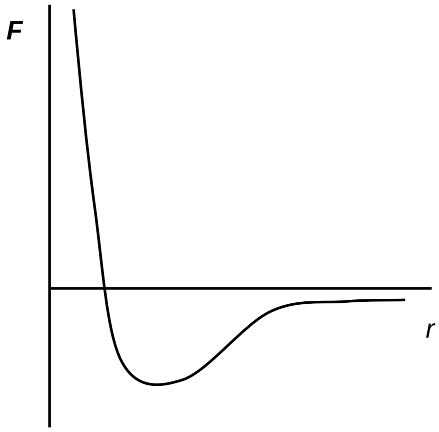
STRUCTURE AND PROPERTIES OF LIQUIDS

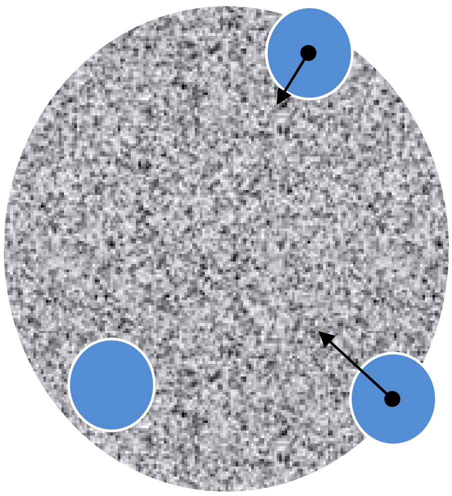
1. Surface tension

a) phenomenon

The surface of a liquid behaves like a stretched elastic membrane (proof – pond skater, small drops – spheres

Explanation:

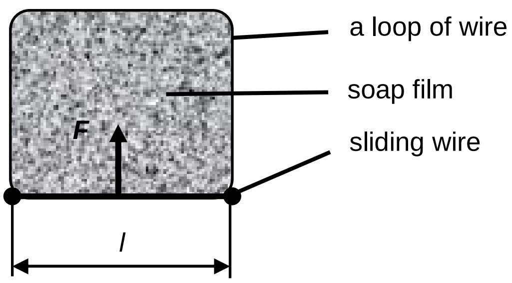




range of attraction $\approx 10 r_0 \approx 1\,\text{nm}$, about 300 molecules

The resultant force acting on the molecule is not equal to zero when the „sphere“ is not „filled“ by the same molecules $\Rightarrow$ the molecules near the surface are attracted into the liquid (the resultant force has a different size for different distances from the surface).

b) physical quantity (γ, in Cz σ)



$l \uparrow \Rightarrow F \uparrow \Rightarrow \frac{F}{l} = \text{const} \approx$ type of liquid, medium around

$\gamma = \frac{F}{l}$

$[\gamma] = \text{N} \cdot \text{m}^{-1}$

- material property in the book of data, big value for mercury (- air)
- affected by temperature (how – why?)
- additional detergents in water lower the surface tension – use? Explain the function

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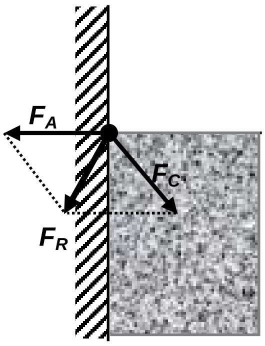
2. Shape of liquid surfaces

The shape of a liquid surface is perpendicular to the resultant force acting on the particular molecules (why?)

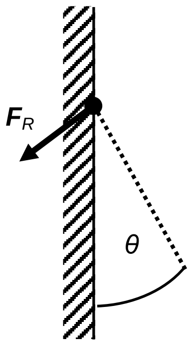


F_A ... adhesive force (attraction of the walls of the container)
F_C ... cohesive force (attraction of the liquid molecules)
force of the air molecules and force of gravity are negligible in comparison with the two previous ones
(what would be their directions?)

Sketch the shape of liquid surface near the wall of the container related to the previous theory

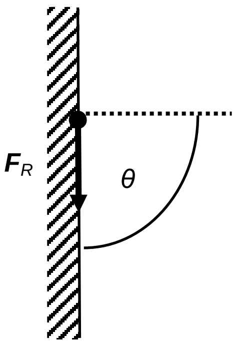
θ ... angle of contact - between ....

a)



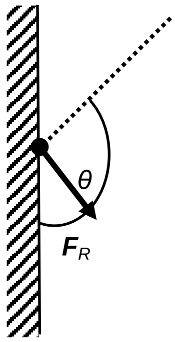
$0 < \theta < 90^0$
water in glass
mercury in copper

b)



$\theta = 90^0$

c)

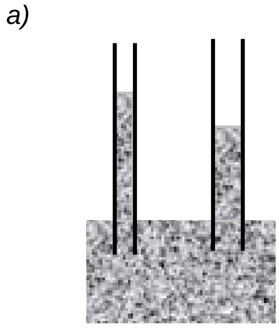


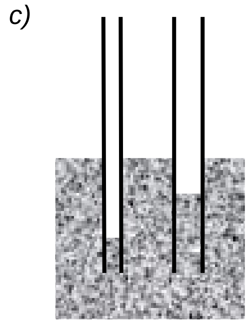
$90^0 < \theta < 180^0$
mercury in glass

Finish the figures above!

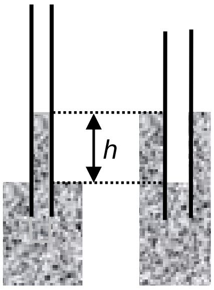
3. Capillarity

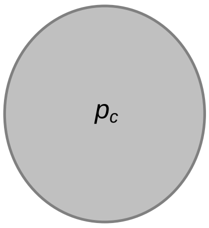
Surface tension + different angle of contact + narrow capillary (relatively more molecules in contact with the container) $\Rightarrow$ liquid inside rises/falls

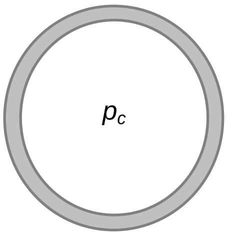




- **equations**







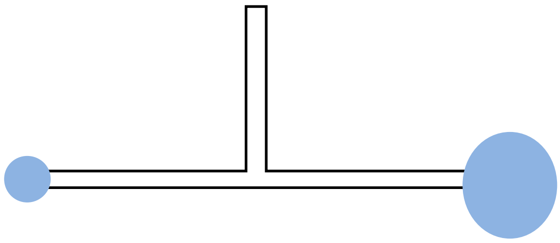
$$h\rho g = \frac{2\gamma}{R}$$

$$p_c = \frac{2\gamma}{R}$$

$$p_c = \frac{4\gamma}{R}$$

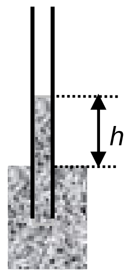
R ... radius of the capillary, drop, bubble

Experiment: Estimate which of the bubbles on the same straw will disappear. Compare with reality, discuss.



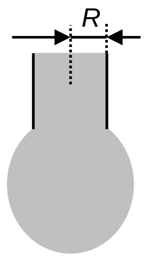
4. Measurement of surface tension

- **capillarity rise method**



$$h\rho g = \frac{2\gamma}{R} \qquad \Rightarrow \qquad \gamma = \frac{h\rho g R}{2}$$

- **drop method**



a drop falls just when its weight slightly exceeds the force holding it together because of surface tension

$$mg = \gamma l$$

$$mg = \gamma 2\pi R \qquad \Rightarrow \qquad \gamma = \frac{mg}{2\pi R}$$

This method can be improved using two liquids – one of known surface tension – and the same capillary. What is the advantage?

$m_1 g = \gamma_1 2\pi R \qquad m_2 g = \gamma_2 2\pi R$

when we divide the equations:

$\frac{m_1}{m_2} = \frac{\gamma_1}{\gamma_2}$ more precise for e.g. 50 drops of each liquid

$$\frac{50m_1}{50m_2} = \frac{M_1}{M_2} = \frac{\gamma_1}{\gamma_2}$$

Measurement: 1 ... water, $\gamma_1 = 72\,\mathrm{mN \cdot m^{-1}}$, $50m_1 =$

2 ... ethanol, $\gamma_2 = ?$, $50m_2 =$

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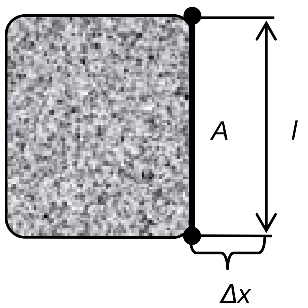
5. Surface energy

= energy needed to create unit area of the new surface (to raise the surface area by 1 m^2)



$$\sigma = \frac{W}{A} = \frac{F\Delta x}{2l\Delta x} = \frac{\gamma 2l\Delta x}{2l\Delta x} = \gamma$$

$$[\sigma] = \mathrm{J \cdot m^{-2}} \left(= \mathrm{N \cdot m \cdot m^{-2}} = \mathrm{N \cdot m^{-1}} = [\gamma]\right)$$

L3/133-135a, b, ×c, 138, 141-5

Questions:

1. A match with a length of 4.4 cm floats on the surface of some water. If we gently pour a little soap solution on one side of the surface divided by the match, it starts moving away from the soap solution towards the pure water. State the force (including direction of this force) acting on the match.
$\gamma_{water} = 73\ \mathrm{mN \cdot m^{-1}}$
$\gamma_{soap} = 40\ \mathrm{mN \cdot m^{-1}}$

2. Liquid flows from a vessel through a narrow capillary with a radius of 0.8 mm. One drop falls per second. How long will it flow if the mass of the liquid is 25 g?
$\gamma = 22 \times 10^{-3}\ \mathrm{N \cdot m^{-1}}$
$g = 9.81\ \mathrm{m \cdot s^{-2}}$

3. Stipulate the pressure of air in a spherical bubble with a diameter of 10^{-3} mm at the depth of 80 cm below the surface of water. Atmospheric pressure is 1000 hPa.
$\gamma = 73\ \mathrm{mN \cdot m^{-1}}$
$\rho_{WATER} = 10^3\ \mathrm{kg \cdot m^{-3}}$
$g = 10\ \mathrm{m \cdot s^{-2}}$

4. Stipulate the mass of water that rises in the capillary of the inner diameter 0.7 mm due to capillary elevation. Assume that water perfectly „wets“ the walls of the capillary. Angle of contact $\theta = 0^{\circ}$.
$\gamma = 73\ \mathrm{mN \cdot m^{-1}}$
$g = 9.81\ \mathrm{m \cdot s^{-2}}$

5. A capillary of a diameter 1 mm is vertically immersed in a vessel with liquid. The liquid rises to the height of 1.1 cm above the free surface of the liquid in the vessel. Which height does the same liquid reach if we immerse in it a capillary with the diameter of 1.5 mm? Assume that water perfectly „wets“ the walls of the capillary.

6. Two glass capillaries of radii 1 mm and 1.5 mm are vertically immersed in ethanol. Calculate γ if the difference of heights of the surfaces is 1.9 mm due to capillary elevation.
$\rho = 789\ \mathrm{kg \cdot m^{-3}}$
$g = 9.81\ \mathrm{m \cdot s^{-2}}$

6. Volume expansion

β ... **volume expansivity / cubic expansivity**

$$\beta = \frac{\Delta V}{V_0 \Delta t} \qquad \{\beta\} = \{\Delta V\} \iff V_0 = 1\,\mathrm{m}^3 \wedge \Delta t = 1\,\mathrm{K}$$

$$[\beta] = \mathrm{K}^{-1}$$

	water	**ethanol**	**glycerol**
$\frac{\beta}{10^{-5}\,\mathrm{K}^{-1}}$	**18**	**110**	**50**

L3/147-149, 151-153

Answers:
1. 1.45 mN
2. 36 min 58 s
3. 400 kPa
4. 16 mg
5. 0.73 cm
6. 22 mN·m^{-1}

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