



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

Sheet 8 / October 28, 2019

Solutions

Exercise 36.

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

$$h = \frac{2\sigma}{\rho g r} = 14.3 \text{ mm}$$

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:

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

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:

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

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:

$$\rho_W V_K g = mg$$

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

$$m = \rho_W V_K = 64 \text{ g}$$

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_o above the wing. We assume that both flow channels are at the same height. We solve the equation for v_o and use $p_u - p_o = 900$ Pa (given in the problem)

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

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:

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