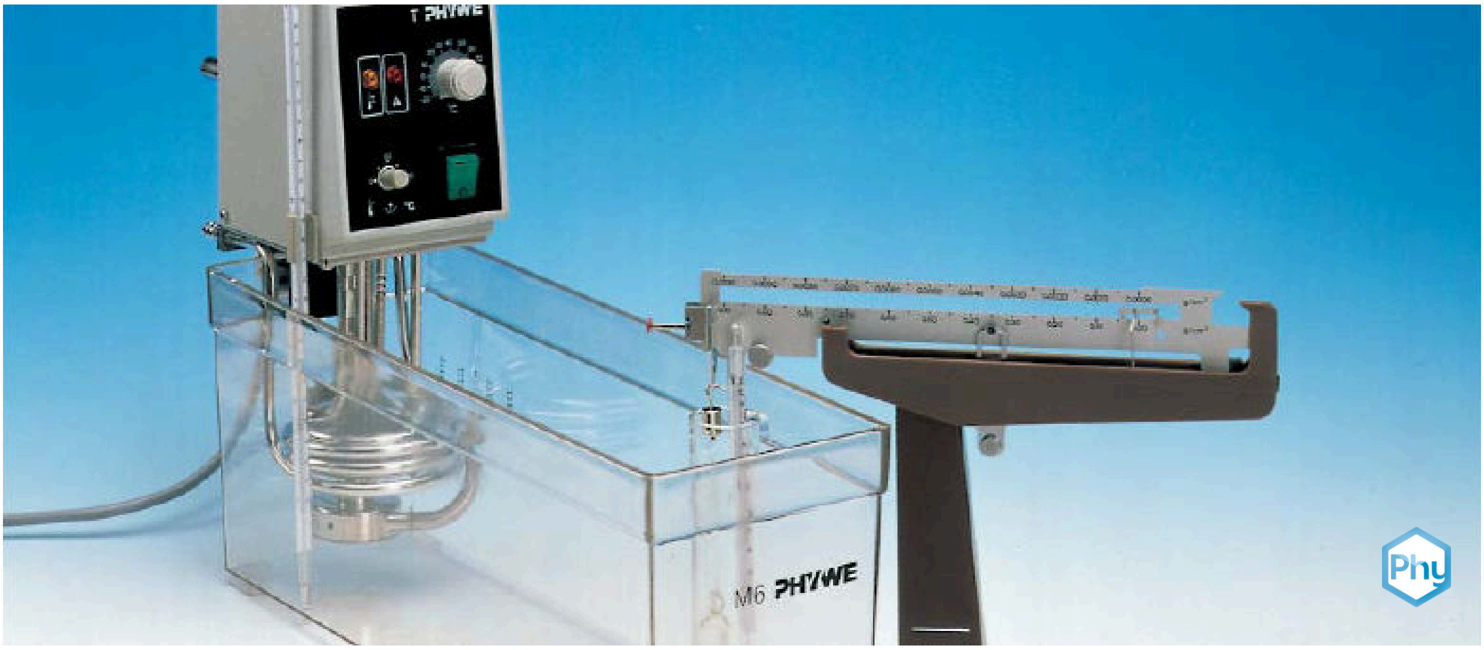
Density of liquids



P2140100

Physics | Mechanics | Mechanics of liquids & gases

Applied Science | Engineering | Applied Mechanics | Fluiddynamics & Aerodynamics

Difficulty level	Group size	Preparation time	Execution time
easy	1	10 minutes	10 minutes

This content can also be found online at:

http://localhost:1337/c/603b98cd1b5b1900032c0d2f

General information

Application

Submarine

Density is an important principle when it comes to buoyancy, which determines whether an object will float or sink in a liquid. It can be seen for example in ships and submarines.

If the ballast tanks of a submarine are filled with air, the tanks weigh less than an equal volume of water and this enables it to float. As the submarine dives, the air is removed from the tanks and water is vented into the tanks. When the submarine's density is higher than water, it begins to dive.

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Other information (1/2)

Prior knowledge

Density is defined as mass per unit volume:

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

Scientific principle

The density of water and glycerol is determined as a function of temperature using the Mohr balance.

Other information (2/2)

Learning objective

Understanding the influence of the temperature change towards the density of liquids.

Tasks

The density of water and glycerol is measured in 1 to 2° steps over a temperature range from 0 to 20 °C, then in larger steps up to 50 °C.

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Safety instructions

For this experiment the general instructions for safe experimentation in science lessons apply.

For H- and P-phrases please consult the safety data sheet of the respective chemical.

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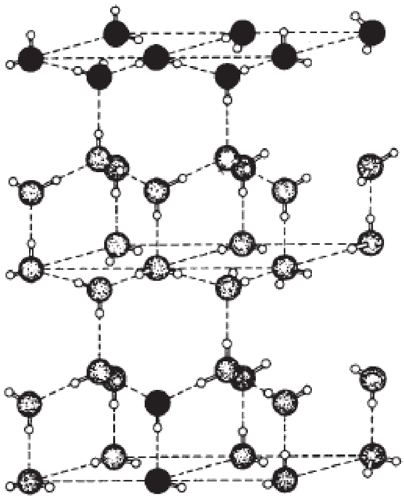
Theory (1/2)

The mutual forces between the molecules of a liquid decrease rapidly with the distance between them. There are, therefore, only small regions with a crystal-like structure (close array) but no long range order. In ice, every atom of oxygen is surrounded by 4 hydrogen atoms in a tetrahedral arrangement.

Two hydrogen atoms are bound by valency forces and are thus closer (10 nm) to the oxygen atom than the two hydrogen atoms bound by the hydrogen bond (17 nm).



Crystal lattice of ice

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Equipment

Position	Material	Item No.	Quantity
1	Westphal/ Mohr density balance	45016-02	1
2	Immersion thermostat Alpha A, 230 V	08493-93	1
3	External circulation set for thermostat Alpha A	08493-02	1
4	Cooling coil for thermostat Alpha A	08493-01	1
5	Bath for thermostat, makrolon	08487-02	1
6	Glycerol, 250 ml	30084-25	2
7	Water, distilled 5 l	31246-81	1
8	Sodium chloride, 500 g	30155-50	1
9	Tubing connector, ID 6-10mm	47516-01	2

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Theory (2/2)

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The arrangement of the water molecules in ice is not the dense packed. On transition to the liquid state a part of the hydrogen bond is broken and the molecules move closer together, which explains the fact that the density of water increases initially as the temperature rises. Chains and rings of molecules also exist in the liquid state.

Glycerol is one of the glass-like substances: it has no sharp melting point, but softens gradually on heating. The density of liquids generally decreases as the temperature increases, so long as there. are no other effects at work as in the case of water.

The coefficient of expansion α can be calculated from the relationship measured between density and temperature, the loss on evaporation being disregarded (boiling point at normal pressure: water 100 °C, glycerol 290.5 °C).

$$\alpha = \frac{1}{V} \cdot \frac{\partial V}{\partial T} = \frac{1}{\rho} \cdot \frac{\partial \rho}{\partial T}$$

Equipment

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Setup and procedure

Setup

Experimental set-up

The experiment set-up is shown in the figurre.

The liquid studied is placed in a glass beaker and its temperature adjusted by the water bath. The circulating pump of the thermostat ensures rapid temperature equilibrium. By addition of NaCl a temperature close to 0 °C can be achieved.

The temperature in the glass beaker is measured with a thermometer.

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Procedure

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The experiment begins with iced water. The temperature of the water bath is raised gradually by switching the heating on for a short time (approx. 30 seconds). From 20 °C the desired temperature can be set on the thermostat, and this is kept constant by a controller.

The density of the liquid is measured by the buoyancy method using the Mohr balance (the operating instructions describe how this works and how to adjust it). The density of the liquid can be accurately measured at 4 points ($\rho < 2\, g/cm^3$) by means of weights in the ratio 1 :10 : 100 : 1000 and ten marked points on the balance beam at which the weights are attached in order to compensate for the buoyancy. This degree of accuracy is required in order to demonstrate the H_2O anomaly.

Evaluation (1/4)

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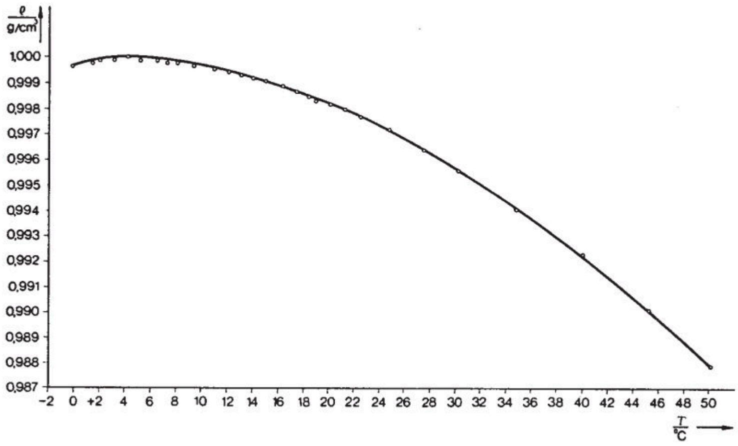

Density of water as a function of temperature

The value obtained for water at 20 °C is:

$\alpha = 0.19 \cdot 10^{-3} / K^{-1}$

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Evaluation (2/4)

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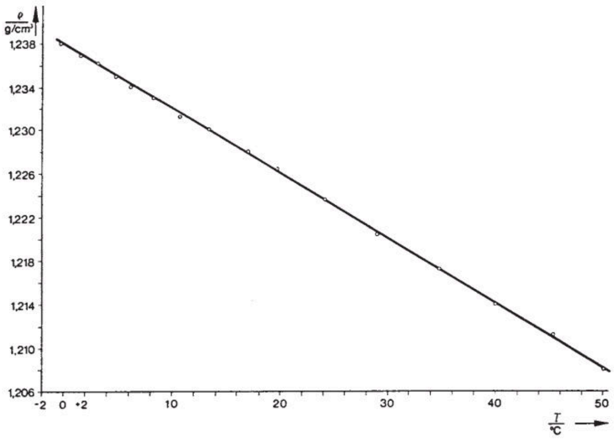

Density of glycerol as a function of temperature

In the case of glycerol, is virtually independent of temperature over the range measured:

$$\alpha = 0.49 \cdot 10^{-3} / K^{-1}$$

Evaluation (3/4)

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Fill in the blanks:

Thermal expansion explains the ______ of thermal energy between materials by the ______ of particles. The changes of ______ between particles influence the volume of the material and hence change its ______.

- density
- transfer
- collisions
- space

Check

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