Workshop Demonstrations with almost nothing: Thirty examples with a glass of water

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Abstract: Suppose you are suddenly assigned to a bare classroom instead of your nicely equipped physics room. What can you do to still have a clear and exciting lesson? In this workshop I present a collection of small and quick demonstrations and visualizations for secondary education, which require no equipment beyond what is present in a typical lecture room or bare classroom (chalk, chairs, students, books, paper, student bags and typical contents). The nature of the demos is varied, some are to verify an explanation, but most are to illustrate, visualize, or simulate. In the workshop participants will add their own ideas.

1. Introduction

One of the key objectives in physics education is that students learn to recognize physics phenomena in their environment and to think back-and-forth between phenomena and concepts and that they observe a phenomenon, identify the relevant concepts, and eventually learn to use these concepts to guide further observation, because with concepts you can see more!

Obviously, this requires bringing the phenomena to the classroom through demonstrations, practical work, and YouTube. Luckily physics provides lots of easy opportunities to bring phenomena into the classroom. Take any common object and it can be used to demonstrate physics phenomena and to visualize physics concepts.

One could wonder whether actual demonstrations are still needed now that there is YouTube. I think a live experience is still different from watching TV/internet. Each type of demo (live versus YouTube) has its own role in the learning process.

The “rules” for demonstrations are of course:

- The demonstration should be visible to all-in the room (or audible).
- There should be a clear learning objective, even in cases where the main purpose is entertainment.
- Take into account typical misconceptions of students and use them productively in the discussion.
- Students should be involved, for example by assisting, by making individual predictions where that is sensible, or other interactive tasks, avoid “show and tell”.
- Details and main points should be clearly distinguished. Include only the most necessary details to understand the situation and focus on the main observations and explanations.

For further wisdom about how to conduct physics demonstrations I would like to refer to others. Liem [3] published a book with over 400 Physics and Chemistry demonstrations with a focus on discrepant events. His demonstration methods are discussed in the introduction and each demo contains teaching suggestions and questions to increase student involvement. Gunstone and White [2] discuss the predict-observe-explain (POE) demonstration method with beautiful examples in chapter 3 of their book Probing Understanding. Actually, it should be called predict-explain-observe-explain (PEOE) as...
predictions should not just be guesses, they should be reasoned predictions. Sokoloff and Thornton [4] published interactive lecture demonstrations with supporting worksheets to optimize intellectual involvement in large enrollment classes using a consistent 8-step format.

2. Examples of demonstrations

In this article we take an object, a glass of water, and then list 30 demonstrations and visualizations which could be inserted into different lessons on liquids or optics or waves, etc. No doubt the reader could add more. One could take any other object such as a ball, a ruler, a coin, a chair, or a student and do a similar exercise. Ehrlich [1] did that with a ruler and produced 34 experiments. A colleague told me about 50 experiments with a match box. With a glass of water, we can show:

1. Water is transparent, light can pass through it so we can see through it;
2. Water, and any other liquid, takes the shape of the container;
3. When we tilt the glass, the liquid surface is always parallel to the floor;
4. Adhesion, the attraction between different substances, is visible between water and glass as the water edge stands up against the glass side; Also, with a wet fingertip we can easily pick up crumbs and small particles, much easier than with a dry fingertip. It is interesting to note that adhesion is different depending on the material of the “glass” or beaker. With glass adhesion is relatively strong. With plastic the upstanding edge of water is much narrower. Try different materials if you have.
5. Adhesion can also be used for weighing. Take a glass of water and fill it to the rim. Then position a credit card or other card on top of it with one side sticking over the edge of the glass. Position coins on the end that sticks out. Two forces are competing. The adhesion force tries to preserve the position of the credit card. The downward force of the coins tries to tip the card. In this demonstration one can discuss adhesion, forces, and moments. The adhesion force can be measured, that requires some further thinking and trying, but it can be done.
6. Cohesion and adhesion: From the glass take some drops of water and position them on different surfaces, on metal, on wood, on a book cover, on regular writing paper. The shape will vary from semi-spherical to rather flat to complete absorption such as in paper, depending on the balance between cohesion and adhesion. The semi-spherical drop is also a nice lens, for example, in chemistry one can add minute amounts of different powders and then observe reactions through the drop lens including bubble formation when a gas is released.
7. Cohesion: the attraction between molecules of the same substance, can be made very visible by filling the glass higher than the rim without spilling water;
8. Cohesion can become spectacular by filling the glass to the edge and then asking the class how many coins can be added into the water without spilling water. This turns out to be an unexpected large number. Just borrow the coins from the students.
9. Floating position: A ping-pong ball or pieces of paper or cork will position themselves on the highest point of a concave or convex surface (figures 1 & 2) as the water and objects on top of it position themselves such that the common center of mass will be as low as possible. In this demonstration, ask students to predict by making an individual sketch.
10. Acceleration: the water surface will be slanted when the glass is accelerated but not when the glass is moved with a constant velocity.
11. Inertia 1: wipe the bottom of the glass dry, put it on top of an A4 sheet of paper, pull paper and glass slowly to the edge of the table (figure 3) and then give a sudden jerk. The glass is left behind, it resists acceleration … we call that property inertia.
12. Inertia 2: Now take the glass with water in your hand and move it in a straight line and then stop it. What happens to the water? It tends to continue its motion and stands up against one side of the glass. If you are a bit wild, it will even spill over the side.
13. Circular motion: Now swirl the water in the glass. It will stand up against the sides. At any point the water will tend to keep moving in a straight line (inertia). The side of the wall provides the centripetal force to push the water around the corner into circular motion.
14. **Floating/sinking 1**: the generalization that heavy or large objects sink and light or small objects float is NOT true. Use objects from the bags and pen pouches or cases of your students.

15. **Floating/sinking 2**: some materials/objects sink, but they can be bent in a shape that will float. Ask a student with chewing gum to demonstrate or bring some play dough.

16. **Surface tension 1**: there are objects which sink when inserted into the water sideways, but float when carefully positioned on top of the water. Did any student bring a shaving blade or an aluminum or other low density coin? I always have a Czech coin of 0.8 g in my purse. Sometimes I can get a paperclip to float, you would need a fork to position it carefully.

17. **Surface tension 2**: With the floating coin or shaving blade, let a student get some drops of soap from the rest room. What will happen when the soap is added to the water?

18. **Surface tension Marangoni effect**: fold a small triangular piece of paper into a 1 cm boat and add some soap behind. It will speed away. Of course, a basin would be better than a glass (http://physicsgirl.org/soapboat/).

19. **Air and liquid pressure**: search for a piece of carton or plastic which could cover the glass. Turn it over. The water does not come out.

20. **Air and liquid pressure, surface tension**: now take your hand kerchief, request assistance of your students to hold it horizontal. Pour some water from the glass on top of the handkerchief, the water will go through. Do this preferably over one of the plants in your classroom, giving it some water. Then fold the wet handkerchief tightly over the glass and turn it over (figure 4). A little water will come out, the rest will stay. Explanation: air pressure in glass + water pressure = air pressure outside the glass. The surface tension prevents the leaking through the handkerchief. Through the initial small leakage, the air bubble in the glass expands slightly so the air pressure in the bubble is smaller than the outside air pressure and the layer of water inside the glass makes up the difference.

21. **Refraction**: stick a pencil in the glass (slanting) and walk around to demonstrate. If you do happen to have a laser pointer in your pocket and one of your students has a few drops of milk, then you can show the refraction of the laser beam after showing the pencil.

22. **Total internal reflection**: look from down below at the water surface but from an angle greater than the critical angle, you can see objects on the other side of the glass. The water surface acts as a mirror. You can also show this with a laser pen, Shone upward from sideways below, the beam will be reflected downward.

23. **A glass of water is a lens**: Put a pencil or your finger straight up in a glass of water (figures 5 and 6). Walk around the class without talking, moving your finger or the pencil back-and-forth between the front and the back of the glass. Students will be surprised. The effect is greater with a small glass (greater curvature). A quick explanation is that the water acts like a lens. A more thorough explanation using light ray diagrams will take more time and could be given as a seatwork assignment.

24. **Breaking**: one can drop the glass (now without water) on different surfaces without breaking it. For example, use clothing or bags of students. In the explanation use the two principles that prevent breaking: spreading the braking forces over the object and extend the distance over which the object is slowed down. A more spectacular demonstration of these principles is throwing a raw egg full force into a towel or into the curtains of the classroom, it will not break.

25. **Evaporation**: let students dip a finger in the water and then blow to dry. If girls bring cosmetics, one could see that nail polish remover evaporates much faster than water.

26. **Condensation, evaporation**: breath against the outside of the glass. We will see some fog on the glass, condensed water. Just leave the glass and the fog will disappear … evaporation.

27. **Waves and reflection**: Create a wave in the glass by dipping your finger or a pencil. For a better view one will need a glass or transparent plastic container on an overhead projector.
28. **Sound**: relationship between pitch and water level, hit the glass with a coin with varying amounts of water.
29. **Transparent/opaque**: Take a sheet of paper, make one spot in the middle a bit wet. Hold the paper against the wall and we see a dark spot. Hold it against the window and we see a light spot. The wet part becomes more transparent (thus a light spot if you hold it in front of a window) and less reflective (dark spot in front of wall).
30. **Dissolving**: find something in the classroom or in bags of students which can dissolve in water. Sugar and salt become invisible, ink remains visible, milk also. Discuss the difference between a solution, an emulsion (a mixture of a liquid with a liquid such as milk) and a suspension (a mixture of a liquid with solid particles such as paint or ink).

3. **Conclusion**

It was easy to think of 30 demonstrations and visualizations with a glass of water. Looking in demonstration books such as Liem’s *Invitations to Science Inquiry* one can easily add more [3]. With simple objects one can show a lot of physics! See also Ehrlich’s [1] 34 experiments with rulers including sophisticated quantitative demo’s. Science on Stage has produced many wonderful demonstrations. A bare classroom is not an excuse to not show any demonstrations. Many of these demonstrations hardly take any lesson time but do contribute to understanding and motivation and thinking back-and-forth between phenomena and physics concepts. A big advantage of these simple demo’s is that students can repeat them at home. A dinner question about what they learned at school today could be answered with “look, here I have a glass of water and ….”!

![Figure 1](image1.png) **Figure 1** Cork on concave surface on the side.

![Figure 2](image2.png) **Figure 2** Cork on convex surface in the middle.

![Figure 3](image3.png) **Figure 3** Inertia: the glass of water resists acceleration.

![Figure 4](image4.png) **Figure 4** Turn over a glass of water covered with a wet handkerchief.
Figure 5: Finger toward front of the glass.

Figure 6: Finger towards the back, the water acts as lens.

4. References

[1] Ehrlich, R. (1994). “Ruler physics”, thirty-four demonstrations using a plastic ruler. *American Journal of Physics*, 62(2), 111-120.

[2] White, R., Gunstone, R. (1992). Probing Understanding. Falmer Press.

[3] Liem, T.K. (1987). Invitations to Science Inquiry. Chino Hills (California): Science Inquiry Enterprises. A pdf can be found on different internet addresses.

[4] Sokoloff, D.R., Thornton, R. K. (2004). Interactive Lecture Demonstrations: Active Learning in Introductory Physics. Wiley.