Leybold Physik Physics Physique

Mechanik
Mechanics
Mécanique

Properties of matter – Liquids

588 012
Students' work sheets
(Masters for copying)

Schülerversuche Naturwissenschaften

SVN STM

Science Teaching Modules

STM-Physics
Mechanics
Properties of Matter/Liquids

Published by the LEYBOLD DIDACTIC editorial staff.
Authors: Ch. Giesen and W. Brauers
with the editorial assistance of A. Schüller.

Design and layout: K. R. Fecht
Graphics: C. Harnischmacher

Catalogue No. 588 012 – Version as of November 1992

We would be happy to answer any questions on the contents of this publication. Please write us or call: 049-02233-604 140

Final artwork and production: 3R Grafisches Herstellungsbüro R. Gehrke, Bonn

Table of contents

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 series) 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 experiment manual from the STM (Science Teaching Modules) series contains basic experiment descriptions from the area of Mechanics which specifically cover a range of topics on the properties of matter and liquids.

All experiments described in the manual may be performed with the aid of the equipment included in equipment sets BMC 1 and BMC 2 (Basic sets for Mechanics and Heat) as well as MEC 1 (Mechanics set 1) and very few additional items.

Time requirement

All experiments have been developed in such a way that they may be run within a double lesson, including preparatory discussion, issuing of equipment, assembly, running and evaluation of the experiment.

By omitting some of the steps of an experiment, a subsection of it or by sharing some aspects of the experiment or its comprehensive evaluation between groups, it is possible to save time.

Thus it should in most cases be easily possible to adapt any of the experiments to the particular requirements of the class.

Given in the section for the instructor are the aims of each experiment.

A quick overview can thus be gained by specifically reading these sections first.

About the apparatus

Setting up the stand

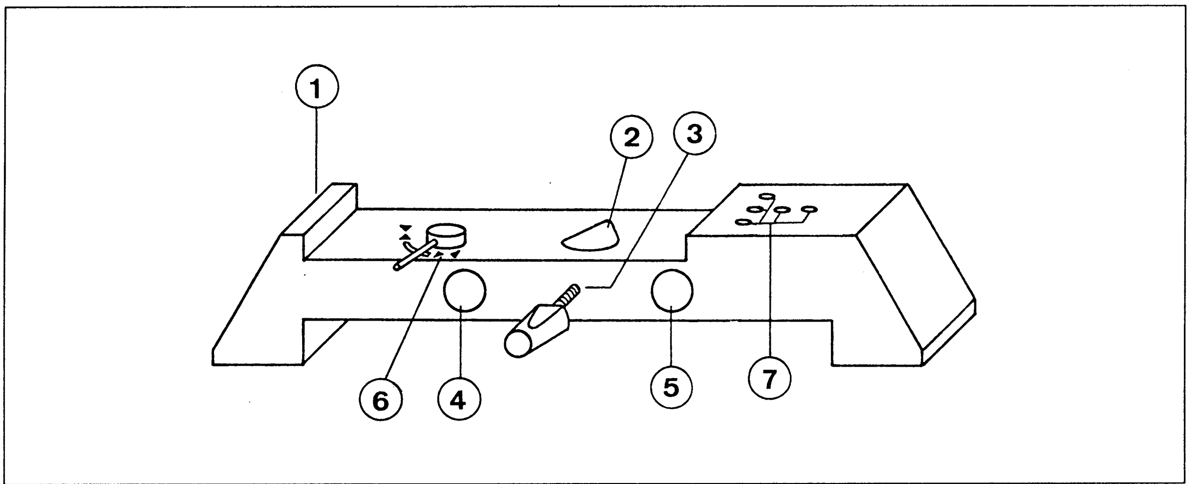


Fig.1 Stand base (301 21)

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 setups 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. ▶ Figs. 2/3. The five other sockets **(7)** are used for holding or mounting various items of apparatus using 4 mm plug pins.

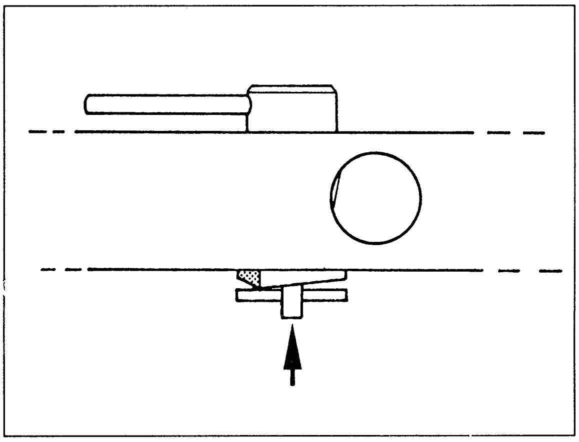


Fig. 2 Toggle on base of stand
▶ Arrow

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 a stand rod.

The undersides of the stand bases are non-slip.

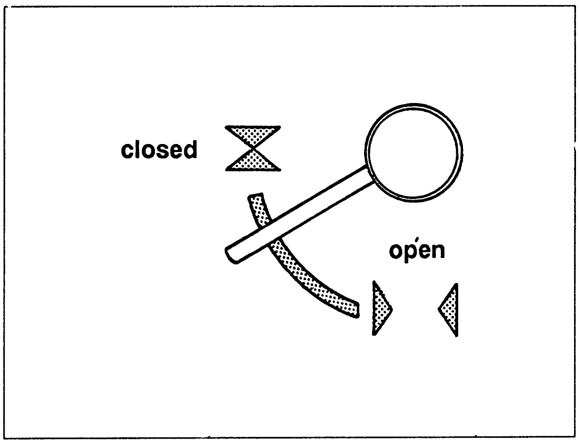


Fig. 3 Different toggle positions

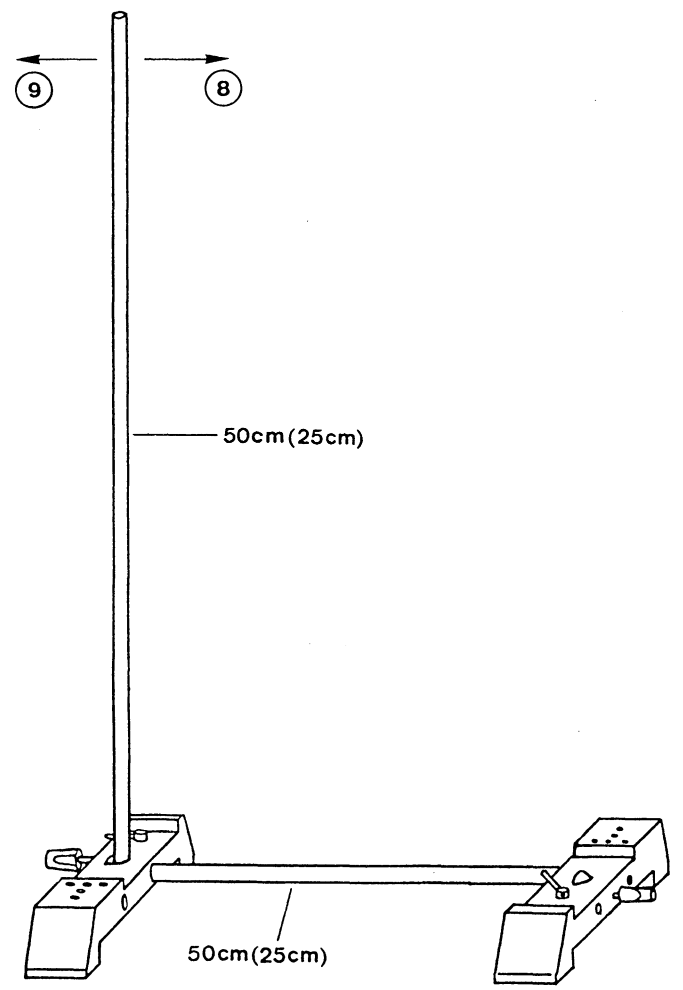


Fig. 4 Popular stand configuration

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

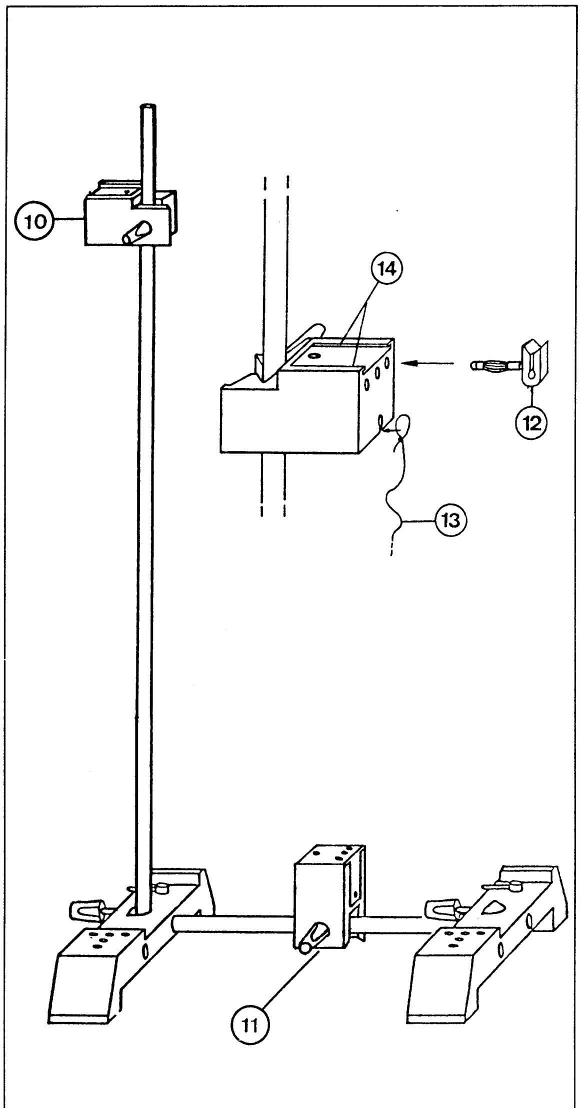


Fig. 5 Sleeve block

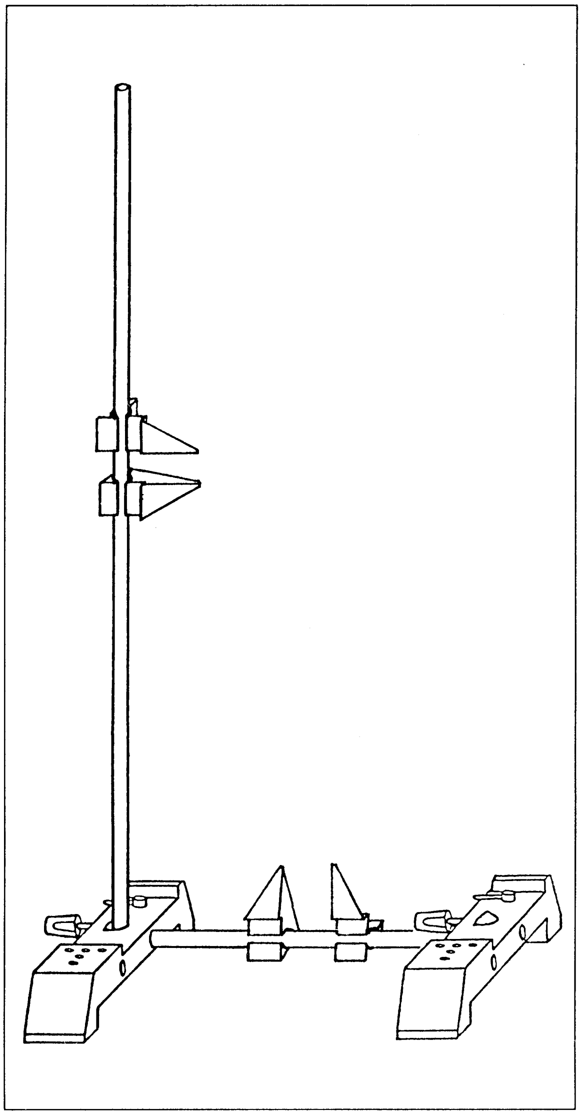


Fig. 6 Pointers

Sleeve block

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

It 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 comparing and measuring lengths are 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 clamp them directly onto the rods.

Student's Sheet 1

Measuring lengths

Assignment: To compare the lengths of various objects in the collection.

Apparatus:
1 tape measure
1 vernier caliper
1 stand rod, 25 cm
1 stand rod, 50 cm
1 sleeve block
1 measuring cylinder, 100 ml
1 pencil

Setup:

1. Lay out all the items of apparatus ready for use on the workbench, as shown in fig. 1.

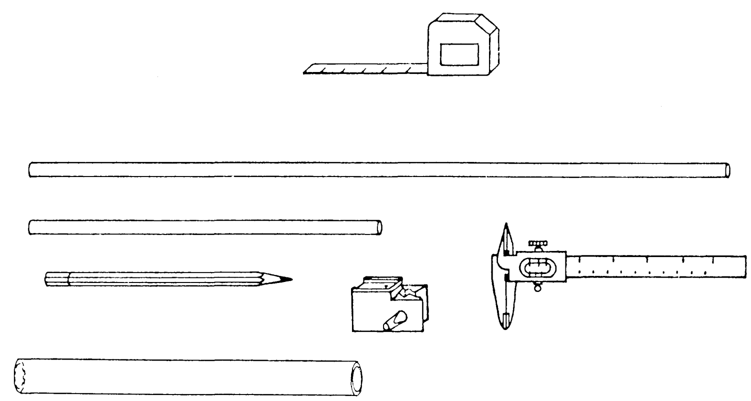


Fig. 1 ▶ 1.

Performing the experiment:

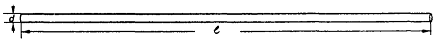
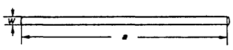
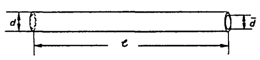
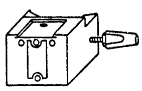
2. Measure the bench's length ℓ and width w. Use the length of your pencil as the unit of length.
   Enter the results ▶ Table 1.
3. Measure the bench's length ℓ and width w. This time, use the tape measure.
   Enter the results ▶ Table 1.
4. Measure the objects listed in table 2.
   Use the most suitable measuring device in each case, placing a cross in the appropriate column.
   ▶ Table 2.

Observations and measurements:

Table 1

Workbench dimensions	Length in pencil units	Length in cm
Length ℓ		
Width w		

Table 2

Object		mm	Measuring devices	
			Tape measure	Vernier caliper
	ℓ			
	d			
	ℓ			
	d			
	ℓ			
	d			
	$\bar{d}$			
	Depth of Holes			

Evaluation:

5. Why is a pencil unsuitable for measuring the length of the workbench? Compare the results of your measurements with the results obtained by other groups.

____

____

6. The basic unit of measurement for measuring length is 1 m. Larger and smaller units of measurement can be derived from this unit of measurement.

1 km = ____ m   1 cm = ____ mm

1 m = ____ cm   1 dm = ____ mm

1 m = ____ mm

7. When do you use a simple ruler for measuring lengths, and when do you use a precise vernier caliper?

____

____

8. Which parts of the vernier caliper do you use to measure depth and thickness and to take inside measurements? ▶ Fig. 2

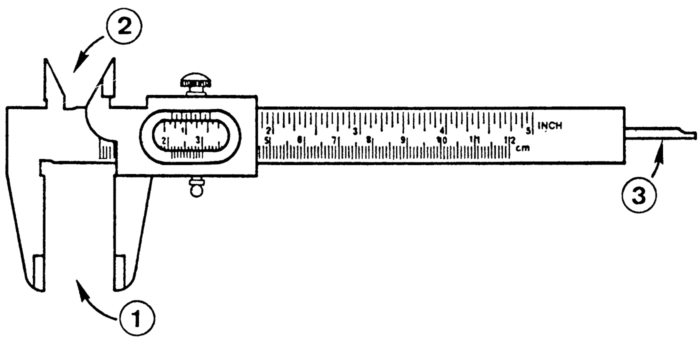


Fig. 2 ▶ 8.

(1) ____

(2) ____

(3) ____

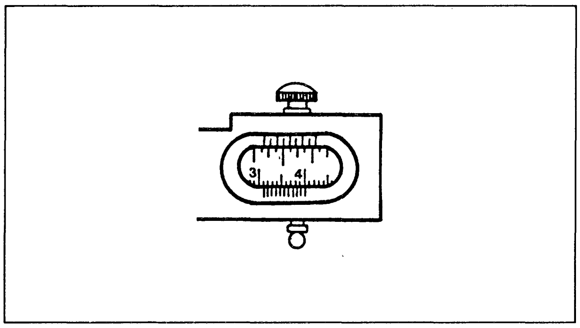


Fig. 3 ▶ 9.

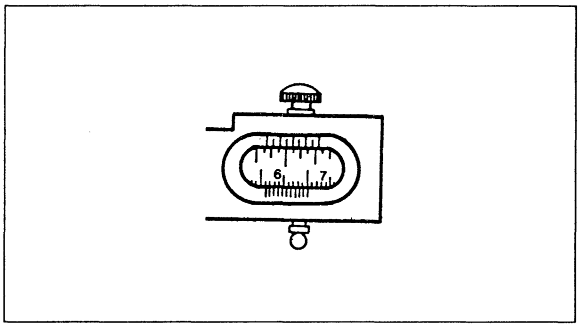


Fig. 4 ▶ 10.

9. Read off the vernier setting shown in fig. 3:

---

10. Read off the vernier setting shown in fig. 4:

Note:

A distinction is made between retrograde vernier (10 divisions on the auxiliary scale ≙ 9 divisions on the main scale) and direct vernier (10 divisions on the auxiliary scale ≙ 11 divisions on the main scale).

The vernier caliper in the collection of experimental apparatus is a retrograde vernier caliper.

The distance between two lines on the vernier scale amounts to 9/10 mm.

When both zero lines coincide, there is a distance of 0.1 mm between the first vernier line and the first main scale line; a distance of 0.2 mm between the second vernier line and the second main scale line, etc.

If you now move the vernier so that e.g. the 6th vernier line coincides with the 6th main scale line, the two zero lines will be 0.6 mm apart.

To find out more about how to take vernier readings, you can use the vernier model (cat. no. 311 27).

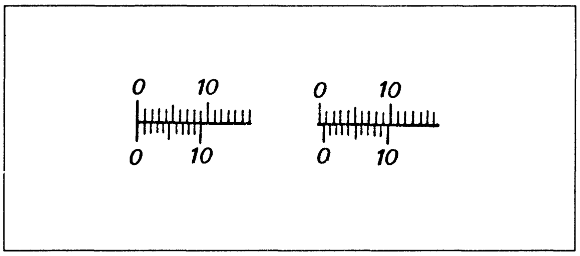


Fig. 5

The fixed unit of 1 m (meter) is one 40 millionth part of the earth's circumference. The original meter, in the form of a platinum-iridium staff, has been preserved in Paris since the French Revolution.

Since 1970, the basic 1 meter unit has been 1650763.73 times the wavelength of the radiation travelling in a vacuum emitted by atoms of the nuclide ^{86}Kr while making the transition from state $5d_5$ to state $2p_{10}$.

Additional assignment:

Compare old measurements of length with the "meter" unit of length in use today, which is the legally valid unit of length in many countries throughout the world.

Planimetry

Assignment: To calculate the size of regular and irregular surfaces.

Apparatus:
1 tape measure
1 vernier caliper
1 aluminium cuboid
1 plastic pipe
1 measuring cylinder, 100 ml

Setup:

Experiment 1:
Calculating the surface area of a cuboid

1. Measure the length ℓ, width w and height h of the aluminium cuboid ▶ Fig. 1.

   Which of the cuboid's linear measurements are the same?

   ____

   Enter the values ▶ Table 1.

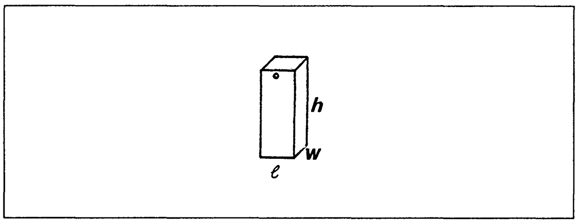


Fig. 1

Experiment 2:
Calculating the surface area of tubes

2. Measure the length ℓ and external diameter d_1 of the plastic pipe.

   Enter your measurements ▶ Table 2.
3. Measure the height h and external diameter d_2 of the measuring cylinder ▶ Fig. 2.

   Enter your measurements ▶ Table 2.

   Note:

   To measure h, turn the measuring cylinder upside down!
4. Take the following measurements using the tape measure shown in fig. 3:

   a) The circumference s_1 of the plastic pipe

   b) The circumference s_2 of the measuring cylinder

   Enter the measured values ▶ Table 2.

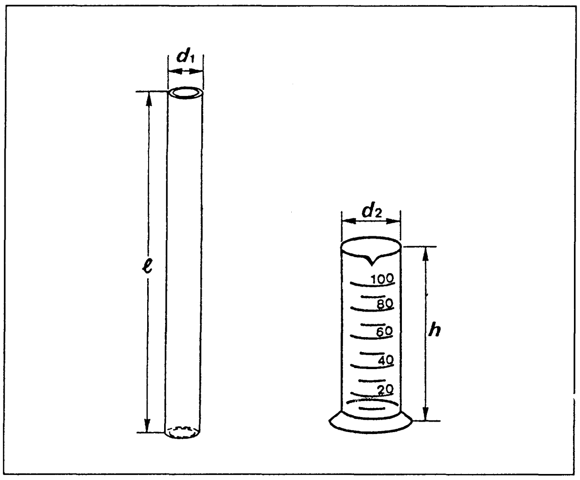


Fig. 2

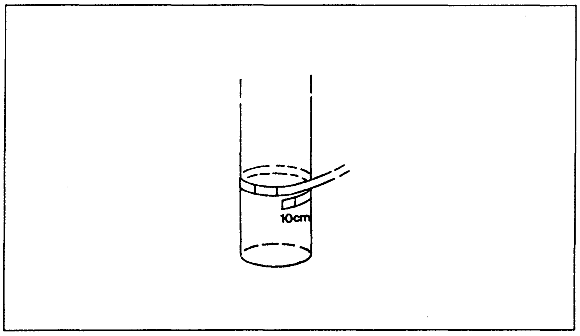


Fig. 3

Student's Sheet 2

Experiment 3:
Calculating surface area by counting up units of area

5. What is the area of a circle with a radius r = 10 cm?

You can work out the surface area of complex or irregular flat shapes by tracing the outline of the shape onto squared paper.

You then count the number of squares enclosed by the shape's outline.

To test this method, you are going to calculate the area of the quarter circle ▶ Fig. 4.

To use the counting method, draw squares in the quarter circle!

Write down your measurements of each of the squares measured in mm^2 and add them together.

Result:

Area of the quarter circle with a radius r = 10 cm.

$A_{\frac{1}{4}}$ = ____mm^2

▶ Fig. 4

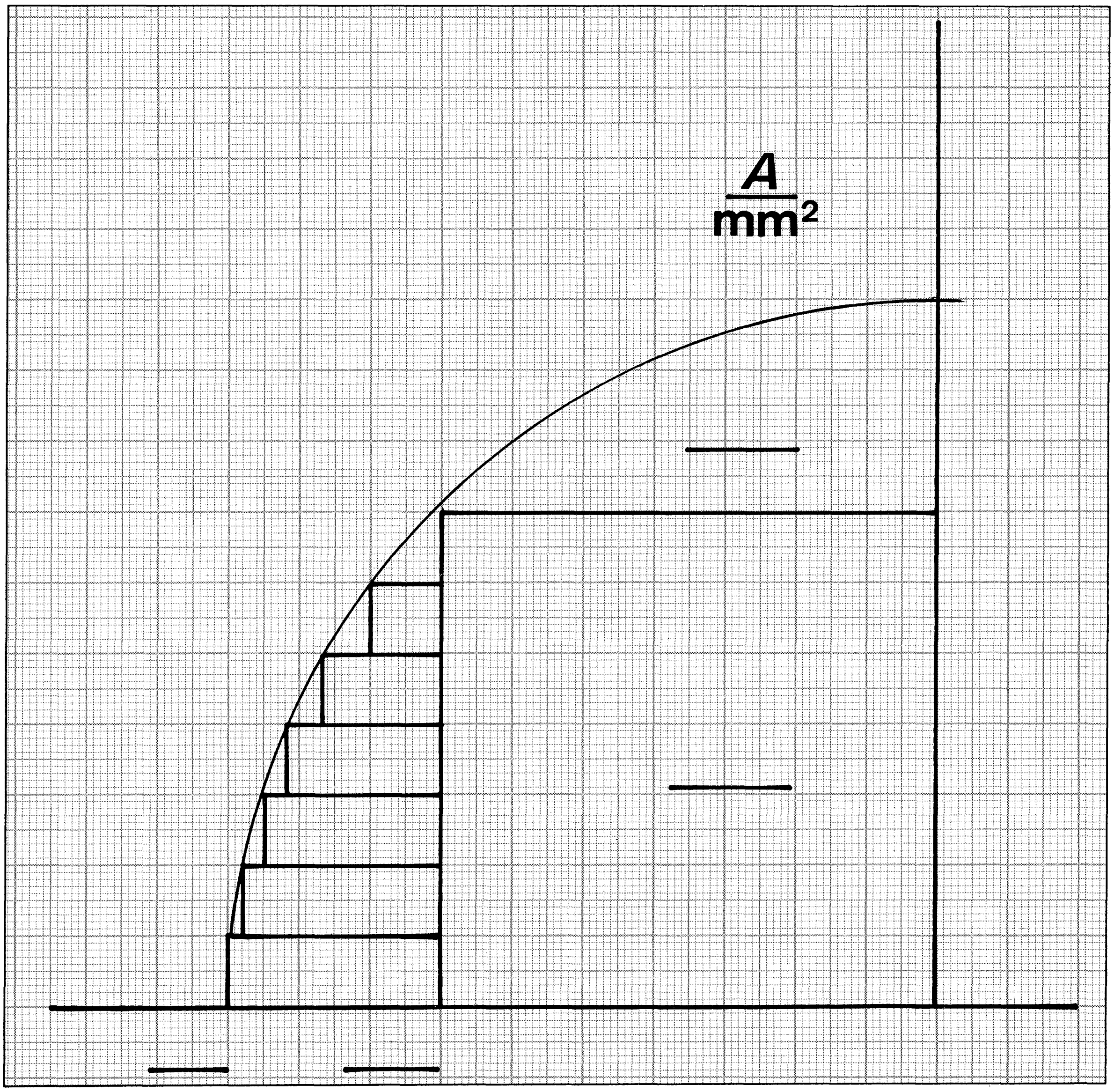


Fig. 4 ▶ 9.

Student's Sheet 3

Table 1

	$\frac{\ell}{\text{cm}}$	$\frac{w}{\text{cm}}$	$\frac{h}{\text{cm}}$	$\frac{A}{\text{cm}^2}$
Sides of cuboid				–
Oblong		–		
Square			–	

Table 2

Body	greatest length	outside diameter	inside diameter	external circumference
a) Pipe	ℓ = cm	d_1 = cm	$\bar{d}_1$ = cm	s_1 = cm
b) Measuring cylinder	h = cm	d_2 = cm	$\bar{d}_2$ = cm	s_2 = cm

Evaluation:

6. Using your measurements of the cuboid's sides, calculate the area A of each surface of the cuboid. Enter the result ▶ Table 1.
7. What is the surface area A of the plastic pipe?

____

____

____

8. How many times n does the plastic pipe rotate if it rolls 1 m without sliding?

____

9. What value for the superficial area A_1 of a circle with r= 10 cm do you get if you use the counting method? Give your answer for the surface area A_1 of the circle in cm^2 ! ▶ Fig. 4.

A_1 ____

____

10. Mathematically, you can calculate the internal area of the circle as follows:
$A = \pi \cdot r^2$ π = 3.1415...
r = radius of the circle
Calculate the area A of a circle where r = 10 cm.
A = ____________
= ____________

11. By what percentage does the value which you obtained by counting differ from a value obtained by mathematical calculation?
Absolute deviation: ________________________
Relative deviation:
____
The value obtained by counting deviates from the calculated value by _______%

Calculating the volume of regularly shaped bodies

Assignment: To calculate the volume of regular bodies.

Apparatus:
1 vernier caliper
1 tape measure
1 aluminium cuboid
1 leaf spring
1 measuring cylinder, 100 ml

Setup:

1. Lay out all the apparatus ready for use on the workbench.

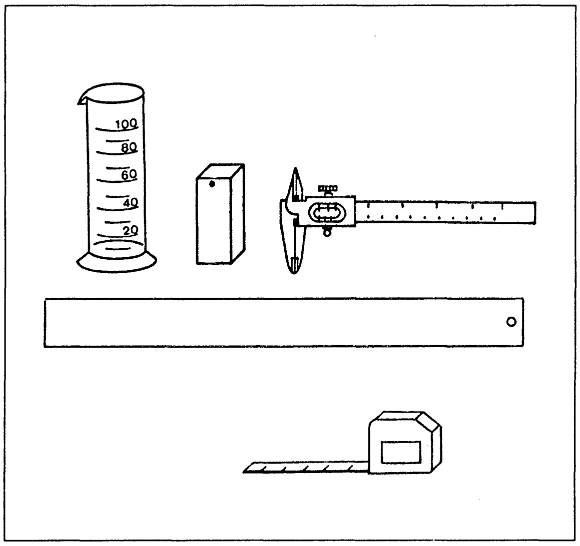


Fig. 1 ▶ 1.

Performing the experiment:

Experiment part 1: volume of the cuboid

2. Measure the length ℓ, width w and height h of the aluminium cuboid.
   Enter the values ▶ Table 1.

Experiment part 2: volume of the leaf spring

3. Measure the length ℓ, width w and height h of the leaf spring.
   Enter the values ▶ Table 1.

Experiment part 3: cross section of the measuring cylinder

4. What is the height *h* of the column of water when the measuring cylinder is filled up to the 100 ml mark?

h = ___ cm

Table

	Length $\frac{\ell}{\text{cm}}$	Width $\frac{w}{\text{cm}}$	Height $\frac{h}{\text{cm}}$	Area $\frac{A}{\text{cm}^2}$	Volume $\frac{V}{\text{cm}^3}$
Cuboid					
Leaf spring					
Measuring cylinder	–	–			

Evaluation:

5. With the help of the measured values, calculate the area $A = \ell \cdot w$ and the volume $V = A \cdot h$ for both cuboid and leaf spring

   Ignore the small hole in the leaf spring.

   Enter the values ▶ Table.

6. Calculate the cross-sectional area *A* of the measuring cylinder.

   A = ______________________________

   Enter the value ▶ Table.

   Note:

   in step 5: The small hole in the leaf spring has a diameter of 4 mm.

   You can calculate the cross-sectional area of the hole by placing a piece of squared paper on top of it.

____

____

Student's Sheet 1

Calculating the volume of solid bodies by the amount of liquid displaced

Assignment: To determine the volume of solid bodies by the amount of a liquid (water) which they displace.

Apparatus:

1 aluminium cuboid
2 weights
1 measuring cylinder, 100 ml
1 glass beaker, 250 ml
1 tape measure
1 cord, 2 x 30 cm
1 plastic pipe
1 stopper without a hole
1 paper strip, adhesive
Water, ca. 200 ml
Cloths

For additional assignment:

1 overflow vessel
or
2 stand bases
1 stand rod, 50 cm
1 stand rod, 25 cm
1 universal clamp
1 double socket

Setup:

1. Lay out the apparatus ready for use, as shown in fig. 1.
2. Tie the cord to the aluminium cuboid.
3. Fill the measuring cylinder with water up to the 50 ml mark.
4. Position the measuring cylinder in such a way that the measuring scale is turned away from the observer.

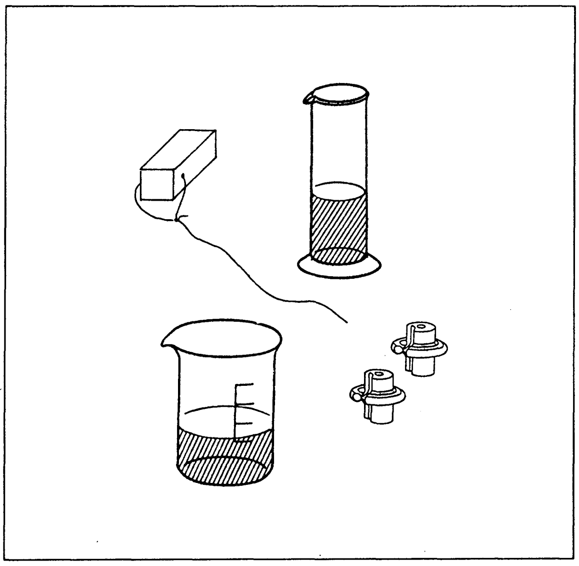


Fig. 1 ▶ 1.

Student's Sheet 2

5. Stick the paper strip to the side of the measuring cylinder which does not have a measuring scale on it ▶ Fig. 2.
6. Mark the water level h_0 (= height of the column of water in the middle of the cylinder) on the paper strip.

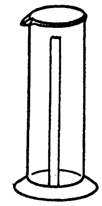


Fig. 2 ▶ 5.

Performing the experiment:

Experiment 1 (measurement and evaluation): Change in water level caused by aluminium cuboid in measuring cylinder

7. Hold the aluminium cuboid by the end of the cord and slowly lower it into the water in the measuring cylinder.
8. Mark the height h_1 of the column of water on the paper strip.

Experiment 2 (measurement): Calculating the volume of a weight using the measuring cylinder

9. Fill the measuring cylinder with water up to the 50 ml mark. V_1 = 50 cm^3
10. Carefully lower a weight into the water on the end of a piece of string. V_2 = 57.5 m^3

    Why is it important that no water should splash out of the cylinder?

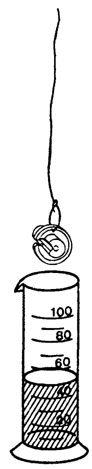


Fig. 3 ▶ Experiment 2

Measuring result:

V (weight) = V_2–V_1 = _____

Student's Sheet 3

Experiment 3:
Calibrating the plastic pipe so we can use it as a measuring cylinder

11. Seal one end of the plastic pipe with a stopper and glue a paper strip along the length of the pipe
▶ Fig. 4.
12. Draw a zero line on the paper strip at the bottom of the resulting container.
13. Pour 50 cm^3 of water out of the measuring cylinder into the plastic pipe and mark the height h of the water column on the paper strip.
14. Measure the distance between the two lines:
h = ___ mm.

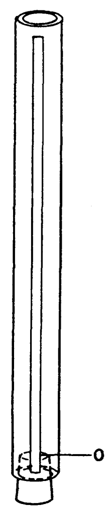


Fig. 4 ▶ 11.

Evaluation:
Experiment 1

15. Determine the volume of the cuboid by measuring the lengths of its sides.
V = ______________________
16. Measure the distance between the height marks $h_2 = h_1 - h_0$ on the paper strip:
h_2 = mm ________________
17. a) Work out what the difference h_3 in the water level in the measuring cylinder is if you add 1 cm^3 of water.
___ cm^3 corresponds to 36 mm
1 cm^3 corresponds to h^3 =

b) Check the result of **(a)** against the scale on the measuring cylinder, with the help of the tape measure.
Describe the procedure:

____

____

c) By what percentage does the value found in **(a)** deviate from the value found in **(b)**?

____

Student's Sheet 4

Experiment 3

18. What would the difference in the water level in the plastic pipe be if you added 1 cm^3 of water?

50 cm^3 corresponds to mm

1 cm^3 corresponds to mm = mm

19. What are the advantages of using an overflow vessel to determine the volume of an irregularly shaped body (▶ fig. 5)?

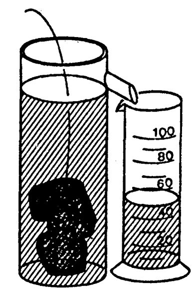


Fig. 5 ▶ 19.

Additional assignment:

20. Determining the volume of a weight using an overflow vessel. If you do not have access to such a vessel, you can use an experimental setup like the one shown in fig. 6 to perform the experiment.

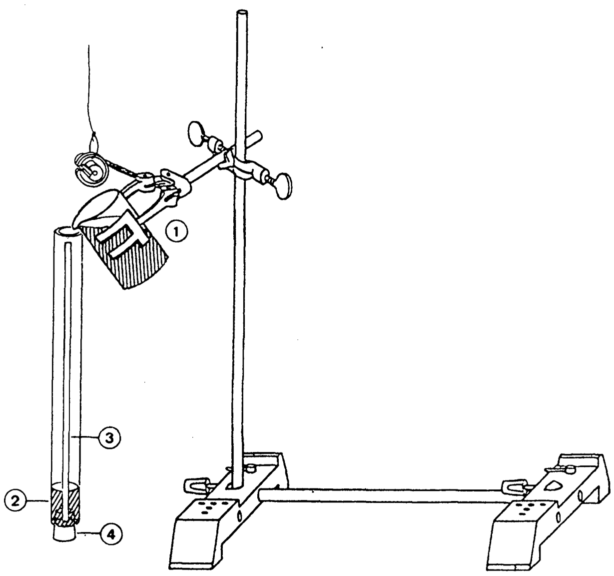


Fig. 6 ▶ 20. Overflow device for determining the volume of solid bodies
(1) universal clamp (2) plastic pipe
(3) adhesive paper strip (4) stopper without hole

Student's Sheet 5

Reading errors:
Parallax is a reading error resulting from a slight skew in the angle between the object to be measured and the measuring scale. For this reason, a mirror is often fixed behind the scale. Whenever you take a reading, you must first make sure that the reading mark M and its reflection M' coincide.

▶ Fig. 6.1.

The meniscus can cause another reading error. This is because a liquid in a container is higher at the edges than in the middle (wetting liquids draw themselves up the side of the container). In order to minimize the resulting error when taking readings, it has been agreed that readings should always be taken from the lowest point of the meniscus. This error has been taken into account by the manufacturers of the measuring cylinder, during the calibration process. (In the case of non-wetting liquids such as e.g. mercury, the liquid is lower at the edges than in the middle. In this case, the reading is taken from the highest point).

▶ Fig. 6.2.

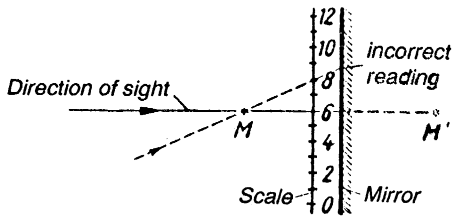


Fig. 6.1 Reading error – parallax

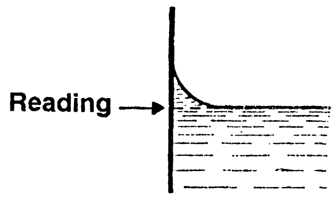


Fig. 6.2 Reading error – meniscus

Student's Sheet 1

Calculating the volume of gaseous bodies

Assignment: To create a setup for determining the volume of gaseous bodies.

Apparatus:

2 stand bases
1 stand rod, 50 cm
1 stand rod, 25 cm
1 double socket
1 plastic pipe, 25 mm (outside)
1 stopper without a hole
1 silicone tube, 1 m
1 glass beaker, 250 ml
1 aluminium cuboid
2 sheets of paper, 3 cm x 3 cm and 1 cm x 1 cm
1 pair of scissors
Water, ca. 250 ml in total

Setup:

1. Set up the apparatus and make the preparations shown in fig. 1.
2. Seal one end of the plastic pipe with the stopper.
3. Fill the beaker with 180 ml of water.

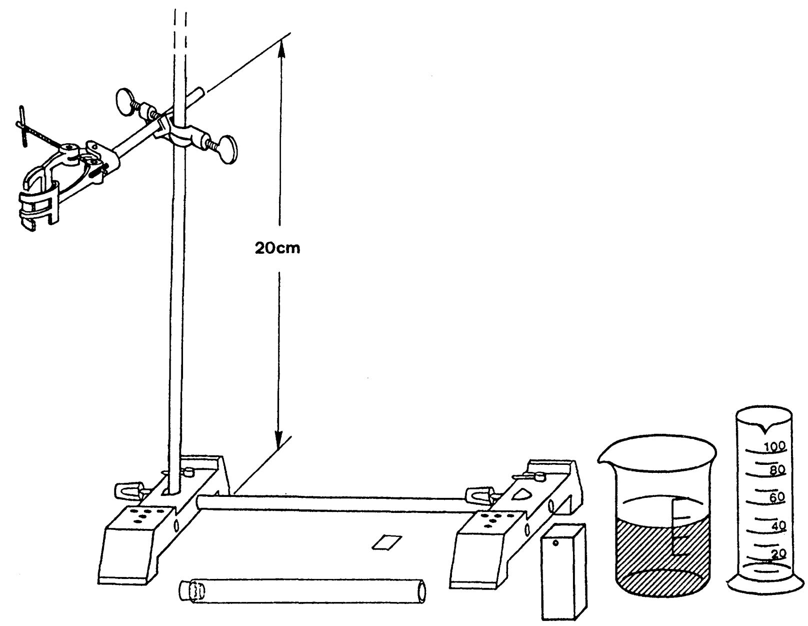


Fig. 1 ▶ 1.

Performing the experiment:

Experiment 1:
Water displaced by air

▶ Fig. 2.

4. Place the 1 cm^2 sheet of paper in the middle of the water's surface.
5. Hold the empty measuring cylinder as shown in fig. 2 and slowly press it down.

   a) *Observation:*

   ____

   ____

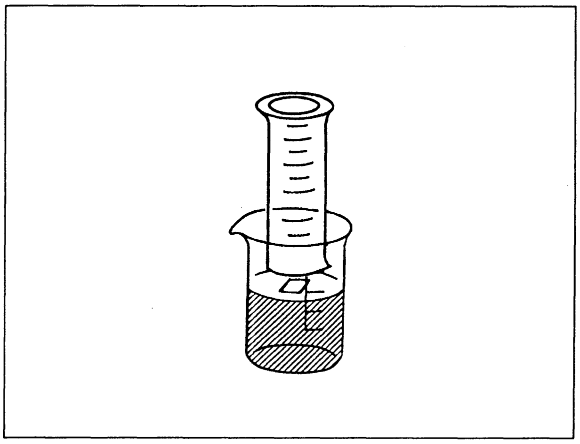


Fig. 2 ▶ Experiment 1.

   b) *Question:* What technical device does this experiment represent?

   ____

Experiment 2:
Air displaced by solid bodies

▶ Fig. 3.

6. Place the aluminium cuboid at the bottom of the beaker. The top surface of the cuboid should just be covered by water: if necessary, add or pour away water until this is the case.
7. Slowly press the measuring cylinder down over the cuboid.

   Observations:

   ____

   ____

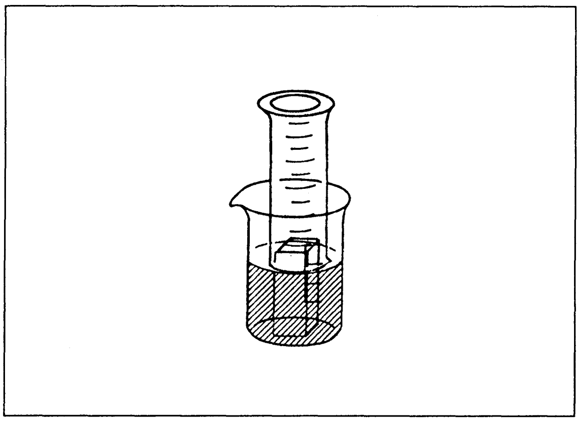


Fig. 3 ▶ Experiment 2.

   ____

   ____

8. Slowly raise the measuring cylinder.

   Observations:

   ____

   ____

Once the two water levels are the same, the water level in the measuring cylinder remains steady at a particular point and then rises as you continue to lift the measuring cylinder.

Experiment 3:
Using water displacement to determine the volume of a gas.

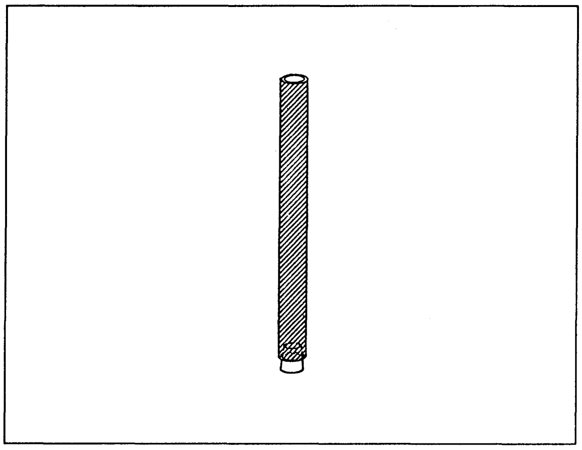


Fig. 4 ▶ 8.

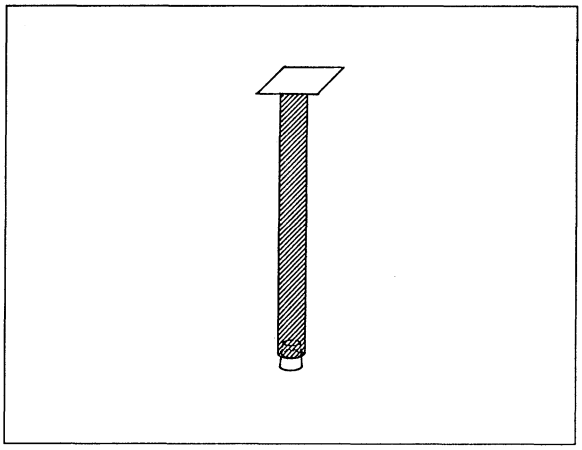


Fig. 5 ▶ 9.

9. Fill the plastic pipe you sealed at one end with water, right up to the brim ▶ Fig. 4.
10. Place the small sheet of paper on the water ▶ Fig. 5.
11. Press the paper tightly against the rim of the pipe and turn the pipe upside down, so that the paper is at the bottom. ▶ Fig. 6.

    What do you observe? Why?

    ____

    ____

    ____

12. Immerse the paper-covered end of the pipe in the water in the beaker.
13. Remove the paper ▶ Fig. 7.

    Observation:

    ____

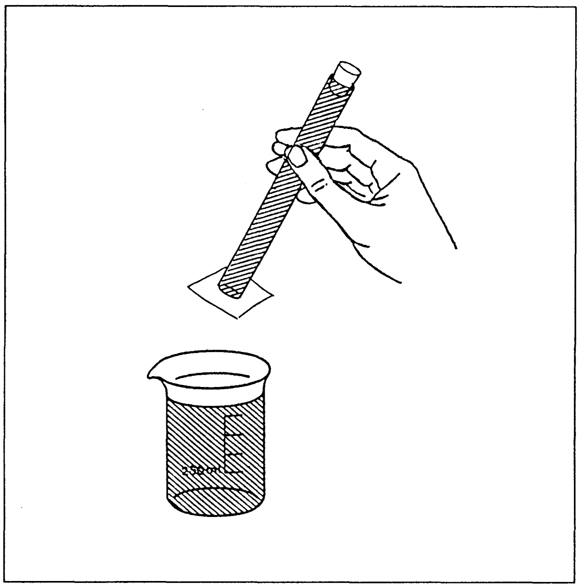


Fig. 6 ▶ 10.

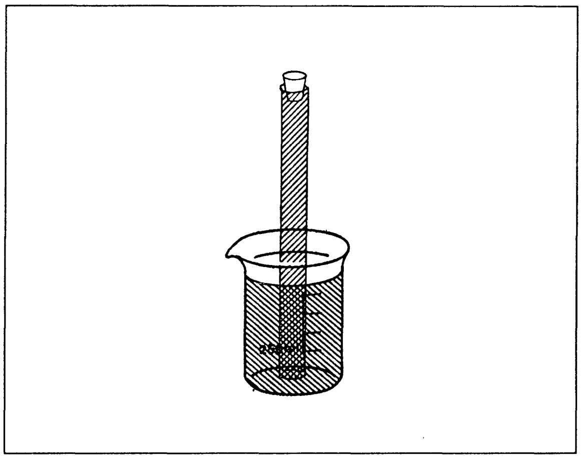


Fig. 7 ▶ 12.

Student's Sheet 4

14. Clamp the pipe in the universal clamp
▶ Fig. 8.
15. Push one end of the tube into the pipe.
16. Test the setup shown in fig. 7:
Blow some air into the tube.
Observation:

____

____

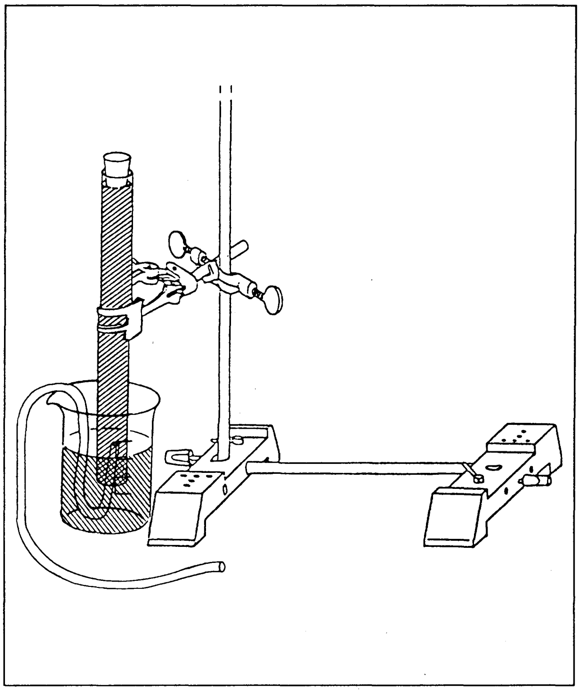


Fig. 8 ▶ 14.
Device for trapping gases and measuring the volumes of gases.

Evaluation:

17. How do you explain the observations made in the course of these experiments?

____

____

____

____

____

____

Student's Sheet 1

Measuring time (chronometry)

Assignment:

- To compare the interval of time between drops of water falling and a pendulum's period of oscillation.
- To measure the pendulum's period of oscillation using a stopwatch.

Apparatus:

2 stand bases
1 stand rod, 50 cm
1 measuring cylinder, 100 ml
1 glass beaker, 250 ml
1 small funnel
1 cord
1 weight
1 tape measure
1 stopwatch
Water, ca. 100 ml
Paper, ca. 5 cm x 5 cm

Setup:

1. Assemble the various items of apparatus as shown in fig. 1.
2. Allow the paper (ca. 25 cm^2) to soften in the water-filled beaker for about 1 minute.
3. Put the paper in the funnel and press it firmly down.
4. Place the funnel on top of the empty measuring cylinder.
5. Pour water into the funnel. A number of drops should start to form. If they do not, loosen the paper plug slightly.

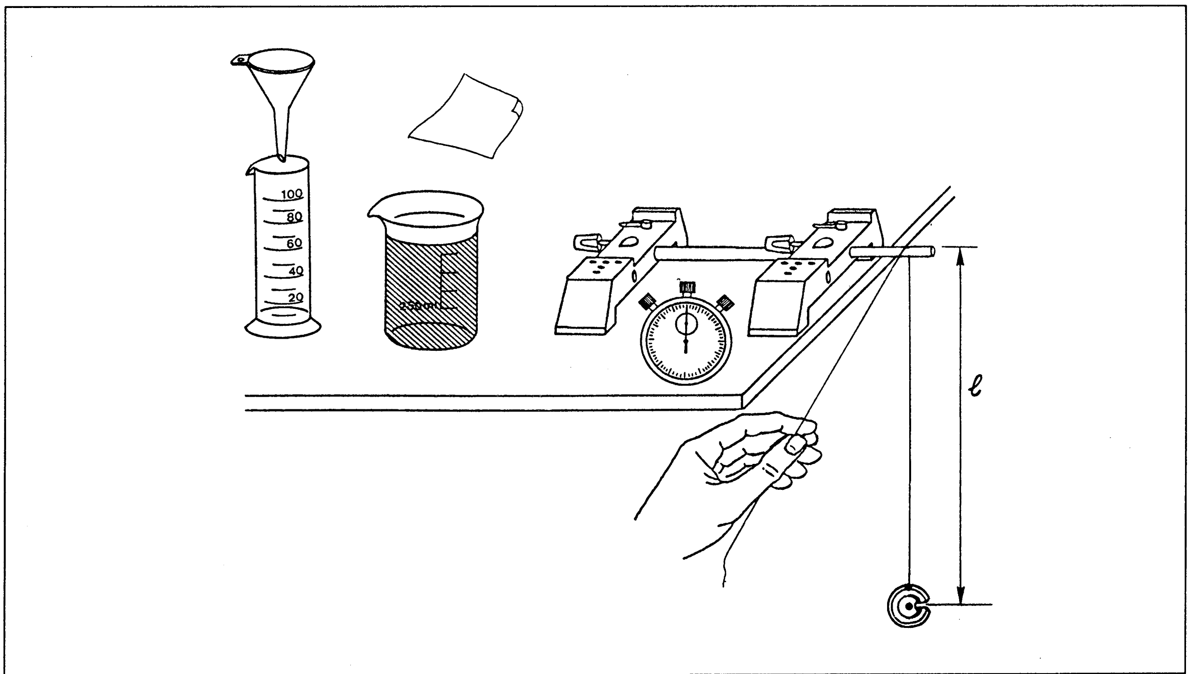


Fig. 1 ▶ 1.

Student's Sheet 2

Performing the experiment:

Experiment 1: dropping time – oscillating time

6. Fill the funnel with water and start the pendulum swinging.
7. Change the length of the pendulum until the pendulum completes one full swing for every drop.
   If necessary, refill the funnel with water.

   Note:

   One full swing of the pendulum is completed whenever the weight on the end of the pendulum travels through the same point in space in the same direction as before.
8. How can you increase the period of oscillation?

   ____

9. Once you have succeeded in matching the two events, do not make any more changes to pendulum length ℓ_1.
   Measure pendulum length ℓ_1.

   The length ℓ_1 of the pendulum is measured from the middle of the stand rod to the middle of the weight ▶ Fig. 1.

   ℓ_1 = ______

Experiment 2: measuring the pendulum's period of oscillation.

10. Measure the period of oscillation T_1 of the pendulum with a length of ℓ_1, using the stopwatch.

    To do so, measure the time taken to complete 10 swings.

    Measurement:

    $10\,T$ = ________________

    T = ______

Additional assignment:

11. Choose a length for the pendulum such that the result is

    $T = 1$ s

    ____

    ____

Evaluation:

12. Name some examples of old-fashioned and modern time-keeping instruments, and state the constant and recurring (periodic) processes on which each instrument's operation is based:

a) ______________________________

b) ______________________________

c) ______________________________

d) ______________________________

e) ______________________________

f) ______________________________

13. The basic unit of measurement used in chronometry is the second (1 s).

Larger units:

Abbreviation	Latin	English	German
1 min	minuta	minute	Minute
1 h	hora	hour	Stunde
1 d	dies	day	Tag
1 a	annus	year	Jahr

Complete the following:

1 min = ____ s

1 h = ____ min = ____ s

1 d = ____ h = ____ min = ____ s

1 a = ____ d = ____ h = ____ min = ____ s

14. Smaller units of measurement derived from the basic 1 *s* unit include:

1 ms (millisecond)

1 µs (microsecond)

1 ns (nanosecond)

1 ps (picosecond).

In engineering – and in electronics in particular – small intervals of time are absolutely crucial.

m, µ, n and p stand for numbers. (There are also other abbreviations like this).

$$m = \frac{1}{1000}$$

$$\mu = \frac{1}{1\,000\,000}$$

$$n = \frac{1}{1\,000\,000\,000}$$

$$p = \frac{1}{1\,000\,000\,000\,000}$$

How many milliseconds are there in the following units?

a) 1 min = ________

b) 1 µs = ______

Note:

The 1 s (second) unit in current use is the 86.000th part of the average solar day.
Since 1970, the SI basic unit of 1 second is equivalent to 9.192.631.770 times the period of oscillation of the radiation corresponding to the transition between the two hyperfine structural levels of the ground state of atoms of the nuclide ^{133}Cs.

Calculating mass

Assignment: To determine the mass of various objects using different measuring balances..

Apparatus:
1 single-pan balance
1 school laboratory balance
1 aluminium cuboid
1 weight
1 measuring cylinder
1 glass beaker, 250 ml

Setup:

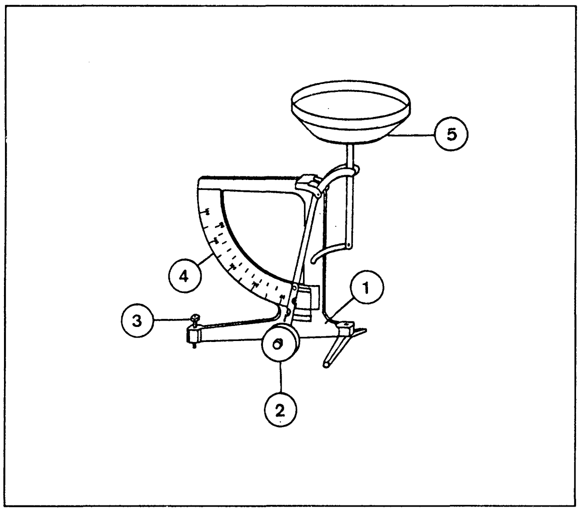


Fig. 1 ▶ 1.

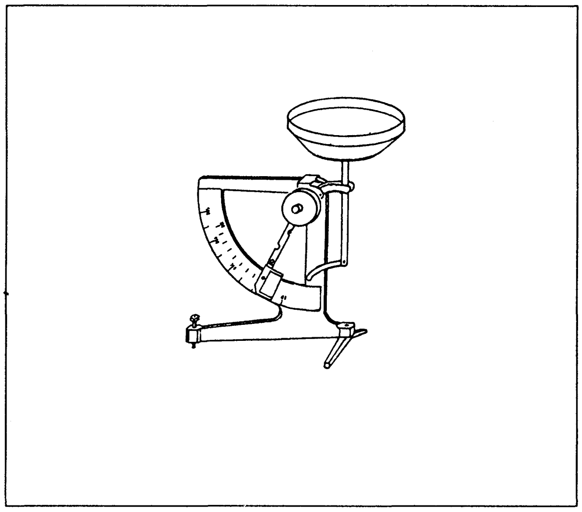


Fig. 2 ▶ 1. **(2)**

1. Set up the single-pan balance as shown in fig. 1.
   The balance consists of the following components:
   (1) stand (tripod base)
   (2) counterweight
   underneath (fig. 1): 0 – 100 g
   on top (fig. 2): 0 – 500 g
   (3) adjusting screw for taring the balance
   (4) double scale
   (5) weighing pan.
2. Use the adjusting screw **(3)** to adjust the balance.

Student's Sheet 2

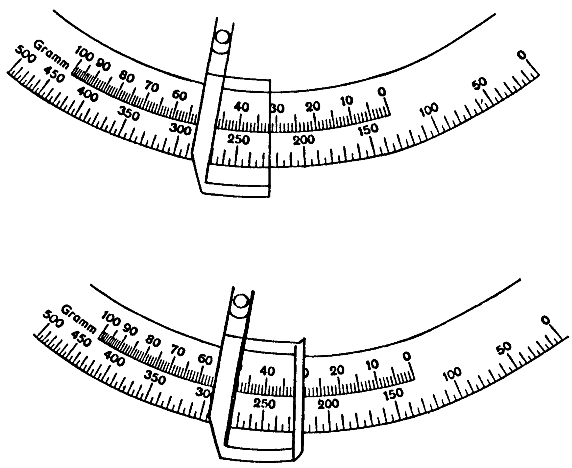


Fig. 3 ▶ 2.

Hint on setting up:

The balance should be separately adjusted for each weighing range.
To take readings, look down at the reading plate from directly above it ▶ Fig. 3.

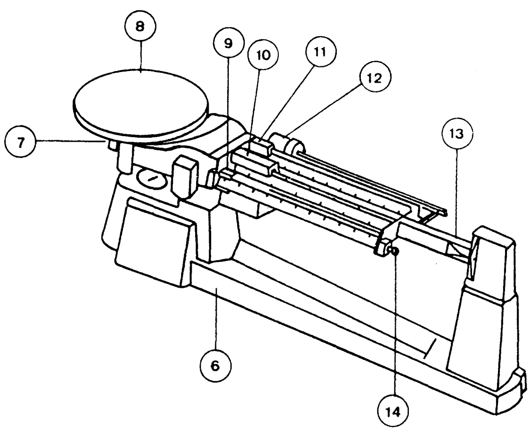


Fig. 4 ▶ 3.

3. Set up the laboratory balance as shown in fig. 4. The balance consists of the following parts:

   (6) baseplate

   (7) adjusting screw for taring the balance

   (8) weighing pan

   (9) sliding weight for 0 – 10 g

   (10) jockey weight for 0 – 500 g

   (11) jockey weight for 0 – 100 g

   (12) tare compensator

   (13) indicator showing the point of equilibrium

   (14) hook for adding extra weight.

4. Use the adjusting screw **(7)** to adjust the balance.

   Note:

   On the tare beam without scale graduations, you will find a jockey weight with an internal screw thread for stepless fine taring. For rough settings, you move the weight up and down the beam: it is held in position by a leaf spring ▶ Fig. 5 a).

   You can extend the weighing range of the triple-scale balance by 2000 g, by adding additional weights. You attach them by the hook **(14)** ▶ Fig. 5 b). While they are not needed, they can be stored in the recess in the baseplate of the balance.

   The balance's equilibrium indicator is magnetically damped. The blade of the indicator swings freely between two magnets ▶ Fig. 5 c).

   For making hydrostatic measurements, the balance has a stand holder (12 mm) in its baseplate **(15)** and a hook underneath the weighing platform **(16)** ▶ Fig. 5 d).

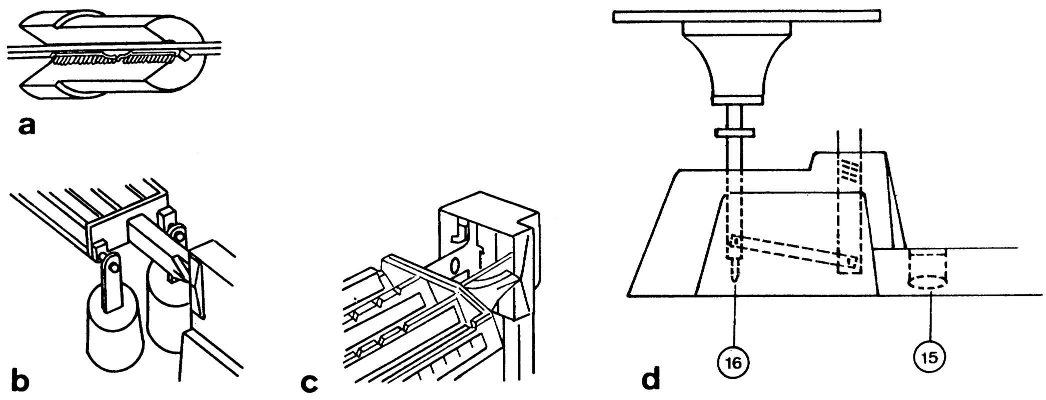


Fig. 5 ▶ Note

Performing the experiment:

Experiment part 1

5. Determine the mass of the objects listed in table 1 using either the single-pan or the laboratory balance.

Experiment part 2

6. Place the beaker on the laboratory balance and move the tare compensator **(12)** until you reach a state of approximate equilibrium.
7. Obtain a state of perfect equilibrium by rotating the tare compensator.
8. Determine the mass of ca. 150 ml water.

Observations and measurements:

Table 1

Object	Mass	
	Single-pan balance	Laboratory balance
Cuboid		
Weight		
Measuring cylinder		
Measuring cylinder + 100 ml water		
ca. 150 ml water	—	

Student's Sheet 4

Evaluation:

9. Complete table 2.

Table 2

	Weighing range	Reading accuracy
Single-pan balance		
Laboratory balance		

10. What peculiar feature does the laboratory balance possess?

____

____

Additional assignment:

Determining the tare compensation factor.

Determining the density of regularly shaped bodies

Assignment: To calculate the mass per cm^3 of the aluminium cuboid.

Apparatus:
1 aluminium cuboid
1 vernier caliper
1 single-pan balance

Setup:

1. Lay out all the apparatus ready for use, as shown in fig. 1.
2. Adjust the balance.

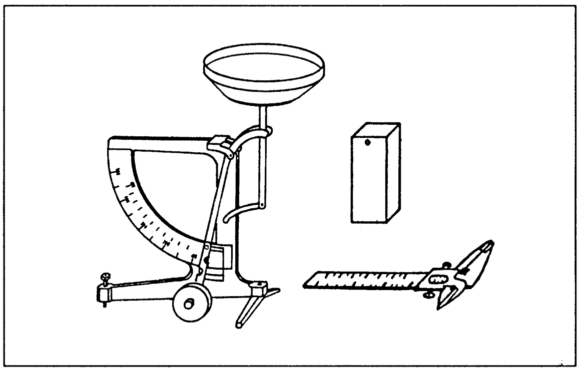


Fig. 1 ▶ 1.

Performing the experiment:

3. Measure the length ℓ, width w and height h of the cuboid.
   Enter your measurements ▶ Table 1.
4. Determine the mass m of the aluminium cuboid. Enter the reading ▶ Table 1.

Table 1

Length ℓ	
Width w	
Heigth h	
Volume V	
Mass m	
Density ρ	

Table 2

Substance	Density $\rho / \frac{g}{cm^3}$	Mass of cuboid $\frac{m}{g}$
Wood Aluminium Steel Gold	0.7 2.8 7.8 19.3	

Student's Sheet 2

Evaluation:

5. Calculate the volume V of the aluminium cuboid.
   Enter the result ▶ Table 1.
6. A substance is identified by its density ρ. Density can be calculated using the formula:

   $$\text{density} = \frac{\text{mass}}{\text{volume}} \qquad \rho = \frac{m}{V}$$

   What is the value for the density of the aluminium of which the cuboid is made?
   Enter the result ▶ Table 1.
7. The densities of various materials are shown in table 2.
   How heavy would the cuboid be (▶ Table 1) if it was made of wood, steel or gold rather than aluminium?
   Calculate the values. Enter your answers ▶ Table 2.

   ____

8. Trick question:
   Which is heavier, 1 kg of feathers or 1 kg of iron?

   ____

   ____

9. How heavy is a wooden board which is 2 m long, 50 cm wide and 3 cm thick?

   ____

   ____

   ____

   ____

   ____

   ____

Determining the density of irregularly shaped bodies

Assignment: To determine the density of two bodies of irregular shape.

Apparatus:
1 weight
1 pointer
1 measuring cylinder, 100 ml
1 glass beaker, 250 ml
1 cord, ca. 30 cm
1 single-pan balance
Water
Cloths

Setup:

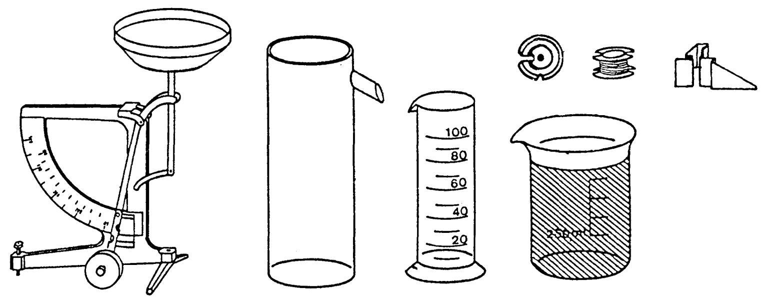


Fig. 1 ▶ 1.

1. Lay out all items of apparatus ready for use, as shown in fig. 1.
2. Adjust the balance.

Performing the experiment:

3. Find out the mass *m* of weight and pointer. Enter the result ▶ Table.
4. Fasten the weight to the cord ▶ Fig. 2.
5. Half-fill the beaker with water and pour water into the measuring cylinder up to the 60 cm^3 mark ▶ Fig. 3.
6. Lift up the weight by the end of the cord and completely immerse it in the water in the measuring cylinder.

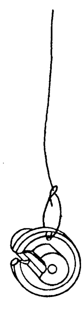


Fig. 2 ▶ 4.

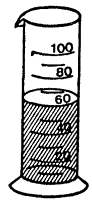


Fig. 3 ▶ 5.

Student's Sheet 2

7. How much water has been displaced by the weight?
   Read off the volume *V* from the scale (difference between this reading and earlier reading of 60 cm^3). Enter the reading ▶ Table.
8. Calculate the volume *V* of the pointer in the same way.
   Enter the value ▶ Table.

Table

	Weight	Pointer
Mass *m*		
Volume *V*		
Density ρ		

Fig. 4 ▶ 8.

Evaluation:

9. Calculate the density ρ of the weight and pointer: $\rho = \frac{m}{V}$
   Enter the values ▶ Table.

Student's Sheet 1

Determining the density of liquids

Assignment: To determine the density of a liquid (water) and illustrate the dependence of mass on volume in the form of a graph.

Apparatus:
1 measuring cylinder, 100 ml
1 glass beaker, 250 ml
1 single-pan balance
Water
Cloths

Setup:

1. Lay out the apparatus ready for use, as shown in fig. 1.
2. Adjust the balance

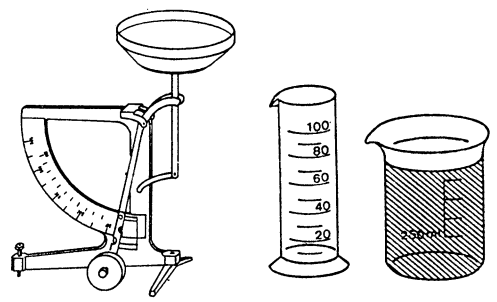


Fig. 1 ▶ 1.

Performing the experiment:

3. Determine the mass m_0 of the measuring cylinder. Enter the value ▶ Table.

Student's Sheet 2

4. Pour 20 cm^3 (ml) of water into the measuring cylinder ▶ Fig. 2.
5. Determine the total mass of the measuring cylinder and water ($m_0 + m$) using the balance.

   Enter the results ▶ Table.

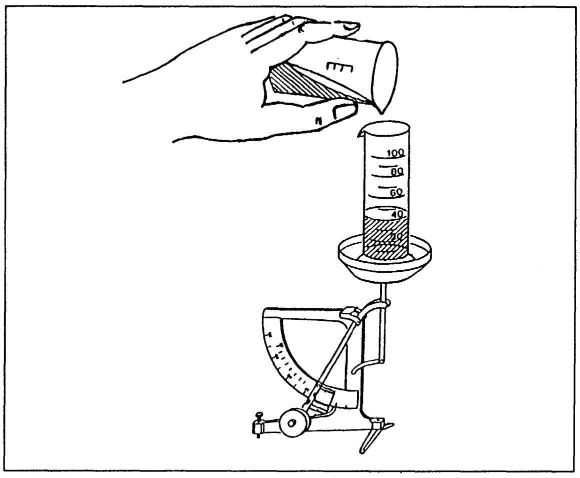


Fig. 2 ▶ 4.

6. Fill the measuring cylinder up with 40, 60, 80 and 100 cm^3 of water, measuring the overall mass ($m_0 + m$) each time.

   Enter the values ▶ Table.

Table

Mass of the measuring cylinder: m_0 =			
Total mass $m_0 + m$	Mass of water m	Volume of water V	Density $\rho = \frac{m}{V}$
g	g	20 cm^3	$\frac{g}{cm^3}$
g	g	40 cm^3	$\frac{g}{cm^3}$
g	g	60 cm^3	$\frac{g}{cm^3}$
g	g	80 cm^3	$\frac{g}{cm^3}$
g	g	100 cm^3	$\frac{g}{cm^3}$

Evaluation:

7. Determine mass m. Enter the result ▶ Table.
8. Calculate the density of water from m and V. Enter the result ▶ Table, last column.
9. Illustrate the mass m of the water as a function of volume in the form of a graph ▶ Fig. 3.
10. What does the graph tell you?

___

___

___

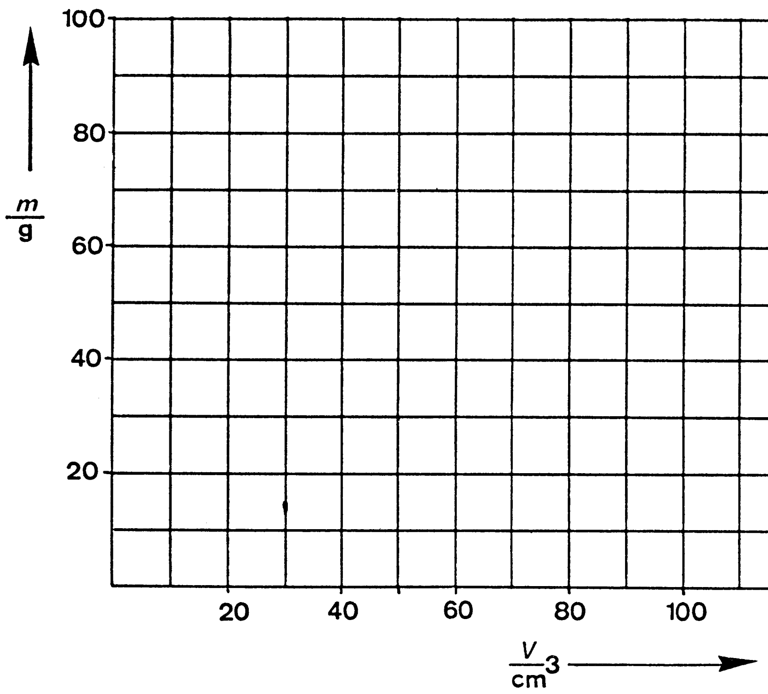


Fig. 3

Other experiments which go into more detail:

Mass and weight

Assignment: To observe and determine the force due to weight of masses.

Apparatus:
1 dynamometer, 1.5 N
3 weights
1 leaf spring
1 cord, 50 cm

Setup:

1. Lay out all the items of apparatus ready for use, as shown in fig. 1. Place the leaf spring on top of two weights.

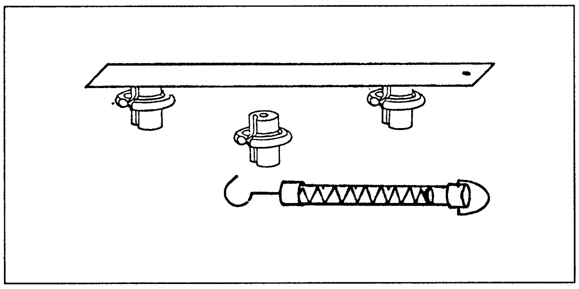


Fig. 1 ▶ 1.

Experiment part 1:
Placing a load on the leaf spring

2. Place a weight on the middle of the leaf spring ▶ Fig. 1.
Note down your observations ▶ Table.

Experiment part 2:
Placing a load on the dynamometer

3. Suspend 1 to 3 weights from the dynamometer, one after the other ▶ Fig. 2.
Note down your observations as you add the weights ▶ Table.

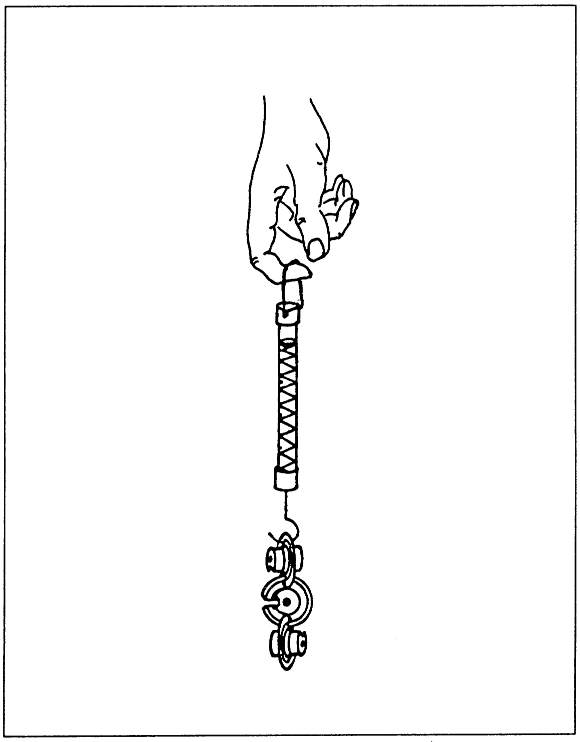


Fig. 2 ▶ 3.

Student's Sheet 2

Experiment part 3:
Free fall ▶ Fig. 3

4. What happens if you hold a body, e.g. a weight, in your hand and then release it?
Note down your observations ▶ Table.

Experiment part 4:
Acceleration of a mass ▶ Fig. 4

5. Hang two weights on the dynamometer and hold it up at eye level.
   a) quickly squat down
   b) quickly stand up again.
   Is there more or less load on the helical spring at the beginning of the movement?
   Note down your observations ▶ Table.

Experiment part 5:
Swinging a mass ▶ Fig. 5

6. Fasten a cord to the dynamometer.
7. Hang a weight from the dynamometer.
8. Swing the dynamometer around just above the floor, so that the weight moves in a circle.
   Note down your observations ▶ Table.

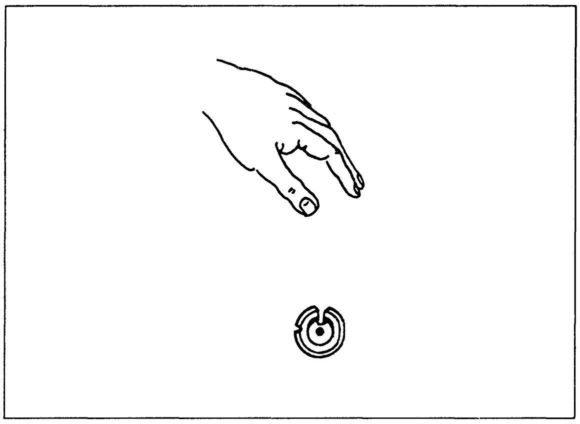


Fig. 3 ▶ 4.

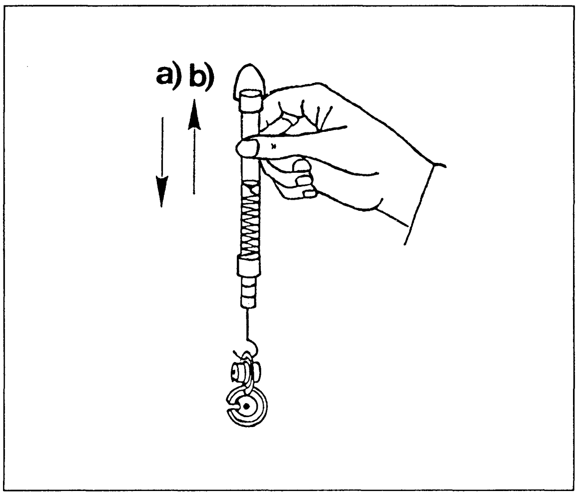


Fig. 4 ▶ 5.

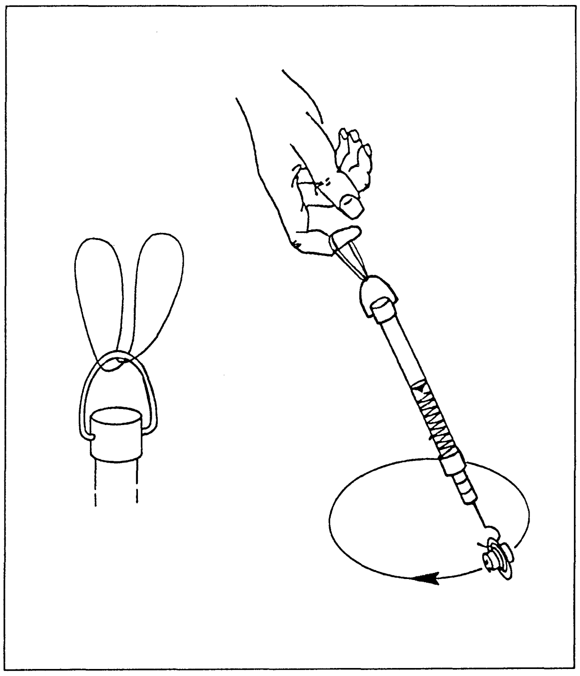


Fig. 5 ▶ 6.

Student's Sheet 3

Table

Experiment part	Observations and measurements
1	The leaf spring *down.*
2	As the load increases, the helical spring
3	The weight *to the floor.*
4 a) b)	There is load load on the helical spring
5	As the of the weight increases, the helical spring is

Evaluation:

9. How does the mass of a resting body make itself noticeable?

____

____

____

____

10. How does the mass of a body become noticeable when it changes the direction of its movement?

____

____

____

11. The unit of force is the Newton (N).
What is the maximum force for which the dynamometer is calibrated?

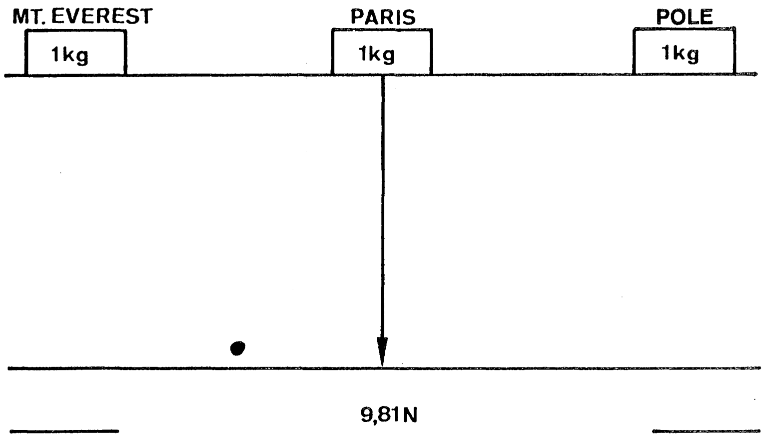
F_{max} = ______

Notes:

Calibration is not the same thing as adjustment.
The unit of force and weight is the Newton (N). 1 N is the weight of the standard platinum-iridium body (preserved in Paris) at a terrestrial latitude of 45° at sea level.

12. Weight (or force due to weight) depends on location, unlike mass, which always remains the same. The further away from the earth's core a body is, the less it weighs.

    A mass of 1 kg has a (force due to) weight of 9.81 N at the standard location (Paris).
    Where does this weight become 9.84 N or 9.79 N?
    Enter the values:



Note:

The poles are flattened and ca. 20 km closer to the centre of the earth than the equator is.

13. The greater the mass of a body, the greater the attraction it exerts upon other bodies.

    Calculate the weight of a mass m= 1 kg on the moon and various planets:

Moon	$\frac{1}{6}$	F = N
Mars	$\frac{3}{8}$	F = N
Venus	$\frac{8}{9}$	F = N
Earth	1	F = 9.81 N
Jupiter	2.65times	F = N
Sun	28times	F = N

14. What dimension of a body do you use a balance to determine?

____

15. Could you use a single-pan balance to measure mass accurately on the moon?

____

____

____

Student's Sheet 1

Interconnected vessels

Assignment: To investigate the water level in a variety of interconnected vessels.

Apparatus:

2 stand bases
1 stand rod, 25 cm
2 stand rods, 50 cm
1 plastic beaker
1 small funnel
1 double pipe holder
1 silicone tube, 30 cm
2 plastic pipes, ∅ 8.5 mm
1 double socket
1 universal clamp
1 stopper with hole
1 pipe connector
1 plastic pipe, ∅ 25 mm

and in addition:
Water

Setup:

1. Set up the stand as shown in fig. 1
2. Pour some water (ca. 150 ml) ready for use in the plastic beaker.

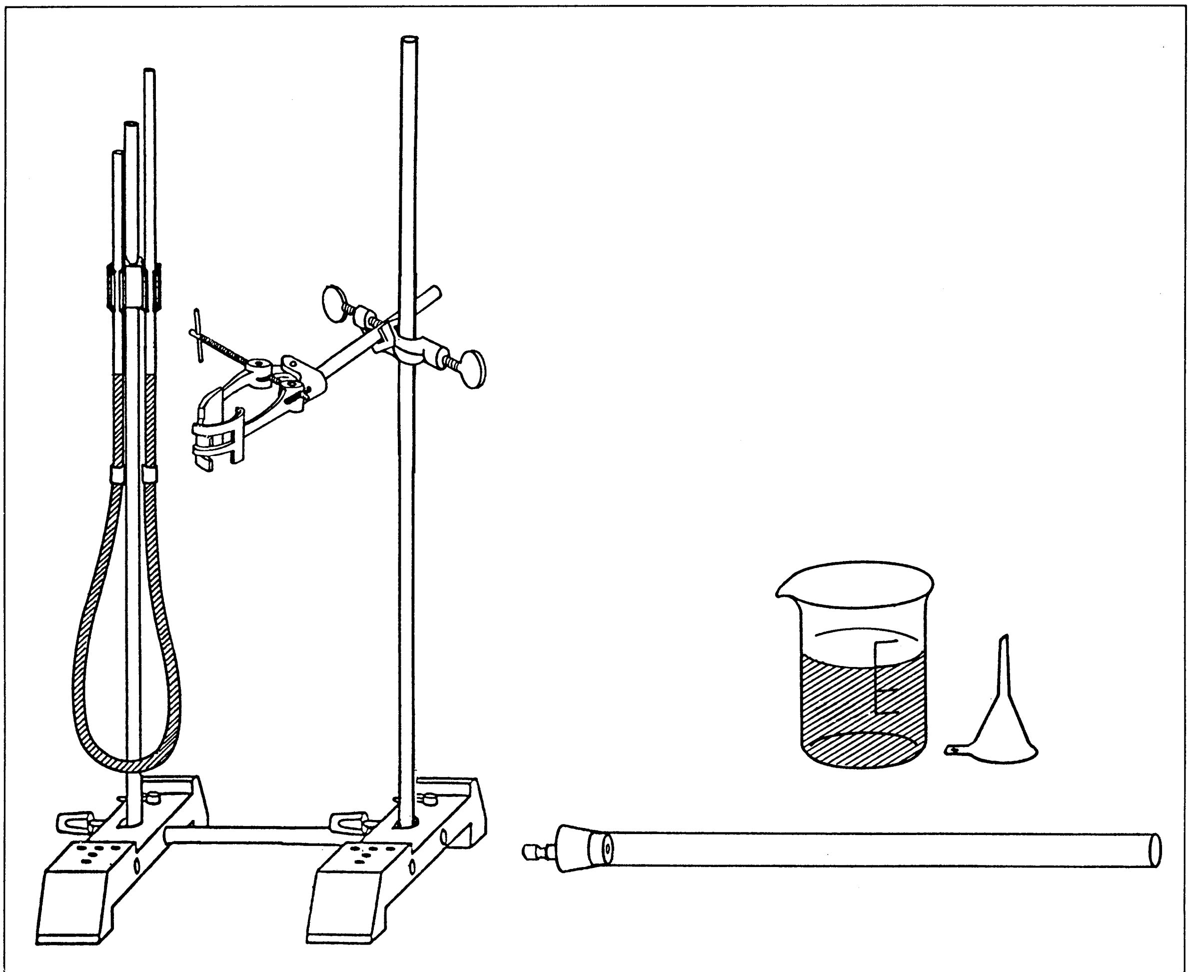


Fig. 1 Setting up the interconnected vessels.

3. Connect the two plastic pipes (⌀ 8.5 mm) using the silicone tube and fix them to the stand rod using the double pipe holder.
   (This setup is also the basis for an U-tube manometer.)
4. Fix the double socket and universal clamp to the other stand rod.
5. Insert the stopper with the tube connector into the plastic pipe (⌀ 25 mm) so that it is ready for use.

Preparing your report:

6. Prepare a worksheet as shown in fig. 2.

Performing the experiment:

7. Fill the U-tube manometer with water using the small funnel, until the water level comes to about half way up the plastic pipes.
8. Enter the water levels on the worksheet (step 1).
9. Take the right-hand limb out of the double pipe holder and hold it next to the left-hand limb, as shown in fig. 2. Enter the water level in each limb on your worksheet (steps 2–4).

   Caution: do not bend the pipe too sharply.
10. Empty the U-tube manometer.
11. Replace one of the plastic pipes (⌀ 8.5 mm) with the larger plastic pipe (⌀ 25 mm) using the stopper and tube connector.

    Make sure the stopper is firmly in place, so that it does not pop out when you fill the tube with water.
12. Clamp the plastic pipe (⌀ 25 mm) in the universal clamp.
13. Pour water into the plastic pipe (⌀ 8.5 mm) with the help of the funnel, until the water level comes to about half way up the plastic pipes.

    Make sure no air bubbles are trapped in the pipe.
14. Enter the water levels on your worksheet (step 5).
15. Take the plastic pipe (⌀ 25 mm) out of the universal clamp and hold it alongside the left limb, as shown in fig. 2. Enter the two water levels on your worksheet (steps 6 and 7).

Student's Sheet 4

Obervations and measurements:

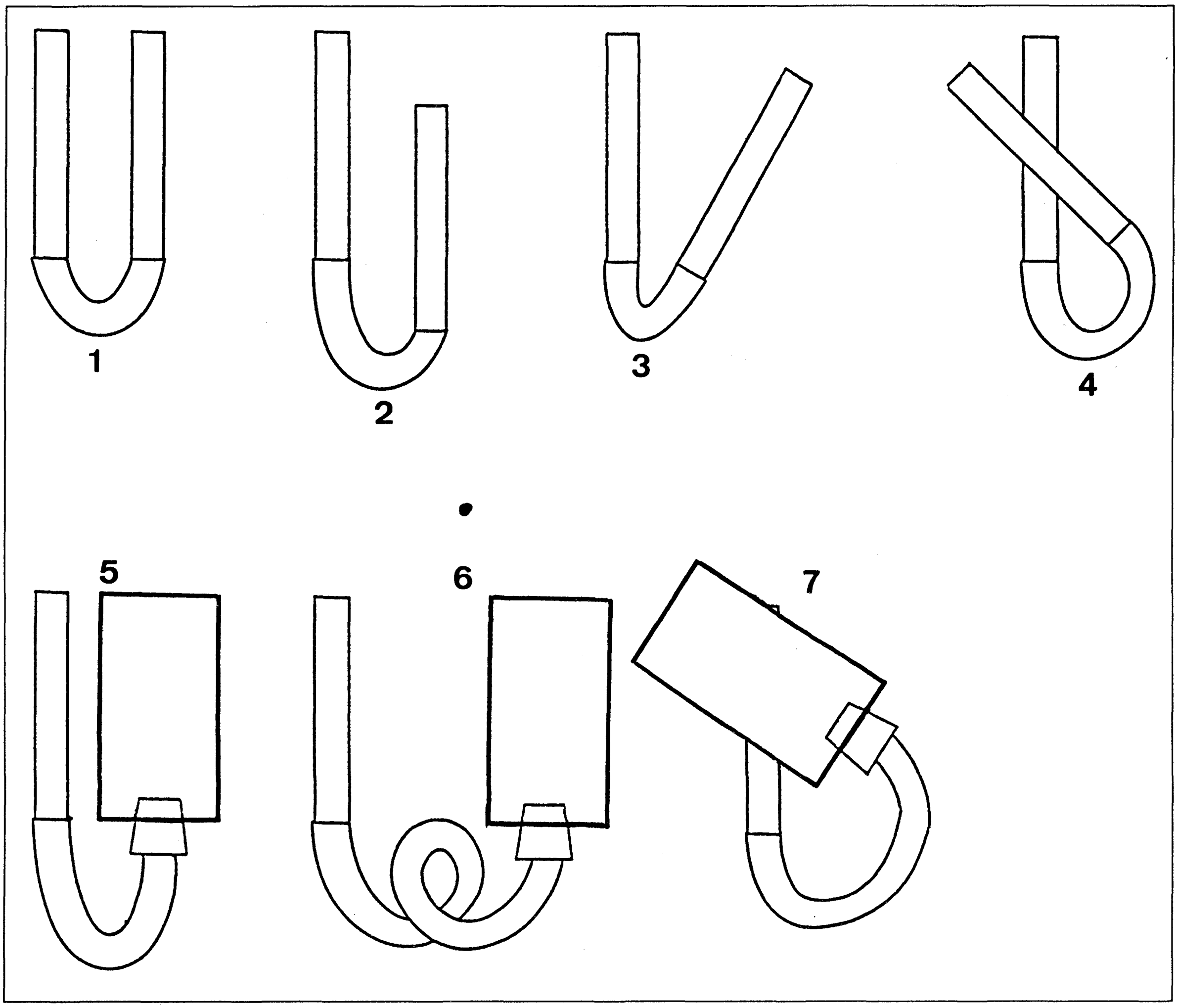


Fig. 2 Worksheet

Evaluation:

16. What do the various water levels in the interconnecting pipes depend on (summarise your observations)?

____

____

Student's Sheet 5

17. Explanation of the way an artesian well works (fig. 3):

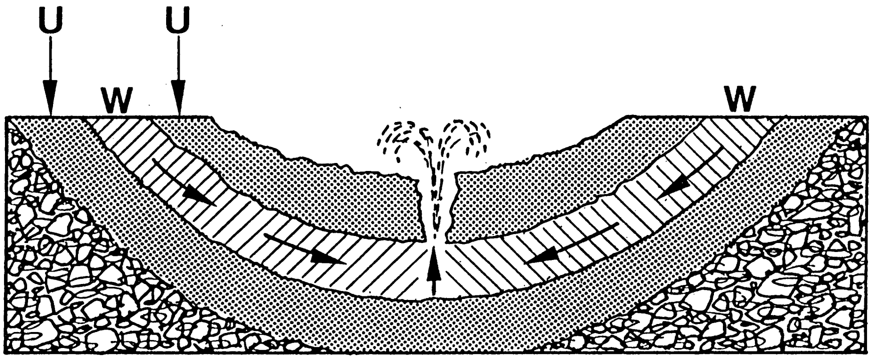


Fig. 3 Schematic drawing of an artesian well:
U: stratum impermeable to water (e.g. clay)
W: water bearing stratum (e.g. sand)

___

___

___

Hydrostatic pressure

Assignment: To investigate the gravitational pressure of water (hydrostatic pressure) as a function of depth and compare pressure on the bottom with lateral pressure and upthrust.

Apparatus:

2 stand bases
1 stand rod, 25 cm
2 stand rods, 50 cm
1 sleeve block
1 double pipe holder
2 plastic pipes, ∅ 8.5 mm
1 silicone tube, 30 cm
1 small funnel
1 tape measure
2 retaining clips
1 manometric capsule
1 glass beaker

and in addition:
Water

Setup:

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

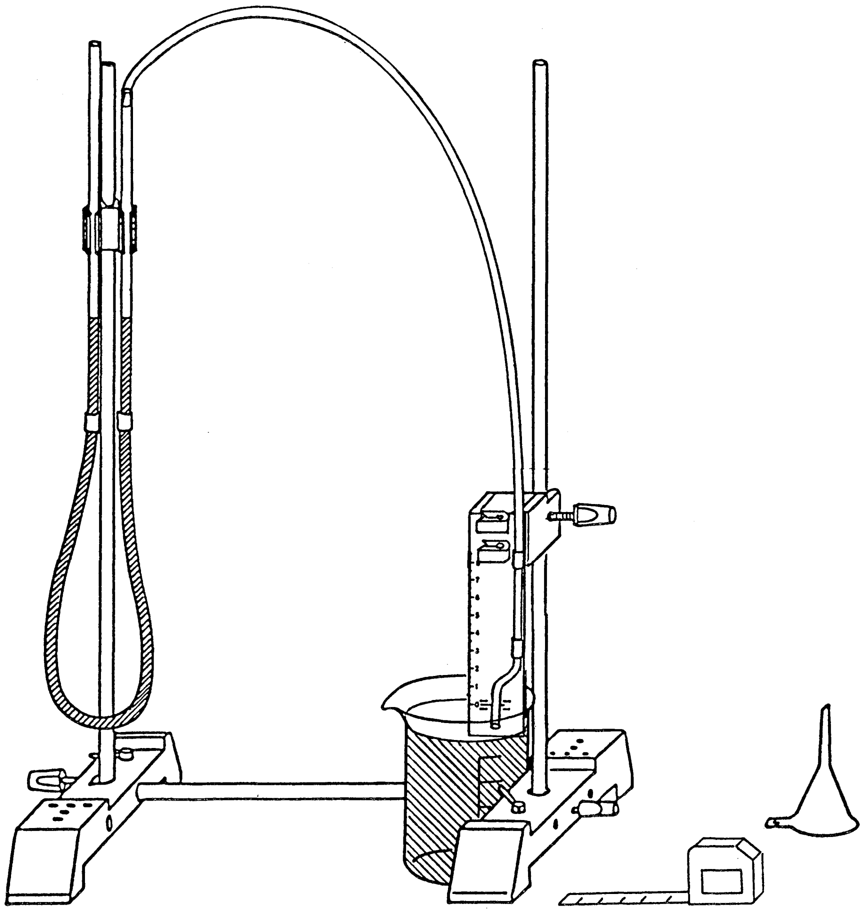


Fig. 1 Setup for investigating hydrostatic pressure

2. Fill the beaker with water (ca. 250 ml) so it is ready for use.
3. Connect the two plastic pipes together using the silicone tube and fasten them to the left-hand stand rod using the double pipe holder (U-tube manometer).
4. Use the small funnel to fill the U-tube manometer with water. The water should come about half way up the two plastic pipes.
5. Fit the manometric capsule to the sleeve block using the retaining clips.
6. Fit the stopper on the end of the manometric capsule's tube to the right-hand pipe of the manometer.

Preparing your report:

7. Draw up tables 1 and 2.

Student's Sheet 3

Performing the experiment:

8. Attach the manometric capsule's tube as shown in fig. 2.1.

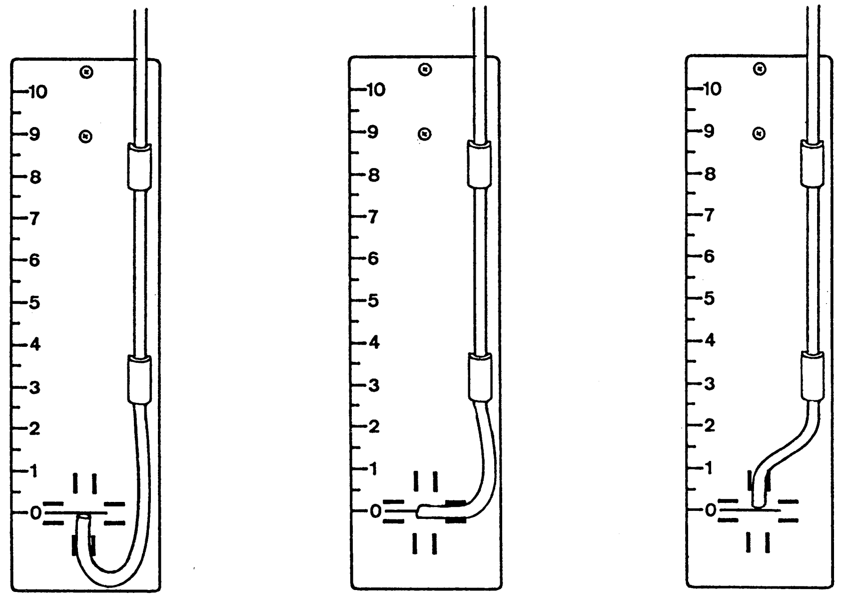


Fig. 2 Preparations for measuring bottom and lateral pressure and upthrust.

9. Lower the manometric capsule into the water by lowering the sleeve block, until it is immersed as far as the 1 (cm) mark.
10. There should not be any water in the manometric capsule's tube. If necessary, move the manometer pipes around.
11. Measure the difference in height Δh of the water levels in the manometer pipes and enter the results in table 1. (Fig. 3)
12. Repeat steps 9, 10 and 11 for the other depths

    Hint:

    If you run out of room to move the pipes, remove the manometric capsule's tube from the pipe, set up the manometer again and re-attach the tube.

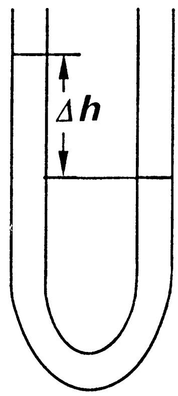


Fig. 3 Setup for measuring the difference in height Δh in the manometer.

13. Take the manometric capsule out of the water and attach the tube as shown in fig. 2.2.
14. Immerse the manometric capsule in the water to a depth of 4 cm and repeat step 10.
15. Measure the difference in height Δh of the water levels in the manometer pipes and enter the results in table 2.
16. Repeat steps 13 to 15, with the tube attached as shown in fig. 2.3.

Observations and measurements:

17. Table 1

Depth of immersion	h	cm	1	2	3	4	5
Difference in height	Δh	cm					

18. Table 2: depth of immersion h = 4 cm

Difference in height	Bottom pressure (fig. 2.1)	
	Lateral pressure (fig. 2.2)	
	Upthrust (fig. 2.3)	

Evaluation:

19. Enter the measured values from table 1 in the graph in fig. 4.
20. The difference in height Δh of the liquid in both pipes of the manometer is a measure of the pressure p, which was being exerted on the (right-hand) water column. What is the relationship between hydrostatic pressure p and depth of immersion h?

____

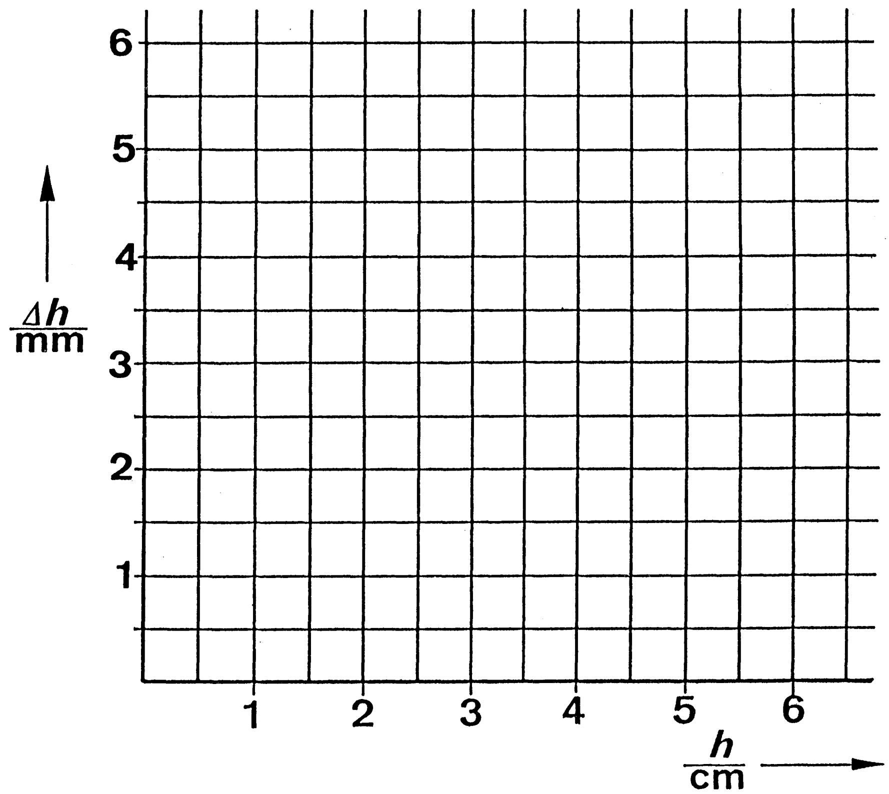


Fig. 4 Graph showing how the difference in height Δh in the manometer depends on the depth of immersion h.

21. Complete table 2 by writing in the value for bottom pressure from table 1.
What can you observe about bottom pressure, lateral pressure and upthrust?

____

____

Effects of air pressure

Assignment: To investigate the effects of air pressure.

Apparatus:
2 stand bases
1 stand rod, 25 cm
2 stand rods, 50 cm
1 double socket
1 universal clamp
1 plastic pipe, ∅ 25 mm
1 stopper without a hole
1 plastic pipe, ∅ 8.5 mm
1 pipe cap
1 small funnel
1 double tube holder
1 plastic beaker

and in addition:
Water

Setup:

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

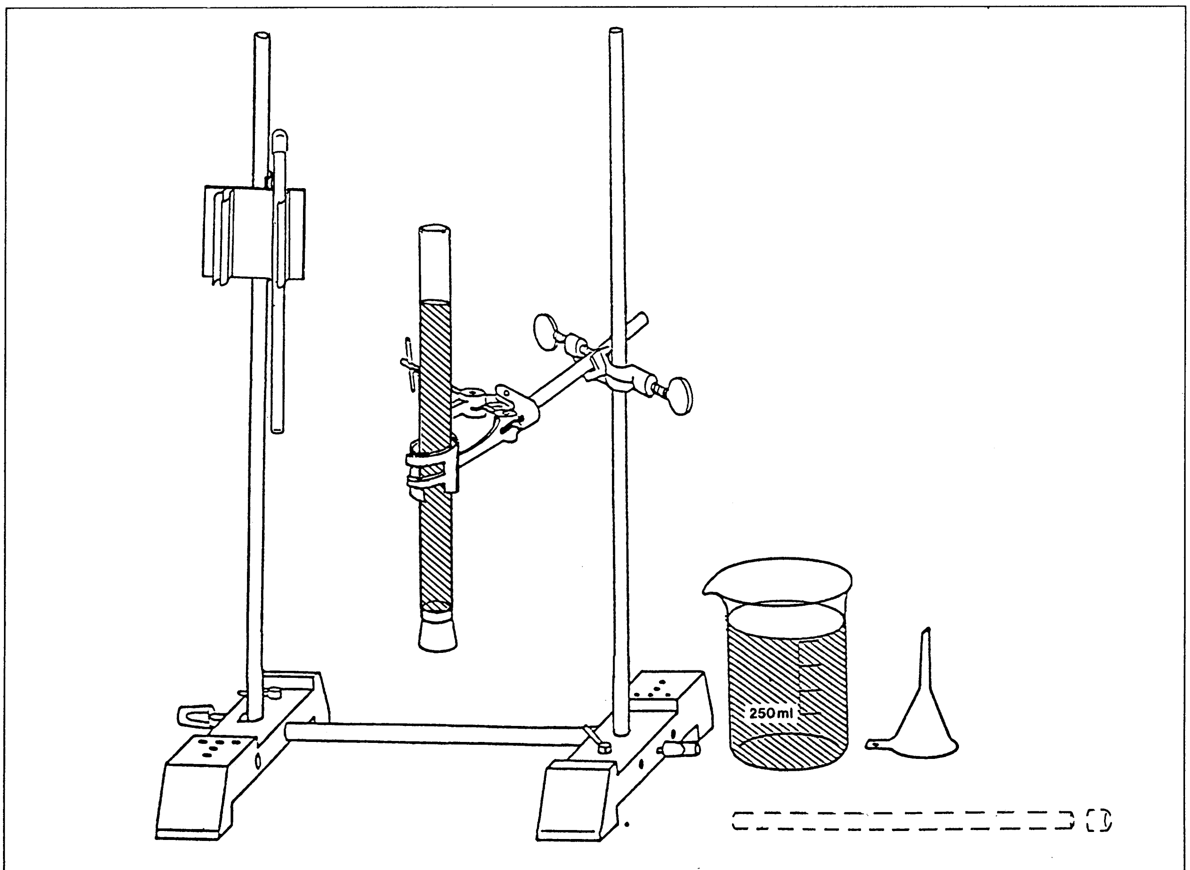


Fig. 1 Setup for investigation into the effects of air pressure.

2. Pour ca. 250 ml of water into the plastic beaker so that it is ready for use.
3. Insert the stopper firmly in the plastic pipe (∅ 25 mm) and clamp the plastic pipe in the universal clamp attached to the right-hand stand rod.

Preparing your report:

4. Prepare for steps 19 to 21.

Performing the experiment:

Experiment part 1:

5. Seal one end of the plastic pipe (∅ 8,5 mm) with the cap and use the funnel to fill it to the brim with water.
6. Close off the other end of the plastic pipe with your finger and hold it upside down in the water in the plastic beaker.
7. Remove your finger and observe the water in the pipe. Lift the plastic pipe out of the water and note down your observations under step 17.
8. Empty out the plastic pipe by shaking it carefully and then remove the cap.

Experiment part 2:

9. Immerse the pipe (∅ 8.5 mm) in the water and then seal the top end by putting your finger across it.
10. Keep holding your finger over the top of the pipe and slowly lift it out of the water. Note down your observations under step 18.
11. Allow the water to flow back out of the pipe again.

Experiment part 3:

12. Fill up the plastic pipe (∅ 25 mm) with water to a level about 5 cm below the rim.
13. Use the cap to seal off the end of the plastic pipe (∅ 8.5 mm) and after turning it so that the open end is facing downwards, fasten it to the left-hand stand rod using the double pipe holder.
14. Set up the apparatus in such a way that the narrower plastic pipe is inserted into the wider plastic pipe, but is not yet immersed in the water.
15. Now move the narrow plastic pipe until about 15 cm of the pipe are immersed in the water. Lower it carefully, so no air bubbles are released.
16. Write down your observations under step 19.

Observations and measurements:

17. The water in the narrow plastic pipe

____

18. While the top of the plastic pipe is sealed,

____

19. The water level in the narrow plastic pipe is

____

Student's Sheet 3

Evaluation:

20. Explanation for the observations made in parts 1 and 2 of the experiment:

____

____

21. In part 2 of the experiment, there is a quantity of air in the tube above the column of water. How great is the pressure in this part of the tube when the tube is lifted out of the water?

____

____

____

22. Why does water push up into the narrow pipe in experiment part 3?

____

____

____

The weight of bodies in water

Assignment: To investigate the weight of bodies immersed in water.

Apparatus:

2 stand bases
1 stand rod, 25 cm
1 stand rod, 50 cm
1 sleeve block
1 retaining clip
1 dynamometer, 1.5 N
1 cord
1 aluminium cuboid
2 weights
1 round tin
1 rubber ring
1 lead shot
1 plastic beaker

and in addition:
Water

Setup:

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

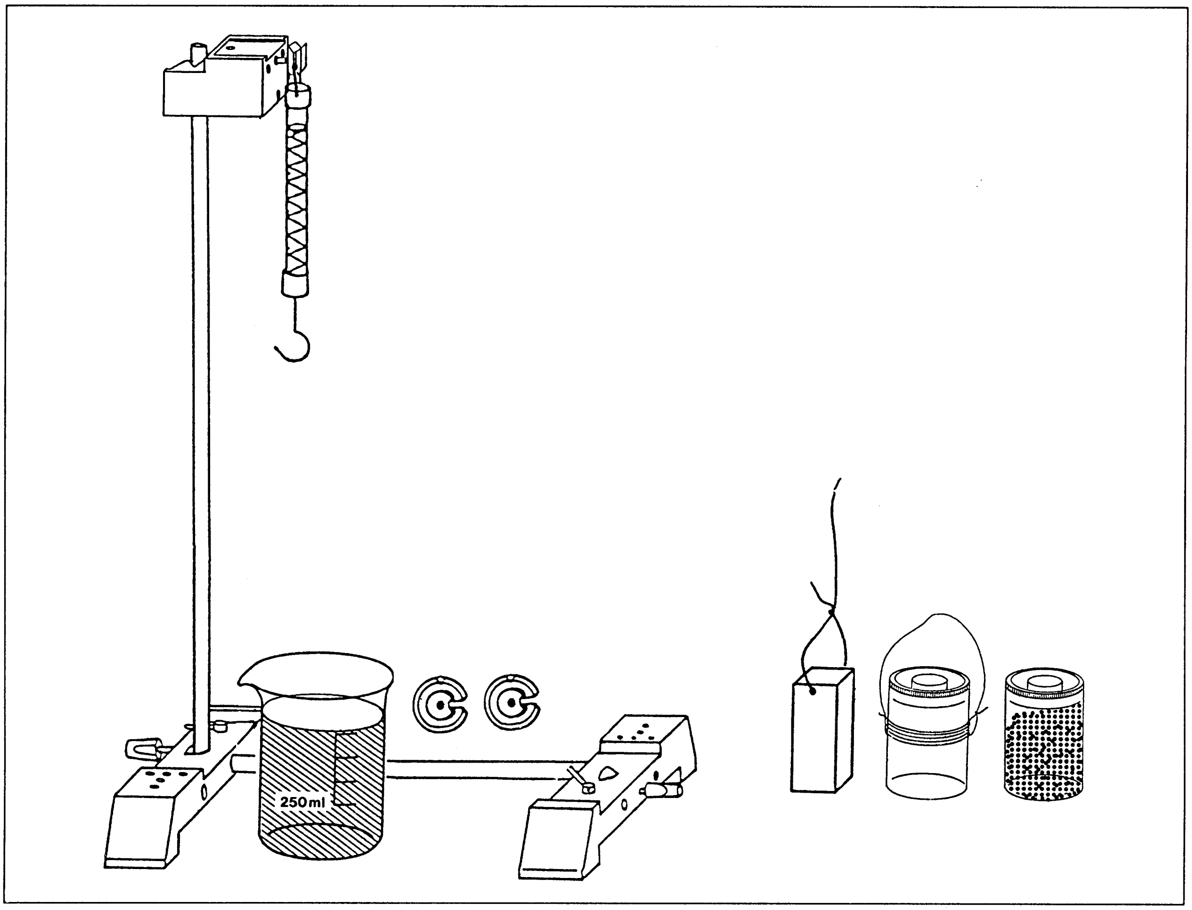


Fig. 1 Setup for investigating the weight of bodies in water

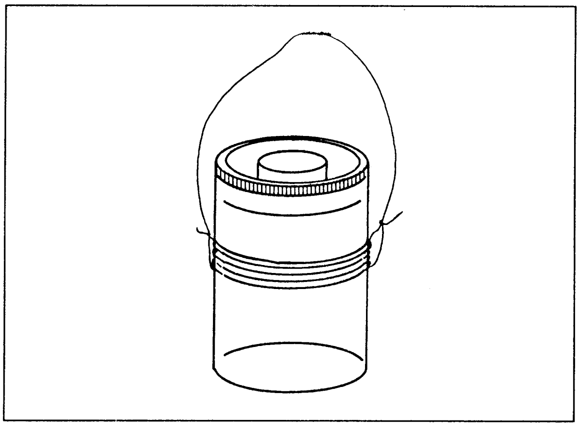


Fig. 1.1 One way of suspending the round tin

2. Attach the rubber ring and cord to the round tin as shown in fig. 1.1. Then fasten the cord (10 cm) to the aluminium cuboid.
3. Attach the dynamometer to the sleeve block using the retaining clip.
4. Fill the plastic beaker with ca. 250 ml of water so that it is ready for use.
5. Position the plastic beaker in such a way that when the sleeve block is lowered, any objects suspended from the dynamometer will be immersed in the water.

Preparing your report:

6. Prepare steps 11 and 12.

Student's Sheet 3

Performing the experiment:

7. Hang a weight from the dynamometer, then immerse the weight in the water by lowering the sleeve block. Watch the dynamometer's indicator while doing so. Enter your observations under step 11.
8. Lift the weight out of the water again. Measure the (force due to) weight F_1 of the weight and enter it in table 1.
9. Re-immerse the weight in the water by lowering the sleeve block, measure the force (immersed weight) F_2 and enter the value in table 1.
10. Repeat steps 8 and 9 using 2 weights, the aluminium cuboid and the round tin filled with lead shot.

Observations and measurements:

11. When the weight is immersed in the water,

____

12. Table 1

Object	Force due to weight $\frac{F_1}{N}$	Immersed weight $\frac{F_2}{N}$	Buoyancy force $\frac{F_3}{N}$
1 weight			
2 weights			
Aluminium cuboid			
Round tin filled with balls of shot			

Evaluation:

13. What happens to a body when it is immersed in water?

____

____

14. Calculate the buoyancy force F_3 and enter the result in table 1
    The following equation is true: $F_3 = F_1 - F_2$
15. Why can a heavy stone be lifted in water but not lifted out of the water?

____

____

Buoyancy force as a function of depth of immersion and body mass

Assignment: To measure buoyancy force in different depths of water and with bodies of differing mass.

Apparatus:

2 stand bases
1 stand rod, 25 cm
1 stand rod, 50 cm
1 sleeve block
1 retaining clip
1 dynamometer, 1.5 N
1 cord
1 weight
1 measuring cylinder
1 tape measure
1 round tin
1 rubber ring
1 lead shot
1 plastic beaker

and in addition:
Water

Student's Sheet 2

Setup:

1. Set up the stand as shown in fig. 1. Attach the dynamometer to the sleeve block using the retaining clip.

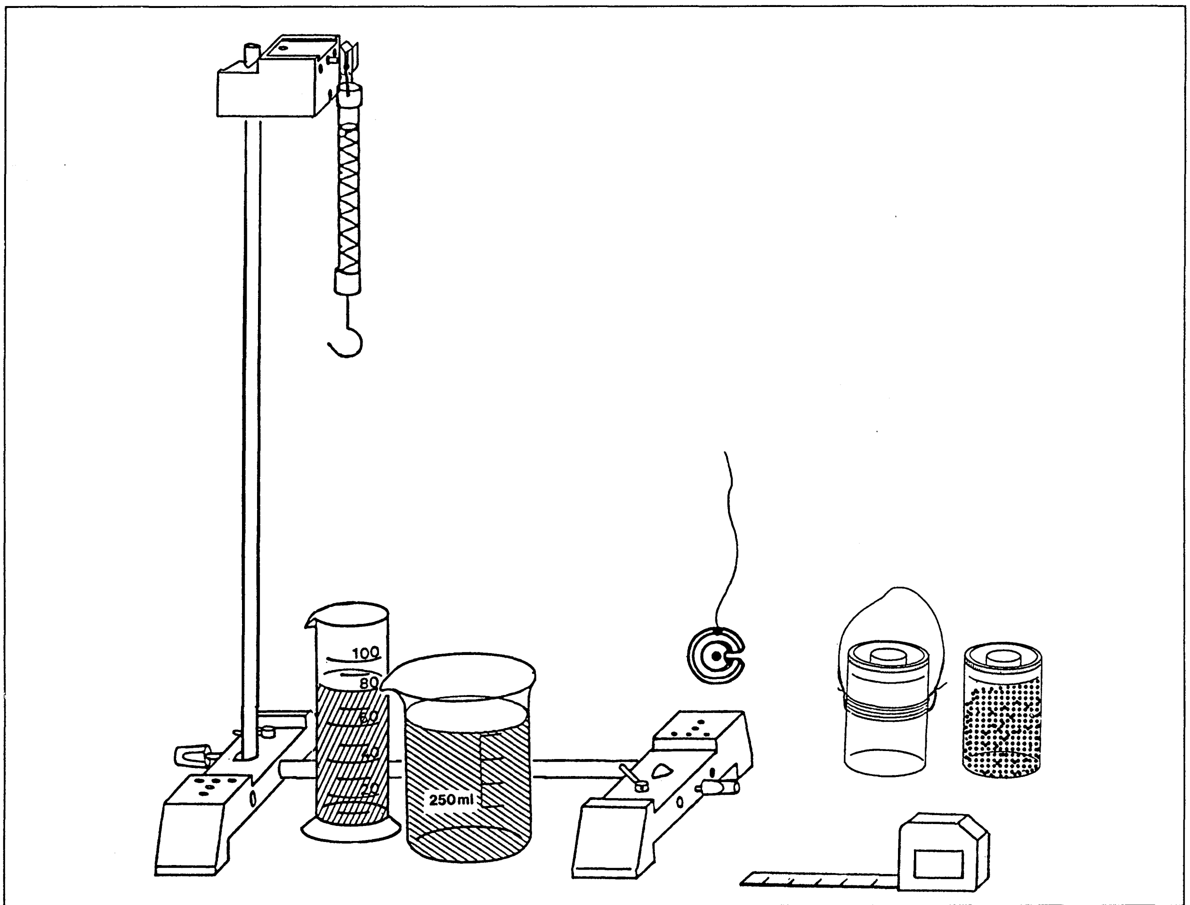


Fig. 1 Setup for investigating buoyancy force.

2. Attach the rubber ring and cord to the round tin, as shown in fig. 1.1. Then fasten the cord (15 cm) to the weight.
3. Fill the plastic beaker with ca. 200 ml of water so that it is ready for use.
4. Pour 90 ml of water into the measuring cylinder.
5. Position the measuring cylinder in such a way that when you lower the sleeve block, any weight suspended from the dynamometer is lowered into the water.

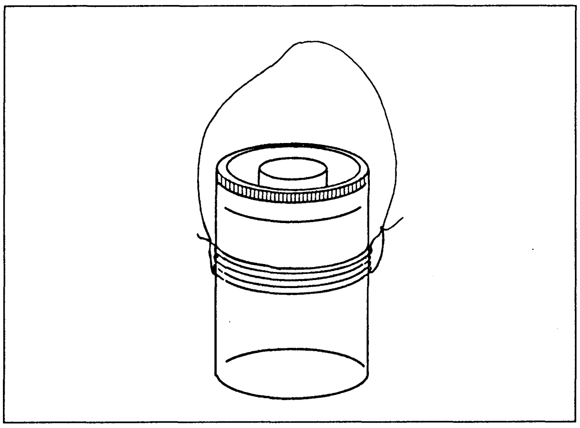


Fig. 1.1 One way of hanging the round tin.

Preparing your report:

6. Prepare steps 14 and 15.

Student's Sheet 3

Performing the experiment:

7. Suspend the weight from the dynamometer. Take a reading of force due to weight F_1 and note it down in table 1.
8. Lower the weight into the water by lowering the sleeve block, so that it is just covered by water. Take a reading for the immersed weight F_2 and enter the result in table 1.
9. Lower the weight 1 cm below the surface of the water. Use the tape measure to measure the depth of immersion (fig. 2). Measure the immersed weight F_2 and enter the result in table 1.
10. Repeat step 9 for the other immersion depths.
11. Release the weight from the dynamometer and put away the measuring cylinder. Place the plastic beaker (filled with ca. 200 ml of water) under the dynamometer.
12. Fill the round tin with lead shot and attach it to the dynamometer. Measure the force due to weight F_1 and enter the reading in table 2.

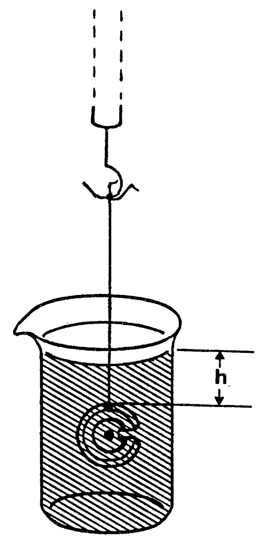


Fig. 2 Depth of immersion of the weight.

13. Immerse the round tin in the water by lowering the sleeve block. Measure the immersed weight F_2 and enter the reading in table 2. Lift the round tin out of the water again.
14. Take out small amounts of lead shot so that the force due to weight is gradually reduced, first to 1.0 N, then to 0.9 N, 0.8 N, 0.7 N and 0.6 N. Repeat steps 12 and 13 every time you change the weight.

Observations and measurements:

15. Table 1: buoyancy force at different depths
    Force due to weight $F_1 = 0.5\ N$

Depth of immersion $\frac{h}{\text{cm}}$	Immersed weight $\frac{F_2}{\text{N}}$	Buoyancy force $\frac{F_3}{\text{N}}$
0		
1		
2		
3		
4		
5		

Student's Sheet 4

16. Table 2: buoyancy force for different masses (V = constant)

Force due to weight $\frac{F_1}{N}$	Immersed weight $\frac{F_2}{N}$	Buoyancy force $\frac{F_3}{N}$

Evaluation:

17. Calculate the buoyancy force $F_3 = F_1 - F_2$ for each of tables 1 and 2 and enter the results in the right-hand column.
18. What is the effect of depth of immersion on buoyancy force?

___

19. What effect does the mass of the immersed body have on buoyancy force?

___

Buoyancy force as a function of the density of a liquid

Assignment: To investigate the buoyancy force of a body in salt water.

Apparatus:
1 plastic beaker
1 round tin
1 lead shot
1 measuring cylinder
and in addition:
Water
Salt

Setup:

1. Fill the plastic beaker with 200 ml of water so that it is ready for use.
2. Put about 40 g of salt into the measuring cylinder.
3. Put enough lead shot into the round tin so that it just sinks into the water.
   Take out some lead shot if the tin is sinking too quickly.
   Add some lead shot if the tin is floating.

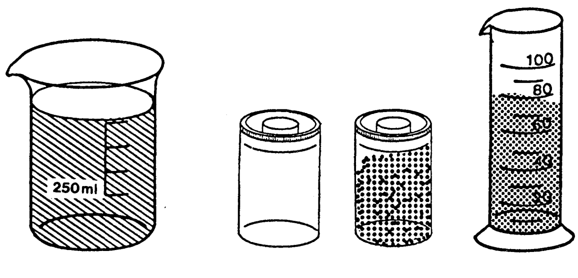


Fig. 1 Apparatus required to investigate buoyancy force in salt water.

Preparing your report:

4. Prepare step 7.

Performing the experiment:

5. Put the tin into the water
6. Slowly shake salt into the water and observe the round tin. Enter your observations under step 7.
   Now thoroughly clean all the apparatus.

Observations and measurements:

7. The round tin

Evaluation:

8. How does buoyancy force in tap water differ from that in salt water?

9. Why is it impossible to drown in the Dead Sea?

Student's Sheet 1

Buoyancy force as a function of the volume of a body

Assignment: To determine the buoyancy force of various bodies.

Apparatus:
2 stand bases
1 stand rod, 25 cm
1 stand rod, 50 cm
1 sleeve block
1 retaining clip
1 dynamometer, 1.5 N
3 weights
1 measuring cylinder
1 plastic beaker

and in addition:
Water

Setup:

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

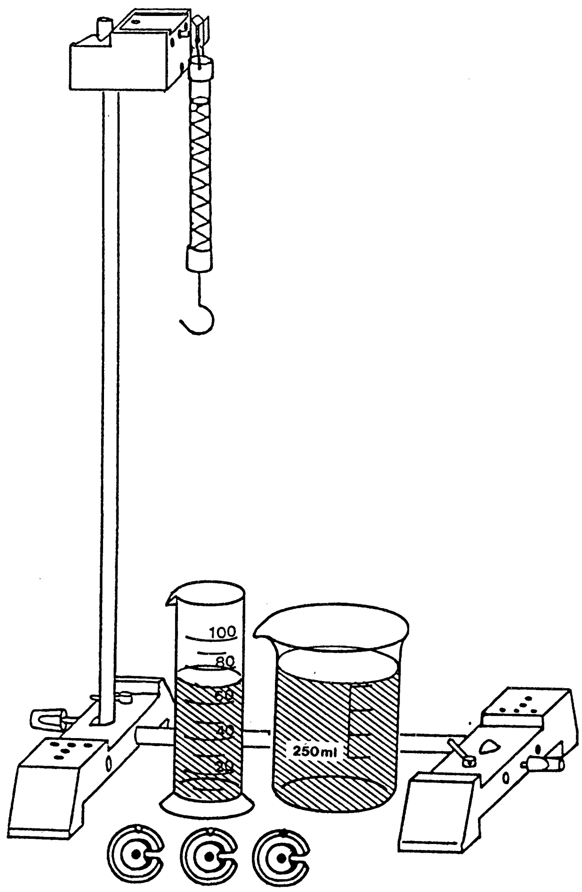


Fig. 1 Setup for determining buoyancy force.

2. Attach the dynamometer to the sleeve block using the retaining clip.
3. Pour ca. 100 ml of water into the plastic beaker so that it is ready for use.
4. Pour 70 ml of water into the measuring cylinder.
5. Position the measuring cylinder in such a way that when the sleeve block is lowered, any bodies suspended from the dynamometer will be immersed in the water.

Preparing your report:

6. Prepare table 1.

Performing the experiment:

7. Take an exact reading of the water level V_1 in the measuring cylinder and enter your reading in table 1.
8. Suspend a weight from the dynamometer. Determine the force due to weight F_1 and enter the result in table 1.
9. Immerse the weight in the water by lowering the sleeve block. Determine the body's immersed weight F_2 and enter your reading in table 1.
   Make sure that no air bubbles are adhering to the weight, and that it is hanging freely in the water, without touching the sides of the cylinder.
10. Read off the water level V_2 in the measuring cylinder and enter the result in table 1.
11. Lift the weight out of the water again.
12. Repeat steps 8 to 11 with 2 and then 3 weights.
    When you remove the bodies from the cylinder, make sure you do not remove any of the water. If necessary, fill up the cylinder again until it contains exactly 70 ml of water.

Observations and measurements:

13. Table 1: buoyancy force of various bodies in water
    Water level V_1 = __ ml

Body	Force due to weight $\frac{F_1}{N}$	Immersed weight $\frac{F_2}{N}$	Water level $\frac{V_2}{ml}$	Volume $\frac{V}{ml}$	Buoyancy $\frac{F_3}{N}$
1 weight					
2 weights					
3 weights					

Evaluation:

14. Calculate the volume of the bodies $V = V_2 - V_1$ and the buoyancy force $F_3 = F_1 - F_2$, and enter the results in table 1.
15. How does buoyancy force change with volume?

___

Student's Sheet 3

16. In the graph in fig. 2, show the buoyancy force F_3 as a function of the bodies' volume.
(1 ml ≙ 1 cm^3)

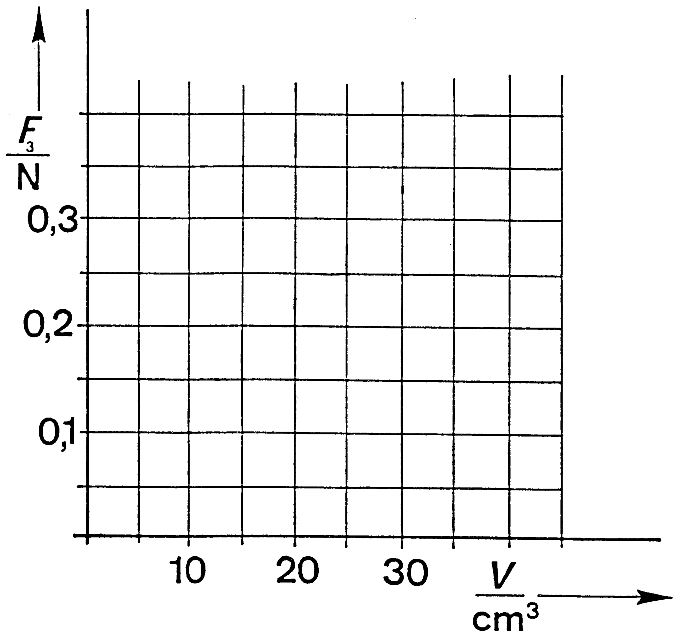


Fig. 2 Buoyancy force F_3 as a function of the volume V of the bodies.

17. What is the relationship of buoyancy force F_3 to volume V?

___

Student's Sheet 1

Archimedes' principle

Assignment: To determine the buoyancy force of a body and compare it with the force due to weight of the displaced water.

Apparatus:

2 stand bases
1 stand rod, 25 cm
1 stand rod, 50 cm
1 sleeve block
1 retaining clip
1 dynamometer, 1,5 N
1 cord
1 aluminium cuboid
1 plastic beaker
1 measuring cylinder

and in addition:
Water

Setup:

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

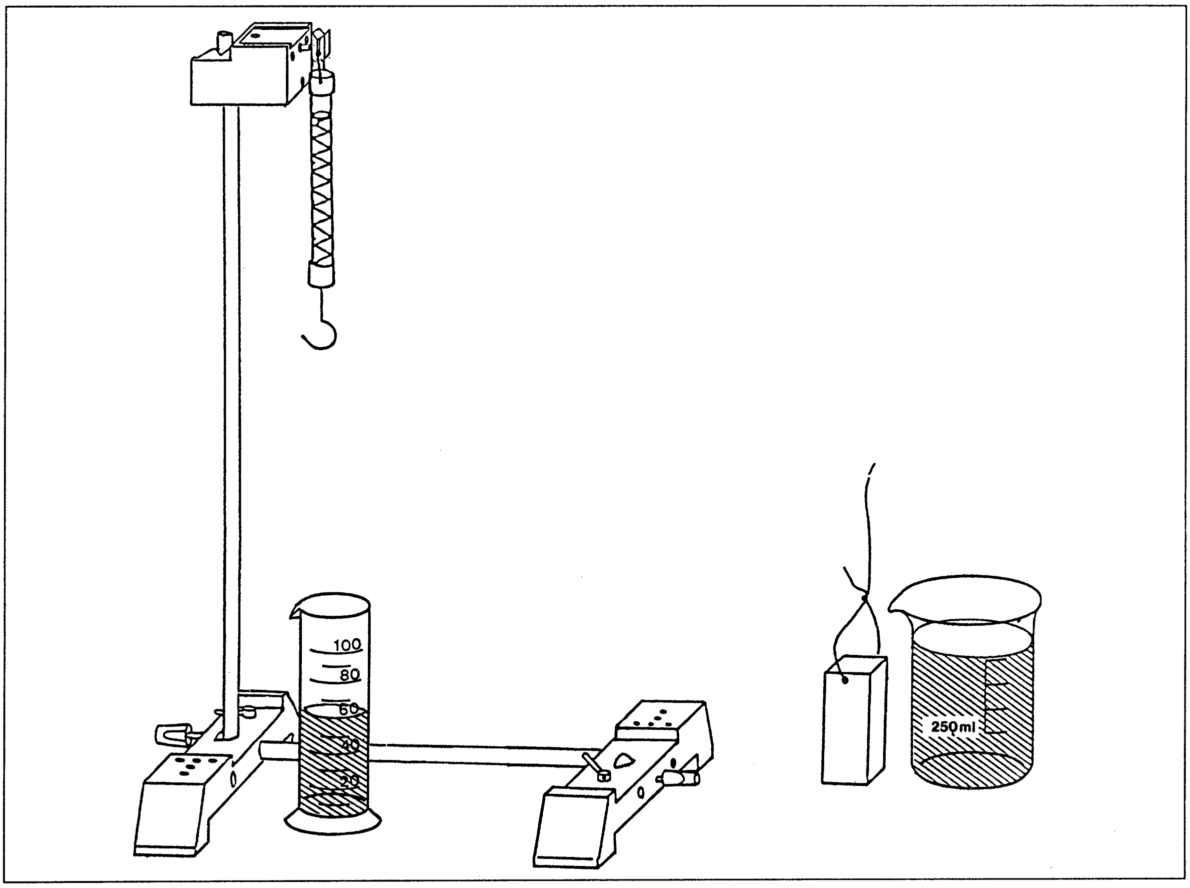


Fig. 1 Setup for determining the buoyancy of a body.

2. Attach the dynamometer to the sleeve block using the retaining clip, and use the cord (ca. 10 cm) to fasten the aluminium cuboid to the dynamometer.

   Make sure that the aluminium cuboid is hanging straight.
3. Put ca. 100 ml of water into the plastic beaker.
4. Pour 60 ml of water into the measuring cylinder.
5. Position the measuring cylinder in such a way that the aluminium cuboid is immersed in the water when the sleeve block is lowered.

Preparing your report:

6. Draw up table 1.

Performing the experiment:

7. Take an exact reading of the water level V_1 in the measuring cylinder and enter the reading in table 1.
8. Determine the force due to weight F_1 of the aluminium cuboid and enter it in table 1.
9. Immerse the aluminium cuboid in the water by lowering the sleeve block. Determine its immersed weight F_2 and enter the reading in table 1.

   Make sure that the cuboid is hanging freely in the water and not touching the sides of the cylinder.
10. Read off the water level V_2 in the measuring cylinder and enter your reading in table 1.
11. Lift the aluminium cuboid out of the water again.

Observations and measurements:

12. Table 1: buoyancy force of the aluminium cuboid in water

Water level	$\frac{V_1}{ml}$	
Force due to weight	$\frac{F_1}{N}$	
Immersed weight	$\frac{F_2}{N}$	
Water level	$\frac{V_2}{ml}$	
Buoyancy force	$\frac{F_3}{N}$	
Volume of displaced water	$\frac{V}{ml}$	

Student's Sheet 3

Evaluation:

13. Calculate the volume V of the aluminium cuboid and the buoyancy force F_3 and enter the results in table 1.

    The following applies:

    The volume of the aluminium cuboid is equal to the volume of displaced water:
    $V = V_2 - V_1$ und $F_3 = F_1 - F_2$

14. What forces are working on the aluminium cuboid in the water and what are they caused by? Label the diagram in fig. 2 to show:

    ____

    ____

    ____

    ____

    ____

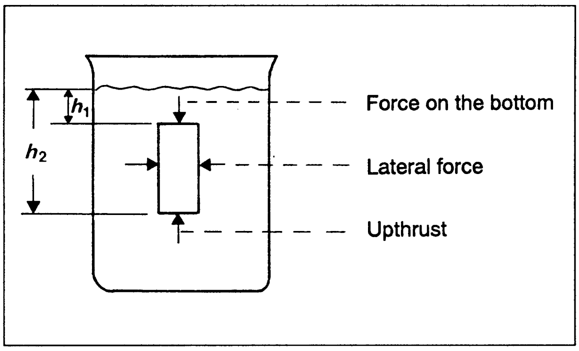


Fig. 2 Forces at work on a body in the water.

15. Calculate the force due to weight F_{water} of the displaced water:

    F_{water} = ____ N

    The following equation applies: $F_{water} = m_{water} \cdot g = \rho \cdot V \cdot g$

    where m_{water} : mass of the displaced water

    g : acceleration due to gravity ($9.81\ m/s^2 = 981\ cm/s^2$)

    ρ : density of water ($1\ g/cm^3$)

    Conversions:

    $1\ ml = 1\ cm^3$ and $1\ \frac{g \cdot cm}{s^2} = \frac{1}{100\,000}\ N = 10^{-5}\ N$

16. What is the relationship between buoyancy force F_3 and force due to weight F_{water} of the displaced water?

    ____

    ____

Sinking – floating suspended in a liquid – floating on a liquid

Assignment: To investigate the conditions in which a body sinks, floats suspended or floats.

Apparatus:

2 stand bases
1 stand rod, 25 cm
1 stand rod, 50 cm
1 sleeve block
1 retaining clip
1 dynamometer, 1.5 N
1 glass beaker
1 plastic beaker
1 round tin
1 rubber ring
1 cord
1 lead shot
1 measuring cylinder
1 test tube

and in addition:
Water

Student's Sheet 2

Setup:

1. Set up the stand as shown in fig. 1. Attach the dynamometer to the sleeve block using the retaining clip.

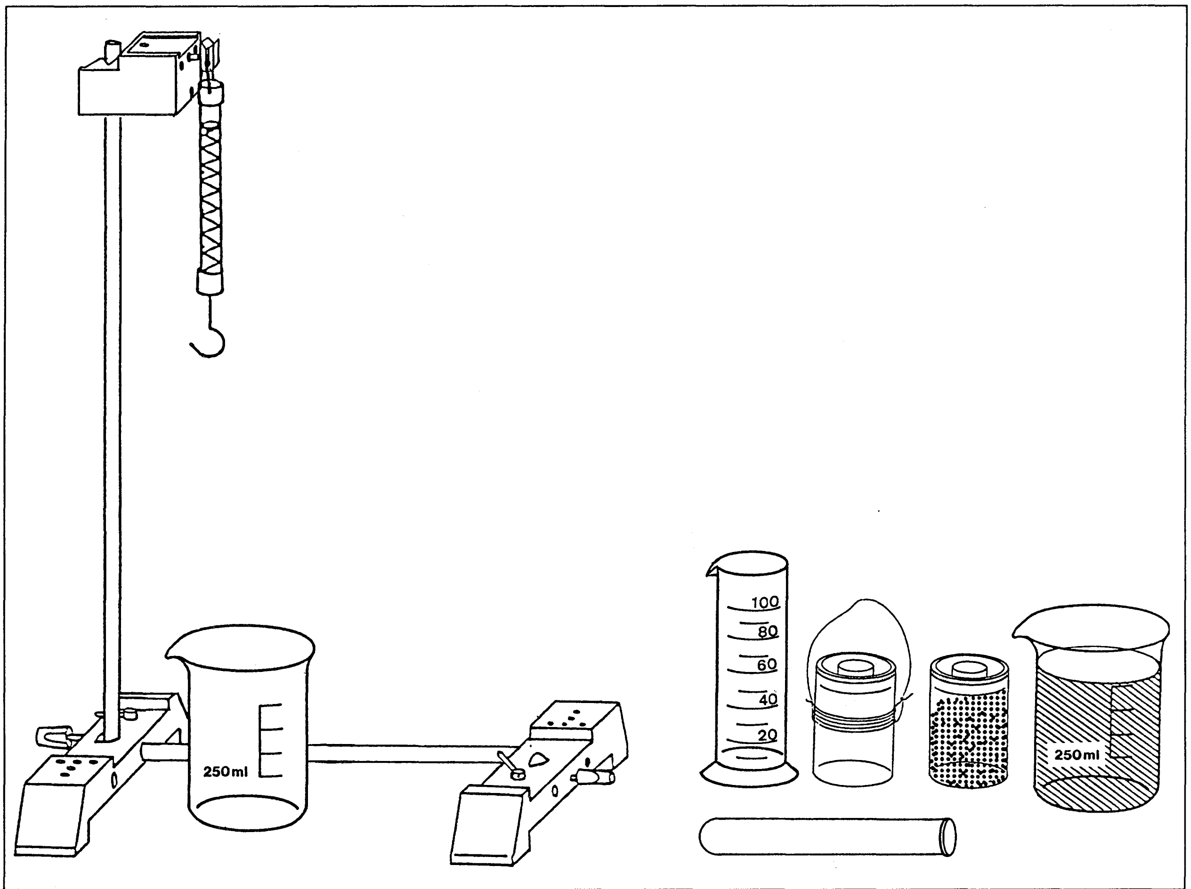


Fig. 1 Setup for investigating sinking, floating and buoyant bodies.

2. Pour ca. 250 ml of water into the glass beaker.
3. Pour precisely 200 ml water into the plastic beaker.
4. Attach the rubber ring and cord to the round tin, as shown in fig. 1.1.
5. Put the lead shot into the round tin and close it.

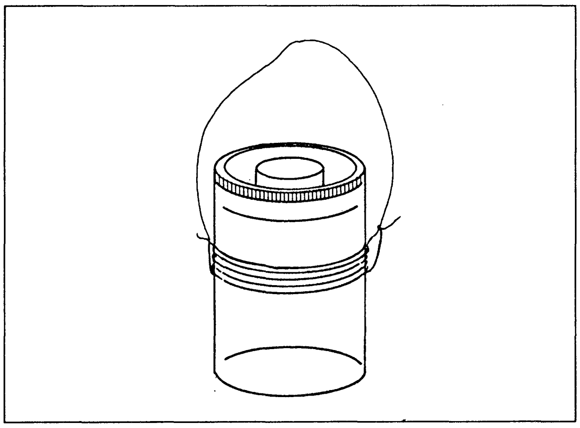


Fig. 1.1 One way of hanging the round tin.

Preparing your report:

6. Draw up tables 1 to 3.

Student's Sheet 3

Performing the experiment

7. Take an exact reading of the water level in the plastic beaker V_1 and enter the reading in table 1.
8. Place the round tin in the plastic beaker. Read off the water level in the plastic beaker V_2 and enter it in table 1.
   Remove the tin from the water.
9. Hang the tin from the dynamometer. Read off its weight F_1 and enter the value in table 2.
10. Take enough lead shot out of the tin so that it floats suspended in the water.
11. Hang the tin from the dynamometer. Read off its weight F_1 and enter the value in table 2.
12. Empty out all the lead shot.
13. Hang the tin from the dynamometer. Read off its weight F_1 and enter the value in table 2.
14. Immerse the tin in the water. Enter your observations in table 2.
15. Fit the rubber ring and the cord round the test tube (as shown in fig. 2).
16. Hang the test tube from the dynamometer. Read off its weight F_1 and enter the value in table 3.
17. Pour exactly 80 ml of water into the measuring cylinder. Enter the water level V_1 in table 3.
18. Place the test tube in the measuring cylinder.
    Observe its behaviour and enter your observations in table 3.
19. Read off the water level V_2 and enter the reading in table 3.

Observations and measurements:

20. Table 1: determining the round tin's buoyancy force

Water level	$\frac{V_1}{\text{ml}}$	
Water level	$\frac{V_2}{\text{ml}}$	
Volume of the body	$\frac{V}{\text{ml}}$	
Buoyancy force of the tin in the water	$\frac{F_3}{\text{N}}$	

21. Table 2: behaviour of the round tin with different masses

Force due to weight $\frac{F_1}{\text{N}}$	Buoyancy force $\frac{F_3}{\text{N}}$	Behaviour in water
		The body sinks
		The body floats suspended in the water
		The body

Student's Sheet 4

22. Table 3: the test tube ______

Weight of the tube	$\frac{F_1}{N}$	
Water level	$\frac{V_1}{ml}$	
Water level	$\frac{V_2}{ml}$	
Displaced volume	$\frac{V}{ml}$	
Buoyancy force	$\frac{F_3}{N}$	

Evaluation:

23. Calculate the volume of the round tin $V = V_2 - V_1$ and then calculate the buoyancy force $F_3 = \rho \cdot V \cdot g$. Enter your readings in tables 1 and 2.

where:

ρ : density of water (1 g/cm^3)

g : acceleration due to gravity (9.81 m/s^2)

Conversions: 1 ml = 1 cm^3 and $1 \frac{\text{g cm}}{\text{s}^2} = \frac{1}{100\,000}$ N

24. *Summarise your observations:*

A body sinks if

____

A body floats suspended in the water if

____

A body rises to the surface if

____

25. Calculate the volume of liquid $V = V_2 - V_1$ displaced by the floating test tube and the buoyancy force F_3 and enter your findings in table 3.

Work out the buoyancy force F_3 as shown in step 23.

26. What condition must be fulfilled if a body is to float ?

____

27. How great is the mass of water displaced by a ship ?

____

Calculating density from volume and mass

Assignment: To determine the density of liquids by measuring their volume and mass.

Apparatus: 1 measuring cylinder, 100 ml
in addition:
1 balance
Water
Salt
Sugar
Milk

Setup:

1. Lay out the apparatus ready for use, as shown in fig. 1.

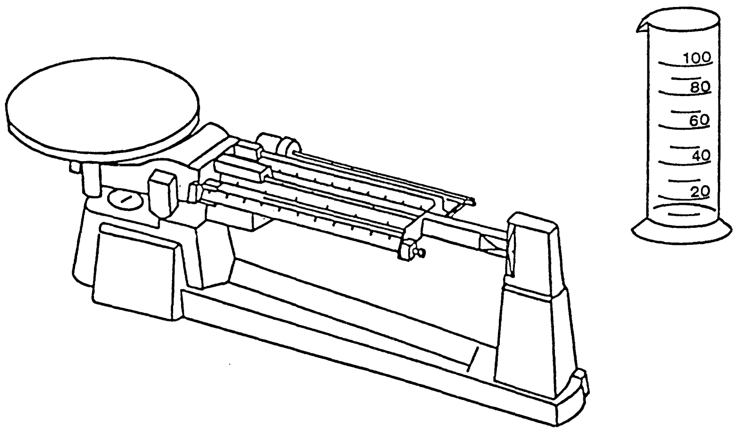


Fig. 1 Experimental apparatus

2. Adjust the balance.
3. Place the measuring cylinder on the balance.
4. Set the balance to "0" using the tare compensator.

Student's Sheet 2

Preparing your report:

5. Draw up table 1.

Performing the experiment:

6. Fill the measuring cylinder with exactly 100 ml of water.
7. Determine the mass *m* of the water and enter the result in table 1.
8. Perform the same experiment using various salt and sugar solutions, as well as milk.

Observations and measurements:

9. Table 1: mass and density of various fluids
   Volume V = 100 ml = 100 cm^3

Fluid	Mass m $\frac{m}{g}$	Density ρ $\frac{g}{cm^3}$
Water		
Saline solution I (10%)		
Saline solution II (20%)		
Sugar solution I (10%)		
Sugar solution II (20%)		
Milk (3.5 % fat content)		

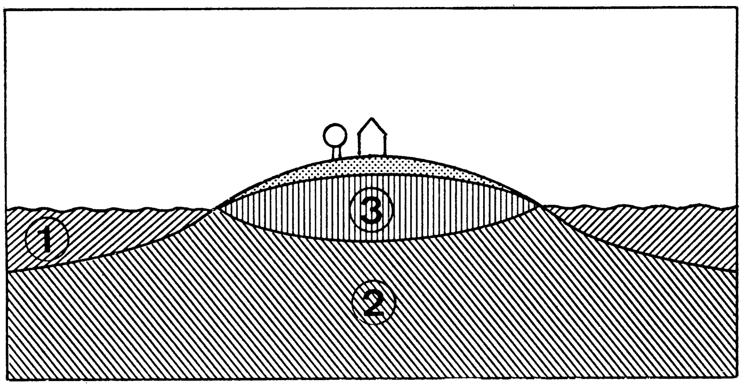
Student's Sheet 3

Evaluation:

10. Calculate the density of the various liquids and enter the results in table 1.

$$\rho = \frac{m}{V}$$

11. Rainwater causes so-called fresh water lenses to build up underneath islands in the sea. Why does this water not intermingle with the salty ground water?



① **Sea water**

② **Salty ground water**

③ **Fresh water lens**

Fig. 2 Fresh water lenses beneath an island in the sea.

The hydrometer

Assignment: To determine the depth of immersion of a hydrometer in various liquids.

Apparatus:

2 stand bases
1 stand rod, 25 cm
1 stand rod, 50 cm
1 double socket
1 universal clamp
1 plastic pipe, ∅ 25 mm
1 stopper without a hole
1 plastic pipe, ∅ 8,5 mm
2 pipe caps
1 lead shot
1 measuring cylinder

in addition:
Paper strip (2 cm x 25 cm)
Water
Salt
Sugar
Milk

Student's Sheet 2

Setup:

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

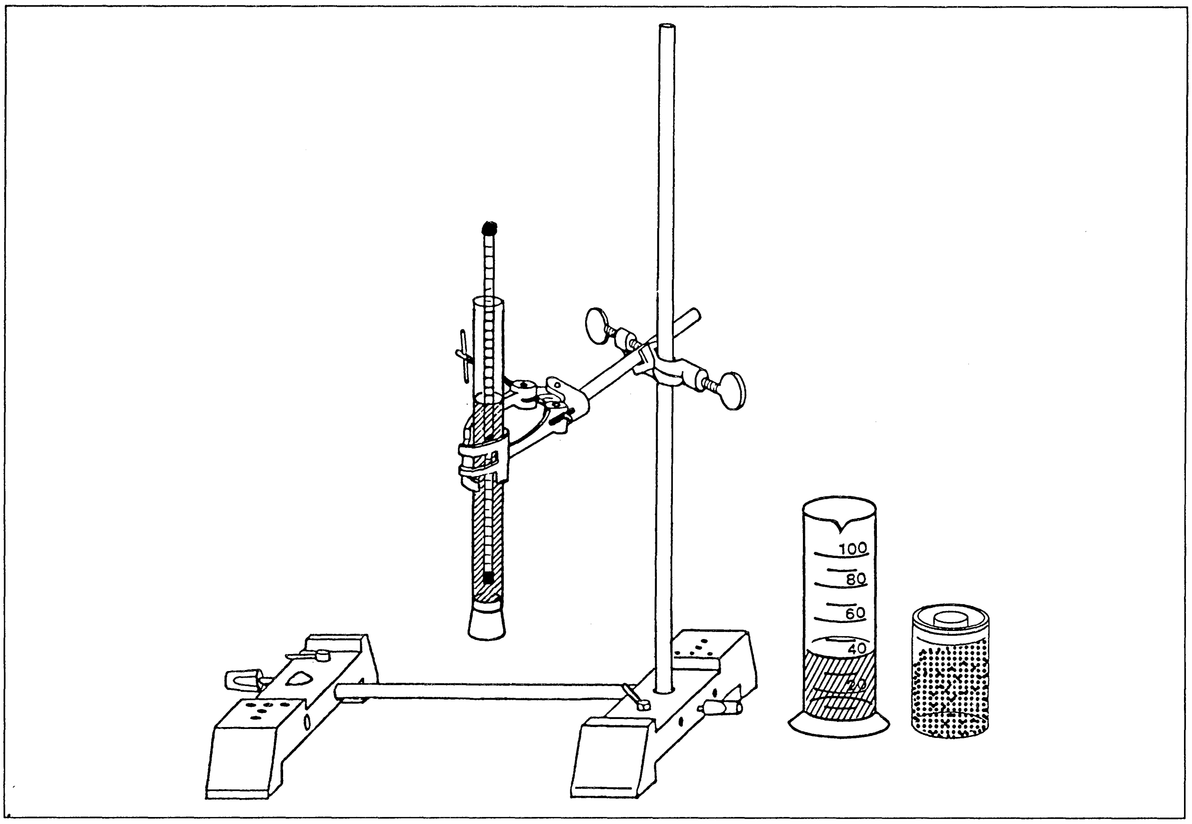


Fig. 1 Setup for determining density using a hydrometer.

2. Draw a scale on the paper strip, as shown in fig. 1.1.
3. Slide the scale into the narrow pipe.

   Hint:

   Roll the scale round the narrow pipe or a pencil before you insert it, so that it is slightly curved. Slide the strip right into the pipe.
4. Fit the lower sealing cap firmly in place, so that no fluid can penetrate into the pipe.
5. Fill up the pipe with lead shot (20 balls) and fit the top cap in place.
6. Seal the large pipe with the stopper and clamp it in the universal clamp.
7. Pour 60 ml of water into the measuring cylinder so that it is ready for use.

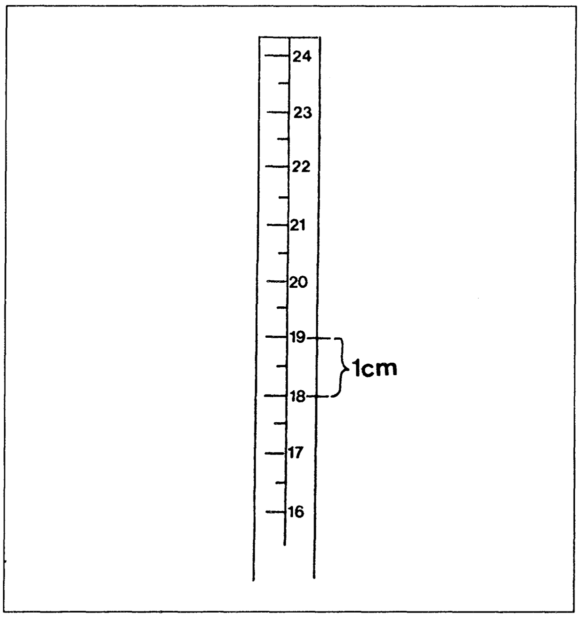


Fig. 1.1

Preparing your report:

8. Draw up table 1.

Student's Sheet 3

Performing the experiment:

9. Pour 60 ml of water into the pipe.
10. Immerse the model hydrometer you have constructed and read off the depth of immersion *h* (fig. 2). Enter your reading in table 1. The model hydrometer should not touch the sides of the large pipe, or you will have difficulty taking your readings.
11. Perform the same experiment with various saline and sugar solutions, as well as with milk.

    After experimenting with each solution, rinse out and dry the pipe.

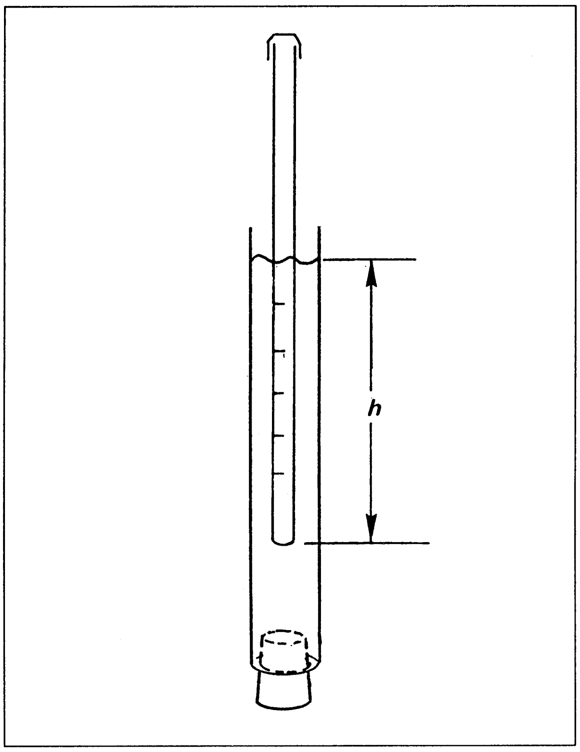


Fig. 2 Reading the depth of immersion *h* of the hydrometer.

Observations and measurements:

12. Table 1: depth of immersion of the hydrometer

Fluid	Depth of immersion *h*	Density ρ $\frac{g}{cm^3}$
Water		1.00
Saline solution I (10%)		
Saline solution II (20%)		
Sugar solution I (10%)		
Sugar solution II (20%)		
Milk (3,5 % fat content)		

Evaluation:

13. Determine the density ρ of the fluids from the depth of immersion h and enter the results in table 1.

The following applies: $\rho_2 = \rho_1 \cdot \frac{h_1}{h_2}$

where

ρ_2 : density of the solution

ρ_1 : density of water ($1 \frac{g}{cm^3}$)

h_1 : depth of immersion in water

h_2 : depth of immersion in the solution

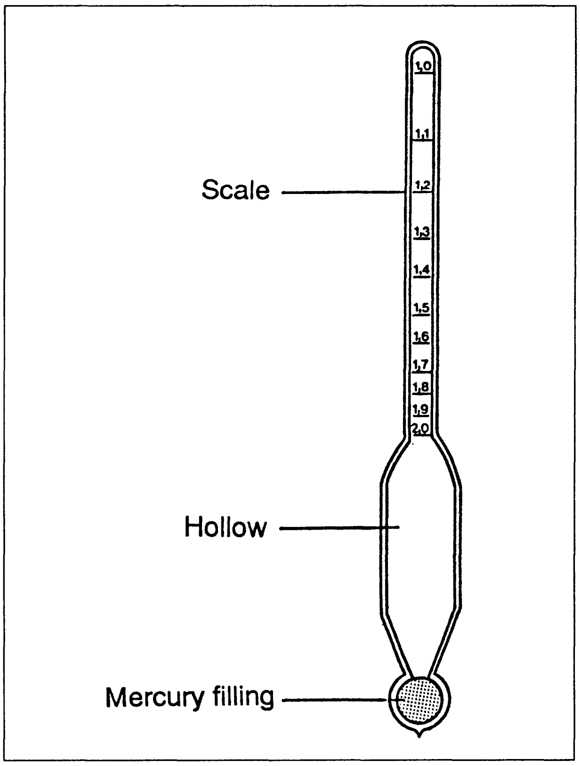


Fig. 3 Hydrometer

Surface tension

Assignment: To investigate the behaviour of bodies at the water's surface.

Apparatus: 1 glass beaker
in addition:
Water
Paper clips
Drop of detergent

Setup:

1. Pour 200 ml of water into a beaker so that it is ready for use.
2. Unbend two paperclips as shown in fig. 1, so they are completely straight.

   Hint:

   You can also use other items of apparatus as experimental objects, e.g. aluminium discs.

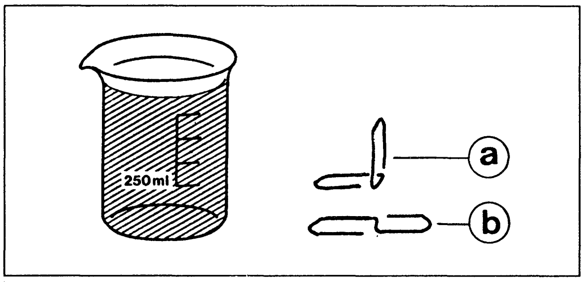


Fig. 1 Investigating surface tension
(a) Support
(b) Object under investigation

Preparing your report:

3. Copy out steps 10 to 12.

Student's Sheet 2

Performing the experiment:

4. Using the support (fig. 1 **(a)**), carefully place the extended paper clip (fig. 1 **(b)** object under investigation) on the surface of the water, as shown in fig. 2.
5. Note down your observations under step 10.
6. Carefully let one drop of detergent fall into the water. Observe the paper clip.
7. Note down your observations under step 11.
8. Try to place the paper clip on the surface of the water again.
9. Note down your observations under step 12.

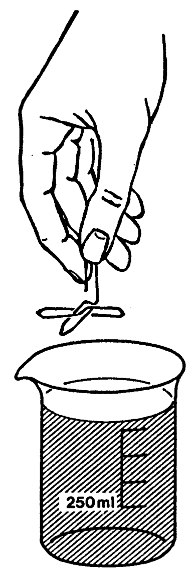


Fig. 2 Using the support to move the object under investigation.

Observations:

10. The paper clip (object under investigation)

____

11. As soon as you put detergent in the water,

____

12. Once the surface of the water has been reduced by the detergent, .

____

Evaluation:

13. How do you know that the paper clip (object under investigation) has a greater specific gravity than water?

____

14. Explanation for the observation under step 10:

____

Student's Sheet 3

15. The phenomenon you have just observed is known as surface tension. What is the effect of the detergent on this surface tension?

___

Capillary action

Assignment: To investigate the behaviour of water in narrow tubes.

Apparatus:

1 capillary device
1 balance pan
1 tape measure
1 plastic beaker
1 universal marker

in addition:
1 powdered dye
1 piece of chalk
Water

Setup:

1. Lay out the apparatus ready for use, as shown in fig. 1.

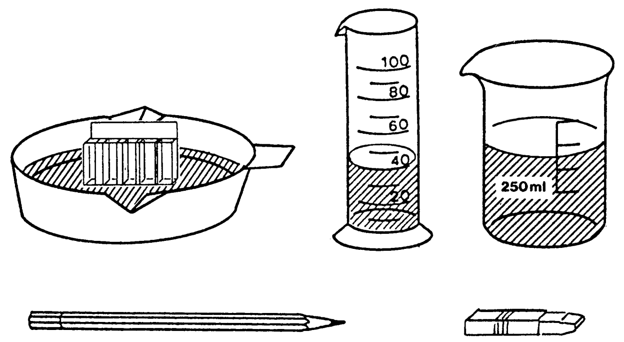


Fig. 1 Investigating capillary action.

2. Pour out ca. 100 ml of water into the plastic beaker so that it is ready for use.
3. Pour a little water into the balance pan.

Preparing your report:

4. Copy out step 13 and table 1.

Performing the experiment:

5. Pour a drop of tinted water onto the workbench.
6. Place one end of the chalk in the water.
7. Note down your observations under step 13.

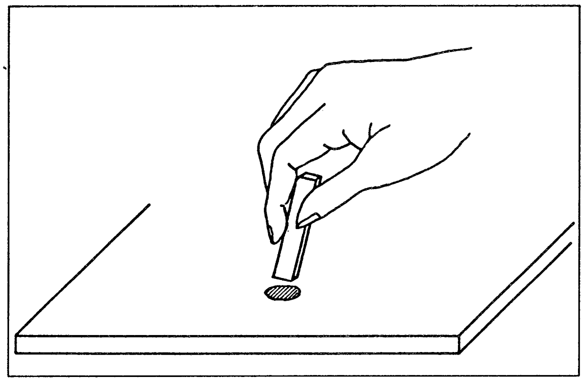


Fig. 2 The chalk makes contact with a drop of water.

8. Place the capillary device in the balance pan.
9. Note down the level of the liquid in the balance pan and in the individual tubes (fig. 3).
10. Take the capillary device out of the balance pan and dry it off.
11. Rinse out the capillary device in the beaker, dry it off and blow any residual fluid out of the tubes.
12. Repeat steps 8 to 10 twice more.
    Measure the capillary rise *h* in the various tubes and enter the results in table 1.

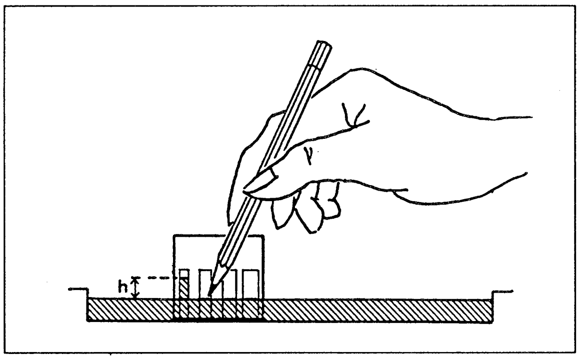


Fig. 3 Marking the liquid levels.

Observations and measurements:

13. The fluid

____

14. Table 1: capillary rise in the various tubes

Diameter of tube	$\frac{d}{\text{mm}}$	1	2	3	4
Measurement 1	$\frac{h}{\text{mm}}$				
Measurement 2	$\frac{h}{\text{mm}}$				
Measurement 3	$\frac{h}{\text{mm}}$				
Mean value	$\frac{h}{\text{mm}}$				

Evaluation:

15. Enter the values in the diagram in fig. 4.

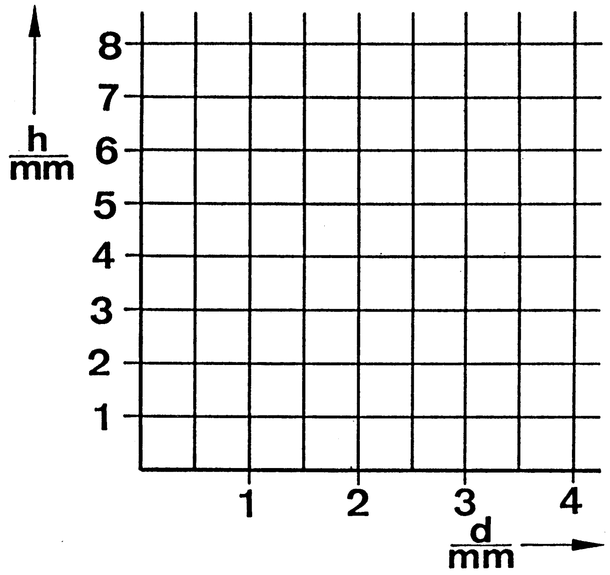


Abb. 4 Diagram showing how capillary rise depends on the diameter of the tubes.

16. The tubes are also known as capillary tubes or simply capillaries, because they have a very small diameter.
    What can you say about the capillary rise in a capillary?

    ____

17. Why does fluid rise up a piece of chalk; how is it absorbed by a sponge?

    ____

18. Examples of capillary action:

    ____

Complete list of apparatus (subject area "Measuring techniques and the properties of material bodies")

Maximum number	Description	Cat. No.	Apparatus required in experiment											Number supplied in STM apparatus set		
			1	2	3	4	5	6	7	8	9	10	11	BMC1	BMC2	MEC1
2	Stand base	301 21				(1)	2	2						2		
1	Stand rod, 25 cm	301 26	1			(1)	1							1		
2	Stand rod, 50 cm	301 27	1			(1)	1	1						2		
1	Sleeve block	301 25	1											2		
1	Double socket	301 09				(1)	1							1		
1	Universal clamp	666 555				(1)								1		
1	Pair of pointers	301 29									1			1		
1	Cord	200 70 322				1		1			1		1	1		
1	Weights, 6 pcs	340 85				1		1	1		1		1	1		
1	Aluminium cuboid	362 32		1	1	1	1		1	1				1		
1	Tape measure	311 78	1	1	1	1		1						1		
1	Small funnel	309 83						1							1	
1	Measuring cylinder, 100 ml	590 08	1	1	1	1		1	1		1	1			1	
1	Glass beaker, 250 ml	664 130				1	1	1	1		1	1			1	
1	Silicone tube, 7/10 mm, 1 m	667 194					1								1	
1	Vernier caliper	311 52	1	1	1					1						1
1	Plastic pipe, 25 mm ⌀	665 240		1		1	1									1
1	Stopper without a hole	667 257				1	1									1
1	Dynamometer, 1.5 N	314 01											1			
1	Leaf spring	352 051			1								1			
	Paper strip, self-adhesive					1										
1	Stopwatch, e.g.	313 07						1								
1	Single-pan balance	315 07							1	1	1	1				
	alternatively:															
1	School and laboratory balance	315 23							1							
	advisable:															
1	Overflow vessel	362 04				(1)										
1	Pair of scissors, e.g.	667 017					1									

Complete list of apparatus (subject area: "liquids")

Maximum number	Description	Cat.-No.	Apparatus required in experiment													Number supplied in STM apparatus set		
			12	13	14	15	16	17	18	19	20	21	22	23	24	BMC1	BMC2	MEC1
2	Stand base MF	301 21	2	2	2	2	2		2	2	2		2			2		
1	Stand rod, 25 cm	301 26	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			2		
1	Sleeve block	301 25		1		1	1		1	1	1					2		
1	Double socket S	301 09	1		1								1			1		
	Universal socket	666 615														1		
1	Universal clamp	666 555	1		1								1			1		
	Pair of pointers	301 29														1		
1	Universal marker	309 45													1	1		
1	Cord	200 70 322				1	1			1	1					1		
2	Retaining clips	314 04		2		1	1		1	1	1					3		
1	Tape measure	311 78		1			1								1	1		
	Double scale	340 82														1		
1	Set of 6 weights (max. 3 pcs)	340 85				(2)	(1)		(3)							6		
1	Aluminium cuboid	362 32				1				1						1		
	Metal plate	200 65 559														1		
1	Double tube holder	200 69 370	1	1	1												1	
2	Plastic pipe, 8,5 mm ⌀	200 69 648	2	2	1								1				2	
2	Pipe caps	200 69 649			1								2				4	
1	Small funnel	309 83	1	1	1												1	
1	Measuring cylinder	590 08					1	1	1	1	1	1	1				1	
1	Test tube from	664 042									(1)						1	
1	Plastic beaker, 250 ml	664 123	1		1	1	1	1	1	1	1						1	
1	Glass beaker, 250 ml	664 130		1							1			1			1	
1	Tube connector, 6 … 8 mm ⌀	665 226	1														1	
1	Silicone tube, 1 m	667 194	1	1													1	
1	Stopper with hole	200 69 304	1														1	
1	Round tin with lid	200 69 647				1	1	1			1						1	
1	Vernier caliper	311 52																1
1	Dynamometer, 1.5 N	314 01				1	1		1	1	1							1
1	Dynamometer, 3 N	314 02																1
	Knockout spindle, 5,5 cm	340 811																1
	Lever with pointer	340 831																1
1	Balace pan with stirrup	342 47													1			1
	Set of weights 1–50 g	590 27																1
	Load hook	340 87																1
	Coupler plug	340 89																1
1	Rubber rings	340 90				(1)	(1)				(1)							10
	Pulley, plug-in, 50 mm ⌀	340 911																2
	Pulley, plug-in100 mm ⌀	340 921																2
	Pulley bridge	340 930																2

Complete list of apparatus (subject area: "liquids") – cont.

Maximum Number	Description	Cat.-No.	Apparatus required in experiment													Number supplied in STM apparatus set		
			12	13	14	15	16	17	18	19	20	21	22	23	24	BMC1	BMC2	MEC1
	Inclined plane S	341 221																1
	Leaf spring	352 051																1
	Helical spring, 5 N, 0.1 N/cm	352 07																1
	Helical spring, 5 N, 0.25 N/cm	352 08																1
1	Manometric capsule for hydrostatics	362 301		1														1
1	Capillary device	362 36													1			1
1	Lead shot in tin, 100 g	362 351				1	1	1			1		1					1
1	Plastic pipe, 250 mm x 25 mm ⌀	665 240	1		1								1					1
1	Stopper without a hole	667 257			1								1					1