated up.

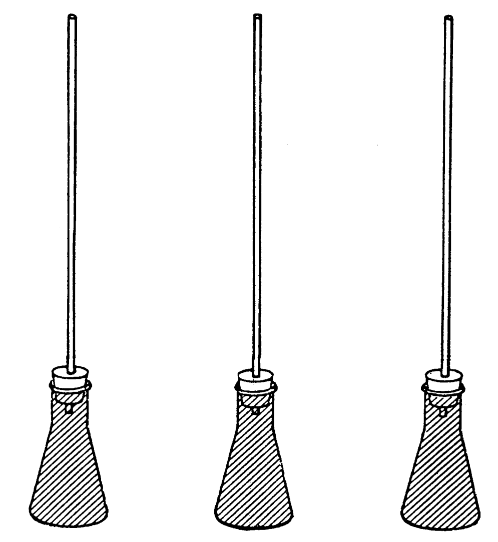

Fig. 2 Water levels

Calibrating a thermometer

Assignment: To mark the level of liquid in a thermometer tube at the freezing point and boiling point of water respectively.

Apparatus:

2 stand bases
2 stand rods, 50 cm
1 double socket
1 universal clamp
1 glass beaker
1 thermometer without a scale
1 universal marker

in addition:
1 source of heat, e.g. alcohol burner
1 pair of scissors
Cardboard, 17 cm x 5 cm
Ice
Water

Student's Sheet 2

Setup:

1. Set up the stand as shown in fig. 1. Attach the double socket and apparatus clamp as shown.

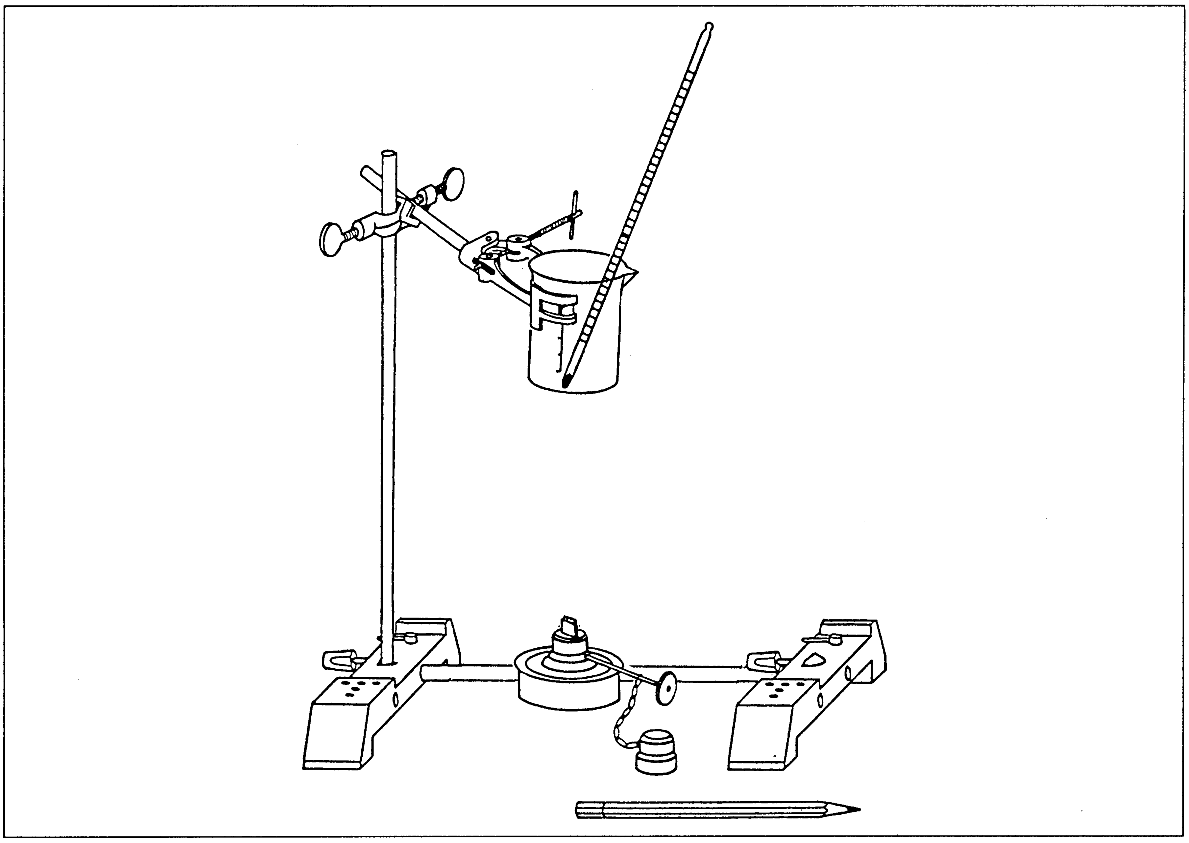

Fig. 1 Setup for calibrating a thermometer

2. Put about 100 ml of ice and water into the beaker.
3. Using the scissors, make two parallel cuts in the cardboard.
4. Push the cardboard down over the thermometer until the upper edge of the cardboard is parallel with the tip of the thermometer (fig. 1.1).
5. Immerse the thermometer in the ice water.

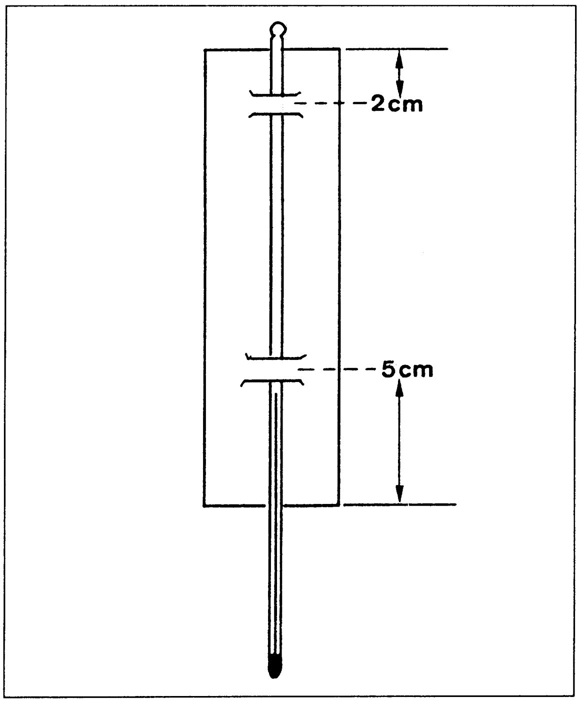

Fig. 1.1 Thermometer with a paper strip ready for graduation.

Performing the experiment:

6. Mark the level of the column of liquid on the strip of cardboard, once it has stopped falling.

7. Light the burner.

8. Turn off the burner once the water is boiling.

9. Make a mark next to the level of the column of liquid.

Observations and measurements:

10. Remove the cardboard from the thermometer.
11. Write 0 °C next to the lower mark, 100 °C next to the upper mark.
12. Divide the gap between them into 10 equal sections.

The scale should look something like this:

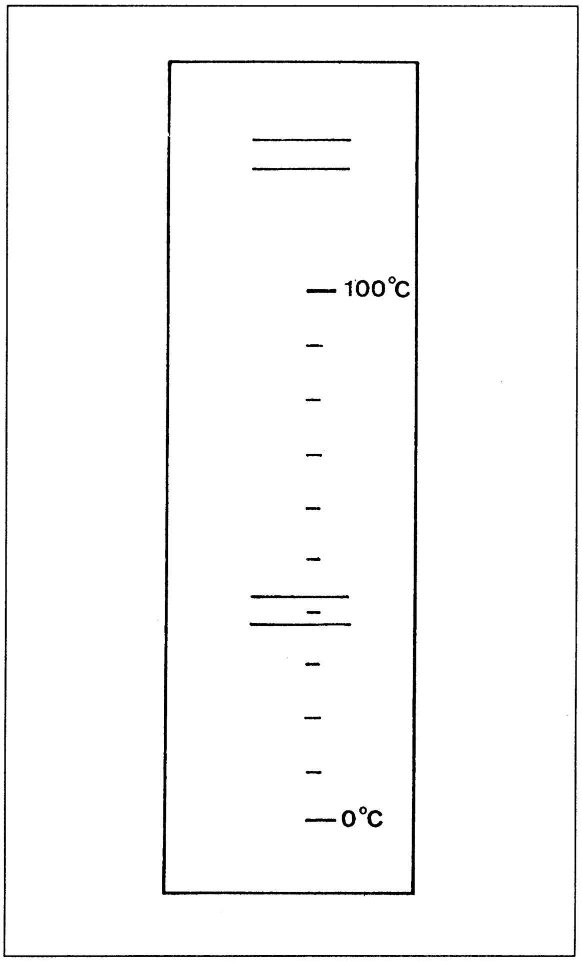

Fig. 2 Scale with graduations

Student's Sheet 4

Evaluation:

13. The level of the liquid in the thermometer remains constant in the ice water. What is this point called?

    1st fixed reference point: ______________________________

14. The level of the liquid in the thermometer remains constant when the water is boiling. What is this point called?

    2nd fixed reference point: ______________________________

15. What are the advantages of dividing up the interval between the two fixed reference points?

    ____

16. Temperature is expressed in degrees Celsius (°C).

    What temperature is showing on the thermometer?

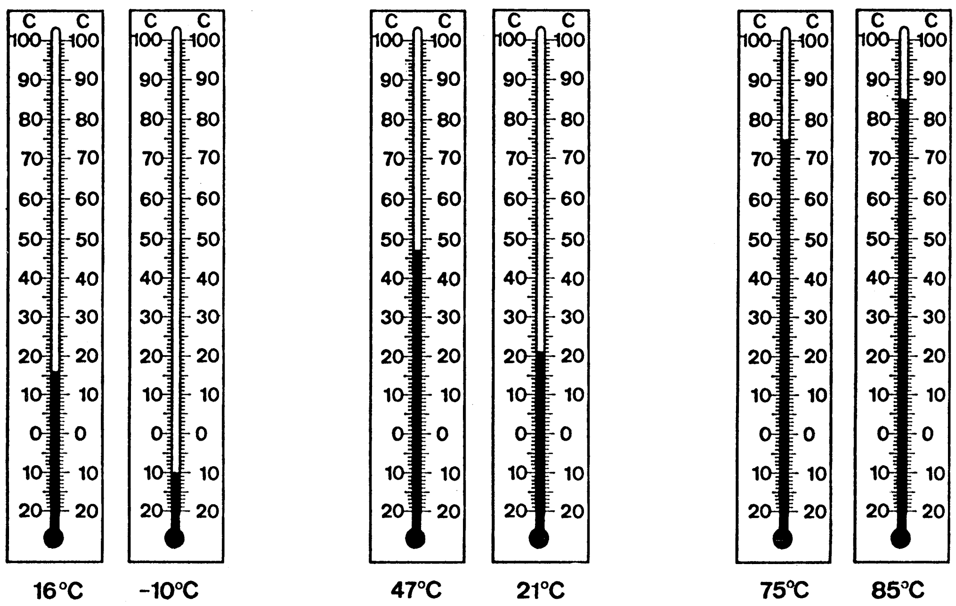

Fig. 3 Thermometer scale

Linear expansion of solid bodies

Assignment: To heat up metal pipes and determine the change in their lengths.

Apparatus:

2 stand bases
2 stand rods, 50 cm
1 stand rod, 25 cm
2 sleeve blocks
1 double socket
1 universal coupling
1 universal clamp
1 conical flask
1 stopper with hole
1 tube connector
1 silicone tube (60 cm and 5–10 cm)
1 round tin
2 retaining clips
1 double scale
1 pointer for indicating linear expansion
1 aluminium pipe
1 iron pipe
1 tape measure

in addition:

1 source of heat, e.g. 1 butane gas burner
1 double socket
1 stand ring
1 wire gauze
Water

Student's Sheet 2

Setup:

1. Set up the stand as shown in fig. 1.

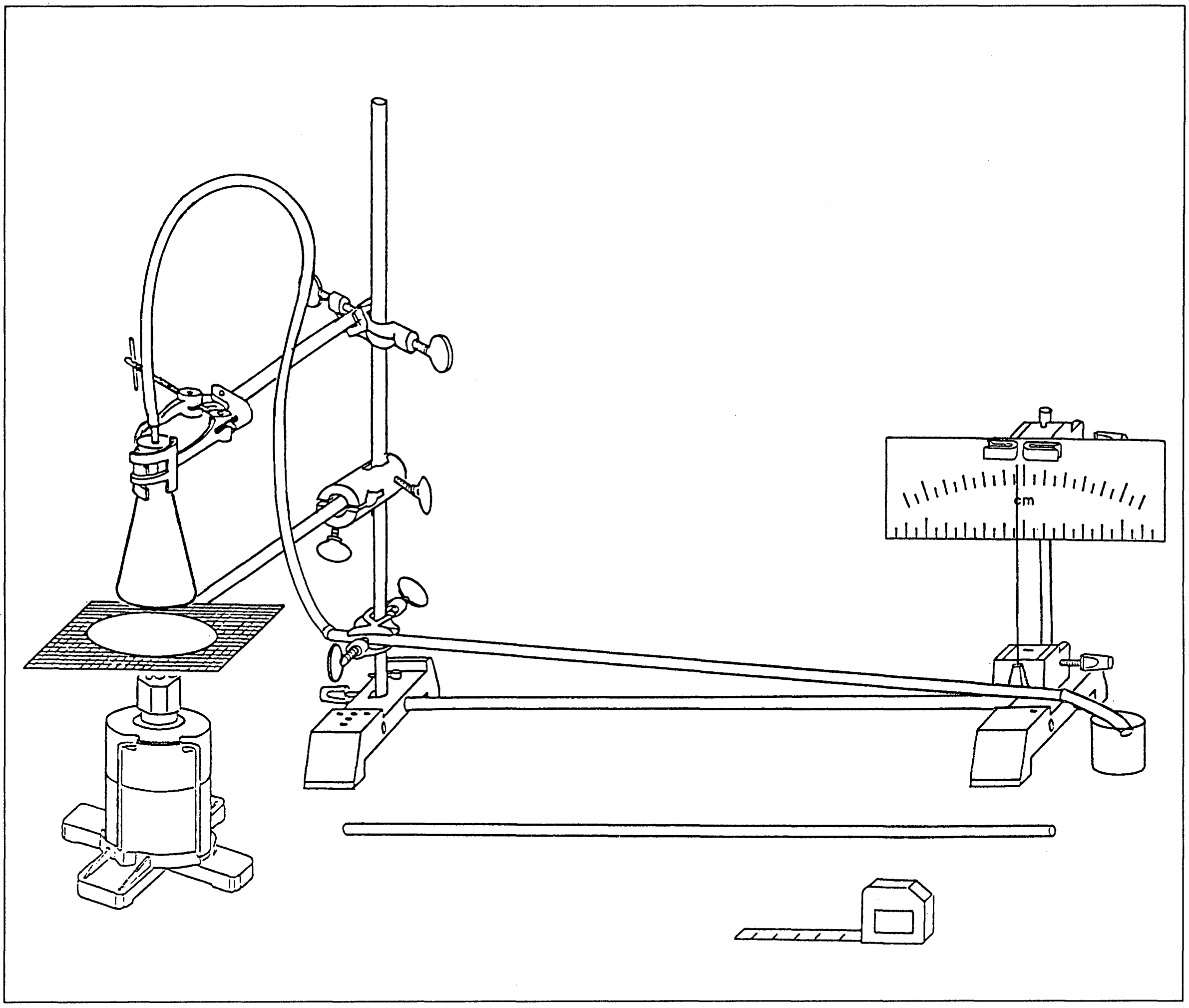

Fig. 1 Setup for investigating linear (thermal) expansion

2. Using two retaining clips, attach the scale to the topmost sleeve block on the right-hand stand rod (curved part of the scale pointing up).
3. Plug the rotary pointer into the lowest hole in the second sleeve block.
4. Push the aluminium pipe through the holes above the rotary pointer's small pin and clamp the other end in the double socket. The double socket is positioned at a slightly higher level, so that a slight gradient results.

5. Move the stand bases so that the distance from the clamping point (double socket screw) to the fulcrum of the rotary pointer l = 400 mm. The pointer should be pointing upwards, towards the line in the centre of the scale (zero point).

6. Clamp the conical flask to the stand using the universal coupling and the apparatus clamp (after filling the flask with ca. 20 ml of water).

Student's Sheet 3

7. Plug the tube connector into the stopper, connect the tube (60 cm) to the tube connector and metal pipe, and plug the stopper firmly into the conical flask.
8. Attach the short piece of tubing (10 cm) to the other end of the pipe and place the round tin underneath it.

Preparing your report:

9. Draw up table 1.
10. Fix the aluminium pipe firmly in position and check the zero position of the pointer, correcting it carefully if necessary.
11. ⚠ Light the burner and heat the water until it is boiling.
    Caution! Hot steam will be emitted from the end of the short tube.
12. Let the water boil until the pointer is no longer moving. Read off the indicated value and write it down in table 1.
13. ⚠ Switch off the burner.
    Caution! All metal parts and tubes are hot.
14. ⚠ Disengage the tubes; carefully, because hot water may run out of them. Grasp the hot pipe with a thick cloth and remove it from its mounting; carefully, because there may still be hot condensation water in the pipe.
15. Replace it with the steel pipe and repeat steps 10 – 13.
16. Measure the room temperature and enter it in table 1.

Observations and measurements

17. Room temperature ϑ_0:______

Table 1

Material	Pointer travel Δx	Temperature difference $\Delta\vartheta$
Aluminium		
Iron (steel)		

Material	Pointer travel Δx	Linear expansion $Dl = \frac{\Delta x}{40}$	Original length l	Temperature difference $\Delta\vartheta$	Linear expansion constant α
Aluminium					
Steel					

Student's Sheet 4

Evaluation:

18. What happens when metal pipes are heated up?

____

19. Which metal expands the most when it is heated up?

____

20. The following table shows the linear expansion coefficient of various substances:

Plexiglass	0.000070 K^{-1}
Aluminium	0.000024 K^{-1}
Iron	0.000012 K^{-1}
Concrete	0.000012 K^{-1}
Porcelain	0.000003 K^{-1}
Copper	0.000019 K^{-1}

Why is iron (steel) used to reinforce concrete, rather than any other material?

____

____

21. Why do the rails on railway lines have expansion gaps?

____

Thermal properties of a bimetal

Assignment: To investigate the properties of a bimetallic strip subjected to changes in temperature.

Apparatus:

2 stand bases
1 stand rod, 25 cm
1 stand rod, 50 cm
1 universal coupling
1 metal plate
1 bimetal

in addition:
Matches
Ice

Setup:

1. Set up the apparatus as shown in fig. 1.
2. Clamp the bimetal and the metal plate in the universal coupling.
   The metal plate protects the bimetal from being damaged by the screw.

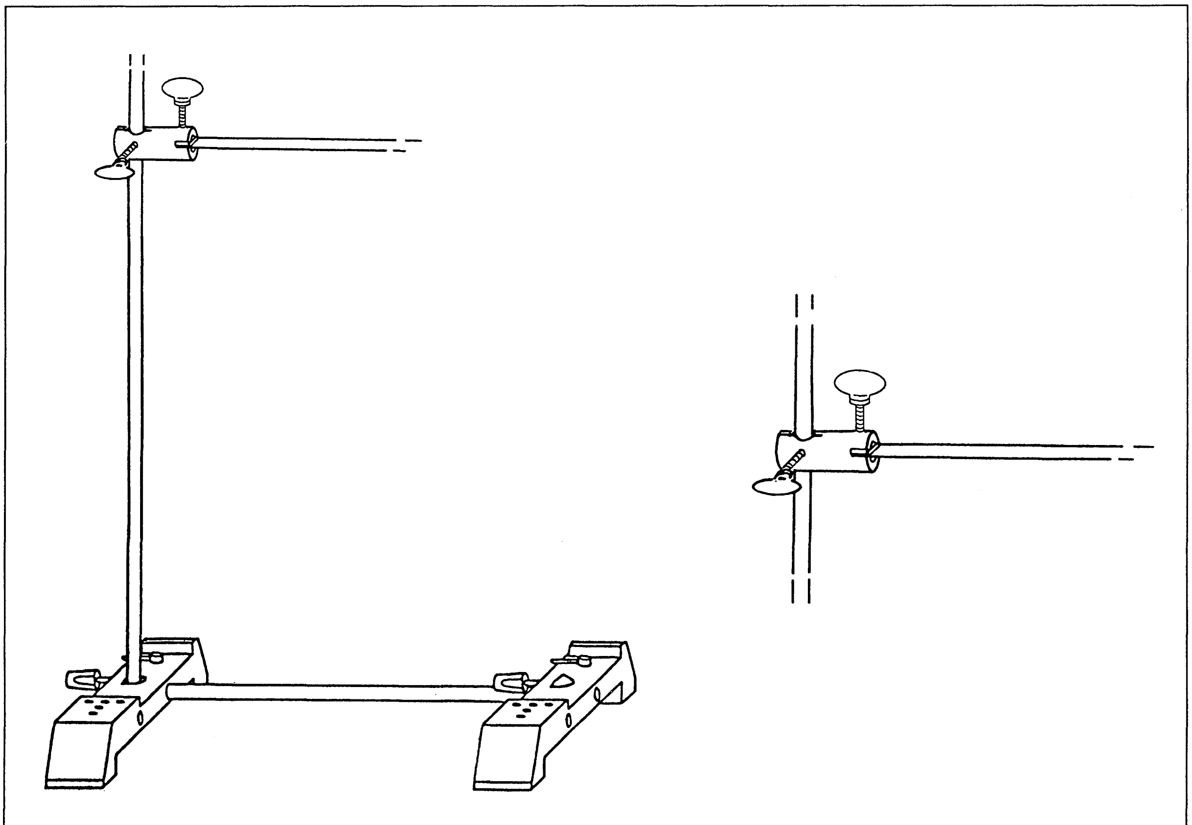

Fig. 1 Setup for investigating the properties of a bimetal

Student's Sheet 2

Performing the experiment:

3. Heat up the bimetal with the flame of a match and observe what happens.
4. Continue to observe the bimetal as it cools.
5. Cool the bimetal with some ice, and observe it.

Evaluation:

6. How does the bimetal behave when it is heated up?

____

7. How does the bimetal behave as it cools, and when it is actively cooled down?

____

8. Explanation:

____

____

____

9. Examples of technical applications:

____

____

____

Heating air (at a constant pressure)

Assignment: To determine the change in volume of air as a function of temperature at a constant pressure.

Apparatus:

2 stand bases
1 stand rod, 25 cm
1 stand rod, 50 cm
1 double socket
1 universal clamp
1 glass beaker
1 conical flask
1 stopper with hole
1 riser tube
1 thermometer with graduated scale
1 tape measure
1 universal marker

in addition:
1 source of heat, e.g. butane gas burner
1 wire mesh
1 ring with stem
1 universal coupling, if necessary from set BMC1

Student's Sheet 2

Setup:

1. Set up the apparatus as shown in fig. 1.

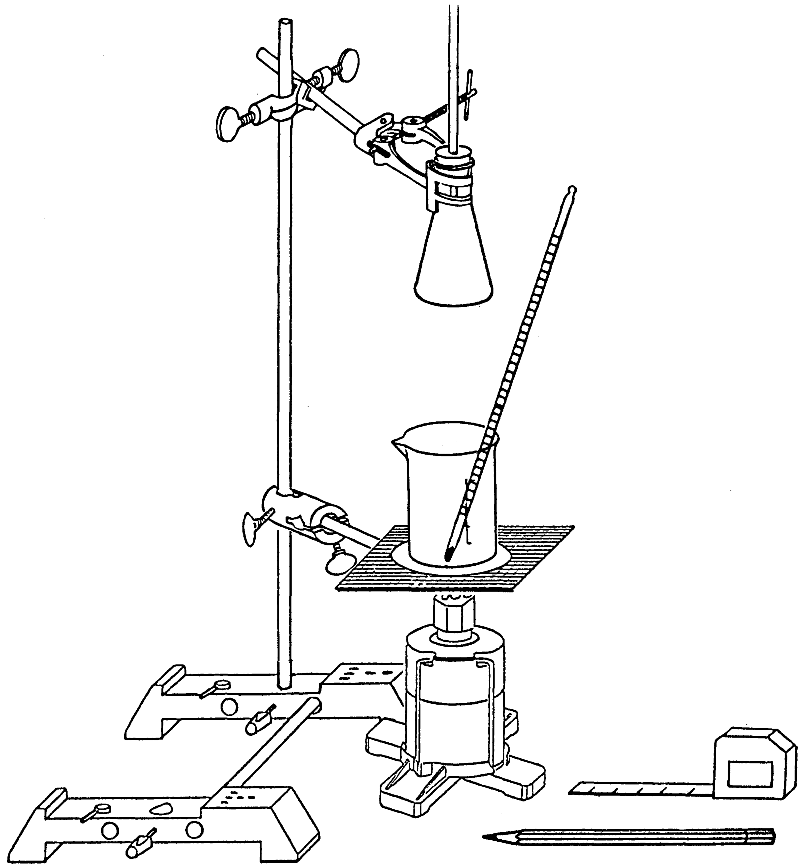

Fig. 1 Experimental setup for heating air

2. Push the riser tube right through the hole in the stopper, so that the end of the tube projects some 2 cm beyond the narrow end of the stopper.

Preparing your report:

3. Draw up table 1.

Observations and measurements:

Table 1

Temperature of water bath t	Height h	Change in temperature Δt	Difference in height Δh

Performing the experiment:

Preliminary experiment:

4. Fill the beaker with between 50 and 75 ml of water.
5. Insert the riser tube so that it projects ca. 1 cm into the water and some water rises into the tube.
6. Close off the tube at the other end with your finger, so that the drop of water cannot escape. Remove the tube from the beaker.
7. Hold the capillary tube horizontally, remove your finger and incline the tube slightly until the drop of water is positioned in the longer portion of the tube, about 2 cm above the stopper. Close the tube with your finger again and insert tube and stopper into the conical flask.
8. Wrap both hands round the conical flask and observe the drop. How does it behave? Enter your observations under step 19.

Main experiment:

9. Clamp the conical flask in the clamp. Position the butane gas burner underneath it, with the wire gauze directly above the burner as shown in fig. 1.
10. Fill the beaker with ca. 200 ml of water and place it on top of the wire gauze.
11. Lower the conical flask until the body of the flask is completely immersed in the water, with only the neck of the flask projecting.
12. Insert the capillary tube into the water bath next to the flask and remove one drop of water (ca. 1 cm of water in the tube). Repeat steps 6 and 7.
13. Place a thermometer in the beaker and measure the initial temperature t_0. Enter your findings in table 1.
14. Mark the height of the water drop on the capillary tube, using the universal marker.
15. Carefully turn up the burner and light it; set the flame so that it is as small as possible.
16. Slowly heat up the water bath. After every 2 K increase in temperature, enter the temperature t in table 1 and mark the height h of the water drop in the capillary tube. While you are taking measurements, stir the thermometer carefully around at the level of the flask.

Student's Sheet 4

17. Switch off the burner and take the capillary tube and stopper out of the conical flask.
18. Dry off the capillary tube. Measure the interval *h* of the markings from the bottom end of the capillary tube, using a ruler. Enter your findings in table 1.

Evaluation:

Preliminary experiment:

19. The drop of water in the capillary tube

____

20. What happens to the air in the conical flask when it is heated up?

____

Main experiment:

21. Determine the temperature difference *t* and heights *h* of the (bottom of the) drop of water above the stopper and enter the values in table 1.
22. Copy the measured values onto the diagram. Fig. 2.
23. What is the connection between changes in the air's volume and any changes in temperature?

____

____

____

____

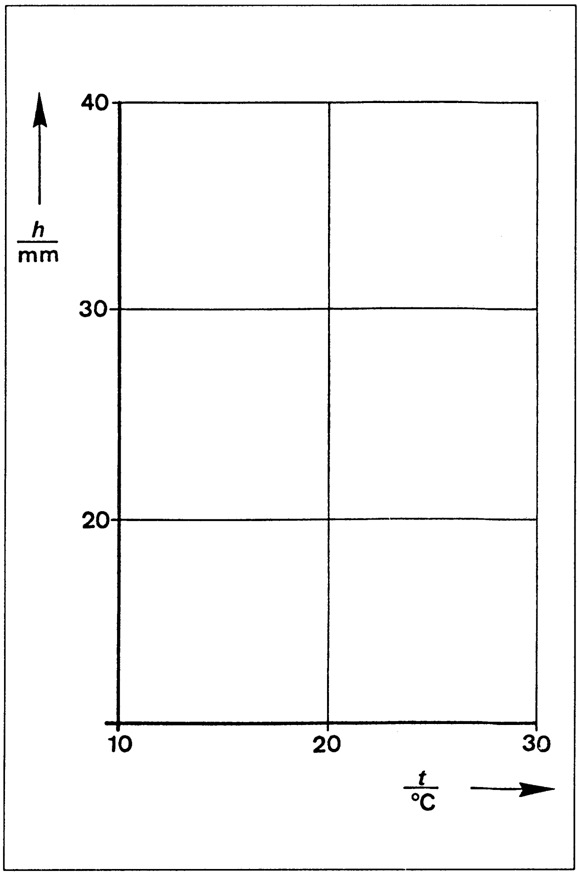

Fig. 2 Diagram showing volume as a function of temperature.

Heating air (at a constant volume)

Assignment: To determine change in pressure as a function of change in temperature at a constant volume.

Apparatus:

2 stand feet
1 stand rod, 25 cm
2 stand rods, 50 cm
1 double socket
1 universal clamp
1 conical flask
1 stopper with hole
1 tube connector
1 silicone tube (60 cm and 30 cm)
2 plastic pipes, 8,5 mm ⌀
1 double pipe holder
1 universal marker
1 tape measure
1 glass beaker
1 plastic beaker
1 small funnel
1 thermometer with scale

in addition:
1 source of heat, e.g. butane gas burner
1 wire gauze
1 ring with stem
1 universal coupling, if necessary from set BMC1
Water

Setup:

1. Assemble the pieces of apparatus as shown in fig. 1.
2. Attach the apparatus clamp to the left-hand rod using the double socket.

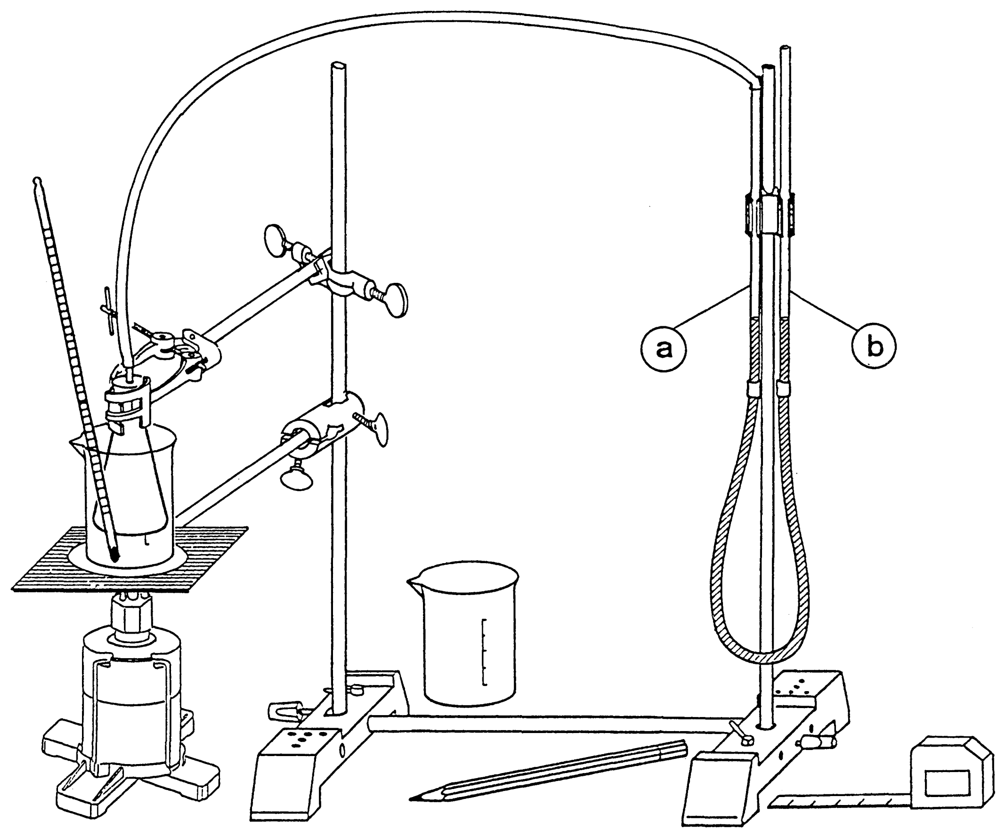

Fig. 1 Experimental setup for heating air with an U-tube manometer connected

3. Place the wire gauze on the ring of the ring with stem.
4. Mount the manometer and fasten it to the right-hand stand rod. Fill the manometer with water until both tubes can be seen to contain water.

5. Plug the stopper, fitted with tube connector and tube, into the conical flask.
6. Fit the free end of the tube to the left-hand limb of the manometer **(a)**

Student's Sheet 3

Preparing your report:

7. Prepare steps 20 to 22.

Performing the experiment:

Preliminary experiment:

8. Wrap your hands round the conical flask and observe manometer limb **(a).** Note down your observations under step 20.
9. In which direction should you move limb **(b)** so that the manometer fluid in it rises higher? Note down your answer under step 21.

Main experiment:

10. Fill the beaker with ca. 200 ml of water and place it on the wire gauze.
11. Clamp the conical flask in the universal clamp.
12. Place the burner and the beaker under the conical flask and lower the flask carefully into the water in the beaker, until the universal clamp is resting on the rim of the beaker.
13. Make sure the water levels in both limbs of the manometer are equal.
14. Mark the height of the water level in limb **(a)**, using the universal marker.
15. Note down the water temperature ϑ_0 under step 22.
16. Light the burner and heat the water bath up by 1 K. Stir it continuously.

    Warning:

    Switch off the burner after the temperature has risen by about 0.5 K, as otherwise the temperature will climb too quickly. Then wait until $\Delta\vartheta$ = 1 K has been reached.
17. Move the water level in limb **(a)** until it is next to the mark you made earlier.
18. Measure the interval *h* between the water level in limb **(a)** and the water level in limb **(b)**, and enter your findings in table 1.
19. Repeat steps 16 to 18 for the temperature changes $\Delta\vartheta$ given in the table.

Student's Sheet 5

25. Copy the measured values into the diagram (fig. 2).
26. What is the connection between the height of the water column *h* and/or the pressure of the enclosed air, and temperature?

____

____

____

____

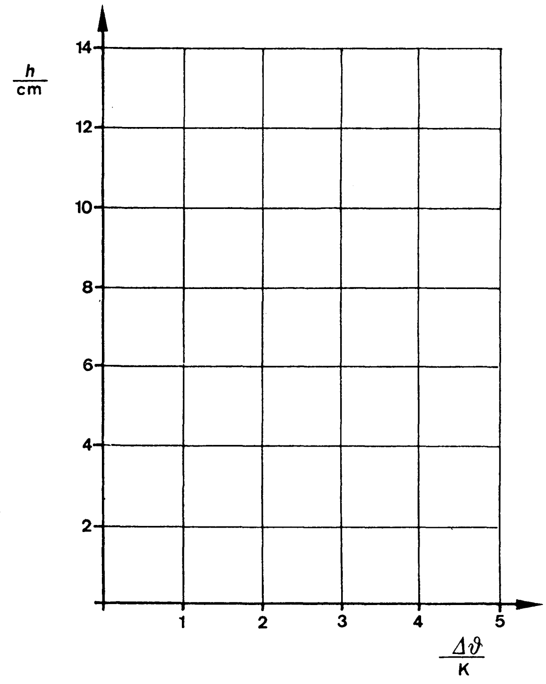

Fig. 2 Diagram showing pressure as a function of temperature.

2.1.1.6

Student's Sheet 4

Observations and measurements:

20. The manometer fluid in limb **(a)** ______________________________

21. Limb **(b)** ______________________________

22. Initial temperature ϑ_0: ______________________________

Table 1

Change in temperature $\Delta\vartheta = \vartheta_1 - \vartheta_0$	Temperature of water bath ϑ_1	Interval h
1 K		
2 K		
3 K		
4 K		

Evaluation:

23. What happens to the air in the conical flask when it is heated up?

____

24. To restore the volume to what it was at the beginning of the experiment, the pressure must be increased. How is this done?

____

Student's Sheet 1

Thermal conduction in solid bodies

Assignment: To investigate the conduction of heat in various metals.

Apparatus:

2 stand feet
1 stand rod, 25 cm
1 stand rod, 50 cm
1 double socket
1 universal clamp
1 conical flask
1 thermometer with scale
1 set of two heat conducting rods
1 plastic beaker

in addition:
1 source of heat, e.g. butane gas burner
1 timer, e.g. stopwatch
Water

Student's Sheet 2

Setup:

1. Set up a stand as shown in fig. 1.

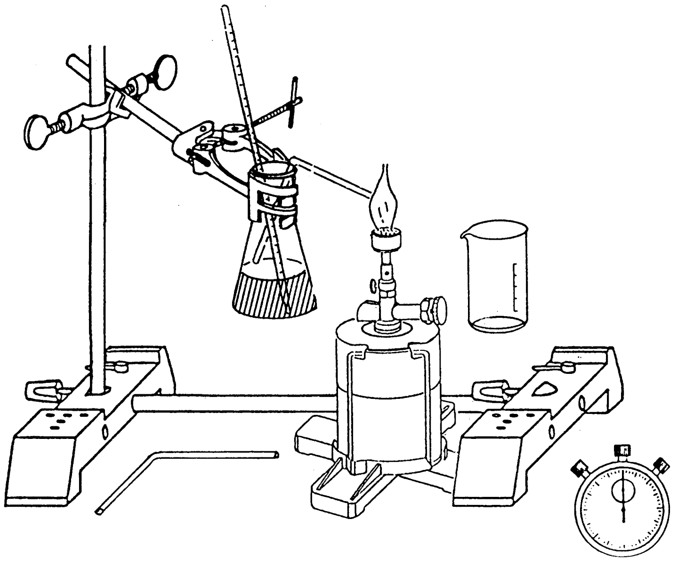

Fig. 1 Experimental setup for investigating thermal conductivitiy in solid bodies

2. Fill the beaker with water.
3. Carefully clamp the conical flask in place and fill it with 20 ml of water from the beaker.
4. Place the heat conducting rod made of copper in the flask.
5. Position the burner under the tip of the heat conducting rod and move the universal clamp until the tip of the heat conducting rod is positioned some 2–3 cm directly above the burner's nozzle.
6. Place the thermometer in the conical flask.

Preparing your report:

7. Copy out table 1.

Performing the experiment:

8. Note down the initial temperature ϑ_0 under step 14.
9. Turn on and light the burner and simultaneously start the stopwatch.
10. Take a reading of the increase in temperature ϑ_1 every minute for five minutes and note down your findings in table 1.
11. Turn off the burner.

Student's Sheet 3

12. Carefully remove the copper heat conducting rod from the flask using a cloth.
    Careful! The rod is hot.
13. Put the thermometer to one side, pour out the water and repeat the experiment with the steel heat conducting rod.

Observations and measurements:

14. Initial temperature ϑ_0 = ________

Tabelle 1

Substance	Time	ϑ_1
Copper	1 min	
	2 min	
	3 min	
	4 min	
	5 min	
Steel	1 min	
	2 min	
	3 min	
	4 min	
	5 min	

Evaluation:

15. During the experiment, the ends of the metal rods are both positioned in the flame, so that they have the same temperature. Why is the change in temperature of the water different for each rod?

    ____

16. Which metal is the better heat conductor?

    ____

Note:

All metals are good heat conductors. Liquids and gases, on the other hand, are poor heat conductors. The latter are sometimes called (thermal) insulators.

Heat transfer in liquids

Assignment: To observe the properties of heated water.

Apparatus:

2 stand feet
1 stand rod, 25 cm
1 stand rod, 50 cm
1 double socket
1 universal clamp
1 glass beaker
1 measuring cylinder
1 riser tube

in addition:
1 source of heat, e.g. alcohol burner
1 colouring agent
Water

Setup:

1. Set up the stand as shown in fig. 1.
2. Clamp the beaker in the apparatus clamp and fill it with ca. 200 ml of water.
3. Fill the riser tube to about halfway with coloured water by sucking, and seal it quickly with your finger.

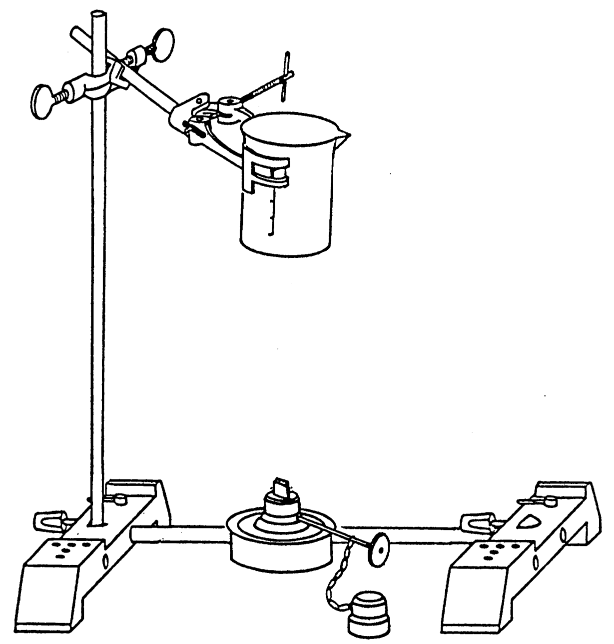

Fig. 1 Experimental setup for investigating heat transfer in liquids

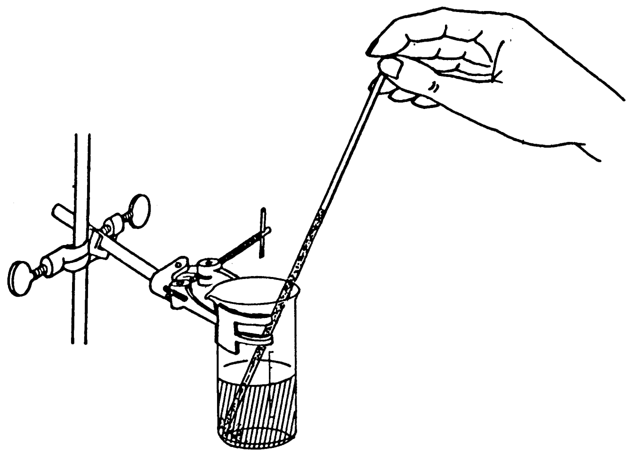

Fig. 2 Introducing coloured water into the beaker

4. Carefully lower the riser tube into the conical flask until it reaches the bottom and let some coloured water run out into the flask.
5. Light the burner and place it directly under the coloured water in the conical flask.
6. Observe carefully and describe your observations.
7. Turn off the burner.

Observations:

8. In the conical flask ______________________________

____

Evaluation:

9. Explain what is happening: ______________________________

____

Student's Sheet 1

Heat transfer in gases

Assignment: To observe the properties of hot air.

Apparatus:

2 stand feet
1 stand rod, 25 cm
1 stand rod, 50 cm
1 double socket
1 universal clamp
1 pointer for indicating linear thermal expansion
or better still: pointer
1 impeller wheel

in addition:
1 source of heat, e.g. alcohol burner

Setup:

1. Set up the stand as shown in fig. 1.
2. Clamp the pointer in the right-hand apparatus clamp and rotate the clamp slightly. Place the impeller wheel on the pointer.

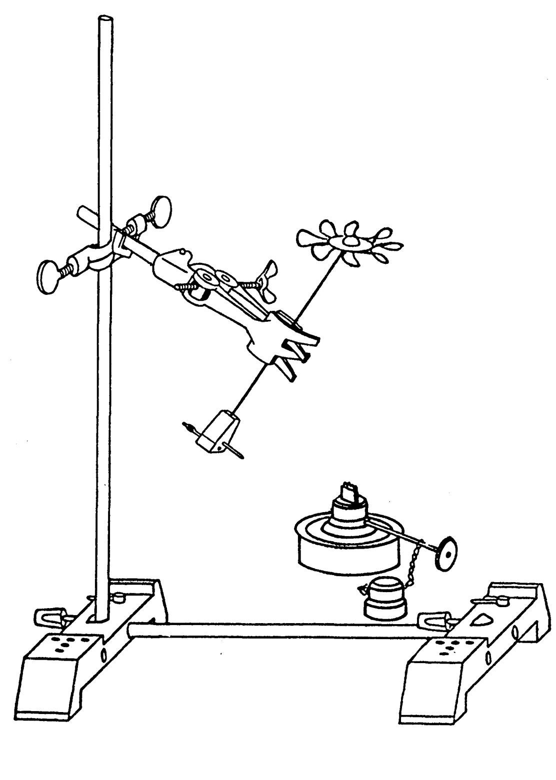

Fig. 1 Setup for investigating the transfer of heat in air

Performing the experiment:

3. Position the burner under the impeller wheel and observe it.
4. Turn off the burner.

Observations:

5. The impeller wheel ____________________

Evaluation:

6. Explain the process:

____

Changes in temperature caused by thermal radiation

Assignment: To investigate heat absorption and heat dissipation by dark and light-coloured (radiant) surfaces.

Apparatus:

2 stand feet
1 stand rod, 25 cm
1 stand rod, 50 cm
1 double socket
1 universal clamp
1 pair of radiometric probes
1 riser tube
1 glass beaker
1 universal marker
1 tape measure

in addition:
1 source of heat, e.g. butane gas burner
1 timer, e.g. stopwatch
1 colouring agent
Water
Paper strip, 2 cm x 15 cm

Student's Sheet 2

Setup:

1. Assemble all parts of the stand as shown in fig. 1.
2. Fill the beaker with ca. 50 ml of coloured water so that it is ready for use.
3. Hold the riser tube in the beaker so that some water (ca. 1 cm) climbs into the tube. Seal the other end with your finger so that the drop cannot flow out again.
4. Remove the riser tube from the beaker, hold it horizontally and carefully insert the end with the drop of water in it into the hole in the stopper of the black radiometric probe. The other end should be unsealed, so that after it has been inserted, the drop is positioned about 5 cm in front of the rubber stopper (fig. 2).
5. Wrap the paper strip round the riser tube and clamp it in position as shown in fig. 2, using the universal clamp. The drop of water should be visible, so you can use the universal marker to mark the zero point on the paper strip.
6. Set up the butane gas burner and radiometric probe in such a way that the probe is located some 5 cm away from the middle of the burner flame (fig. 1).

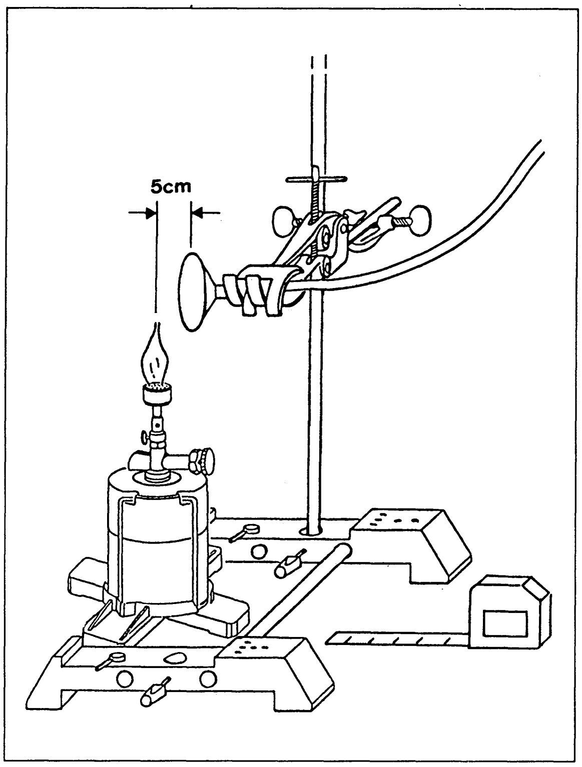

Fig. 1 Setup for investigating the absorption of thermal radiation

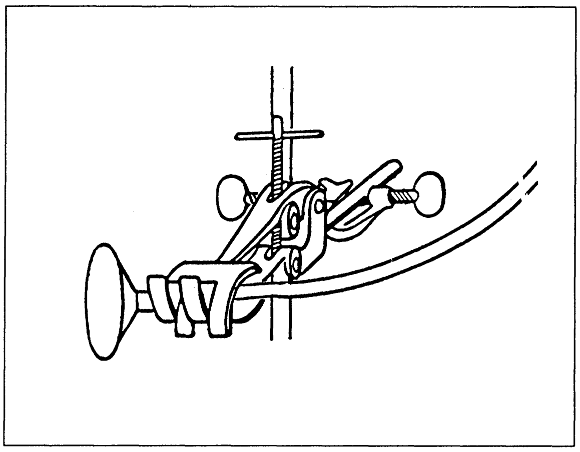

Fig. 2 Radiometric probe with riser tube and clamped sheet of paper

Preparing your report

7. Draw up table 1.

Performing the experiment:

8. Mark the zero point on the paper strip.
   For the heating and cooling phases, the strip should be marked as shown in fig. 3.

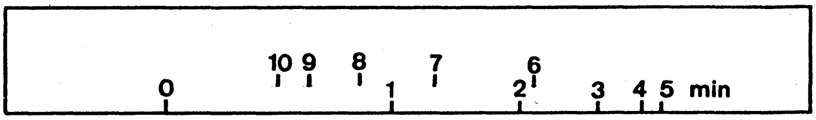

Fig. 3 Calibrating the paper strips

9. Light the burner and simultaneously start the stopwatch.
10. Mark the position of the water droplet once every minute for 5 minutes.
    Always mark the same side of the drop.
11. Turn off the burner after 5 minutes and repeat step 10.
12. Repeat steps 2 to 11 using the second radiometric probe.

Observations and measurements:

Table 1

Time *t*	Distance *x*	
	black	light-coloured
1 min		
2 min		
3 min		
4 min		
5 min		
6 min		
7 min		
8 min		
9 min		
10 min		

Student's Sheet 4

Evaluation:

13. Measure the distances *x* between the water droplet and the zero point mark by measuring the marks you made every minute and entering the results in table 1.

14. What quality should the surface of the body possess if it is to heat up more quickly?

____

15. Copy the values from table 1 over into the system of coordinates.

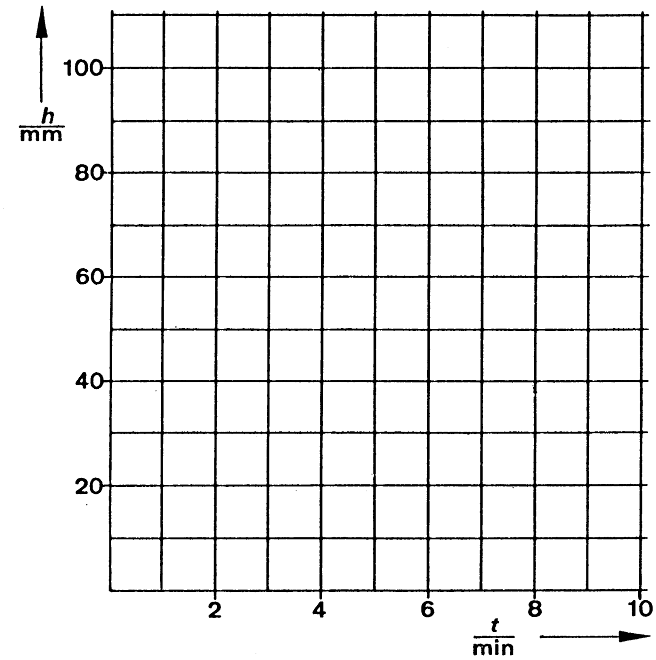

Fig. 4 Diagram showing temperature as a function of time

Student's Sheet 1

Cooling down water

Assignment: To investigate the properties of hot water when cooling.

Apparatus:

2 stand feet
1 stand rod, 25 cm
1 stand rod, 50 cm
1 double socket
1 universal clamp
1 glass beaker
1 thermometer with scale

in addition:
1 source of heat, e.g. butane gas burner
1 wire gauze
1 ring with stem
1 universal coupling (if necessary from set BMC1)
1 timer, e.g. stopwatch
Cardboard, 10 cm x 10 cm
Water

Student's Sheet 2

Setup:

1. Assemble the stand as shown in fig. 1.

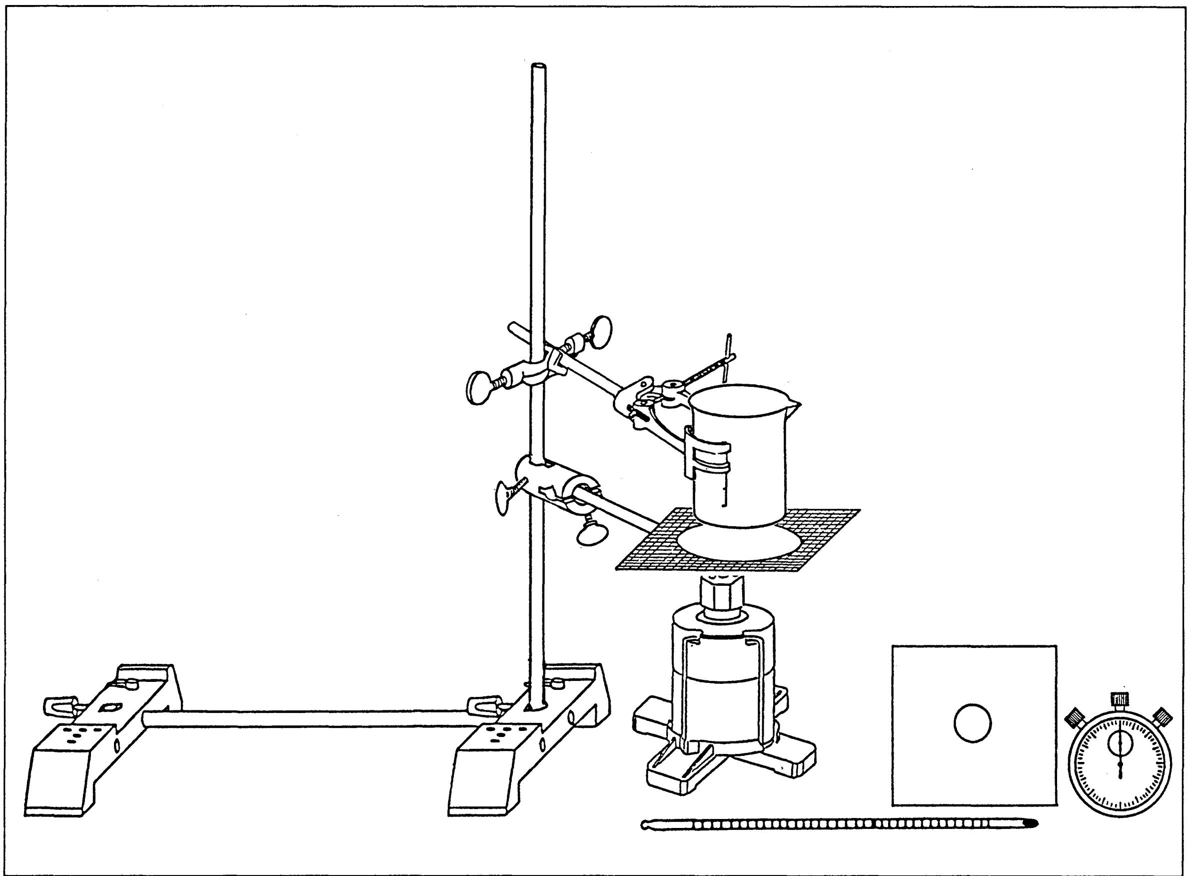

Fig. 1 Setup for investigating the properties of hot water when cooling

2. Fill the beaker with ca. 100 ml of water.
3. Clamp the beaker firmly in the universal clamp.
4. Position the burner under the beaker.

Preparation:

5. Copy out table 1.

Performing the experiment:

6. Light the burner.
7. Wait until the water is boiling. Turn off the burner.
8. Place the thermometer in the hot water.
9. Take a temperature reading every minute for 10 minutes, entering each reading in the table.
10. Make a small hole in the middle of the cardboard, into which the thermometer fits.
11. Repeat steps 6 and 7.
12. Place the thermometer in the beaker of hot water with the cardboard acting as a lid.
13. Repeat step 9.

Student's Sheet 3

Observations and measurements:

Table 1

Time t in min	Temperature	
	Beaker without a lid	Beaker with a lid
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Evaluation:

14. Copy the values from the table over into the system of coordinates. How does hot water cool? (Describe the temperature gradient!)

____

____

15. What is the effect of the lid?

____

____

____

____

____

____

____

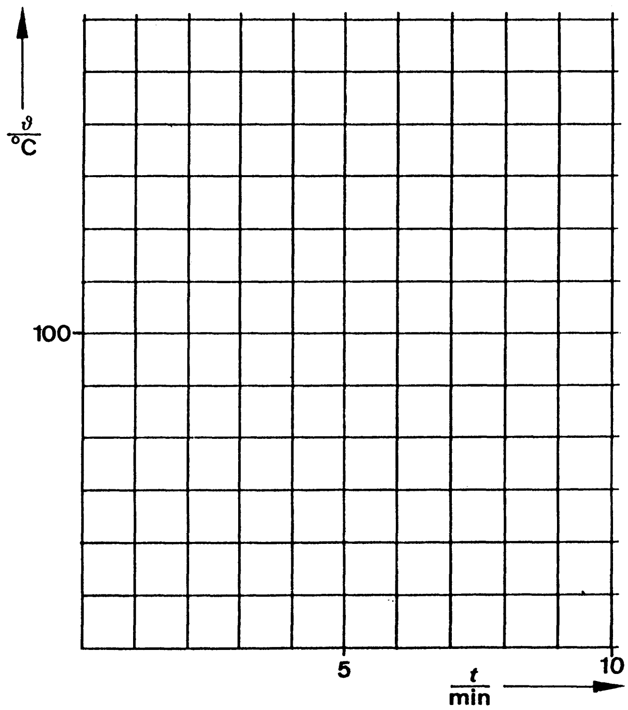

Fig. 2 Diagram showing temperature as a function of time

Heating up different volumes of water

Assignment: To investigate temperature increases in different volumes of water.

Apparatus:
2 stand feet
1 stand rod, 25 cm
1 stand rod, 50 cm
1 double socket
1 universal clamp
1 glass beaker
1 measuring cylinder
1 plastic beaker
1 thermometer with scale
1 tape measure

in addition:
1 source of heat, e.g. alcohol burner
1 timer, e.g. stopwatch
Water

Setup:

1. Set up the stand as shown in fig. 1, attaching the double socket and apparatus clamp.

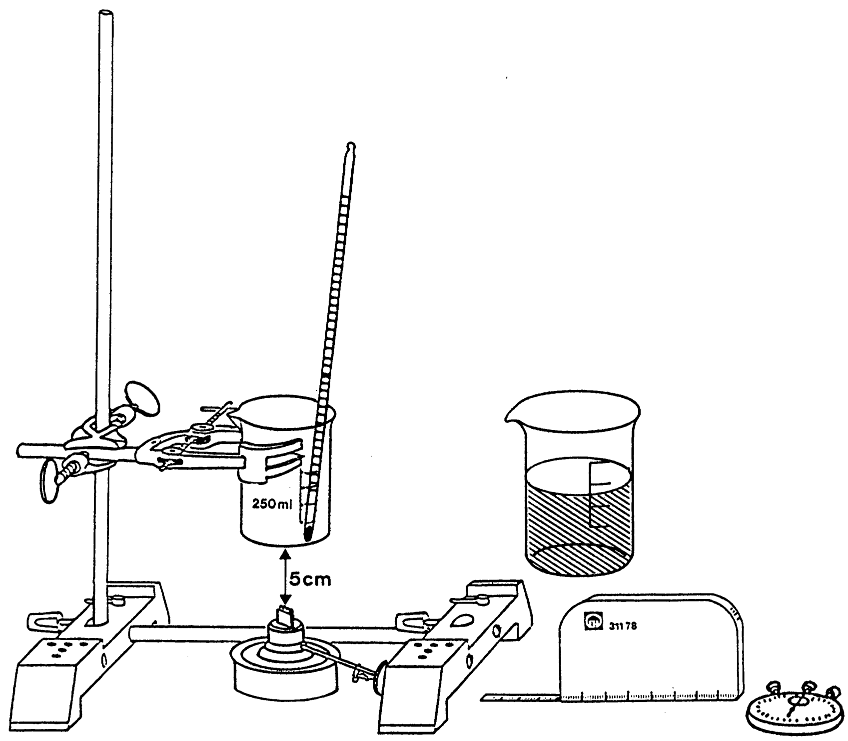

Fig. 1 Setup for investigating the behaviour of water when heated.

2. Fill the beaker with 100 ml of water and clamp it in the clamp.
3. Set a precise distance between the beaker and the burner.
4. Pour about 250 ml of water into the plastic beaker so that it is ready for use.

Preparing the report:

5. Copy out table 1.

Performing the experiment:

6. Measure the initial temperature of the water in the beaker (100 ml) and enter the value in table 1.
7. Light the burner and push it under the beaker as soon as it is burning properly. Simultaneously start the stopwatch.
8. Stir the water continuously and measure the temperature ϑ every half minute, entering your measurements in table 1.
9. After five minutes, turn off the flame and pour out the water.
   Careful! Hot apparatus.
10. Repeat steps 6 to 9 with 200 ml of water.

Observations and measurements:

11. Table 1

Time t min	100 ml of water		200 ml of water	
	Temperature ϑ °C	Rise in Temperature $\Delta\vartheta$ K	Temperature ϑ °C	Rise in Temperature $\Delta\vartheta$ K
0		–		–
0.5				
1.0				
1.5				
2.0				
2.5				
3.0				
3.5				
4.0				
4.5				
5.0				

Mean value: ________ Mean value: ________

Evaluation:

12. Enter any rises in temperature $\Delta\vartheta$ in table 1 and calculate the mean values.
13. Copy the measured values from table 1 into the diagram in fig. 2.
14. What is the relationship between the amount of heat Q supplied and the rise in temperature $\Delta\vartheta$ when the amount of water remains constant?

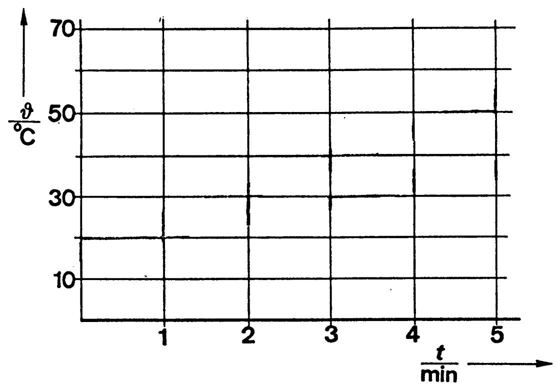

Fig. 2 Diagram showing rises in temperature as a function of time for different volumes of water.

15. What is the relationship between the amount of heat Q supplied and the amount of water m where the temperature rises by the same amount?

Heating different liquids

Assignment: To investigate temperature rises in different liquids.

Apparatus:

2 stand feet
1 stand rod, 25 cm
1 stand rod, 50 cm
1 double socket
1 universal clamp
1 glass beaker
1 thermometer with scale
1 tape measure

in addition:

1 source of heat, e.g. alcohol burner
1 time, e.g. stopwatch
Water
Oil

Setup:

1. Set up the stand as shown in fig. 1. Attach the double socket and apparatus clamp.

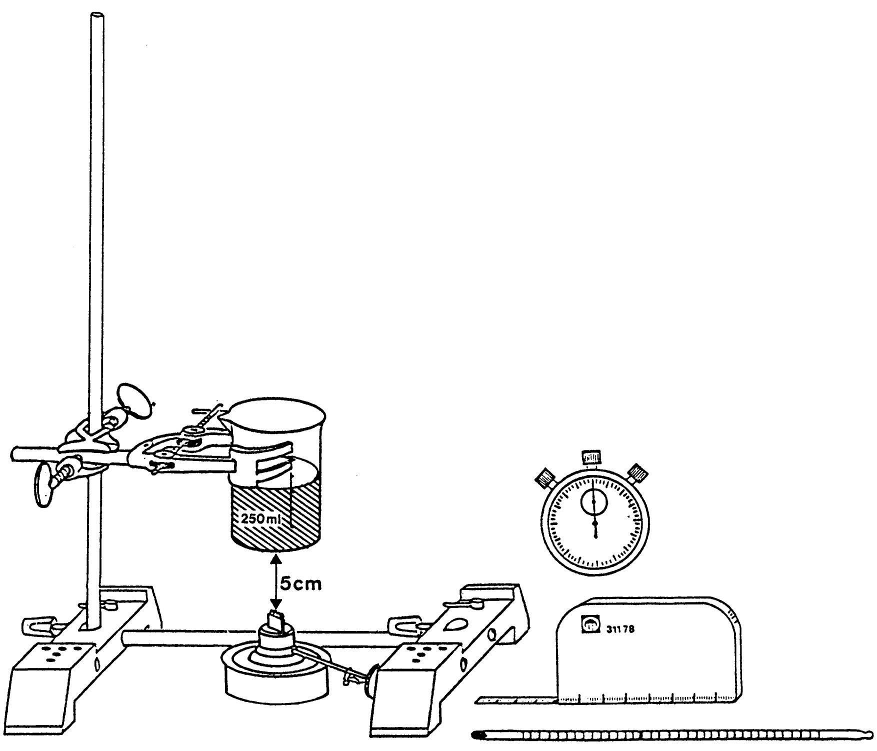

Fig. 1 Setup for investigating temperature rises in liquids.

Student's Sheet 2

2. Fill the beaker with 100 ml of water and clamp it in the clamp.
3. Set a given distance between the beaker and burner.
   Protect the experimental setup from draughts.

Preparing your report:

4. Copy out table 1.

Performing the experiment:

5. Determine the temperature of the water with the thermometer and enter the reading in table 1.
6. Light the burner and push it under the beaker when it is burning properly. Simultaneously start the stopwatch.
7. Stir the water continuously, taking temperature readings with the thermometer every half minute and entering them in table 1.
8. After 3 minutes, turn off the flame and pour out the water.
   Careful! Hot apparatus.
9. Repeat steps 5 to 8 with 100 ml of oil.
   Immediately after the experiment, clean the thermometer and beaker with soapy solution.

Observations and measurements:

10. Table 1

Time *t*	100 ml of water		100 ml of oil	
min	Temperature ϑ °C	Rise in Temperature $\Delta\vartheta$ K	Temperature ϑ °C	Rise in Temperature $\Delta\vartheta$ K
0				
0.5				
1.0				
1.5				
2.0				
2.5				
3.0				

Mean value: _______ Mean value: _______

Student's Sheet 3

Evaluation:

11. Enter rises in temperature $\Delta\vartheta$ in table 1 and calculate mean values.
12. Copy the measured values into the diagram in fig. 2.
13. How great is the rise in temperature $\Delta\vartheta$ in 100 ml of water and 100 ml of oil over 3 minutes?

    $\Delta\vartheta_{water}$ = $\Delta\vartheta_{oil}$ =

14. Where the amount of heat supplied remains constant, the rise in temperature does not just depend on the amount of liquid.
    What else does it depend on?

____

____

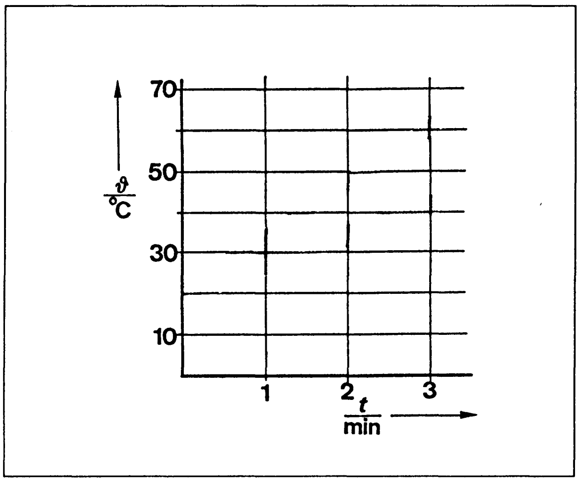

Fig. 2 Diagram on the dependence of the temperature increase as a function of time for different liquids

Mixture temperature

Assignment: To mix together various quantities of water with different temperatures and determine the mixture temperature.

Apparatus:

2 stand feet
1 stand rod, 25 cm
1 stand rod, 50 cm
1 double socket
1 universal clamp
1 glass beaker
1 plastic beaker
1 measuring cylinder
1 thermometer with scale

in addition:
1 source of heat, e.g. butane gas burner
1 wire gauze
1 ring with stem
1 universal coupling (if necessary from set BMC 1)
Water

Student's Sheet 2

Setup:

1. Assemble the stand setup shown in fig. 1.

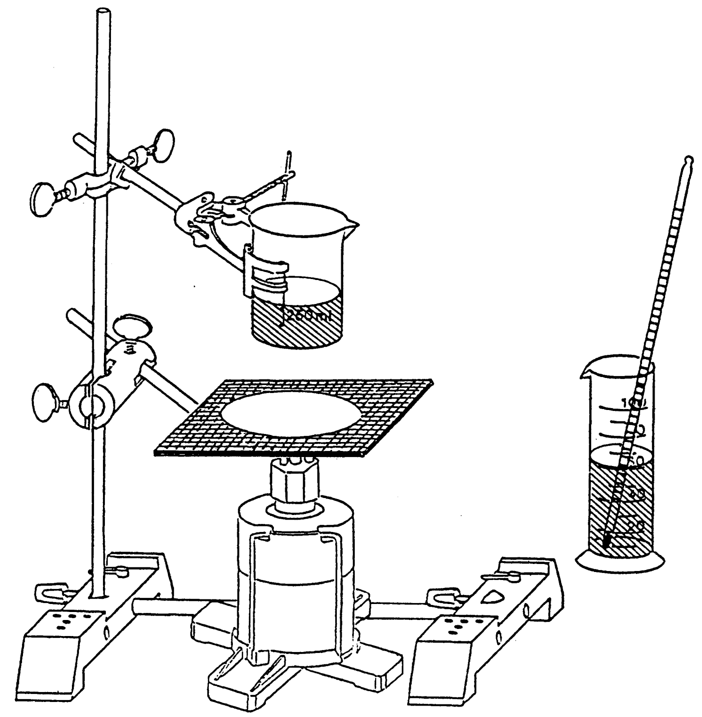

Fig. 1 Setup for mixing quantities of water

2. Measure out 100 ml of water (m_1) into the measuring cylinder and pour it into the beaker.

3. Position the butane gas burner underneath the beaker.

Preparing your report:

4. Copy out table 1 ▶ 11.

Performing the experiment:

5. Measure out m_2 = 100 ml of water in the measuring cylinder and pour it into the plastic beaker.
6. Measure the temperature of the water (ϑ_2) in the plastic beaker and note it down ▶ 11.
7. Place the thermometer in the beaker, light the burner and heat the water up to 60 °
8. Turn off the burner, stir the water and wait until the temperature stops changing, then take a reading for ϑ_1 and note it down in table 1 ▶ 11.

Student's Sheet 3

9. Pour the hot water into the cold water in the plastic beaker, stir it and take a reading of the temperature ϑ_m once it has stopped changing. ▶ Enter your reading in table ▶ 1.

   Careful, the beaker is hot. It makes sense to remove the universal clamp and beaker from the setup together, using the clamp as a handle. Otherwise, hold the beaker in a cloth.

10. Repeat the experiment with the volumes of water shown in table 1 ▶ 11.

Observations and measurements:

11. Table 1

$\frac{m_1}{g}$	$\frac{m_2}{g}$	$\frac{\vartheta_1}{°C}$	$\frac{\vartheta_2}{°C}$	ϑ_m measured / °C	ϑ_m calculated / °C
100	100				
100	50				
150	100				

Note:

1 ml of water ≙ 1 g of water

Evaluation:

12. The amount of heat (energy) Q_{abs} absorbed by the cold water is equal to the amount of heat (energy) Q_{em} emitted by the hot water.

$$Q_{abs} = Q_{em}$$

With the help of the equation

$$\vartheta_m = \frac{m_1 \cdot \vartheta_1 + m_2 \cdot \vartheta_2}{m_2 + m_1}$$

calculate the mixture temperatures for the quantities of water shown in table 1.

13. 250 g of water at 17° C are mixed with 110 g of water at 90° C. What mixture temperature would you expect?

Student's Sheet 1

Specific heat capacity of water

Assignment: To investigate the rise in temperature of water as a function of the energy supplied.

Apparatus:
1 plastic beaker
1 glass beaker
1 measuring cylinder
1 thermometer with scale
1 immersion heater

in addition:
1 voltage source, 12 V, e.g. transformer
1 timer, e.g. stopwatch
Water

Setup:

1. Pour ca. 150 ml of water into the beaker so that it is ready for use.

Preparing your report:

2. Copy out table 1.

Performing the experiment:

3. Using the measuring cylinder, measure 100 ml of water out into the plastic beaker.
4. Put the immersion heater into the plastic beaker so that it is completely covered by water.
5. Connect the immersion heater to the voltage source and stir the water continuously for 1 minute using the thermometer.
6. Take a reading of the temperature and simultaneously start the stopwatch. Enter the temperature in table 1.
7. Take a temperature reading every half minute and enter your readings in table 1. Stir continuously, so that the heat is evenly distributed.

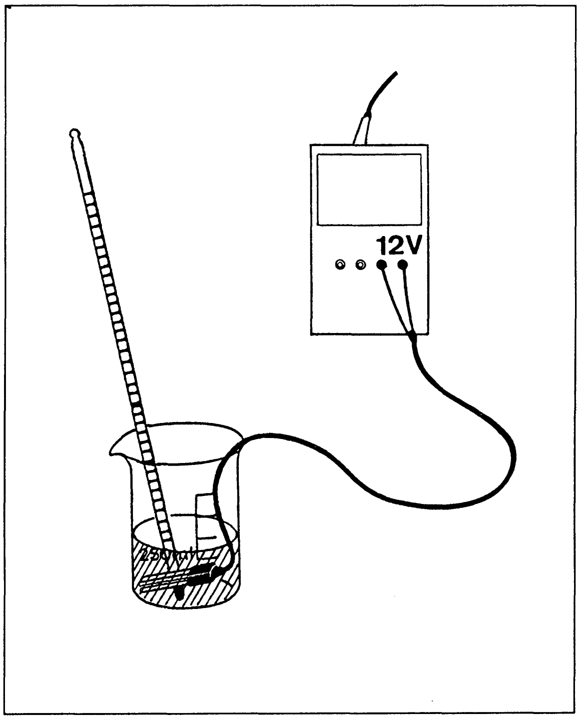

Fig. 1 Heating up water using an immersion heater.

Student's Sheet 2

Observations and measurements:

8. Table 1

	100 ml of water	
Time $\frac{t}{min}$	Temperature $\frac{\vartheta}{°C}$	Change in Temperature $\frac{\Delta\vartheta}{K}$
0		
0.5		
1		
1.5		
2		
2.5		
3		
3.5		
4		
4.5		
5		

Mean value: _____

Evaluation:

9. Enter the changes in temperature $\Delta\vartheta$ in table 1 and calculate the mean value.
10. Copy the values from table 1 into the diagram in fig. 2.
11. From where is the energy for heating up the water obtained?

____

____

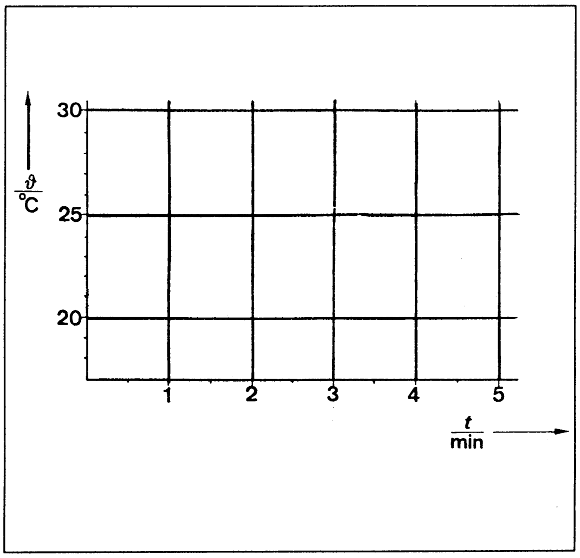

Fig. 2 Increases in temperature as a function of time (when using an immersion heater)

Student's Sheet 3

12. Calculate the specific heat capacity C_{H_2O} using the equation:

$$C_{H_2O} = \frac{P \cdot t}{m \cdot \Delta \vartheta}$$

where P: electrical output

$$C_{H_2O} = \frac{10\,W \cdot 300\,s}{100\,g \cdot 7\,K} = 4.3\,g\,\frac{J}{g\,K}$$

Student's Sheet 1

Specific heat capacity of solid bodies

Assignment: To investigate the heat capacity of the weights and aluminium cuboid.

Apparatus:

2 stand feet
1 stand rod, 25 cm
1 stand rod, 50 cm
1 double socket
1 universal clamp
1 glass beaker
1 plastic beaker
1 measuring cylinder
1 thermometer with scale
1 aluminium cuboid
2 weights
1 cord

in addition:
1 balance
1 source of heat, e.g. butane gas burner
1 wire gauze
1 ring with stem
1 universal coupling (if necessary from set BMC1)
Water

Student's Sheet 2

Setup:

1. Set up the stand as shown in fig. 1.

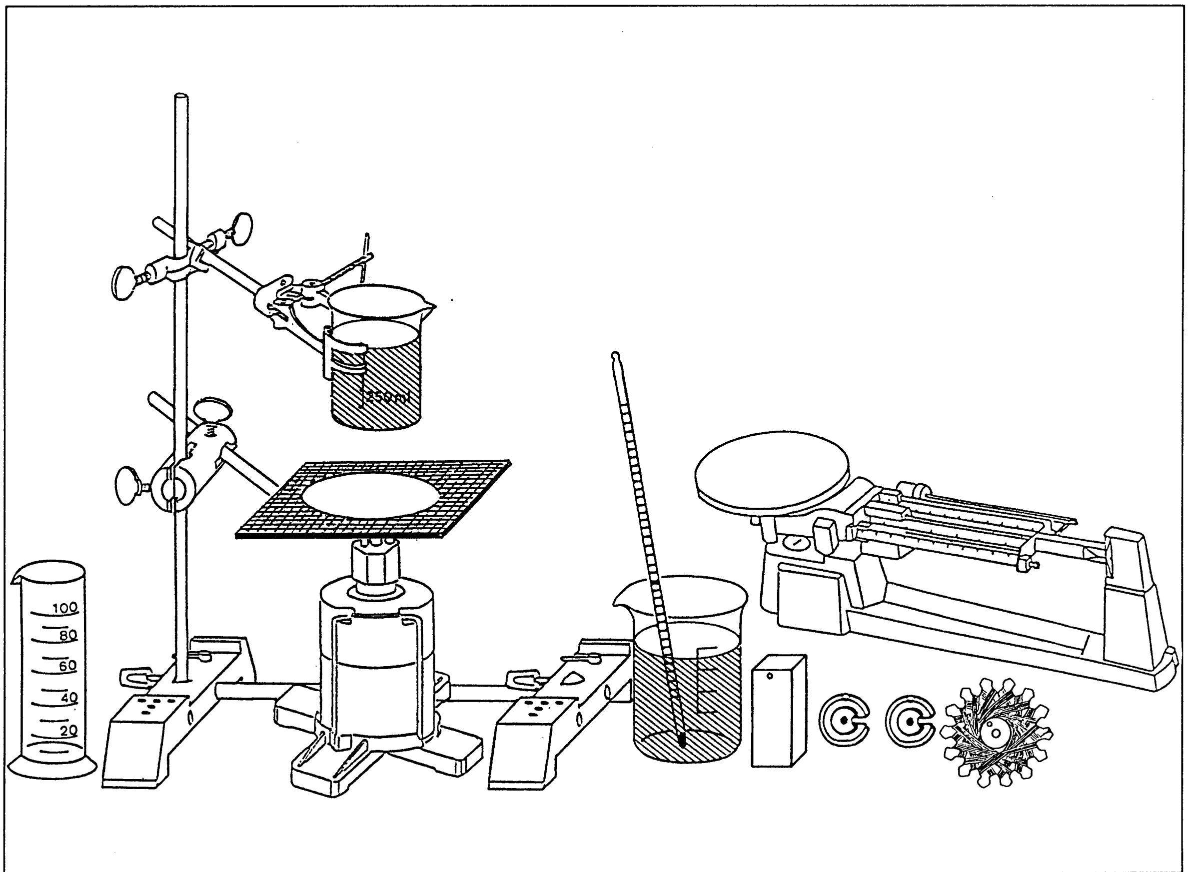

Fig. 1 Setup for investigating the specific heat capacity of solid bodies.

2. Clamp the beaker in the clamp.
3. Tie a 25 cm cord round the aluminium cuboid and another round each of the weights.

Preparing your report:

4. Copy out table 1.

Performing the experiment:

5. Determine the masses m_1 of the bodies and enter them in table 1.
6. Pour 200 ml m_2 of cold water into the plastic beaker and measure the temperature t_2.
7. Fill the beaker with 200 ml of water, light the burner and bring the water to boiling point.
8. Carefully suspend a weight in the boiling water and allow it to hang there for 2 – 3 minutes.
9. Remove the hot metal body from the beaker, place it in the plastic beaker and stir well.

Student's Sheet 3

10. Measure the mixture temperature t_m in the plastic beaker and note it down in table 1.

11. Turn off the burner.
12. Repeat steps 5 to 11 with two weights and the aluminium cuboid.

Observations and measurements:

13. Table 1

			1 weight	2 weights	Aluminium cuboid
Mass of the bodies	m_1	g			
Mass of the water	m_2	g			
Temperature of the water	t_2	°C			
Temperature of the bodies	t_1	°C	100	100	100
Mixture temperature	t_m	°C			
Heat capacity	C	$\frac{J}{K}$			
Specific heat capacity	c	$\frac{J}{g\,K}$			

Evaluation:

14. Determine the heat capacity C of the bodies and enter the value in table 1.

$$C = \frac{c_{water} \cdot m_2 \cdot (t_m - t_2)}{t_1 - t_m}$$

where $c_{water} = 4.19 \frac{J}{g \cdot K}$

15. What effect does mass have on heat capacity?

____

16. What is the effect of the substance itself on heat capacity?

____

____

17. Determine the specific heat capacities and enter the values in table 1.

$$c = \frac{C}{m_1}$$

Student's Sheet 4

Heat capacity of a calorimeter

Assignment: To investigate mixture temperatures in a glass vessel used as a calorimeter.

Apparatus:

2 stand feet
1 stand rod, 25 cm
1 stand rod, 50 cm
1 double socket
1 universal clamp
1 glass beaker
1 plastic beaker
1 measuring cylinder
1 thermometer with scale

in addition:
1 source of heat, e.g. butane gas burner
1 wire gauze
1 ring with stem
1 universal coupling (if necessary from the BMC1 set)
Water

Student's Sheet 2

Setup:

1. Set up the stand as shown in fig. 1. Clamp the beaker in the universal clamp, held by the double socket.

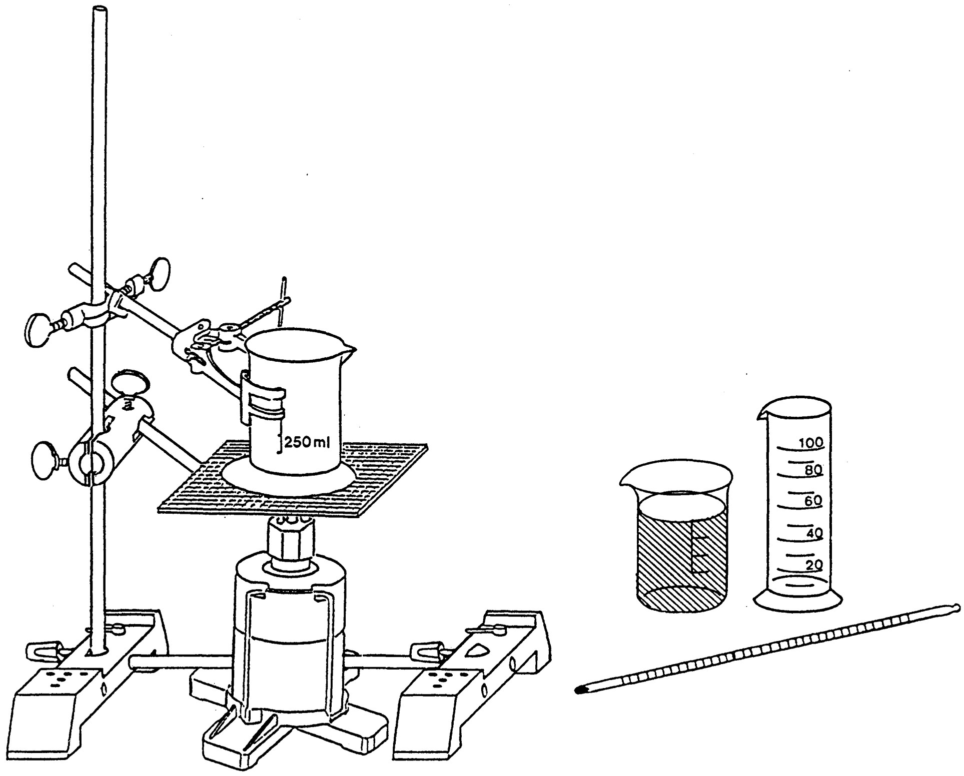

Fig. 1 Experimental setup for investigating the heat capacity of a calorimeter

2. Pour out about 250 ml of water into the plastic beaker so it is ready for use.
3. Measure out 100 ml of water in the measuring cylinder and pour it into the beaker.
4. Measure out 100 ml of water in the measuring cylinder.

Preparing your report:

5. Copy out table 5.

Performing the experiment:

6. Determine the temperature t_1 of the cold water in the measuring cylinder and enter the value in table 1.
7. Light the burner and heat up the water to ca. 60 °C, stirring continuously with the thermometer.
8. Turn off the burner and place it to one side. Push the ring with stem with a piece of wire gauze on top of it under the beaker.
9. Determine the temperature t_2 of the hot water in the beaker and enter the value in table 1.
10. Pour the cold water into the beaker. Determine the mixture temperature t_m and enter the reading in table 1.
    If necessary, pause briefly until the temperature indicator stops falling.

Student's Sheet 3

Observations and measurements:

11. Table 1

Physical size		Unit	Numerical values
Mass of the cold water	m_1	g	
Temperature of the cold water	t_1	°C	
Mass of the hot water	m_2	g	
Temperature of the hot water	t_2	°C	
Mixture temperature, measured	t_m	°C	
Mixture temperature, calculated	$t_{m,calc}$	°C	

Evaluation:

12. Calculate the mixture temperature t_m and enter the result in table 1.

The following applies: $t_{m,calc} = \frac{m_1 \cdot t_1 + m_2 \cdot t_2}{m_1 + m_2}$

or in special cases: $t_{m,calc} = \frac{t_1 + t_2}{2}$.

13. Explanation for the difference between the measured and calculated mixture temperatures:

____

____

14. Determine the heat capacity of the calorimeter: $C_{calorimeter} = \quad \frac{J}{K}$.

The following applies: $C_{calorimeter} = \frac{m_1 \cdot (t_m - t_1) - m_2 \cdot (t_m - t_2)}{t_2 - t_m} \cdot c_{water}$

where $C_{water} = 4.19 \frac{J}{g \cdot K}$ (specific heat capacity of water)

Temperature changes during heating

Assignment: To investigate temperature changes in water as a function of time where the supply of heat is constant.

Apparatus:

2 stand feet
1 stand rod, 25 cm
1 stand rod, 50 cm
1 double socket
1 universal clamp
1 conical flask
1 thermometer with scale
1 measuring cylinder

in addition:
1 source of heat, e.g. butane gas burner
1 wire gauze
1 ring with stem
1 universal coupling (if necessary from set BMC1)
1 timer, e.g. stopwatch
Water
Ice

Setup:

1. Set up the stand as shown in fig. 1.

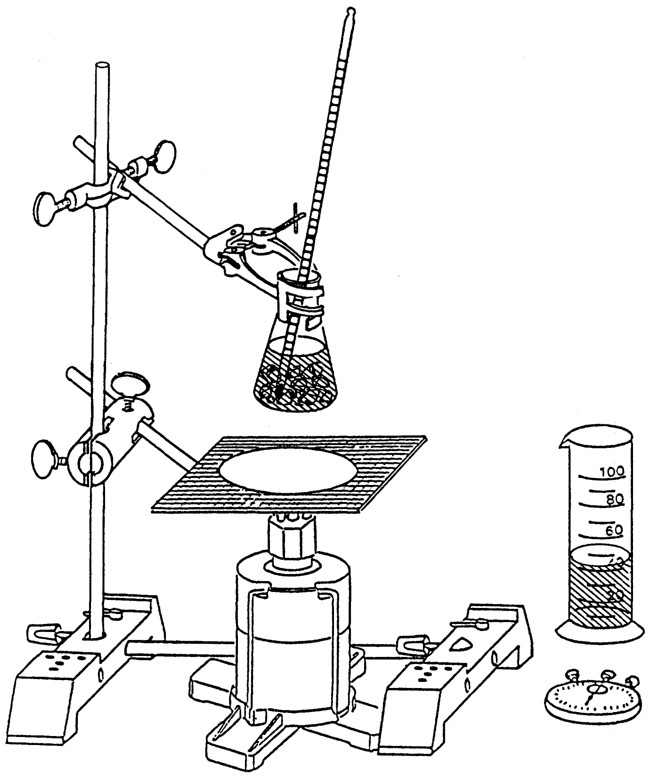

Fig. 1 Experimental setup for heating water

2. Fill the conical flask with ice and water, up to the 50 ml line.

3. Put the thermometer in the conical flask and stir.
4. Place the burner under the conical flask.

Preparing your report:

5. Copy out table 1.

Performing the experiment:

6. Measure the initial temperature of the ice water mixture and enter the value in table 1.
7. Light the burner, read off the temperature every half minute and enter the results in table 1. Before you take each reading, stir well.

8. Turn off the burner after the water has simmered for about one minute and the temperature has not increased for a while.

   Careful! All the apparatus used is 100 °C hot!

Student's Sheet 3

Observations and measurements:

9. Table 1

Time	t	min	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
Temperature	ϑ	°C												

Time	t	min	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5
Temperature	ϑ	°C												

Evaluation:

10. Copy the values from the table into the diagram shown in fig. 2.

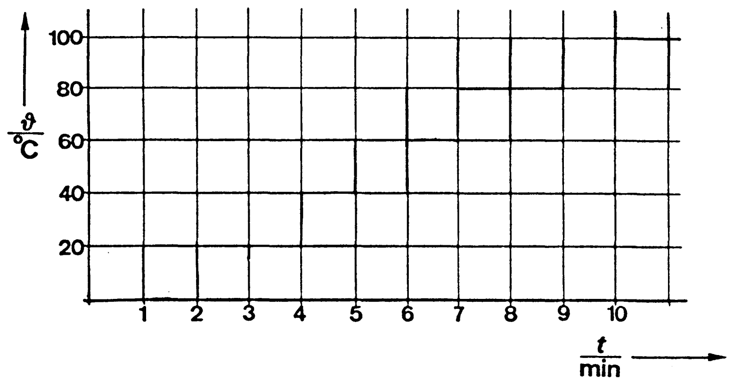

Fig. 2 Diagram showing temperature as a function of time when the supply of heat is constant.

11. Describe the change in temperature (fig. 2) while heat is being supplied:

____

____

Student's Sheet 1

Fusion heat of ice

Assignment: To melt ice using hot water and determine the mixture temperature.

Apparatus:

2 stand feet
1 stand rod, 25 cm
1 stand rod, 50 cm
1 double socket
1 universal clamp
1 glass beaker
1 thermometer with scale
1 measuring cylinder
1 plastic beaker
in addition:
1 source of heat, e.g. alcohol burner
1 balance
Water
Ice

Setup:

1. Set up the apparatus as shown in fig. 1.

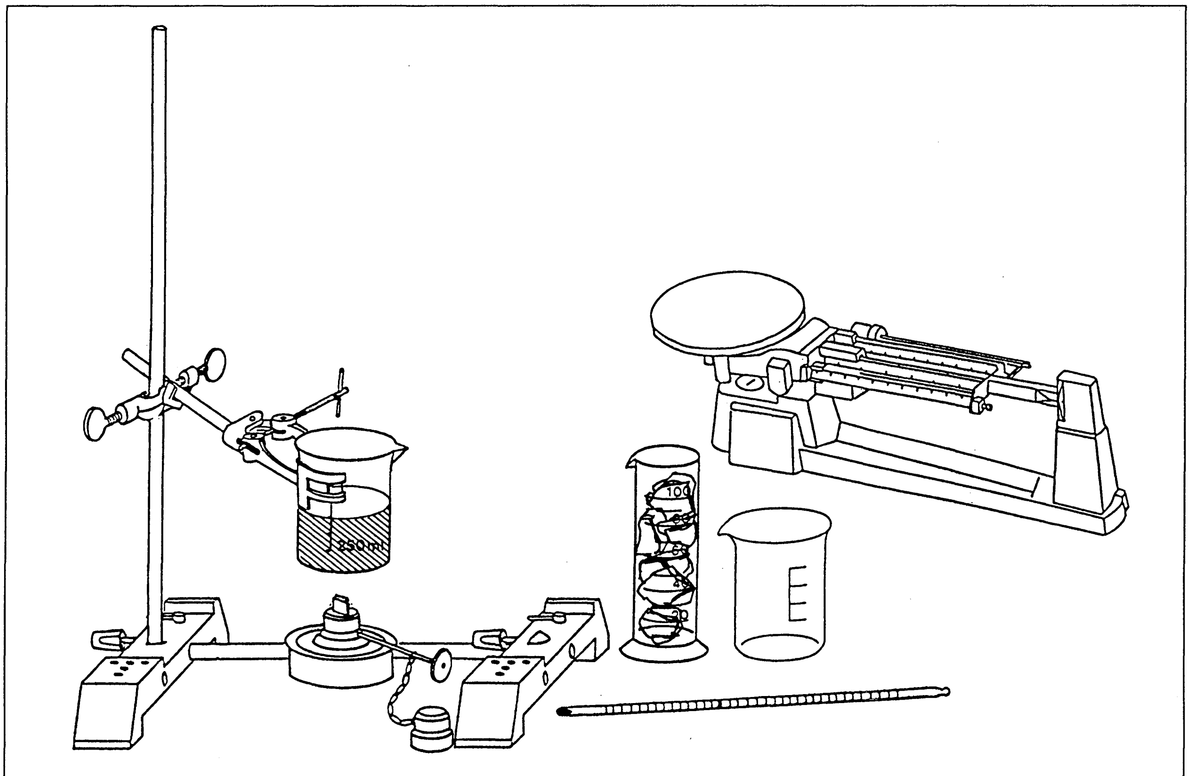

Fig. 1 Setup for melting ice using hot water

Student's Sheet 2

2. Fill the beaker with ca. 150 ml of water and clamp it in the universal coupling.
3. Place some ice cubes ready for use in the measuring cylinder. The ice cubes should not be too small, so that they can be dried off before they are transferred to the beaker.

Preparing your report:

4. Copy out table 1.

Performing the experiment:

5. Determine mass m_1 of the plastic beaker and enter the value in table 1.
6. Light the burner and heat up the water to ca. 35 °C.
7. Turn off the burner.
8. Pour the water into the plastic beaker, determine the mass m_2 of the plastic beaker filled with hot water and enter the value in table 1.
9. Determine the temperature t_{water} of the hot water and enter the measurement in table 1.
10. Place pieces of ice in the plastic beaker, determine the mass m_3 of the plastic beaker filled with ice and water and enter the result in table 1.
11. Stir the water and ice with the thermometer until the ice has completely melted. Determine the mixture temperature t_m and enter the value in table 1.

Observations and measurements:

12. Table 1

Mass of the plastic beaker	m_1	g	
Mass of the plastic beaker filled with hot water	m_2	g	
Temperature of the hot water	t_{water}	°C	
Mass of the plastic beaker filled with water and ice	m_3	g	
Temperature of the ice	t_{ice}	°C	
Mixture temperature	t_m	°C	
Mass of the hot water	m_{water}	g	
Mass of the ice	m_{ice}	g	

Student's Sheet 3

Evaluation:

13. Calculate the mass of the hot water m_{water} and the mass of the ice m_{ice} and enter the values in table 1:

$m_{water} = m_2 - m_1$

$m_{ice} = m_3 - m_2$

14. Calculation of the mixture temperature of cold water at 0 °C ($m = m_{ice}$) and hot water ($m = m_{water}$) with a temperature of t_{water}:

$$t_{calc} = \frac{m_{water} \cdot t_{water}}{m_{water} + m_{ice}}$$

$t_{calc} =$ ______

15. Explanation for the difference of mixture temperatures of cold water at 0 °C (t_{calc}) or the same amount of ice (t_m), with hot water:

____

____

16. Calculation of the specific fusion heat of ice: q = 305 $\frac{J}{g}$

$$q = \frac{c \cdot m_{water} (t_{water} - t_m) - c\, m_{ice} (t_m - t_{ice})}{m_{ice}}$$

where c = 4.19 $\frac{J}{gk}$

Student's Sheet 1

Condensation of water vapour

Assignment: To condense water vapour into water and determine the mixture temperature.

Apparatus:

2 stand feet
1 stand rod, 25 cm
1 stand rod, 50 cm
1 double socket
1 universal clamp
1 conical flask
1 stopper with hole
1 tube connector
1 silicone tube (60 cm)
1 glass beaker
1 plastic beaker
1 thermometer with scale

in addition:
1 source of heat, e.g. butane gas burner
1 wire gauze
1 ring with stem
1 universal coupling, (if necessary from set BMC1)
1 balance
Water

Student's Sheet 2

Setup:

1. Set up the stand as shown in fig. 1.

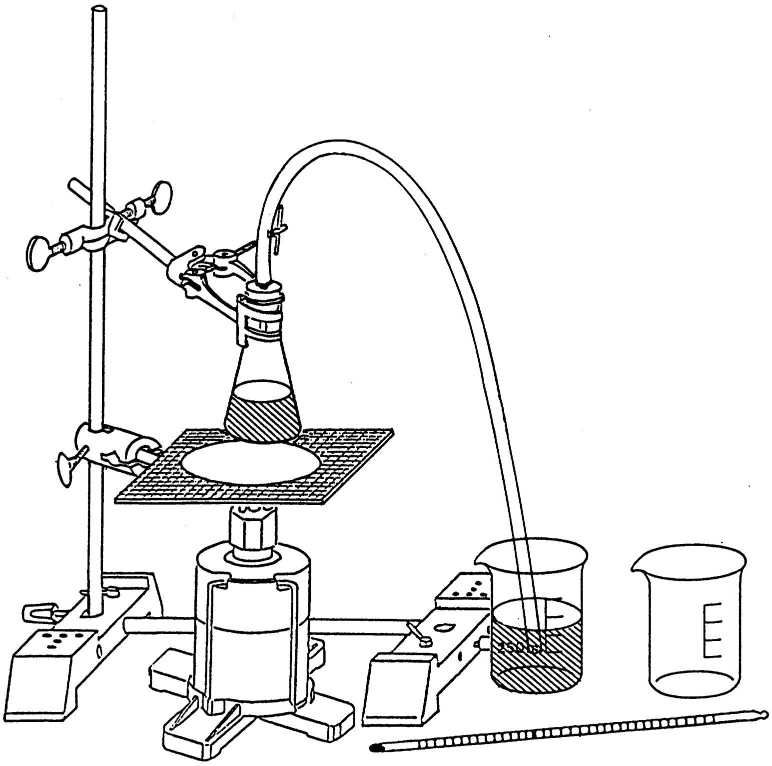

Fig. 1 Experimental setup for condensing water vapour

2. Pour ca. 100 ml of water into the beaker and ca. 30 ml into the conical flask, ready for use.
3. Clamp the conical flask in the universal clamp.
4. Connect the silicone tube to the conical flask using the tube connector and stopper. The stopper should completely seal the conical flask.

Preparing your report:

5. Prepare table 1.

Performing the experiment:

6. Determine the mass m_1 of the plastic beaker and enter the value in table 1.
7. Pour ca. 100 ml of water into the plastic beaker, determine the mass m_2 and enter the value in table 1.
8. Determine the temperature t_1 of the water and enter the value in table 1.
9. Put the disconnected end of the silicone tube into the beaker.
10. Light the burner and wait until water vapour starts to emerge from the free end of the silicone tube.
    Caution! Hot steam!

Student's Sheet 3

11. Carefully insert the free end of the silicone tube (careful: hot steam) into the water in the plastic beaker.
12. Direct the steam into the water for several minutes.

13. Carefully put the free end of the silicone tube back into the beaker (careful: hot steam).
14. Turn off the burner.
15. Determine the temperature t_2 of the water and enter the value in table 1.
16. Determine the mass m_3 of the plastic beaker and enter the result in table 1.

Observations and measurements:

17. Table 1

Mass of the plastic beaker	m_1	g	
Mass of the plastic beaker filled with water	m_2	g	
Temperature of the cold water	t_1	°C	
Mixture temperature	t_m	°C	
Mass of the plastic beaker filled with water (and condensed steam)	m_3	g	
Mass of the cold water	m_{water}	g	
Mass of the condensed steam	m_{steam}	g	

Evaluation:

18. Calculate the mass of the cold water m_{water} and condensed steam m_{steam} and enter the results in table 1.

$m_{\text{water}} = m_2 - m_1$

$m_{\text{steam}} = m_3 - m_2$

Calculation of mixture temperature of hot water at 100 °C ($m = m_{\text{steam}}$) with cold water ($m = m_{\text{water}}$) at a temperature of t_1:

19. $$t_{\text{calc}} = \frac{m_{water} \cdot t_1 + m_{steam} \cdot 100\ °C}{m_{water} + m_{steam}}$$

$t_{\text{calc}} =$ ________

20. Explanation for the difference in the mixture temperatures of hot water at 100 °C (t_{calc}) and the same amount of water vapour (t_m), with cold water.

____

Student's Sheet 1

Temperatures in water-salt mixtures

Assignment: To mix salt with ice or water.

Apparatus:
1 plastic beaker
1 glass beaker
1 measuring cylinder
1 thermometer with scale

in addition:
Water
Ice
Salt

Setup:

1. Lay out all the apparatus ready for use.
2. Put about 40 ml of salt into the measuring cylinder and about 100 ml of ice into the beaker, so that they are both ready for use.

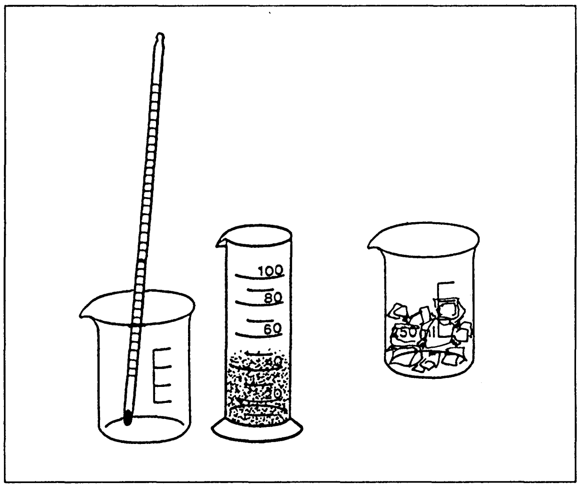

Fig. 1 Apparatus for experiments involving water-salt mixtures

Preparing your report:

3. Prepare steps 11 – 15.

Performing the experiment:

4. Fill the plastic beaker with some 100 ml of ice and measure the temperature. Enter the result under step 11.
5. Pour some 20 ml of salt onto the ice and stir.
6. Note down your observations under step 12.
7. Measure the temperature of the ice-salt mixture and enter the result under step 13.
8. Empty the plastic beaker and fill it with ca. 100 ml of water.
9. Measure the temperature of the water and enter the result under step 14.
10. Pour the remaining salt into the water and stir. Measure the temperature and enter the result under step 15.

Student's Sheet 2

Observations and measurements:

11. Temperature of the ice:______
12. The ice________
13. Temperature of ice-salt mixture:___________
14. Temperature of the water:_______________
15. Temperature of the saline solution:_________

Evaluation:

16. What happens if you mix together ice and salt?

____

17. Explanation:

____

18. Thermal energy is also required to dissolve the solid body (salt) in the liquid (water). How is this manifested?

____

19. Write the terms you have just learned on the graph.

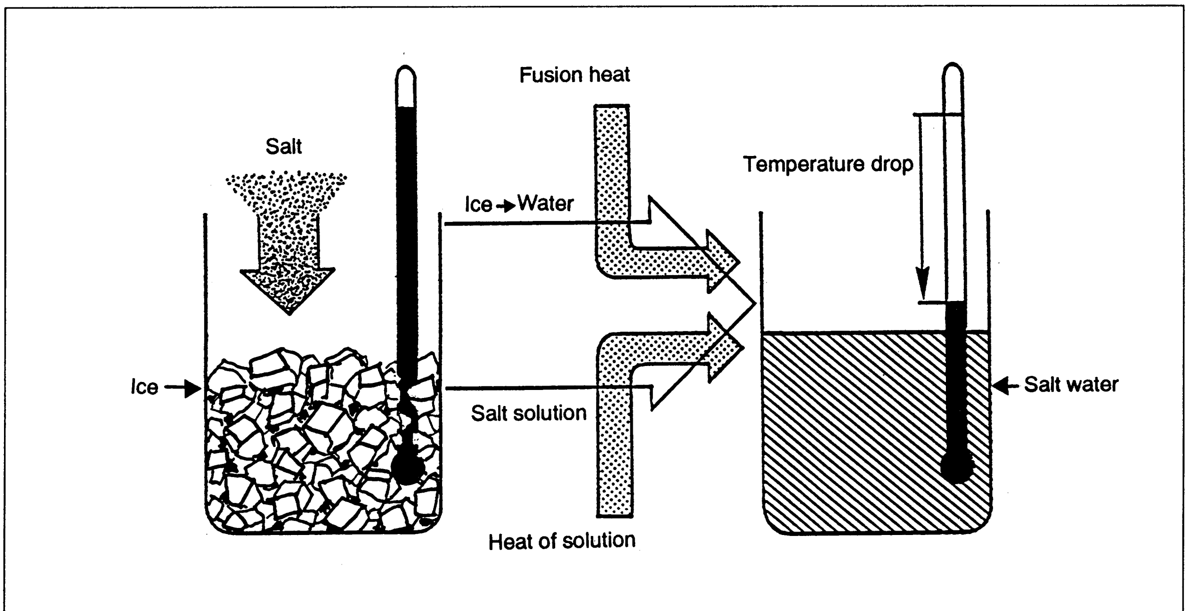

Fig. 2 Diagram showing the volume of water in saline solutions

Distillation

Assignment: To evaporate coloured water, condense the steam and collect it again.

Apparatus:

2 stand feet
1 stand rod, 25 cm
1 stand rod, 50 cm
1 double socket
1 universal clamp
1 conical flask
1 stopper with hole
1 tube connector
1 silicone tube (60 cm)
1 measuring cylinder

in addition:
1 source of heat, e.g. butane gas burner
1 universal coupling, (if necessary from set BMC1)
1 ring with stem
1 wire gauze
1 colouring agent
Water

Setup:

1. Set up the stand as shown in fig. 1. Attach the double socket and apparatus clamp as shown.
2. Fill the conical flask with 30 ml of coloured water and clamp it in the apparatus clamp.
3. Fit the tube connector, stopper and tube together and fit them in place on the conical flask.
4. Put the disconnected end of the tube into the measuring cylinder.

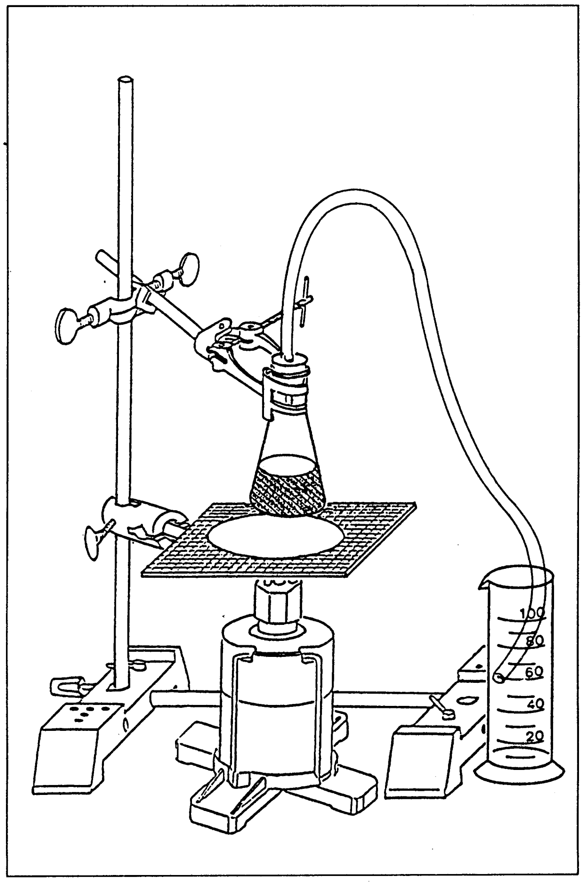

Fig. 1 Setup for distillation

Student's Sheet 2

Performing the experiment:

5. Light the burner and place it under the conical flask.
6. Bring the coloured water to boiling point.
7. Direct the water vapour (steam) into the measuring cylinder.
8. Wait until about 10 ml of liquid have been collected in the measuring cylinder.
9. Turn off the burner.
10. Compare the two liquids with one another.

Observations and measurements:

11. Colour of the original liquid:______
12. Colour of the final liquid:_________

Evaluation:

13. Describe the process of distillation.

____

____

14. Enter the missing terms in the diagram:

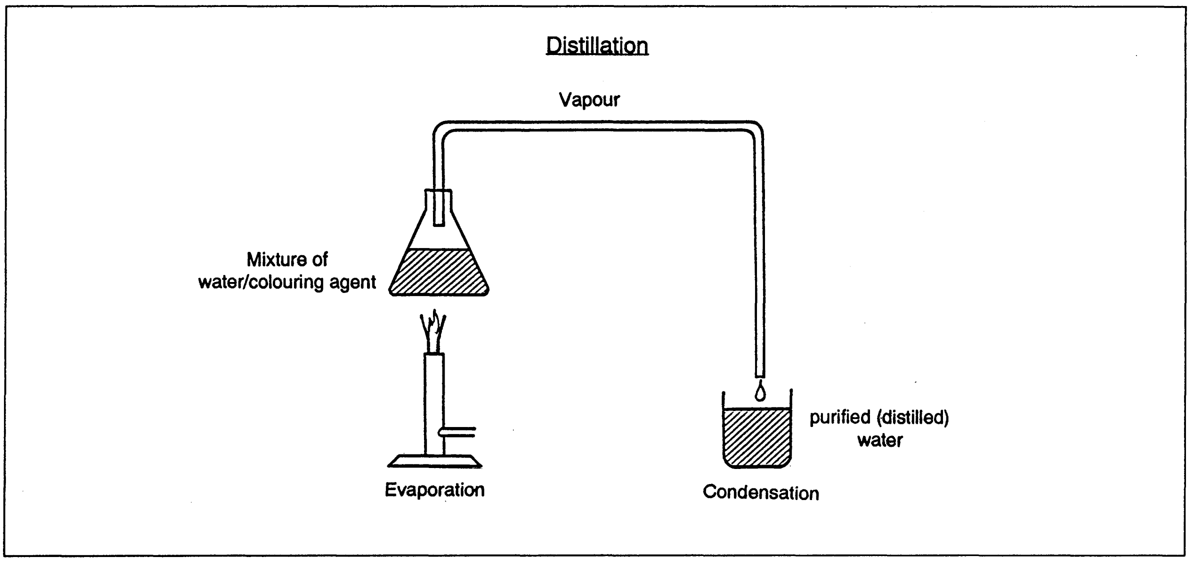

Fig. 2 Schematic representation of distillation

15. In the original liquid, solid particles of colour and liquid water are mixed together.
What happens during distillation?

____

____

List of apparatus

Maximum Quantity	Item	Cat.-No.	Number of items required in experiment																						Quantity in STM set		
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	BMC1	BMC2	CAL1
1	Double scale	340 82			1																				1	–	–
1	Universal clamp	666 555	1	1	1		1	1	1	1	1	1	1	1	1	1		1	1	1	1	1		1	1	–	–
1	Stand rod, 25 cm	301 26			1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1		1	1	–	–
2	Stand rod, 50 cm	301 27	2	2	2	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1		1	2	–	–
1	Double socket	301 09	1	1	1		1	1	1	1	1	1	1	1	1	1		1	1	1	1	1		1	1	–	–
1	Universal clamp	666 615			1	1	1	1					1			1		1	1	1		1		1	1	–	–
1	Metal plate	200 65 559				1																			1	–	–
3	Retaining clip	314 04			2																				3	–	–
2	Stand bases	301 21	2	2	2	2	2	2	2	2	2	2	2	2	2	2		2	2	2	2	2		2	2	–	–
2	Sleeve blocks	301 25			2																				2	–	–
1	Pair of pointers	301 29									1														1	–	–
1	Universal marker	309 45	1	1			1	1				1													1	–	–
1	Set of weights, 6 pcs.	340 85																1							1	–	–
1	Aluminium cuboid	362 32																1							1	–	–
1	Tape measure	311 78			1		1	1				1		1	1										1	–	–
1	Cord	200 70 322																1							1	–	–
1	Glass beaker, 250 ml	664 130	1	1			1	1		1		1	1	1	1	1	1	1	1		1	1	1		–	1	–
1	Measuring cylinder, 100 ml	590 08								1				1		1	1	1	1	1	1		1	1	–	1	–
1	Plastic beaker, 250 ml	664 123						1	1					1		1	1	1	1		1	1	1		–	1	–
1	Silicone tube, 1 m	667 194			1			1														1		1	–	1	–
2	Plastic pipes, 25 cm	200 69 648						1																	–	2	–
1	Round tin	200 69 647			1																				–	1	–
1	Double pipe holder	200 69 370						1																	–	1	–
1	Tube connector	665 226			1			1														1		1	–	1	–
4	Caps	200 69 649																							–	4	–
1	Small funnel	309 83						1																	–	1	–
1	Stopper with hole	200 69 304	1		1		1	1														1		1	–	1	–
2	Test tubes	664 042																							–	2	–
1	Immersion heater, 12 V/11 W	597 48															1								–	–	1
1	Set of 2 heat conducting rods	384 501							1																–	–	1
1	Aluminium pipe, 44 cm	381 332			1																				–	–	1
1	Iron pipe, 44 cm	381 333			1																				–	–	1
1	Impeller wheel	387 79									1														–	–	1
1	Pointer for indicating linear thermal expansion	381 331			1						1														–	–	1
1	Pair of radiometric probes	384 531										1													–	–	1
1	Bimetal	381 311				1																			–	–	1
1	Conical flask, 50 ml	664 248	1		1		1	1	1											1		1		1	–	–	1

List of apparatus – cont.

Maximum Quantity	Item	Cat.-No.	Number of items required in experiment																						Quantity in STM set		
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	BMC1	BMC2	CAL1
1	Thermometer with scale	666 160					1	1	1				1	1	1	1	1	1	1	1	1	1	1		–	–	1
1	Thermometer without a scale	382 20		1																					–	–	1
1	Riser tube, 40 cm	381 10	1				1			1		1													–	–	1
1	Alcohol burner	303 22	1	1						1	1			1	1						1				–	–	–
1	Colouring agent	309 42	1							1		1												1	–	–	–
1	Pair of scissors	667 017		1																					–	–	–
1	Butane gas burner	666 711			1		1	1	1			1	1			1		1	1	1		1		1	–	–	–
1	Ring with stem	302 68						1					1			1		1	1	1		1		1	–	–	–
1	Wire gauze	666 685			1		1	1					1			1		1	1	1		1		1	–	–	–
1	Timer (stopwatch)	597 41							1			1	1	1	1		1			1					–	–	–
1	Balance	315 23																1			1	1			–	–	–
1	Voltage source, 12 V: Transformer	562 73															1								–	–	–

Overview of Experiment Manuals for STM Physics (Version: June '92)

The STM experiment manuals presented in the following table are currently under systematic revision in order to take into account new apparatuses and equipment sets. The manuals which are already available in the new concept (ring binder), as well as those still in preparation, may be ordered using the *new* catalogue number given below. In the case of those manuals for which the revision process has not yet been completed, we can provide you with the existing manuals in the familiar paper-bound brochure format structured according to the concept which has been used up to now, under the *old* catalogue number (next column). Further information is available upon request.

Subject Area Titles (Group of Topics)	Cat.-No.		Number of	
	new	previous	Titles	Experiments
Mechanics				
Properties of Matter/Fluids	588 012	589 002 / 589 032	23	62
Forces/Simple Machines	588 022	589 012 / 589 022	28	35
Oscillations	588 062	589 072	12	41
Waves	588 072	589 082	8	24
Linear Motion	in preparation	589 042	13	26
Heat				
Expansion and Propagation of Heat/ Heat Energy and States of Matter	588 152	589 052 / 589 062	22	51
Magnetism				
Magnetic Forces and Fields	588 302	589 112	12	22
Electrostatics				
Charges and Forces (Electroscope-Experiments)	588 312	589 162	29	59
Charges and Fields (Electrometer-Amplifier-Experiments)	588 322	589 172	12	40
Electrochemistry				
Current and Voltage in Fluids	588 402	589 142	7	20
Electricity				
Simple Electric Circuits	588 332	–	19	36
Electromagnetism and Induction	588 342	–	20	39
Electronics				
Basic Electronics	588 422	579 912	21	44
Transistor-Circuits	588 432	579 922	29	51
Opto-Electronics	588 442	–	approx. 20	approx. 35
Electro-Technics				
Generators and Motors	588 352	584 052	17	36
Controlling	in preparation	–	31	39
Optics				
Geometrical Optics				
Propagation and Reflection of Light	in preparation	589 202	19	46
Refraction and Lenses	in preparation	589 212	20	49
Optical Instruments	in preparation	589 222	14	39
Raybox Experiments	in preparation	589 232	20	40
Wave Optics				
Diffraction	in preparation	589 252	14	24
Interference	in preparation	589 262	10	10
Polarisation	in preparation	589 272	11	30
Nuclear Physics				
Radioactivity	588 482	589 502	35	50
Computer Science/Digital Technology				
Basic Logic Operations Switching Networks and Units	in preparation	571 172	68	68