Mechanics of Fluids - Description to the videos.

Experiment 1: Pouring gas

Task

Testing the gas fluidity.

Materials needed:

3 same glass jars,

propane gas cartridge,

3 covers on jars (cardboard ones are sufficient),

lighter opener,

skewers,

candle.

Procedure:

- Light the candle from which you will light the skewer to test the flammability of the contents of the glass.
- Test the flammability of the glass filled with air.
- Release propane gas from the cartridge into the jar.
- The existence of propane gas is proved by ignition of the gas in the jar.
- Pour the propane into the second and the third jar.
- The existence of propane gas is proved by ignition of the gas in the second and third jar.

Observation:

- We can pour also gas.

Additional tasks, questions, comments

What physical property of propane gas was necessary to perform the experiment?

- To perform this experiment, we used the gas with greater specific density.

Experiment 2: Extinguishing candle.

Task

Testing the gas fluidity.

Materials needed:

Baking soda,

vinegar,

candle,

lighter opener,

beaker.

Procedure:

- Light the candle.
- Give approximately 100 ml of vinegar into the beaker.
- Add tea spoon of baking soda to prepare carbon dioxide.
- Pour the carbon dioxide on the lighted candle.

Additional tasks, questions, comments

What physical property of carbon dioxide was necessary to perform the experiment?

Carbon dioxide is the gas with higher density than air. (Carbon dioxide - 1,98 kg/m^3, air -1,29 kg/m^3).

Because of that we were able to pour it on the candle and extinguish it.

<u>Experiment 3: Syringes with water and air.</u>

Task

Testing the compressibility of liquids.

Materials needed:

Syringes of different sizes (pairs of the same size).

Fill one syringe of the pair with water in full.

(In one couple fill one syringe only in one half)

Give each group one pair.

Procedure:

- Ask students to compress syringe with air and then with water.
- What is the difference?
- Syringe with air is easily compressible — the particles can be squeezed closer together. When we try to compress syringe with water it does not work, because water as liquid is incompressible.

For the teacher:

When discussing with students wait for the group with syringe partly filled with water. Hopefully they will disagree and object that they were partly able to compress they syringe with water. It's a link to the problem with air in brake fluid.

Experiment 4: U shape funnel with balloon under the water

Task:

Investigate the relationship between the hydrostatic pressure and the depth.

Materials needed:

U-shaped tube (preferably glass),

plastic hose (the same diameter as the U-shaped tube)

funnel,

balloon,

water (to enhance visibility you can use food coloring),

ruler

clamp or stand (to hold the U-tube in place),

rubber bands or string (to secure the balloon).

Procedure:

- Set up the U-shaped tube in the vertical position, and attach plastic hose to one arm of the tube.
- Securely attach the funnel to the end of plastic hose and prevent any leakage.
- Attach the balloon securely to outer end of the funnel using rubber bands or string.
- The balloon should be attached tight.
- Fill the U-shaped tube with water.
- Slowly lower the funnel with the attached balloon into the water.
- Observe and record the changes in the water levels in the U-shaped tube as the funnel with the balloon goes deeper.
- Note that at the same depth, the difference in water levels remains constant in all directions.

Experiment 7: Pascal's Hedgehog

Task

Test the Pascal's law

Materials needed: If you do not have the original device, you can find some suggestions on the Internet. The following is the one suggested by Creative Science Project. https://www.youtube.com/watch?v=veKcyKyG-mE

Plastic bottle,

one larger syringe,

four smaller ones,

glue gun,

soldering iron for making holes in the bottle and lid,

instead of soldering iron you can also use heated metal reusable straw,

gloves.

Procedure:

- Make holes in the lid and at four places of the bottle so that you can insert needle hubs.
- Insert the needle hubs and glue them with the help of a glue gun.
- Fill the bottle with water.
- Fill the syringe glued to the lid with water, it should be filled with 4ml.
- Push the syringe with water.
- All four syringes will move and will be filled with 1ml. The pressure exerted on the surface of the liquid is transmitted to every syringe, causing them to fill up with an equal amount of water.

For the teacher:

When making the device in the class, only place the necessary items on the table.

It is possible that the results will not be optimal, and the reason is that there is always friction between the tube and the piston. If the friction differs in the used syringes, the amount of water pushed into them will be different.

It is a good idea to spend some time discussing the experiment and let the students come with possible reasons for the outcome and potential solutions.

Having an oil bottle on the table can help them understand that Pascal's law is not wrong, but we have to consider the impact of friction, which can be reduced by oiling the pistons.

<u>Experiment 8: Competing syringes.</u>

Task

Compressing the syringes filled with air and water.

Materials needed:

Two syringes of different sizes (one with a larger cross-sectional area and another with a smaller cross-sectional area),

connecting tube or small rubber tubing,

water or any other suitable fluid (coloured water for doing it in class)

stand holder.

Procedure:

- Fill both syringes with water, ensuring there are no air bubbles trapped inside.

- Attach the connecting tube between the syringes, ensuring a tight seal.
- Put both syringes in a stand holder, positioning them vertically so that you can push each syringe with your thumbs independently.
- Apply a downward force on the piston of the larger syringe with your thumb pushing it inward.
- Apply a downward force on the piston of the smaller syringe with your thumb pushing it inward.
- Apply a downward force on both syringes with your thumbs simultaneously.
- How does it feel? Which syringe wins?

Observations:

The experiment helps us understand the concept of hydraulic lift, as mentioned in the student book. If the area of the large piston is 100 times that of the small piston, the total force on the large piston is 100 times greater that on the small one. However, the work done (force × distance) remains the same in the absence of friction. Thus, the small piston must be pushed down 100 times farther than the large piston rises

<u>Experiment 9: Comunicating vessels.</u>

Task

Provide a visual representation of how fluids distribute and balance themselves when connected in a system. If you do not have the professional set up. you can make your own. It can be easily done by students alone, We found one example for you on the Internet: https://www.youtube.com/watch?v=_8jUDd_ZpBk

Materials needed:

Two or more containers/vessels of different sizes, plastics cups of different sizes will do,

transparent tubes or flexible hoses,

colored water,

glue gun.

soldering iron for making holes in the bottle and lid,

instead of soldering iron you can also use heated metal reusable straw,

gloves.

Procedure:

- Set up the containers/vessels on a flat surface.
- Make holes at the same level.
- Connect the containers using the transparent tubes or hoses.
- Pour water into all containers. The tubes should be submerged in the water, ensuring a tight seal between the containers.

- Observe the initial water levels in each container.

Observations:

As the containers are interconnected, the water in each container will find a balance and equalize itself across the vessels.

Initially, the water levels may be different due to the varying container sizes, but as time passes, the water levels will adjust and become the same in all connected vessels. The liquid level is horizontal.

Additional tasks, questions, comments

The communicating vessels experiment demonstrates the principle of fluid equilibrium. According to this principle, when the vessels are connected, the pressure in the liquid is the same at any given horizontal level. This means that if one container has a higher water level, the pressure at that level will force the water to flow through the tubes into the lower containers until the levels become equal.

It's important to note that the equalization of the water levels happens due to the difference in height between the vessels, not the total volume of water.

<u>Experiment 11: Air weight</u>

The experiment on the video was done with a special tool from the laboratory, but there are other ways to measure air density, we will explain two of them with citations of the source, but there are many similar ones.

Task

Measure the weigh and density of air

Materials needed:

Airtight pressure vessel of constant shape (like a basketball),

bicycle pump,

measuring cylinder,

a container with water;

digital scales with an accuracy of 0.1g

Procedure

- Get the basketball and make sure it has a valve that lets air in but won't let it escape during the experiment.
- Find out how much air is inside the ball with one press of the pump.
- Fill the measuring cylinder with water up to the top.
- Turn the cylinder upside down and put it in the container with water. The water won't fall out because the opening is under the water.
- Pump as much air as you can into the pump.

- Release the air from the pump into the cylinder.
- Check the volume of air on the scale with one push of the pump.
- Repeat this process ten times and find the average number.
- Deflate the ball, but keep its round shape.
- Weigh the deflated ball.
- Inflate the ball with five to ten pumps.
- Weigh the ball again after inflating it.
- Calculate the weight of air for one inflation.
- Now that you know the volume and weight for one inflation, you can calculate the density of air.
- Compare your result with the values given in the tables.
- Discuss ways to improve your results, especially if there are big differences, and then repeat the measurement.

Source:https://www.science-on-stage.sk/documents/sos_workshopy_dokazeme_odvazit_vzduch.pdf

Another way to measure the density of air by Zdeněk Drozd - Department of Physics Education Charles University Prague - Rande s fyzikou.
https://www.youtube.com/watch?v=BF49soKgUKY

Materials needed:

2 plastic bottles,

bicycle valve,

bicycle pump,

a container with water;

digital scales with an accuracy of 0.1g

Procedure

Procedure:

- Attach the bicycle valve securely through the lid of one of the plastic bottles (this requires some skill to ensure it is air-tight).
- Fill the second bottle of known volume (usually 1.5 liters) with water.
- Fill the container with water.
- Turn the bottle filled with water upside down and submerge it in the container with water. The water won't fall out because the opening is below the water level. Ask someone to hold it in place.
- Pump as much air as you can into the bottle with the attached valve.
- Measure the weight of the bottle using the digital scales.
- Release the air from the bottle into the second bottle filled with water until all the water is displaced. This will indicate that the volume of air released is 1.5 liters.

- Measure the weight of the bottle again.
- The difference in weight before and after releasing 1.5 liters of air is the weight of 1.5 liters of air.
- Calculate the density of air using the collected data.
- Discuss ways to improve your results, especially if there are significant differences, and then repeat the measurement if necessary.

<u>Experiment 12: Crashing can</u>

Task:

Test the strength of the atmospheric pressure

Materials needed:

aluminum soda can,

hot plate or a Bunsen burner,

small amount of water

gloves,

goggles

tongs to keep the can.

Procedure:

- Add a small amount of water to an aluminum soda can.
- Bring to boiling. Use the gloves and goggles.
- Quickly immerse this can in cold water, upside down using tongs.
- The can get crashed.

Explanation:

Bringing the amount of water to boiling, gas molecules of vaporized water will occupy all the space inside the can since the air molecules have been pushed out. The hot gas molecules are the same pressure as the air outside the can. If we quickly immerse this can in cold water upside down, the molecules inside will cool down again and reduce its volume. The pressure inside will decrease. The difference between the atmospheric pressure in the surroundings and the pressure inside the can is so great that the outside pressure will crash the can.

<u>Experiment 13: Blowing into plastic hose</u>

Task

Find out why snorkel is only 60 cm long.

Materials needed:

plastic hose around 3m long and diameter approximately 1cm (can be purchased in building materials or gardening supplies),

food coloring,

duct tape,

measuring tape.

Procedure:

- Fill the plastic hose with colored water.
- Attach the hose to a vertical wall and secure it with duct tape. This creates a simple manometer.
- A manometer measures the pressure acting on a column of fluid.
- It is made from a U-shaped tube of liquid in which the difference in pressure acting on the two straight sections of the tube causes the liquid to reach different heights in the two arms.
- In this way, we can measure the pressure we create in our mouth, for example.
- Start by breathing out and observe one arm of the manometer rise up. Mark the level of water.

- Then breathe in and watch the other arm rise up. Mark the level of water.
- By our measurement, the difference of heights was approximately 1 meter, it means we created a pressure:

$$p = 1000\mathrm{kg.m^{-3}} 10\mathrm{ms^{-2}} 1\mathrm{m} = 10\ 000\mathrm{Pa}$$

- Therefore, if we had a snorkel 1 m long, it would be like a 60 kg person would sit on our chest, back, and both sides. We would be squeezed from all sides, and as a result, breathing out would be easier than breathing in.
- The calculation is as follows:

$$F = pA = pressure.Area\ of\ our\ chest\ = 10000\mathrm{Pa}(0{,}3\mathrm{m}.\ 0{,}2\mathrm{m})$$
$$= 10000\mathrm{Pa}\ 0{,}06\mathrm{m^2} = 600\mathrm{N}$$

- Force 600N means mass 60kg.
- Do the calculation with your own height difference.

Task of the following experiments is to help student understand Archimedes' principle.

Archimedes' principle is a fundamental principle in physics that relates to buoyancy. It states that an object submerged in a fluid experiences an upward buoyant force equal to the weight of the fluid displaced by the object. This principle helps explain why objects float or sink in a fluid.

Experiment 14: Archimedes - Different material – same liquid

Task

Find out whether Buoyant force depends on the material the two identical blocks are made from.

Materials needed:

Two identical blocks from different material,

dynamometer,

a container with water.

Procedure:

- Attach the blocks one after another to the dynamometer and immerse into the liquid.
- Watching the dynamometer, watch the difference when block is in air and immersed in the liquid.
- This difference is not the same for both blocks, it depends on the material it was made from. (In our case the second one even floats in the liquid).

<u>Experiment 15: Archimedes' Double cylinder</u>

Task

Demonstrate Archimedes' principle using a double cylinder setup.

Materials:

Archimedes' double cylinder apparatus (consisting of two cylinders, one solid and one hollow),

water container (large enough to submerge the cylinder),

colored water

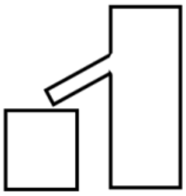
stand with changeable hight.

Procedure:

- Set up the stand and suspend the dynamometer from the hook.
- Attach the full cylinder to the hollow cylinder and suspend both from the dynamometer.
- Read the dynamometer and record the value.
- Fill the water container with colored water
- Gradually raise the stand until the solid cylinder is completely immersed in the water.
- Read the value on the dynamometer and record the value. The value will be lower due to the Buoyant force acting on the solid cylinder.
- While keeping the solid cylinder in water pour water into the hollow cylinder. You will see that the solid cylinder will touch the bottom of the container.
- Carefully move the stand upwards until the solid cylinder is not touching the bottom of the vessel but is still immersed as before.
- Read the dynamometer again and record the value. The value should be the same as in the beginning (before we immersed the solid cylinder in the water) because we just added the same amount of water that was displaced by the solid cylinder and its weight was equal to the Buoyant force.If you do not have the stand with the changeable height, you can modify experiment as follows.

Materials needed:

Two vessels, one with opening through which you can catch the overflowed water,



stand with a hook,

dynamometer,

double cylinder set up.

Procedure:

- Set up the stand and hang the dynamometer from the hook.
- Connect the solid cylinder to the hollow one and hang them both from the dynamometer.
- Read the weight shown on the dynamometer and write it down.
- Fill the vessel with overflow to such an extent with water that it just stops to overflow. Before filling the vessel with water close its opening with something like plasticine.
- Put the beaker next to the vessel to collect any water that overflows.
- Slowly lower the dynamometer until the solid cylinder is completely immersed in the water. Immediately after it starts immersing free the opening for

overflowing (you will need someone's help) Collect the overflowed water into the beaker.

- Read the new value on the dynamometer. The difference between the two readings is the Buoyant force acting on the full cylinder.
- Keep the full cylinder in water and pour the overflowed water into the hollow cylinder.
- The full cylinder should be fully immersed but not touching the vessel's bottom. The dynamometer will show the initial value again.

Experiment 17: Archimedes: Same amount of matter -different shape.

Task

Test whether there is a difference in Buoyant force when the same amount of matter has different shape.

Materials needed:

Plasticine or modeling clay,

a container or basin filled with water,

dynamometer.

Procedure:

- Take a fixed amount of plasticine or modeling clay, ensuring that the same amount is used for each shape.
- Shape the plasticine into different forms or objects of your choice, such as a ball, a cube, or any other irregular shape you desire.
- Attach each plasticine shape to the dynamometer.
- Carefully lower each plasticine shape, attached to the dynamometer, into the water, ensuring complete submersion.
- Observe and record the readings on the dynamometer for each shape.

Additional tasks, questions, comments:

When selecting the shapes for the objects, it is important to note that altering the shape to resemble a boat or any hollow structure might change the overall density of the object. This is because air gets trapped inside the hollow part, affecting the object's total density. To maintain consistency, it is recommended to avoid shapes that introduce air pockets or hollow spaces.

Ensure that the plasticine shapes are securely attached to the dynamometer to accurately measure the buoyant force.

Experiment 18: Archimedes - Same material different liquid

Task:

Test whether there is a difference in Buoyant force when the same object is immersed into different liquids.

Materials needed:

A solid object (such as a small metal or plastic object),

two or more different liquids (water, oil, salted water),

dynamometer,

containers to hold the liquids

Procedure:

- Select an object with density higher than water.
- Fill one container with water and another one with liquid with different density than water.
- Carefully place the solid object into the containers, attached to the dynamometer.
- Compare the Buoyant force of the same object in those two liquids.
- You can use another liquids of your choice with known density

Additional tasks, questions, comments:

Archimedes' principle can help explain the behavior of the solid object in different liquids. The principle states that an object submerged in a fluid experiences an upward Buoyant force equal to the weight of the fluid it displaces. If the Buoyant force is greater than or equal to the weight of the object, the object will float. If the Buoyant force is less than the weight of the object, it will sink.

By using the same material object and varying the liquids, you can observe how the density of the liquids affects the Buoyant force. Liquids with higher densities will exert greater Buoyant forces on the object, making it more likely to float. Liquids with lower densities may result in the object sinking due to insufficient Buoyant force.

Through this experiment, you can explore the relationship between buoyancy and the densities of different liquids. It helps demonstrate how Archimedes' principle applies to objects submerged in various fluids and how the Buoyant force depends on the density of the liquid.