Name of student:……………………………

1 DENSITY DETERMINATION BY PYCNOMETER

Task: Determine the densities of one solid material and one liquid

Density

The density (ρ) is elementary physical property of matter. For a homogeneous object it is defined as the ratio of its mass (m) to its volume (V) – Eq.1

$$\rho = \frac{m}{V} \qquad [\text{kg m}^{-3}] \qquad [1]$$

Numerically it represents the mass per unit volume of matter. As it follows from equation [1], the SI unit of density is kg m^{-3}. However, g cm^{-3} is another unit commonly used in a laboratory. Its conversion is:

$$1 \text{ g cm}^{-3} = 1000 \text{ kg m}^{-3} \qquad [2]$$

The volume of an object increases with increasing temperature, because of the matter's volumetric thermal expansion. Therefore, according to equation [1], the density of an object depends on its temperature, with higher temperature resulting in lower density. The density of a gas further depends on the pressure as well. Nevertheless, this effect is negligible in a case of liquid and/or solid matter.
There are several experimental methods used for density determination of liquids. We will learn how to use pycnometer in this assignment.

A. Density determination of liquids by pycnometer

Density determination by pycnometer is a very precise method. It uses a working liquid with well-known density, such as water. We will use distilled water, for which temperature dependent values of density (ρ_{H2O}) are shown in Table 1. The pycnometer (Figure 1) is a glass flask with a close-fitting ground glass stopper with a capillary hole through it. This fine hole releases a spare liquid after closing a top-filled pycnometer and allows for obtaining a given volume of measured and/or working liquid with a high accuracy.

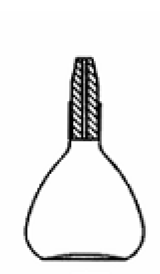

Figure 1 Pycnometer

- First we fill pycnometer with distilled water. According to equation [1], the volume of water that is filling the pycnometer and the stopper is:

$$V = \frac{m_{H2O}}{\rho_{H2O}} \qquad [3]$$

where: m_{H2O} is experimentally determined weight of water (empty pycnometer weight subtracted).

- We repeat the procedure for the liquid with unknown density (ρ_L) and determine its weight $\mathbf{m_L}$ (measured weight minus weight of empty pycnometer). Volume V obtained in this measurement is the same as the volume of water determined from equation [3]. It follows alternated equation:

$$V = \frac{m_L}{\rho_L} \qquad [4]$$

- Combining equations [3] and [4]:

$$\frac{m_{H2O}}{\rho_{H2O}} = \frac{m_L}{\rho_L} \qquad [5]$$

yields a relation that provides the density of measured liquid (ρ_L):

$$\rho_L = \frac{m_L}{m_{H2O}} \rho_{H2O} \qquad [6]$$

B. Density determination of solid matter by pycnometer

Pycnometer can be also used to determine the density of homogeneous solid object that does not dissolve in working liquid (water). First, we need to measure the weight of pycnometer together with inserted object $\boldsymbol{m_0+m_S}$. We add water and determine the weight m'_{H2O} (weight $\boldsymbol{m_0+m_S+m_{H2O}}$). First, we need to measure the weight of pycnometer together with inserted object m_0+m_S. We add water and determine the weight m'_{H2O} (measured weight minus $\boldsymbol{m_0+m_S}$). The volume of added water V'_{H2O} can be obtained as:

$$V'_{H2O} = \frac{m'_{H2O}}{\rho_{H2O}} \qquad [7]$$

The volume of measured solid object $\boldsymbol{V_S}$ is the difference between the volume of water that fills the empty pycnometer $\boldsymbol{V}$ and volume V'_{H2O}

$$V_T = V - V'_{H2O} = \frac{m_{H2O} - m'_{H2O}}{\rho_{H2O}} \qquad [8]$$

Density of measured object ρ_S can be then calculated as

$$\rho_S = \frac{m_S}{V_S} \qquad [9]$$

Experimental procedure:
Accuracy of herein described method for density determination of liquid and/or solid matter relies on precise measurements of weight and volume. Since it is important to determine weight of empty pycnometer in its dry state, we do so at the beginning.

1. Determine the weight of empty, dry pycnometer $\mathbf{m_0}$ and write value to the Table 2.
2. Fill about 1/3 of pycnometer volume with objects made of examined material and measure the weight $\mathbf{m_1}$.
3. Add water such that pycnometer as well as capillary hole in the stopper is filled with water. Dry the spare water that leaks through the capillary hole with a filter paper and measure total weight $\mathbf{m_2}$.
4. Empty pycnometer filled with distilled water only. Use the filter paper to dry the spare water again and measure the weight $\mathbf{(m_3)}$.
5. Empty pycnometer. Rinse it once with a liquid whose density you are going to determine next. Fill pycnometer with the liquid as previously and measure the weight $\mathbf{m_4}$.
6. Clean pycnometer carefully after finishing the experiment. Rinse it with distilled water and let dry.
7. Measure the laboratory temperature ***t***, which determines the temperature of examined liquids and solid objects.
8. Calculate the weight of water $\mathbf{m_{H2O} = m_3 - m_0}$, weight of measured liquid $\mathbf{m_L = m_4 - m_0}$ and determine density of liquid according Equation 6.
9. Calculate objem volume $\boldsymbol{V_S}$ following Equation 8 and its density ($\boldsymbol{\rho_S}$) according Equation 9

Table 1 Temperature dependence of distilled water density ρ_{H2O}.

t [°C]	ρ_{H2O} [g cm^{-3}]
15	0.99996
16	0.99940
17	0.99990
18	0.99985
19	0.99978
20	0.99820
21	0.99799
22	0.99777
23	0.99754
24	0.99730
25	0.99705

Table 2 The weight of empty pycnometer $\boldsymbol{m_0}$, pycnometer with solid object $\boldsymbol{m_1}$, pycnometer with solid object and added water $\boldsymbol{m_2}$, pycnometer with water $\boldsymbol{m_3}$ and pycnometer with liquid $\boldsymbol{m_4}$

t = …….°C

m_0 [g]	
m_1 [g]	
m_2 [g]	
m_3 [g]	
m_4 [g]	
ρ_S	kg m^{-3} g cm^{-3}
ρ_L	kg m^{-3} g cm^{-3}

Calculations:

Conclusion: