Wetting and capillarity – what to do at physics lessons?

Vera KOUDELKOVA
Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic

Abstract. We present in the contribution an activity which is focused on wetting and capillarity. Experiments with hydrophobic coating are part of the activity too. We use this activity at lower and upper secondary school level, detailed description of the activity and our experience with it is discussed in the paper.

1. Introduction
Capillarity and wetting play very important role in many everyday activities – from agriculture on the one side to washing dishes on the other side.

During the latest years some hydrophobic coatings have become available and are used in many (not only) industrial uses. It is possible to use it for example for walls off which water would flow; terrace without rime; car window which is (according to advertisement) always clean; protective impregnation for clothes… and many other applications (see for example [1], [2]). (Many advertisements and products video can be seen for example if one put keywords “(super)hydrophobic coating” or “nano waterproof” on YouTube.)

The topic is interesting and attractive for students – it is possible to show them many applications for their normal life, and some experiments, which are very surprising. They usually ask many questions concerning impregnation, detergents, behaviour of specific outdoor materials etc. Furthermore, it is an interdisciplinary topic, so it could be included to not only in the physics curriculum (as is the case in my country) but in chemistry or science curriculum too.

Experiments with superhydrophobic surface are very attractive for public too, so it is possible to use them for informal teaching, science shows etc.

The teaching-learning activity we present in the paper shows what is possible to show students in regards to this topic.

2. About the activity
The whole activity is prepared for one or two lessons. In the first part, students discuss few photos of water droplets on different surfaces. The next part concerns modification of surfaces or liquids, which we used for less or more wetting. The third part of the activity is about behavior of water on hydrophobic surfaces.

2.1. Photos of water droplets
In this first part of the activity students discuss few photos of water droplets on different surfaces (see examples in figure 1). First, they should arrange them from less wetting to more wetting droplets. The second task is to recognize what surfaces could be in the photos. The main goal of this part of the activity is to show students that wetting of (not only water) depends on both – the liquid and the surface. Is it possible to continue working with these photos – teacher could explain students in this part how to measure wetting (what is contact angle and how is it possible to measure it), students could try to
measure contact angle of some droplets too, in following discussion teacher can tell students what the hydrophobic surface is, etc.

Figure 1. Water droplets on different surfaces: plexiglass (left), Teflon (center), paper (right).

Technical note: The contact angle is angle between surface and edge of a droplet. To measure it with students we use Geogebra. First step is to put three points on the edge of the droplet. From these points a circle is made. Next step is to make a tangent to this circle in the point where the droplet touches the surface. The last step is to measure contact angle between this tangent and surface. It is necessary to put the first three points very precisely and close to the surface. The contact angle can be measured on both sides of the droplets – they could be approximately the same. The result can be seen in fig. 2 – the angle on the left is 76.42°, on the right side is 76.62°.

Figure 2. Measurement of the contact angle.

2.2. Modification of a surface or a liquid

The second part of the activity concerns modification of liquids or surfaces, which we use for less or more wetting.

One branch is about detergents. Students can observe how droplets of water and water with detergents look on the same surface (see figure 3). It is better to do this part hands on, but if it is necessary students can discussed only photos (which teacher prepared before). For students it is interesting to see the difference and found that one of the reasons why we use detergents is to let the water wet some surface better. They can discuss different examples of using detergents.

Technical note: All droplets should be made from the same amount of water for it to be possible to compare them. This is not so problematic in the first part of the activity, because there we use only water (with some food coloring), so the droplets which we drip are the same because of the same surface tension. In this part, we use water and water with detergent, so it is necessary to measure the same amount of water (the “droplet” of water with detergent should be made from several droplets).

1 More precise definition can be found for example in [3].
Figure 3. Water (left) and water with detergent (right) on a Teflon surface.

The second branch is about impregnation – students usually know and use different types of impregnations but it is interesting for them to see how it works. If it is possible, students can put water on the same clothes with different brand of impregnation and compare behaviour of water on it. In figure 4 a comparison between a droplet on a cloth (left), the same cloth with two different impregnation can be seen – waterproof spray (centre) and waterproof liquid (right). We can see that both the waterproof spray and liquid made the cloth hydrophobic – the contact angle is about 145°, the cloth without impregnation has contact angle about 90°.

Figure 4. Water droplets on cloth (left) and cloth with impregnation (center and right).

In this case not only the shape of droplets is interesting. Some impregnation for clothes changes how the cloth is able to absorb water – the contact angle is nearly the same on the cloth with and without this impregnation at the beginning, but water on non-impregnated cloth is absorb more quickly. This can be seen in fig. 5 – there is the same softshell jacket without impregnation (left top on both pictures) and with three brands of spray impregnations. The contact angle seems to be nearly the same, but after ten seconds can be seen a big difference.

Figure 5. Comparison of different type of impregnation on a cloth – in the beginning (left) and after few seconds (right).
The other possibility is to compare currently used impregnations with some which were used in the past (wax, fat etc.), too.

2.3. Superhydrophobic surface
In the third part, students discuss the droplets on superhydrophobic surfaces. The definition says that hydrophobic surface have the contact angle bigger than 90°, superhydrophobic surface should have contact angle bigger than 150° (is it named lotus effect too). Several products which promised superhydrophobicity can be found, but not all of them make really superhydrophobic layer. We use spray Never Wet [5] to make this surface, some students know the video [6] in which a different coating is used. Both sprays have two separated coating – first of them acts as glue for the second one. Because of this, it is possible to use this coating nearly on any surface. The contact angle of Never Wet is about 170°.

Examples of droplets on hydrophobic coating applied on different material can be seen in figure 6.

![Figure 6. Water droplets on plexiglass (left), cloth (center) and paper (right), all with superhydrophobic coating.](image)

3. Other experiments with hydrophobic surface
The behaviour of water on superhydrophobic surface is very strange and surprising, so this topic is a good opportunity to show students some experiments using it.

Technical note: The hydrophobic spray makes the surface white, so it is necessary to take it into consideration, when we for example want to show the hydrophobic layer as a surprise (for students, during some public show, etc.). Because of this we use transparent plexiglass (if we want to show, where the hydrophobic surface is), or paper plate (because behaviour of water on “only a paper” is surprising for students), or laminated white paper (the layer is almost invisible and it is more resistant to water on opposite side than the paper alone).

Some experiments are briefly described below, teachers (or students) can come up with some other ones.

3.1. Comparison between behavior of water on a normal and a hydrophobic surface
The simplest experiment is just a comparison between behaviour of water on the same surface, but with hydrophobic coating of one half. Example can be seen in figure 7 – left part of the plexiglass plate is without, the right part with hydrophobic coating. In the figure can be seen that the left side is wet in comparison with right side where only droplets are formed.
3.2. Falling of water droplets on a hydrophobic paper

For this experiment we use paper plate with superhydrophobic coating. The colour of the coating is very similar to the colour of the plate, so dripping of water on it could be very surprising. But, there are few other interesting physical effects which can be seen:

- The water droplets behave as if they had some elastic film on the surface not only during falling, but during movement on the plate too – students named them “amoebas”.
- Elastic collisions between two droplets can be observed.
- Using slow-motion video it can be seen how the droplets fall down and rebound from the plate again – screenshots from this video can be seen in figure 8.

![Figure 8. Falling and rebounding of water droplet from a hydrophobic paper.](image)

3.3. Water rectangle

This experiment can be seen in the video [2] – in the middle of some plate we can make a rectangle, which will not be coated. The space outside the rectangle is coated (see figure 9a). In this case water tries to go only inside the rectangle and makes a few-millimetre-high layer (see figure 9b).

![Figure 9. Water rectangle.](image)
3.4. Secret text
The same principle as we use for water rectangle could be used for another very surprising experiment – we can prepare some picture or secret text, which can be seen only after pouring into it. For this experiment we use laminated paper, the picture can be prepared using masking tape (see figure 10).

![Secret text preparation](image10)

**Figure 10.** Secret text. Preparation (left), the text is hidden after coating (centre), it can be seen after pouring water (right).

3.5. Total internal reflection
Half of an orange ping-pong ball with some weight inside was coated from the outer side and put in water. Because of the hydrophobic coating, there is a layer of air between the water and the ball. So, it is possible to see total internal reflection on the interface between water and air (see figure 11).

![Total internal reflection](image11)

**Figure 11.** Total internal reflection on a ping-pong ball with superhydrophobic coating.

4. Conclusion
The topic concerning surface tension, wetting and capillarity is obligatory in the Czech curriculum. Teaching-learning activities described in this paper offer a possibility how to show students that this topic is connected to their normal life. It is an opportunity to show them some experiments which are surprising for them and can show them that “physics is beautiful”. The activities were used in a few classes at both lower and upper secondary school level, student’s feedback was very positive. They express enthusiasm for it, it was fun, and “cool”, of course, but not only that – they said that the activity helped them to understand some things, which they usually use in their normal life. Most of them know
some advertisement mentioned in the introduction, so they appreciated the opportunity to see with their own eyes the behaviour of water on superhydrophobic surface too.

5. References

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