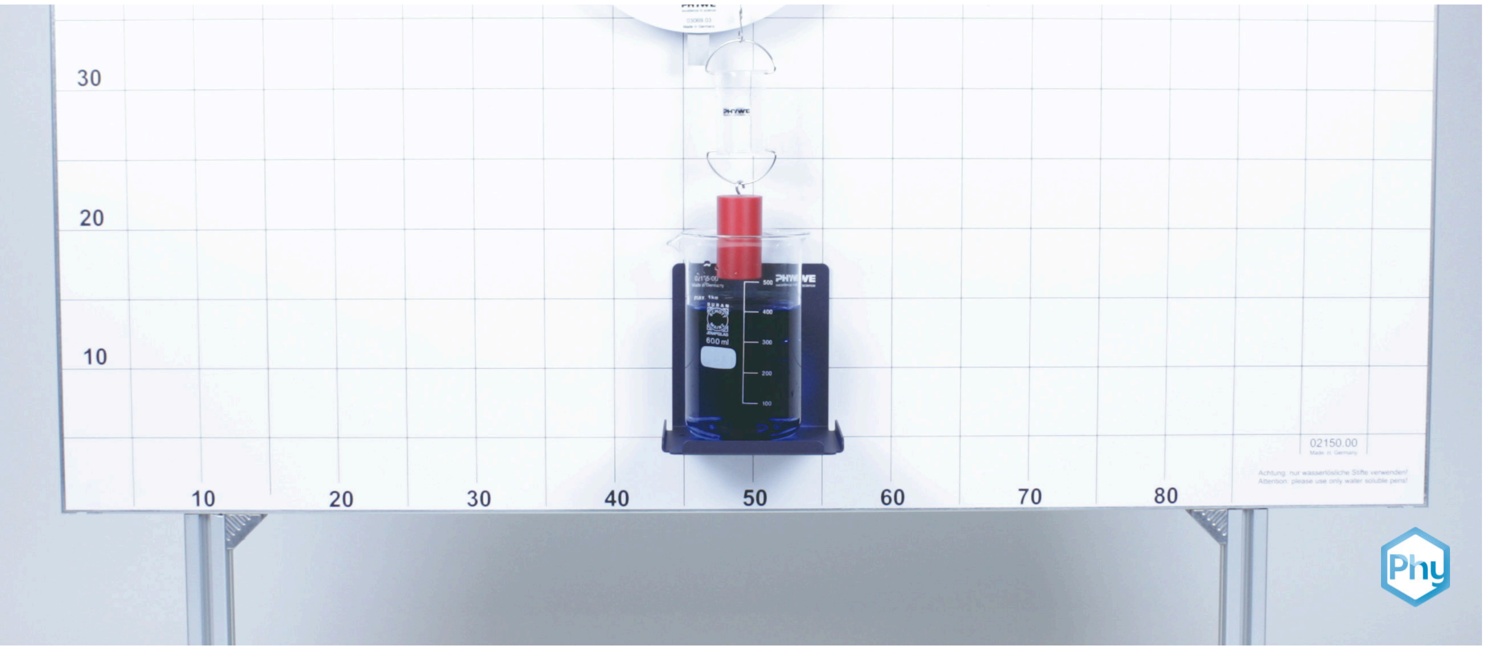
Archimedes' principle



P1297200

Physics > Mechanics > Mechanics of liquids & gases

Difficulty level	Group size	Preparation time	Execution time
medium	-	10 minutes	20 minutes

This content can also be found online at:

http://localhost:1337/c/66d81eee18d9350002b0b70b

General information

Application

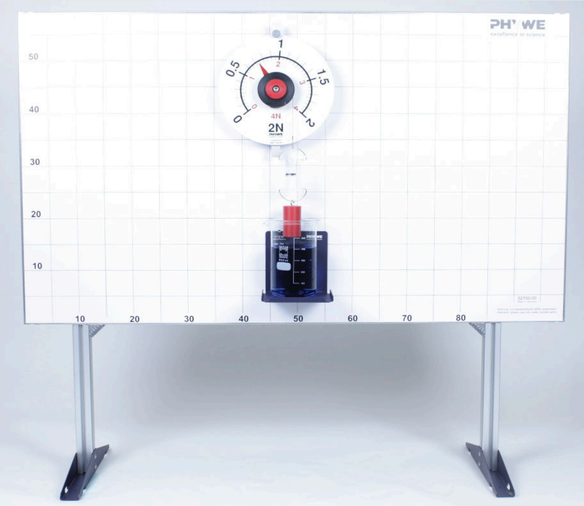


Fig. 1: Experimental setup

Why does a ship float even though it is so heavy? Archimedes' principle describes this fact.

When a body is fully or partially immersed in a fluid, it experiences an upward force equal to the weight of the fluid it displaces.

This was discovered by the famous Greek mathematician and scholar Archimedes. The principle can explain why large ships can sail on the ocean. The reason is that they displace water and thus gain buoyancy. A ship submerges until it has displaced enough water for sufficient buoyancy.

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Other information (1/2)

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Prior knowledge

The students should have prior knowledge of Archimedes' principle and the buoyant force. It is an advantage if the students know the relationship between the hydrostatic pressure and the weight force in Archimedes' principle.

Principle

The aim is to show that solid bodies immersed in liquids experience buoyancy and how the buoyant force can be calculated.

Other information (2/2)

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Learning objective

The students are supposed to understand Archimedes' principle extensively. The students are supposed to be familiarised with the buoyant force in this experiment. The students also learn how to calculate the buoyant force.

Tasks

In this experiment, the students should first observe the measurement data from the solid cylinder, hollow cylinder and weight force on the dynamometer. The students should be familiar with Archimedes' principle and understand the buoyant force. At the end, the students learn how to calculate the buoyant force.

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Safety instructions

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The general safety instructions for experimentation in science lessons apply.

Theory (1/2)

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Archimedes' principle is defined by the following fact:

If a body is completely or partially immersed in a fluid, it experiences an upward force equal to the weight of the fluid it displaces.

This is about an "upward force" - the buoyant force. The buoyant force is a force opposing gravity that acts on a body in a medium such as liquid and gas. The amount of buoyant force acting on the body is equal to the amount of the weight of the displaced medium.

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Theory (2/2)

The force of gravity (F_g) and buoyancy force (F_A) together determine the situation of a body in liquid:

1. $F_g > F_A$: The body will sink

2. $F_g > F_A$: The body will rise

3. $F_g = F_A$: The body will float in the submerged position

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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	Hollow and solid cylinder	02637-00	1
5	Beakers, Boro, high form, various sizes (600 ml)	46029-00	1
6	Beaker, 100 ml, plastic (PP)	36011-01	1
7	Patent blue-V, 25 ml	48376-05	1
8	Microspoon, steel	33393-00	1
9	Screw clamp	02014-01	2

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Setup and procedure

Setup and procedure (1/2)

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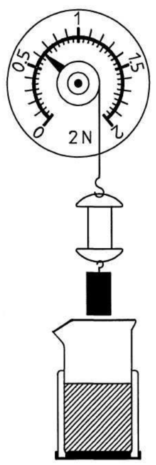

Fig. 2

- Attach the dynamometer to the top of the demo panel.
- Demonstrate that the solid cylinder fills the hollow cylinder exactly.
- Attach the hollow cylinder to the dynamometer and set its pointer to zero.
- Attach the solid cylinder to the hollow cylinder and determine its weight force $F_{G,L}$; note $F_{G,L}$ (1).
- Attach the plate to the lower edge of the demo board and place the beaker with 400 ml of coloured water on it. (Fig. 2)
- Lower the dynamometer until the solid cylinder is completely immersed in the water and measure and note $F_{G,w}$ (2).

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Setup and procedure (2/2)

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- Fill the beaker with about 50 ml of coloured water and pour from it into the hollow cylinder until it is full to the brim.
- Measure and note the weight force F_G (3) displayed now.

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Evaluation

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Observation

1. $F_{G,L} = 0,64N$

2. $F_{G,W} = 0,20N$

3. $F_G = 0,64N$

Evaluation (1/2)

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The force with which the solid cylinder pulls on the dynamometer in the air is $F_{G,L} = 0,64N$ and decreases by $0,44\ N$ when the solid cylinder is immersed. The reason for this is the buoyant force F_A which acts in the water and is directed vertically upwards, i.e. counteracts the force of weight.

If the solid cylinder is completely immersed in water, the buoyant force is exactly the same as the weight force acting on the water held by the hollow cylinder. However, this is exactly the weight of the water displaced by the solid cylinder.

The following therefore applies: $F_A = F_{G,L} - F_{G,L}$,

and because of $V_{Vollz.} = V_{Hohlz.} = V_W = V_{F1}$

it follows that: $F_A = V_K \cdot \rho_{F1} \cdot g$

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Evaluation (2/2)

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with the parameters:

V_K = volume of the immersed body = volume of the displaced liquid,

ρ_{F1} = density of the liquid,

g = gravitational acceleration.

The equation for F_A is called Archimedes' law (traditionally also Archimedes' principle): The buoyant force acting on a body immersed in a liquid is equal to the weight of the liquid displaced by the body.

Notes (1/3)

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The buoyant force F_A results from the pressure forces acting on the submerged body, which are proportional to the height of the liquid column. The lateral pressure forces on the body compensate each other. The upward pressure force F_u acting on the lower boundary surface is larger than the one above F_o .

These surfaces are the same for the solid cylinder, so the following applies:

$$F_A = F_u - F_o = p_u \cdot A - p_o \cdot A = (p_u - p_o) \cdot A$$

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Notes (2/3)

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Because of $p = \rho \cdot g \cdot h$ for the upward buoyancy force follows in general:

$$F_A = \rho \cdot g \cdot h \cdot A(h_u - h_o) = \rho \cdot g \cdot A \cdot h$$

whereby h is height of the cylinder.

Thus the following applies:

$$F_A = \rho \cdot g \cdot V = \rho_{F1} \cdot g \cdot V_K .$$

Notes (3/3)

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Archimedes' law also applies if only part of the body is immersed in a liquid. With $\triangle V_K$ as the volume of the immersed part the following applies:

$$F_A = \triangle V_K \cdot \rho_{F1} \cdot g.$$

A body sinks in the liquid if $F_A < F_{G,L}$, rises in the liquid if $F_A > F_{G,L}$, floats, if $F_A = F_{G,L}$ and swims, if $F_A = \triangle V_K \cdot \rho_{F1} \cdot g = F_{G,L}$

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