Exercises in Introductory Physics I

Exercise Sheet 12
due to 22.01.24, 11:59 AM

Fluids

1. The deep sea diver Piccard is diving down the Philippine trench in a steel sphere with an outer diameter of $d = 3\,\mathrm{m}$ until he reaches a depth of $10000\,\mathrm{m}$. (air pressure at sea level: $p_0 = 101325\,\mathrm{Pa}$, density of water: $\rho_{H_2O} = 997\,\mathrm{kg/m^3}$)

   a) How big are the pressure and the force on the sphere at this depth? (1P)

   b) What is the absolute change of the radius due to compression, if the sphere is solid (bulk modulus $K_{steel} = 1.67 \times 10^{11}\,\mathrm{N/m^2}$)? (1P)

2. A hollow sphere with a wall made of titanium has a weight of $2.5\,\mathrm{N}$ and dips into water with half of its volume.

   a) What is the diameter d of the sphere and the thickness x of the titanium wall? (2P)

   b) What is the work W needed to pull the sphere out of the water? (2P)

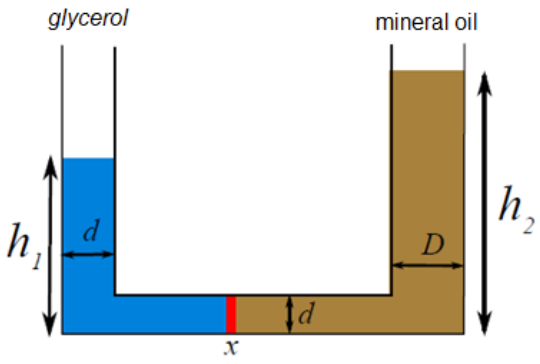
3. A steel sphere (radius $R = 2\,\mathrm{mm}$, density $\rho_{steel} = 8000\,\mathrm{kg/m^3}$) is immersed in water (density $\rho_{H_2O} = 997\,\mathrm{kg/m^3}$, viscosity $\eta = 1\,\mathrm{mPa \cdot s}$) and held at rest. At $t = 0$ the sphere is released and starts to sink.

   a) Sketch the forces acting on the sphere right at the beginning of the decent and after it sunk for a large distance. (1P)

   b) Calculate the speed $v(t)$ of the sphere as a function of time. (2P)

   c) After which time has the speed reached $1 - 1/e \approx 0.6321$ of the terminal speed? (1P)

4. In a u-shaped tube with a circular cross-section, glycerol (Density: $\rho_{oil} = 890\,\mathrm{kg/m^3}$) and mineral oil (Density: $\rho_{glycerol} = 1260\,\mathrm{kg/m^3}$) are separated by a movable membrane as depicted in the figure below.



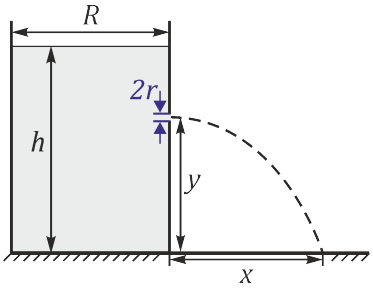
a) What is the ratio q of the heights $h_{glycerol}/h_{oil}$ when the system is in equilibrium? (1P)

b) Now the membrane is temporarily fixed and the glycerol is filled up until the height of both liquids is equal. After it is released the whole system oscillates. At what distance to the original position is the new equilibrium position? (2P)

c) What is the maximum speed of the membrane during the oscillation set off in b)? (2P)

Note: The diameter d of the connecting tube is significantly smaller than the heights of the liquids. Assume that the mass of the membrane $m_{membrane}$ is much higher than the total mass of both liquids and that no energy is dissipated during the oscillation.

5. **Bonus task**: In a container with a circular base ($R = 0.2\,\mathrm{m}$) water is filled up to a height $h = 0.5\,\mathrm{m}$.



a) At which height from the bottom of the container an opening should be put so that the water hits the ground at the furthest distance from the jar? (1P)

b) Now the opening (circular, $r = 0.5\,\mathrm{mm}$) is put at $y = 0.3\,\mathrm{m}$. Calculate how the water level $h(t)$ changes over time. (2P)