Archimedes' Principle (Item No.: P1297200)

Curricular Relevance

Area of Expertise: Physik
Education Level: Klasse 7-10
Topic: Mechanik
Subtopic: Mechanik der Flüssigkeiten
Experiment: Archimedisches Prinzip

Difficulty
Intermediate

Preparation Time
10 Minutes

Execution Time
20 Minutes

Recommended Group Size
1 Student

Additional Requirements:

Experiment Variations:

Keywords:

Principle and equipment

Principle

It is to be shown first that a solid body immmersed in a liquid is buoyed up, and then how the buoyant force can be calculated.

Set-up

Position No.	Material	Order No.	Quantity
1	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	02636-00	1
5	Glass beaker DURAN®, tall, 600 ml	36006-00	1
6	Beaker, low form, plastic, 100 ml	36011-01	1
7	Patent Blue V (sodium salt), 25 g	48376-04	1
8	Microspoon, steel	33393-00	1

Set-up and procedure

- Fit the torsion dynamometer onto the demo-board.
- Demonstrate that the hollow cylinder exactly fills the solid cylinder.
- Hang the hollow cylinder on the dynamometer and set the dynamometer to zero.
- Hang the solid cylinder on the hollow cylinder and determine the weight force $F_{G,L}$ of it; note $F_{G,L}$ (1).
- Position the shelf at the lower edge of the demo-board and place the glass beaker containing 400 ml of coloured water on it (Fig. 1).
- Lower the dynamometer until the solid cylinder is completely immersed in the water; measure $F_{G,w}$ and note the value of it (2).
- Pour about 50 ml of coloured water into the beaker, and so much in the hollow cylinder, that it is full to the brim.
- Measure the weight force F_G now displayed and note it (3).

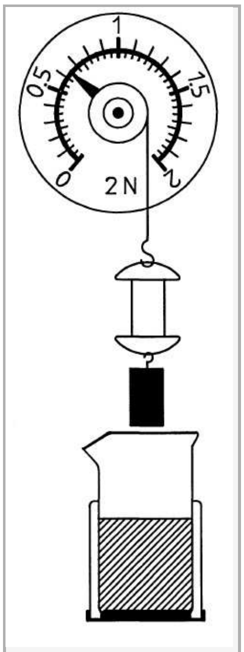

Fig. 1

Observations and evaluation

Observations

1. $F_{G,L} = 0.64N$
2. $F_{G,W} = 0.20N$
3. $F_G = 0.64N$

Evaluation

The pulling force which the solid cylinder exerts on the dynamometer is $F_{G,L} = 0.64N$ in air, and decreases on lowering the solid cylinder into water by 0.44 N. The cause of this is the buoyant force F_A which is in effect in water and is directed from vertically below, i.e. opposite to the weight force.

When the solid cylinder is completely immersed in water, the buoyant force is exactly the same as the weight force which acts on the water that the hollow cylinder contains. This is, however, exactly the weight force of the water displaced by the solid cylinder.

We therefore have:

$$F_A = F_{G,L} - F_{G,W} \text{ ,}$$

and because

$$V_{solid} = V_{hollow} = V_W = V_{Fl}$$

we have:

$$F_A = V_K * \rho_{Fl} * g$$

where

V_K = The volume of the immersed body

= The volume of displaced liquid,

ρ_{Fl} = The density of the liquid,

g = The acceleration due to gravity.

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

Remarks

The buoyant force F_A results from the pressure forces which act on the immersed body and are proportional to the height of the liquid column. The pressure forces acting sideways on the body compensate each other. The upwardly directed pressure force F_u which acts on the bottom boundary area is larger than that acting on top F_o.

These areas are equal for the solid cylinder, so that:

$$F_A = F_U - F_O = p_U * A - p_O * A = (p_U - p_O) * A$$

Because $p = \rho * g * h$ it follows that, in general for the upwardly directed buoyant force:

$$F_A = \rho * g * h * A(h_U - h_O) = \rho * g * A * h \text{ ,}$$

where h is the height of the cylinder.

We therefore have:

$$F_A = \rho * g * V = \rho_{Fl} * g * V_K \text{ .}$$

Archimedes' Law is also valid when only a part of the body is immersed in a liquid. Using ΔV_K as the volume of the immersed part, we have:

$$F_A = \Delta V_K * \rho_{Fl} * g$$

A body

sinks down in the liquid, when $F_A < F_{G,L}$,

rises up in the liquid, when $F_A > F_{G,L}$,

floats, when $F_A = F_{G,L}$ and

swims, when $F_A = \Delta V_K * \rho_{Fl} * g$

$= F_{G,L}$