Similar but different

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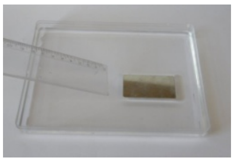
The similarity of the elements used in the proposed sets of experiments, that are coming from various areas of physics, suggests the likeness of the process but brings about different observed results. The sets can be used during the lessons and physics quizzes to stimulate and motivate the students to ask the question „why".

The leading subject of the selected experiments is water.

Experiment 1

We put a flat aluminum plate and a boat made of aluminum foil into a dish filled with water. Next we approach an electrified ruler to it. The aluminum plate is moved by the ruler away but a boat approaches to the ruler.



The experiment explanation:

If you bring a charged ruler closer to a metal plate then the ruler affects both a plate and water. The plate is charged by induction and attracted by the ruler. Water is also charged by the ruler. The metal plate which is floating on the water ‚bends' its surface down thus it is further from the ruler than the surface of water. That is why the interaction between the ruler and water is also important. The surface of water due to its interaction with the ruler is locally risen creating ‚a small hill'. Therefore there appears the component of gravity force which counteracts electrostatic force. That is why moving the ruler makes ‚a hill' to move altogether with the plate.

On the other hand a metal boat floating on the water is much closer to the ruler than the surface of water and that is why the interaction of the ruler and water is unimportant. The boat is attracted by the ruler.

Experiment 2

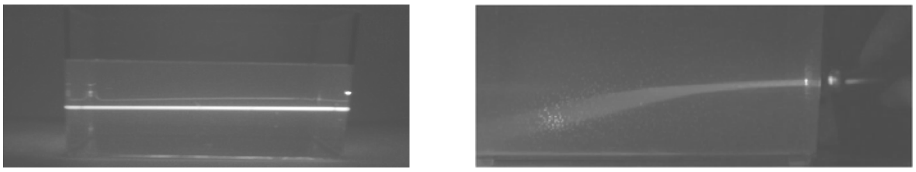
We put sheets of paper on two glasses filled with water and we turn the glasses upside down. Water does not pour out. The column of liquid is held in both containers by those sheets of paper. Next we take away sheets of paper from under the glasses. Water pours out from one glass, but not from the other.

The experiment explanation:

One glass has a net with small openings glued to its top. Surface tension enables to keep water in it, even if we take away a sheet of paper.

Experiment 3

We direct a laser beam into containers filled with different fluids. There is pure water in one container, and there is a solution of water and salt (which it is not mixed to show a salt density gradient) in the second one. In the first case a laser beam goes straight through container, in the second case the beam is curved.



Experiment 4

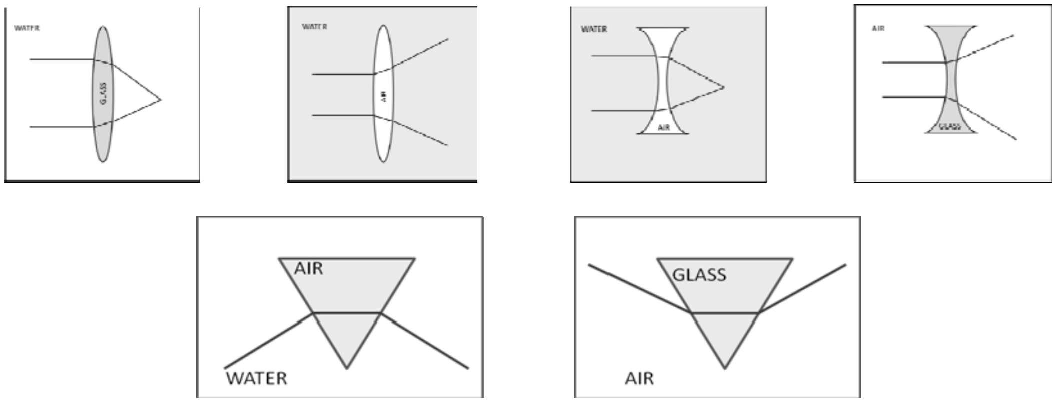
We put two identical stickers (one under the other) onto a jar half filled with water. The stickers look identical if we look at them from the front of the jar, but they differ in shape if we turn the jar round and we look at one sticker through a layer of air and at the second one through a layer of water.

Experiment 5

We use three sets in this experiment:

1. convex lenses: glass and air ones
2. concave lenses: glass and air ones
3. prisms: glass and air ones

We put glass elements (lenses or prisms) in an empty aquarium and we put 'air' elements (lenses or prisms) into an aquarium filled with water. The beam of laser going through a glass element in an empty aquarium is deflected differently than the beam going through an 'air' element immersed in the water.

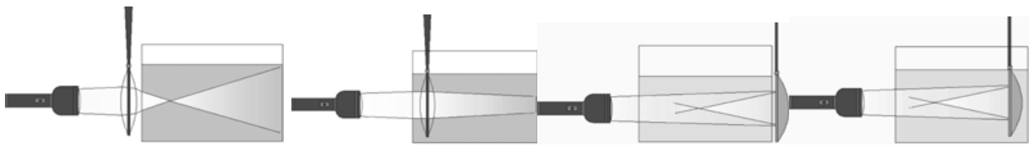


Experiment 6

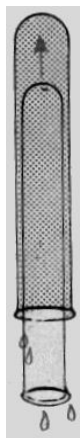
A convex lens in air and in water versus a concave mirror in air and in water.

A beam of light goes through a convex lens placed in front of an aquarium filled with water. You can see it focused. If the same beam of light goes through a lens submerged in an aquarium then the focus of the beam is minimal.

A similar beam of light after going through an aquarium with water is reflected from a concave mirror. This mirror is placed behind the aquarium. You can see the beam focused in an aquarium. If we submerge a concave mirror in an aquarium, then a beam of light after reflecting from a mirror will be focused exactly the same way as in the previous case.



Experiment 7



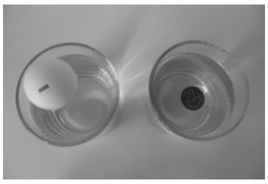
A test tube with a smaller diameter falls out from a test tube with a little bigger diameter (after turning them upside down), if there is air between them. If we push a smaller tube into the bigger one filled with water, then a test tube with a smaller diameter is pulled into the bigger test tube (after turning them upside down).

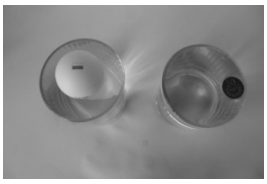
The experiment explanation:

The phenomenon is created by the lowering of pressure between the tubes caused by leaking water. Unbalanced atmospheric pressure sucks the smaller tube into the bigger one.

Experiment 8

We take two glasses filled with water then we put a table-tennis ball into one glass. A ball clings to the glass wall. Later we carefully put a coin on a surface of water in a second glass. The coin floats on the surface of water right in the middle. If we repeat this experiment after filling up the glass with a convex meniscus, the effect of this experiment is reversed. The ball floats in the middle of a water surface and the coin sticks to glass wall.





The experiment explanation:

(To simplify the explanation it has been done for the cylinder-shaped object.)

If the liquid surface between the vessel wall and a floating object forms a concave meniscus then under such a curved surface the pressure is lower than the atmospheric one:

$$p = p_{at} - 2\sigma/r$$

Due to this fact the liquid rises locally in the vessel for h. As you see in the figure 1: on the h level from the side of the middle of the vessel the pressure on the object is $p_A = p_{at}$ and from the side of the vessel wall is $p_B = p_{at} - 2\sigma/r$. This pressure difference creates the force acting on the object in the direction of the vessel wall. The closer to the vessel wall the object is the effect is stronger because the surface tension forces make the radius of meniscus curve smaller and lower the pressure under the curved surface.

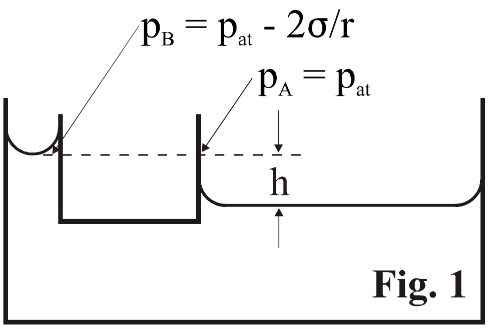


Fig. 1

In a similar way you can explain the effect of attracting the object to the vessel wall when the liquid forms convex meniscus (fig. 2).

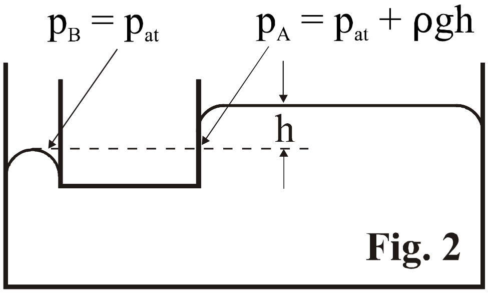


Fig. 2

If the liquid surface between the vessel wall and the floating object forms convex meniscus then under the surface curved in such a way the pressure is higher than the atmospheric one:

$$p = p_{at} + 2\sigma/r$$

This fact causes local lowering of liquid level for h in comparison to the liquid level in the vessel. In such a situation from the side of vessel wall to which the object is closer the pressure on the object over the curved liquid surface is pB=pat. On the other side of the object, on the same level the pressure on the object is pA=pat+ρgh . Thus the force acting on the object will be directed to the vessel wall.

Repelling the object from the vessel wall appears when the curvature at the vessel wall is of the opposite direction to the curvature at the side of approaching object. This means that on one side of this liquid surface there is a convex meniscus and a concave meniscus on the other side. Let us analyze one of the cases shown in the figure 3.

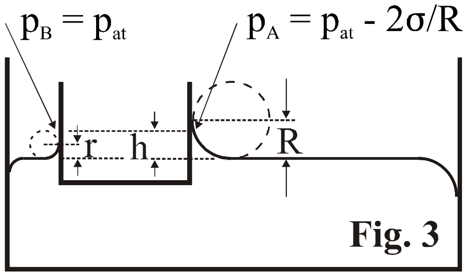


Fig. 3

If you move the object towards the vessel wall then similarly as in previous cases the liquid surface will be curved more but in this case at one wall a bigger curvature of concave meniscus will be formed and at the other wall a bigger curvature of convex meniscus will appear. The level of liquid will not change because the surface between meniscuses does not form a curve ($2\sigma/r = 0$).

The increase of the curvature of liquid surface at the object side from the side of the vessel wall to the curvature on the other side of the object makes the liquid rise on one side of the object on the height of r and on the other side on the height $R > r$ (fig.3). Because of this on the level h with $r<h<R$ the pressure from the vessel wall side is $p_B = p_{at}$ and on the other side is $p_A < p_{at}$. This pressure difference is the cause of the force repelling the object from the vessel wall.

Experiment 9

We submerge the same egg into two containers filled with different fluids. There is water in one container and there is saturated solution of water and salt in the other one. You can see the result of this experiment in the photographs.

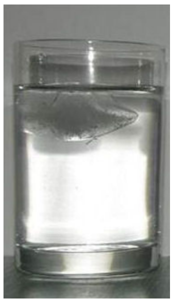

Experiment 10


We put an aerometer in a container with cold water and then in a container with warm water. We observe the differences in its immersion. The aerometer in hot water goes deeper than in cold water as illustrated in the pictures.

Experiment 11


We put two cans of identical volume, filled with fizzy drinks, into the same container filled with water. One of the cans floats, the other one sinks. We use in Pepsi and Pepsi Light this experiment. Those drinks have different density because of different sweetening substances used in them: sugar and sweetener.

Experiment 12




We put ice cubes into glasses filled with transparent fluids. In one glass ice floats, in the second one it sinks. Two kinds of fluids with different density were used in this experiment: water and spirit.

References

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