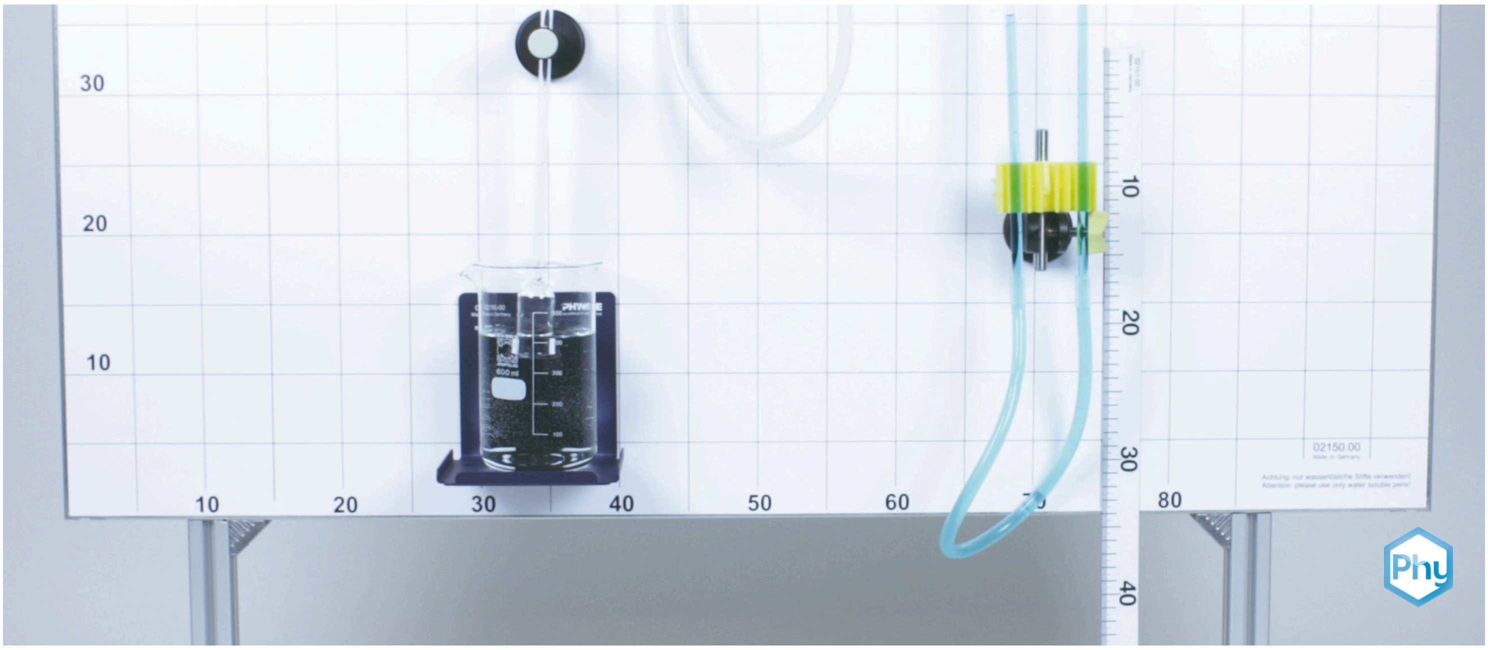
Hydrostatic pressure



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/66bc4ef7cebcd40002cdd796

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General information

Application

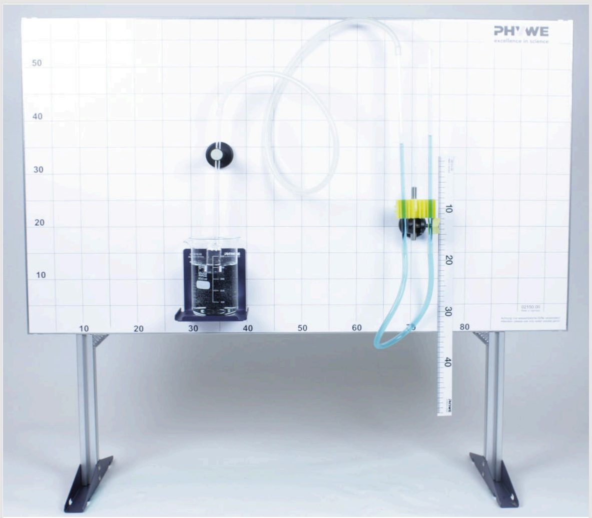

Fig. 1: Experimental setup

Hydrostatic pressure is the pressure within a fluid at equilibrium, which arises due to gravitational interaction between the fluid particles and the earth. The term is not only used for water, but also for other liquids and even gases.

All divers will already be familiar with the term "hydrostatic pressure". During a dive, the diver's body becomes heavier and heavier the deeper he goes into the water. Even at a shallow diving depth of just one metre, the hydrostatic pressure is already noticeable in the ears. This is why humans cannot dive to unlimited depths.

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Other information (1/2)

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Prior knowledge

Students should have knowledge of hydrostatic pressure. It is also important to know "Pascal's Law".

Principle

It will be demonstrated that the hydrostatic pressure depends on the immersion depth h and the density ρ of a liquid and what relationship exists between the pressure p and the sizes h and ρ.

Other information (2/2)

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Learning objective

The students are supposed to understand hydrostatic pressure. In this experiment, the correlation between the pressure p and the sizes h and ρ is to be shown exemplary to the students.

Tasks

The task of this experiment is to determine the relationship between the pressure p and the sizes h and ρ.

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Safety instructions

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The general safety instructions for experimentation in science lessons apply.

Theory

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Hydrostatic pressure is the pressure within a fluid at equilibrium that arises due to the gravitational interaction between the fluid particles and the earth.

Hydrostatic pressure has the same value in all directions within a fluid and always acts vertically on any surface that is in contact with the fluid.

This is about "Pascal's law". According to Pascal's law, the hydrostatic pressure for a fluid with a constant density in a homogeneous gravitational field can be calculated as follows

$$p(h) = \rho \cdot g \cdot h + p_0$$

$\rho =$ Density, $g =$ Gravity acceleration, $h =$ Height of the liquid level above the point under consideration, $p_0 =$ Pressure at the liquid surface, $p(h) =$ Hydrostatic pressure in relation to of the height of the liquid level

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Equipment

Position	Equipment	Item no.	Quantity
1	PHYWE Demo Physics board with stand	02150-00	1
2	Clamp on fixing magnet	02151-01	1
3	Hook on fixing magnet	02151-03	1
4	Clamping holder, 0-13 mm, fixing magnet	02151-07	1
5	Scale for demonstration board	02153-00	1
6	Pointers f. Demonst.Board, 4 pcs	02154-01	1
7	Support plate on fixing magnet	02155-00	1
8	Immersion probe	02632-00	1
9	U-tube manometer	03090-00	1
10	Beakers, Boro, high form, various sizes (600 ml)	46029-00	1
11	Silicone tubing, various diameters (7 mm)	39296-00	1
12	Funnel, diameter = 50 mm, plastic (PP)	36890-00	1
13	Beaker, 100 ml, plastic (PP)	36011-01	1
14	Microspoon, steel	33393-00	1
15	Patent blue-V, 25 ml	48376-05	1
16	Glycerine, 250 ml	30084-25	3
17	Marker, black	46402-01	1
18	Screw clamp	02014-01	2

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Setup and procedure

Setup (1/2)

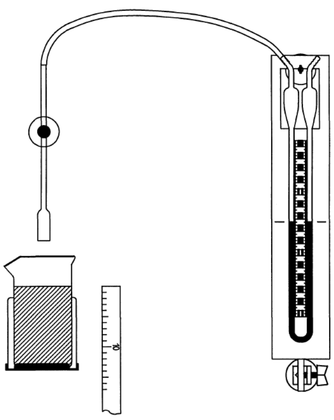

Fig. 2

- Place the U-tube manometer on the demo board using the clamp and secure it with the hook on the fixing magnetic.
- Attach a piece of silicone tubing approx. 50 cm long to the left leg of the manometer.
- Colour the water in the beaker and carefully fill the U-tube about half way with it through the funnel (to avoid large air bubbles).
- If there are still air bubbles in the hose or manometer, squeeze the hose to remove them.
- Attach the support plate next to the manometer at the bottom edge of the board.

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Setup (2/2)

- Place the clamping holder above the support plate and attach the immersion probe.
- Push the free end of the hose onto the tube of the immersion probe.
- Use a foil pen to mark the height of the water columns (lower edge of the menisci) on the U-tube (see Fig. 2)

Procedure (1/2)

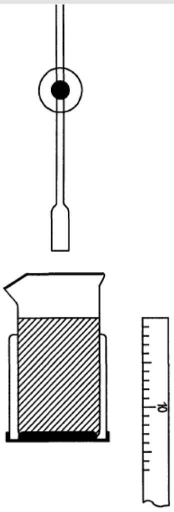

Fig. 3

- Place the beaker with about 600 ml of water on the support plate.
- Lower the clamp holder with the immersion probe until the edge of the bell is about 2 cm below the water level.
- Place the scale next to the beaker on the board and use a pointer to demonstrate the immersion depth.
- For the exact measurement of the immersion depth h use a suitable transparent ruler; note that h is the distance between the lower edge of the meniscus of the water in the beaker and at the lower edge of the immersion probe.
- Measure the height difference on the manometer h_M between the lower edges of the menisci of the water columns.
- Note the measured values in Table 1.

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Procedure (2/2)

- After loosening the clamp of the clamp holder, lower the immersion probe further step by step, e.g. by about 2 cm at a time.
- Measure h and h_M in each case and enter the measured values.
- Exchange the water in the beaker first with ethyl alcohol and then glycerine, determine a series of measured values for h and h_M and note the results in tables 2 and 3.

Observations (1/3)

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The table shows the height of the probe in the water in cm in the first column, the difference in height of the probe in the water in cm in column two and the quotient of the height of the probe divided by the difference in height of the probe in column three.

h / cm	h_m / cm	h_m / h
2,0	2,1	1,05
4,3	4,4	1,02
6,8	6,7	0,99
8,7	8,8	1,01
11,5	11,5	1,00

Tab. 1 : Water

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Observations (2/3)

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The table shows the height of the probe in the alcohol in cm in the first column, the difference in height of the probe in the alcohol in cm in column two, and the quotient of the height of the probe divided by the difference in height of the probe in column three.

h / cm	h_m / cm	h_m / h
2,9	2,4	0,83
5,5	4,6	0,84
7,7	6,5	0,84
10,2	8,6	0,84
12,4	10,6	0,85

Tab. 2 : Ethy alcohol

Observations (3/3)

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The table shows the height of the probe in the glycerine in cm in the first column, the height difference of the probe in the glycerine in cm in column two, and the quotient of the height of the probe divided by the height difference of the probe in column three.

h / cm	h_m / cm	h_m / h
2,4	3,0	1,25
4,7	5,6	1,19
7,1	8,6	1,21
9,8	11,8	1,20
12,2	14,8	1,21

Table 3: Glycerine

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Evaluation (1/3)

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In a shared coordinate system, the values for h_M as a function of h for water, ethyl alcohol and glycerine (Fig. 4) are shown. There are three straight lines through the origin of the coordinates, which have different slopes: The increase is greatest for the glycerine and smallest for the ethyl alcohol.

The following applies to every liquid:

$h_M \sim h$ or $h_M/h = konstant.$

This is corroborated by the calculation of the quotients (see Table 1-3, 3rd column).

h_M is a measure of the pressure p which is called hydrostatic pressure or gravitational pressure. Thus the experiment results in $p \sim h$

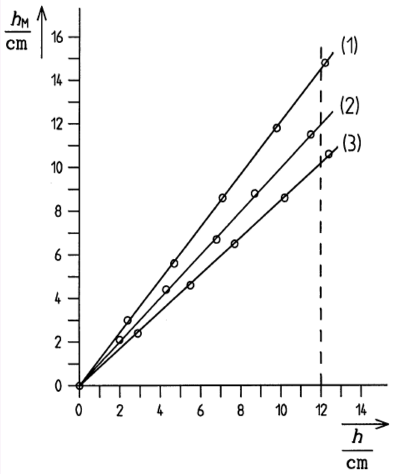

Fig. 4: (1) glycerine, (2) water, (3) ethyl alcohol

Evaluation (2/3)

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Substance	h / cm	$\frac{\rho}{g/cm^3}$	h_M/cm	$\frac{h_M/\rho}{cm^4/g}$
Water	12	1,00	12,0	12,0
Ethyl alcohol	12	0,85	10,2	12,0
Glycerine	12	1,20	14,5	12,1

Tab. 4

i.e. the hydrostatic pressure is proportional to the immersion depth of the probe. Or: The hydrostatic pressure p which is contained in a liquid at depth h is proportional to the height h of the liquid column, which produces the hydrostatic pressure at the depth h. Tables 1-3 show that the mean value for water is 1.01, for alcohol 0.84 and for glycerine 1.21. Within the limits of measurement accuracy, these values correspond to the numerical values for the densities of the substances in g/cm^3: $\rho_W = 1,00 g/cm^3$, $\rho_S p = 0,85 g/cm^3$ and $\rho_G l = 1,20 g/cm^3$.

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Evaluation (3/3)

That $p \sim \rho$ applies can be demonstrated as follows: From the coordinate system in Fig. 4 the values for h_M for a certain immersion depth h are taken and displayed graphically in accordance to the values for P from the tables (see Table 4 and Fig. 5). A straight line is obtained through the coordinate origin or a constant quotient h_M/ρ. The following therefore applies: $p \sim \rho$

i.e. the hydrostatic pressure is proportional to the density of the liquid. Overall, from $p \sim h$ and $p \sim \rho$ follows $p \sim \rho \cdot h$

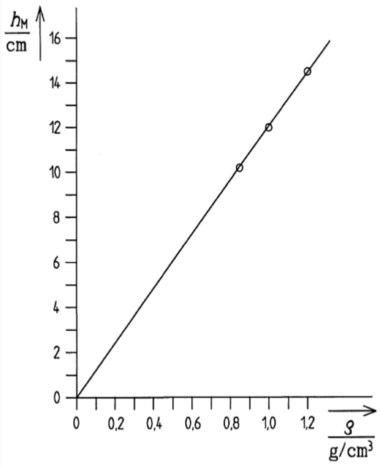

Fig. 5

Notes

It is advisable to apply coloured water to the manometer before the lesson. The gravitational pressure or hydrostatic pressure at depth h of a liquid is determined by the force of weight F_G of the liquid column, which is located above a surface A. According to the equation for pressure, $p = F/A$, the following applies to the hydrostatic pressure:

$p = F_G/A = m \cdot g/A = \rho \cdot V \cdot g/A$

and because of $V = A \cdot h$,

$p = \rho \cdot g \cdot h$ follows with $g = 9,81 m/s^2$.

The hydrostatic pressure at depth h does not depend on the shape of the vessel and acts equally in all directions.

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