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Exercises and Complements for the Introduction to Physics I for Students of Biology, Pharmacy and Geoscience

Sheet 8 / 9.11.2020 **Solutions**

Exercise 36.
The height of the water column due to capillary forces can be described by the following equation:

$$h = \frac{2\sigma}{\varrho g r} = 14.3\,\mathrm{mm}$$

where σ is the surface tension and ρ is the density of water.

Exercise 37.
According to the Hagen-Poiseuille equation, the pressure difference ΔP depends on the volume flow rate I_V:

$$\Delta P = \frac{8\eta l}{\pi r^4} I_V$$

where η is the viscosity, l the length and r the radius of the capillary. The volume flow rate I_V is determined by the product of the cross-sectional area A of the capillary and the flow rate v: $I_V = A_{Kap} v = \pi r^2 v$. By inserting this in the previous equation and solving it for the viscosity η we obtain:

$$\eta = \frac{\pi r^4 \Delta P}{8 l I_V} = \frac{r^2 \Delta P}{8 l v} = 3.98\,\mathrm{mPa \cdot s}$$

Exercise 38.
The gravitational force of the mass m added on the right side need to be compensated by the buoyancy force F_A acting on the cube in the water. From this the following equation results:

$$|F_A| = F_{G,W} = m_W g = \varrho_W V_W g = \varrho_W V_K g$$

where V_W is the volume of the suppressed water which is equal to the volume of the cube V_K. The gravitational force of the mass m added on the right side is $F_G = mg$. The absolute value of it should be equal to the buoyancy force:

$$\varrho_W V_K g = mg$$

From this it follows for m added on the right side:

$$m = \varrho_W V_K = 64\,\mathrm{g}$$

Exercise 39.
We use the Bernoulli equation:

$$p_u + \frac{1}{2}\rho v_u^2 = p_o + \frac{1}{2}v_o^2$$

where p_u is the pressure on the surface below the wing, p_o is the pressure on the surface above the wing, ρ is the density of the air, v_u is the velocity of the airflow below and v_0 above the wing. We assume that both flow channels are at the same height. We solve the equation for v_0 and use $p_u - p_o = 900\,\mathrm{Pa}$ (given in the problem)

$$v_o = \sqrt{\frac{2(p_u - p_o)}{\rho} + v_u^2} = 116\,\mathrm{m/s}$$

Exercise 40.
There is a force equilibrium, since we have a stationary system ($a = 0$):

$$\sum \vec{F} = 0$$

Three different forces act on the system:

- The weight force of the sphere (downwards): $F_{W,sph} = m_{sph} \cdot g$
- The buoyancy force on the sphere (upwards): $F_{B,sph} = \rho_{glyc} \cdot V_{sph} \cdot g$
- The frictional force against the sphere's movement (upwards): $F_F = 6\pi \cdot \eta_{glyc} \cdot r_{sph} \cdot v$

So applies:

$$F_{W,sph} - F_{B,sph} - F_F = 0$$

Rearranged it results in:

$$F_{W,sph} = F_{B,sph} + F_F$$

Inserting results in:

$$m_{sph} \cdot g = \rho_{glyc} \cdot V_{sph} \cdot g + 6\pi \cdot \eta_{glyc} \cdot r_{sph} \cdot v$$

After rearrangement and inserting of $m_{sph} = \rho_{steel} V_{sph}$ and $V_{sph} = \frac{4}{3}\pi r^3$ it follows:

$$\frac{4}{3}\pi r^3 \cdot g \cdot (\rho_{steel} - \rho_{glyc}) = 6\pi \cdot \eta_{glyc} \cdot r_{sph} \cdot v$$

The equation can be solved to get v by:

$$v = \frac{\frac{4}{3}\pi r^3 \cdot g \cdot (\rho_{steel} - \rho_{glyc})}{6\pi \cdot \eta_{glyc} \cdot r_{sph}}$$

This leads to:

$$v = \frac{2r^2 g}{9\eta}(\rho_{steel} - \rho_{glyc}) = 2.45 \cdot 10^{-3}\,\mathrm{m/s}$$