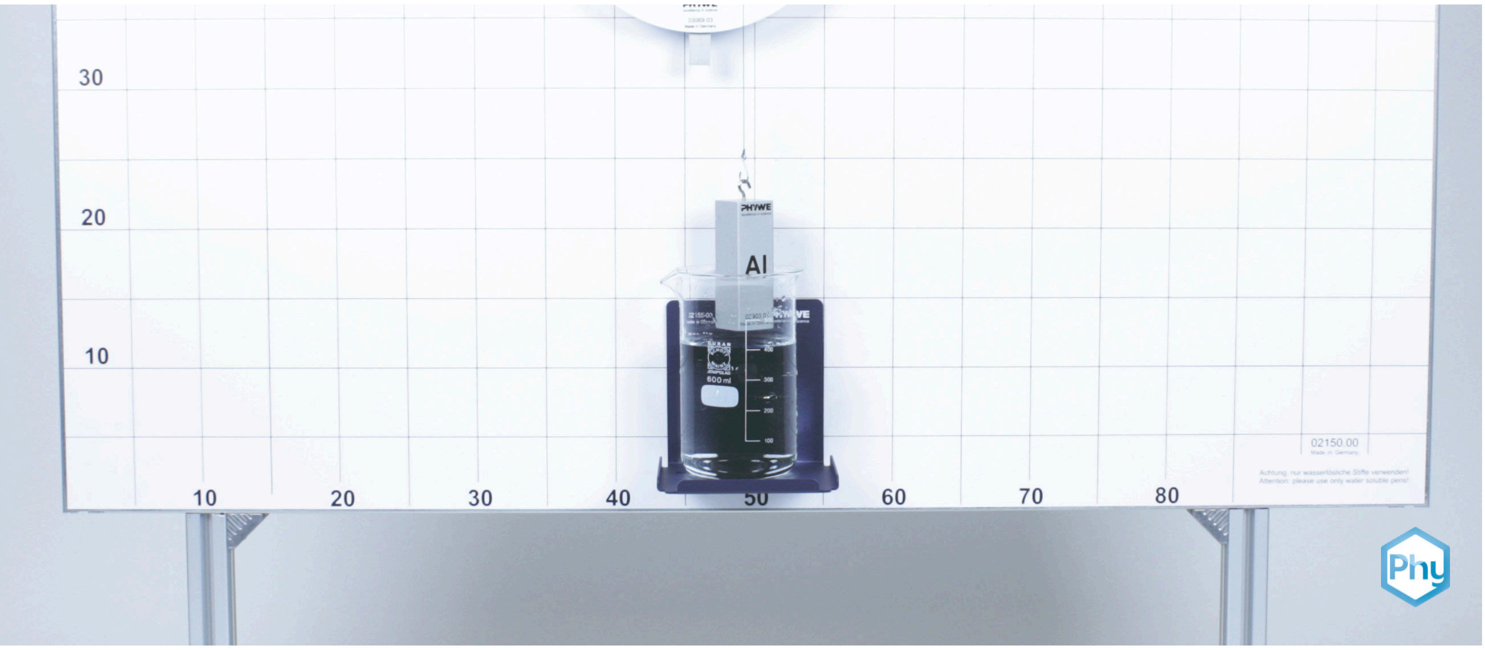
Density determination by measuring the buoyancy



P1297300

Physics | Mechanics | Mechanics of liquids & gases

Difficulty level	Group size	Preparation time	Execution time
medium	-	10 minutes	10 minutes

This content can also be found online at:

http://localhost:1337/c/66d8307af284a400027dc679

General information

Application (1/2)

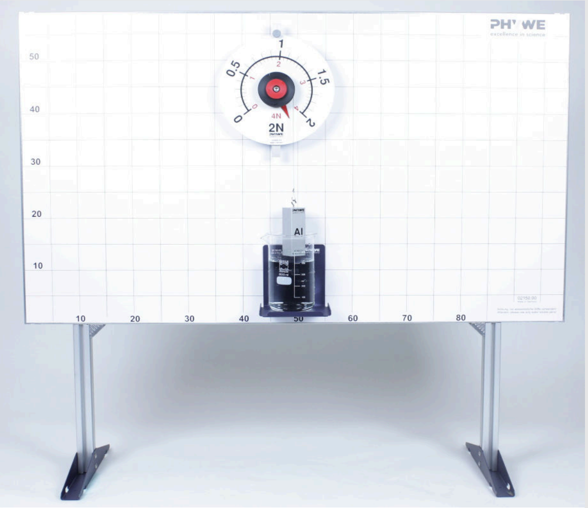


Fig. 1: Experimental setup

According to Archimedes' principle, the density of solid and liquid substances can be determined by their buoyancy.

This principle is used, for example, in a hydrometer. The hydrometer is a measuring device for determining the density or specific weight of liquids. This is based on Archimedes' principle: a body is immersed in a liquid until the weight of the displaced liquid corresponds to the weight of the immersed body.

Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Application (2/2)

PHYWE

This has two consequences:

1. The lower the density of the liquid, the further a body of the same weight is immersed in it. (Hydrometer)
2. If a body is supposed to sink to a certain point in liquids of different densities or different specific weights, its weight must be artificially increased to the same extent as the density increases. (Density meter)

Other information (1/2)

PHYWE

Prior knowledge

The students should have prior knowledge of "Archimedes' principle" and buoyancy.

Principle

The aim is to show how the density of solid and liquid substances can be determined by measuring buoyancy according to Archimedes' principle.

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Other information (2/2)

PHYWE

Learning objective

The students are supposed to learn how to determine density by measuring buoyancy and get a deeper understanding of Archimedes' principle.

Tasks

The students should determine the density of solid and liquid substances by measuring the buoyancy. In addition, they can determine the density according to the obtained density (ρ) to determine the substances.

Safety instructions

PHYWE

The general safety instructions for experimentation in science lessons apply.

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Theory (1/2)

The density of a homogeneous substance is defined by the ratio of its mass m and its volume V:

$$\rho = m/V$$

Before the density (ρ) is determined, the mass (m) and the volume (V) should be known.

Theory (1/2)

1st experiment: Determining the density of solids

The mass (m) can be known by the buoyancy force. When a body floats, two forces act on it: the weight force (F_G) which pulls it downwards, and the the upward buoyancy force (F_A). This means that the body is only immersed in the liquid until the two forces equalise.

Therefore applies:

$$F_A = F_G \rightarrow \rho_{F_l} \cdot A \cdot h \cdot g = m \cdot g$$

The volume can be determined by the mass of the displaced water.

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Theory (2/2)

2nd experiment: Determining the density of liquid substances

The volume (V) is known. And the mass (m) can be determined by the buoyancy force because, according to Archimedes' principle, a body experiences an upward force equal to the weight of the fluid it displaces when it is completely or partially immersed in a fluid.

Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Equipment

Position	Equipment	Item no.	Quantity
1	PHYWE Demo Physics board with stand	02150-00	1
2	Torsion dynamometer	03069-03	1
3	Support plate on fixing magnet	02155-00	1
4	Sinker, aluminium	03903-01	1
5	Beakers, Boro, high form, various sizes (600 ml)	46029-00	1
6	Glycerine, 250 ml	30084-25	2
7	Screw clamp	02014-01	2

Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Setup and procedure

Setup and procedure (1/2)

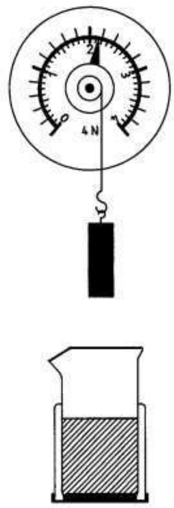


Fig. 2

1st experiment

- Place the torsion dynamometer on the upper edge of the demo board.
- Suspend the sinker and measure and record its weight in air ($F_{G,L}$).
- Place the support plate underneath the sinker at the bottom edge of the board and place the beaker with approx. 400 ml of water on it (Fig. 2).
- Lower the dynamometer with the sinker until the latter is completely immersed in the water.
- Measure the force $F_{G,W}$ with which the sinker now pulls on the dynamometer and note $F_{G,W}$.

Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Setup and procedure (2/2)

Fig. 3

2nd experiment

- Leave the setup as in experiment 1 but now replace the water in the beaker with ethanol.
- Lower the torsion dynamometer with the sinker attached until it is completely immersed in the alcohol.
- Measure the force $F_{G,Sp}$ with which the sinker pulls on the dynamometer and note $F_{G,Sp}$.
- Add glycerol to the beaker instead of ethanol and determine the force $F_{G,Gl}$ in the same way.

Evaluation

Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

PHYWE

Evaluation

Observation

PHYWE

1st experiment

$F_{G,L} = 2,15N$

$F_{G,W} = 1,35N$

2nd experiment

$F_{G,Sp} = 1,47N$

$F_{G,Gl} = 1,19N$

$F_{G,L} = 2,15N$

$V = 82cm^3$

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Evaluation (1/3)

PHYWE

1st attempt

The buoyancy force acting on the sinker is

$F_a = F_{G,L} - G_{G,W} = 0,8N$

F_A is equal to the weight of the water displaced by the immersed body according to Archimedes' law. The mass of the displaced water is therefore $m_W = 82g$ (1^ N = 102 g) and its volume is $V_W = 82cm^3$. The sinker therefore has the volume $V = V_W = 82cm^3$ and because of $F_{G,L} = 2,15N$ the mass is $m = 219g$.

For the required density of aluminium this results in:

$\rho = m/V = 219g/82cm^3 = 2,7g/cm^3$

This corresponds to the table value.

Evaluation (2/3)

PHYWE

Liquid	V/cm^3	F_A/N	m/g	$\frac{\rho}{g/cm^3}$
Water	82	0,80	82	1,00
Ethanol	82	0,68	69	0,84
Glycerol	82	0,96	98	1,20

Tab. 1

The value measured in experiment 1 for $F_{G,L}$ as well as the one calculated for the volume $V (V = V_W = V_{Sp} = V_{Gl})$ are accepted as results. Now the buoyancy force F_A for ethanol and glycerol and the from this resulting masses of the displaced liquids are calculated and finally the densities.

It is advisable to summarise all the results from experiments 1 and 2 in a table (see Table 1):

$m = F_G/g$,

$\rho = m/V$

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Evaluation (3/3)

PHYWE

Within the scope of the measurement accuracy the results agree well with the table values for the densities :

$\rho_{Sp} = 0,85 g/cm^3$,

$\rho_{Gl} = 1,20 g/cm^3$.

Notes (1/2)

PHYWE

1st experiment

To simplify matters and within the limits of measurement accuracy, it can be assumed that 1 N corresponds to the weight force acting on a body with the mass $m = 100g$and the evaluation facilitated:

$F_A = 0,80N \rightarrow m_W = 80g \rightarrow V_W = V = 80cm^3$;

$F_{G,L} = 2,15N \rightarrow m = 215$;

$\rho = m/V = 215g/80cm^3 = 2,7g/cm^3$.

If the students do not know that the sinker is made of aluminium, in addition to the determination of ρ the experiment can also be used to determine the possible material of the sinker. In this case the symbol on the sinker should be taped over before the experiment.

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de