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PHARMACEUTICAL PHYSICS

EXPERIMENTAL WORK

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PHARMACEUTICAL PHYSICS - EXPERIMENTAL WORK

LABOR PROTECTION RULES IN THE PHARMACEUTICAL PHYSICS LABORATORY

General rules

- During the hours of practical work, a protective gown will be worn and synthetic clothing will be avoided

- Only the presence of the experimental instruments, the workbook and the computer is allowed on the work table. Personal items will be stored in places designated for their storage

- Practical works will be carried out only under the supervision of the teacher

- Before using substances check the label (three times)

- The ongoing experiment will not be left unattended

- It is strictly forbidden to taste the chemicals from the laboratory

- The use of laboratory glassware for the purpose of drinking or eating is strictly prohibited

- Glassware will be checked to be in good working condition and washed before and after use (three times with distilled water)

- In order to avoid contamination of substances, it is not allowed to exchange stoppers between containers, nor to insert pipettes from one container to another, without first washing it

In case of chemical accident

In case of a burn with corrosive substances, it is necessary to wash the wound with plenty of water and treat with various substances, depending on the chemical agent that caused the burn:

- *burns caused by acids* : a base will be used for neutralization - 2% sodium bicarbonate solution

- *burn caused by bases:* an acid will be used for neutralization - 2% boric acid solution

- *thermal burn:* apply special pharmaceutical preparations addressed for the treatment of burns eg: OXIMED

A medical visit is mandatory after any accident, for all the people who were involved in it !

PHYSICAL QUANTITIES AND UNITS OF MEASUREMENT

Physical quantities define properties of their bodies characterize processes in which the changes that occur can be described quantitatively.

Examples of physical quantities are: mass, temperature, speed, electric charge.

Physics has long been called the science of measurement, because the study of physical phenomena involves the measurement of the quantities that characterize them.

Measurement is a process by which it can be compared the respective physical quantity with a well-defined quantity, of the same nature, which a was chosen as the unit of measure. This comparison (or measurement) is done by means of a measuring instrument.

EXAMPLES OF UNITS OF MEASUREMENT:

1 meter for length , 1 second for duration , 1 kg for mass .

Some physical quantities are fundamental quantities, being defined only by

description of the measurement procedure.

For example, distance is determined by measurement with a ruler, and time by measuring with a clock. Other physical quantities are derived quantities, as they are obtained through calculation formulas that use the fundamental quantities.

 For example, speed represents the ratio between the distance traveled by a body in a period of time.

Over time, different systems of measurement units have been used such us, fundamental/basic quantities and also other corresponding units of measurement.

Today, the **International System of Units,** SI, is used most frequently, employing the following fundamental sizes and units of mesurement:

No. crt	Physical quantity	Unit of measurement	SI	CGS
1	Time	Second (s)	$[t]_{SI} = 1s$	$[t]_{CGS} = 1s$
2	Distance	Meter (m)	$[d]_{SI} = 1m$	$[d]_{CGS} = 1cm$
3	Mass	Kilogram (kg)	$[m]_{SI} = 1kg$	$[m]_{CGS} = 1g$
4	Temperature	Kelvin	$[T]_{SI} = 1K$	$[T]_{CGS} = 1K$
5	Amount of substance	Mole	$[\nu]_{SI} = 1mol$	$[\nu]_{CGS} = 1mol$
6	The intensity of the electric current	Amps	$[I]_{SI} = 1A$	$[I]_{CGS} = 1A$
7	Luminous intensity	The candle	$[E]_{SI} = 1cd$	$[E]_{CGS} = 1cd$

METER - UNIT OF LENGTH (**m**) The meter is the length equal to 1650763.73 vacuum wavelengths of the radiation that corresponds to the transition between the 2p10 and 5d5 energy levels of the Krypton 86 atom.

Observation

The definition of the meter was adopted by the 11th General Conference of Weights and Measures in 1960 through the 6th resolution.

THE KILOGRAM - UNIT OF MASS (**Kg**): **The kilogram is the mass of the international prototype. The term weight denotes the same quantity with a force G = m · g - where g is the gravitational acceleration; g=9.80665 m/s^2**

Observation:

The definition of the kilogram was adopted by the first and third General Conferences of Weights and Measures in 1889 and 1901, respectively. The kilogram as an "international prototype" is kept at the International Bureau of Weights and Measures in Sevres, under the conditions set by the General Conference of Weights and Measures from 1889.

SECOND - TIME UNIT (**s**) The second is the duration of 9192631770 periods of the radiation that corresponds to the transition between the two hyperfine levels of the fundamental state of the Cesium 133 atom.

Note:

The definition of the second was adopted by the 13th Conference of Weights and Measures from 1967 through the 1st resolution.

AMPERE - THE UNIT OF INTENSITY OF ELECTRIC CURRENT (**A**) The ampere is the intensity of an electric current which, maintained in two straight parallel conductors of infinite length and with negligible circular section, placed in a vacuum, at a distance of 1m from each other, will produce between these conducting a force of 1 N over a length of 1 m.

Observation:

The definition of the Ampere was adopted by the 9th conference of Weights and Measures from 1948 through the 2nd resolution.

CANDELA - THE UNIT FOR LUMINOUS INTENSITY (**Cd**) The candela is the luminous intensity in a given direction of a source that emits monochromatic radiation with a frequency of 540.10^{12} Hz and whose energy intensity in this direction is

Observation:

The definition for the candle was adopted by the 16th Conference of Weights and Measures from 1979

THE KELVIN - UNIT OF THERMODYNAMIC TEMPERATURE (**K**) A Kelvin is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.

Observation:

The Kelvin definition was adopted by the 13th Conference of Weights and Measures in 1967 through the 4th resolution.

The same unit of measurement and the same symbol are used to evaluate a temperature range.

THE MOLE-UNIT FOR THE QUANTITY OF SUBSTANCE (mol)

a) The mole represents the amount of atoms determined experimentally to be found in 0.012 Kg of C12.

b) Whenever the mole is used, the elementary entities must be specified, they can be atoms, molecules, ions, electrons, other particles or groups specified by such particles.

Observation:

The definition of the Mole was adopted by the 14th Conference of Weights and Measures from 1971

Other units of measure:

The plane angle is measured in **radians** .

The radian is the plane angle with the vertex at the center of a circle that delimits on the circumference of the circle an arc whose length is equal to the radius of the circle.

The definition of the radian was adopted by the International Organization for Standardization (ISO) through recommendation R31, part 1.

The solid angle - is measured in **steradians** .

The steradian is the solid angle with the apex in the center of a sphere that delimits on the surface of the sphere an area equal to the area of a square whose side is equal to the radius of the sphere.

The definition of the radian was adopted by the International Organization for Standardization (ISO) through recommendation R31, part 1.

The first length standard was a bar made of a platinum-iridium alloy called a standard meter, in 1959 the Yard is defined: 1 yard=0.9144m;

1 inch = 2.54 cm

OTHER UNITS OF MEASUREMENT:

Units of measurement for force :

1 dyn= 10^{-5} N

1 kgf=9.81 N

Units of measurement for mass:

1 pound (lb) = 453.5923 g = 0.4535923 Kg

1 ounce (oz) = 28.35 g

Units of measurement for energy

1 erg = 10^{-7} J

1 kcal= $4,186.10^3$ J

1 eV = $1,602.10^{-19}$ J

1 kWh= $3.6.10^6$ J

Units of measurement for length

1 inch = 25.4 mm

1 yd (yard) = 0.9144 m

1 mile = 1609.344 m

1 nautical mile = 1853.18 m

Units of measurement for area

1 ar =100 m^2

1 ha =10000 m^2

1 acre = 4046.86 m^2

1 in ^{2} (sq inch)=6.452 mm^2

1 yd ^{2} (sq yard)= 0.9144 m^2

Units of measurement for volume

1 US gallon = 3.785 l = 3785 m^3

1 gallon England = 4.546 l=4546 m^3

1 US barrel for oil = 158.98 l

1 ounce (liquid) = 28.413 cm^3 = 1.7339 in^3

Units of measurement for temperature

Temperature in degrees Fahrenheit: tF=(9/5).tC+32

Temperature in Reaumur degrees: tR=TK-218.52

1 gram (SI)=0.03527 ounces

1 feddan (Egypt)=1.038 acres=0.42 ha

1 ardeb (Egypt) = 191.612 l

1 hamlah (Egypt)= 74,890 kg

1 drachma (Turkey) = 3.207g

1 cuffisco (Sicily)= 22.1981 l

1 cuartilo (Mexico)=0.547 l

1 cuarteron (Spain) for oil=0.151 l

1 dinero (Spain) = 1.199 g

1 chittak (India) = 58.319 g

1 buncal (Indonesia)=46.344 g

1 bercocvic (Russia) = 163.85 kg

1 pud (Russia)=16.381 kg

1 barrel for cement (USA)=170,550 kg

1 barrel for oil (USA) = 158.987 kg

1 iron (mass unit for skin thickness)=1/48 in=0.539 mm

1 koku (Japan)= 180.4857 dm^3

1 kivan (Japan)=3.75 kg

MEASURED LENGTHS – EXAMPLES

Distance	Unit of measurement meters (m)
Distance to the most distant quasar	$6 \cdot 10^{25}$
Distance to the nearest nebula (The Andromeda Sea Nebula)	$2 \cdot 10^{22}$
The radius of our galaxy	$6 \cdot 10^{19}$
Distance to the nearest star (Alpha Centauri)	$4,3 \cdot 10^{16}$
Ray of the Sun	$6,9 \cdot 10^{8}$
Earth Ray	$6,4 \cdot 10^{6}$
The height of a man	$1,8 \cdot 10^{0}$
The thickness of a book	$4 \cdot 10^{-2}$
The thickness of a page in a book	$1 \cdot 10^{-4}$
The size of a polio virus	$1,2 \cdot 10^{-8}$
The radius of a hydrogen atom	$5 \cdot 10^{-11}$
The effective radius of a proton	$1,2 \cdot 10^{-15}$

MEASURED TIME INTERVALS

Time intervals	Unit of measurement Seconds (s)
Age of the Earth	$1,2 \cdot 10^{17}$
The average lifespan of a human	$2 \cdot 10^{9}$
The duration of the Earth's revolution around the Sun (1 year)	$3,1 \cdot 10^{7}$
The duration of the Earth's rotation around its axis (1 day)	$8,6 \cdot 10^{4}$
The half-life of free neutrons	$7 \cdot 10^{2}$
The time between two normal heartbeats	$8 \cdot 10^{-1}$
The period of the tuning fork that gives the note A	$2,3 \cdot 10^{-3}$
The typical rotation period of a molecule	$1 \cdot 10^{-12}$
The half-life of neutral pawns	$2,2 \cdot 10^{-16}$

For force: 1 dyn= 10^{-5} N or 1kgf= 9.81 N

For mechanical work : 1 erg= 10^{-7} J

1P (poise) = 1 dyn.s/cm^2 =0.1 Pa.s

1 st = (stokes) = 1 cm^2/s = 10^{-4} m^2 /s

1 gauss = 1 Gs = 10^{-4} T

1 oersted = 1 Oe= (100/4 Pi).(A/m)

1 inch = 25.4 mm

1 yard = 0.914 m

Temperature T=5/9(tF-32)+273.15 where tF is the Fahrenheit temperature.

Other units of measurement for mass		
No.	**Name**	**CGS**
1	1 grain	0.065g
2	1 scruple (apoth) (=20g)	1.29g
3	1 drachma (apoth) (=60g)	3.88g
4	1 ounce (avdp)	1.77g
5	1 ounce (apoth) (480 grains)	31.10g
6	1 ounce (avdp) (437.5 grains)	28.35g
7	1 livra or pound (apoth)	373.24 g
8	1 livra or pound (avdp) 16oz = 7000 grains	453.59 g

PREFIXES USED FOR MULTIPLES AND SUBMULTIPLES OF MEASUREMENT UNITS

10^{-1}	deci	10^{1}	deca
10^{-2}	centi	10^{2}	hecto
10^{-3}	mili	10^{3}	kilo
10^{-6}	micro	10^{6}	mega
10^{-9}	nano	10^{9}	giga
10^{-10} m	Å (Angstrom)		
10^{-12}	pico	10^{12}	tera
10^{-15}	femto	10^{15}	peta
10^{-18}	atto	10^{18}	exa
10^{-24}	yocto	10^{21}	zetta
10^{-27}	ronto	10^{24}	yotta
10^{-30}	quecto	10^{27}	ronna
		10^{30}	quetta

THEORY OF ERRORS

1. CALCULATION OF ERRORS FOR DIRECTLY MEASURED QUANTITIES

Measurements can only be made with a limited degree of precision and consequently the real value of a quantity cannot be known.

The results of the measurements represent only an approximate value more or less close to the real one. The impossibility of knowing the real value of the quantities to be measured is explained by committing errors during the measurement process.

ERROR represents the difference between the real value and the measured one. Making errors is inevitable, but they can be reduced by taking certain precautions. It is inevitable to know the degree of precision of the measurements which can be appreciated by evaluating the committed error.

The determination of a physical quantity can be done directly, when the result is read directly from the measuring instrument, or indirectly, when it is obtained by calculating it from other directly determined physical quantities (for example, the length l, time t, mass m are read directly, whereas the speed v is obtained from the calculation.)

Errors are classified as *systematic errors* or *accidental errors*.

Characteristic of *the systematic errors* is the distortion of the measurements every time in the same direction, either increasing or decreasing all the measurements.

The accidental errors , which are due to random causes, take different values in both directions, in the successive measurements of the same quantity. They are not equal in absolute value, generally differing in different measurements.

Accidental errors obey the laws of probability calculation and are characterized by the following properties:
- ✓ The probability of committing a positive error is equal to that of committing a negative error.
- ✓ The probability of making a small error is equal to that of making a large error.
- ✓ The sum of accidental errors produced when measuring the same quantity, tends to zero when the number of measurements is very large.

The real error is the difference between the measured value and the real value of a quantity:

$$\Delta x_1 = x_1 - x$$
$$\Delta x_2 = x_2 - x$$
$$\Delta x_3 = x_3 - x$$
$$............$$
$$\Delta x_n = x_n - x$$
$$--------$$
$$\sum_{i=1}^{n} \Delta x_i = \sum_{i=1}^{n} x_i - nx$$

or $x = \dfrac{\sum_{i=1}^{n} x_i}{n} = \dfrac{\sum \Delta x_i}{n} = \bar{x} = \varepsilon$

where $\bar{x}$ - is the average of the values of x_i

ε is the average of the errors

for a large number of errors: $\varepsilon \to 0$

AVERAGE OF ABSOLUTE VALUES OF INDIVIDUAL ERRORS

$$|\Delta x_1| = |x_1 - x|$$
$$|\Delta x_2| = |x_2 - x|$$
$$|\Delta x_3| = |x_3 - x|$$
$$............$$
$$|\Delta x_n| = |x_n - x|$$

and $\bar{x} = \dfrac{|\Delta x_1| + |\Delta x_2| + |\Delta x_3| + ... + |\Delta x_n|}{n}$

A possibility of choosing individual error squares is:

$$(\Delta x_1)^2 = (x_1 - x)^2$$
$$(\Delta x_2)^2 = (x_2 - x)^2$$
$$(\Delta x_3)^2 = (x_3 - x)^2$$
$$.................$$
$$(\Delta x_n)^2 = (x_n - x)^2$$

If x representes the average of the squares, then the sum of the squares of the errors becomes minimal:

$$S(x) = (x_1 - x)^2 + (x_2 - x)^2 + (x_3 - x)^2 + ...(x_n - x)^2$$

The derivative with respect to x is canceled and it can be obtained as follows:

$$x = \bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$ which is called **THE AVERAGE VALUE**

It can be determined as follows: **THE MEAN SQUARED ERROR** :

$$m = \pm\sqrt{\frac{(\Delta x_1)^2 + (\Delta x_2)^2 + (\Delta x_3)^2 + ... + (\Delta x_n)^2}{n}}$$

or $$m = \pm\sqrt{\frac{\sum_{i=1}^{n}(\Delta x_i)^2}{n}}$$

This parameter depends very little on the number of measurements, if a sufficient amount of determinations are made.

m^2 is called **DISPERSION** – it represents the square of the mean squared error.

APPARENT ERRORS :

$$v_1 = x_1 - \bar{x}$$
$$v_2 = x_2 - \bar{x}$$
$$v_3 = x_3 - \bar{x}$$
....
$$v_n = x_n - \bar{x}$$
$$- - - - - - - -$$

$$\sum_{i=1}^{n} v_i = \sum_{i=1}^{n} x_i - n\bar{x} = \sum x_i - \frac{n\sum x_i}{n}$$

$$\sum_{i=1}^{n} v_i = 0$$

The link between the real and the apparent error is the following:

$$\sum x_i - v_i = \bar{x} - n = \varepsilon$$

The mean squared error can also be expressed by using the apparent errors: $\sum x_i = v_i + \varepsilon$

$$\varepsilon = \Delta x_1 - v_1$$
$$\varepsilon = \Delta x_2 - v_2$$
$$.............$$
$$\varepsilon = \Delta x_n - v_n$$

$$\overline{}$$

$$n\varepsilon = \sum \Delta x_i - \sum v_i = \sum \Delta x_i$$

$$\text{so } \varepsilon = \frac{\sum \Delta x_i}{n}$$

$$\sum (\Delta x_i)^2 = \sum v_i^2 + 2\varepsilon \sum v_i + n\varepsilon^2$$

$$\sum (\Delta x_i)^2 = \sum v_i^2 + n\varepsilon^2$$

$$\frac{\sum (\Delta x_i)^2}{n} = \frac{\sum v_i^2}{n} + \frac{\sum (\Delta x_i^2)}{n} = \frac{\sum v_i^2}{n} + \frac{\sum (\Delta x_i^2)}{n} + \frac{2\sum_i \sum_j \Delta x_i \Delta x_j}{n^2}$$

as a result, the folowing formula is obtained: $m^2 = \dfrac{\sum (\Delta x_i)^2}{n}$

afterwards, the following formula is obtained for the mean squared error: $m = \pm \sqrt{\dfrac{\sum v_i^2}{n-1}}$

where $v_i = x_i - \bar{x}$ and **n** represents the number of measurements.

THE MEAN SQUARED ERROR becomes: $m = \pm \sqrt{\dfrac{\sum (x_i - \bar{x})^2}{n-1}}$

If a certain value of a measurement xi and m is known, then it is expected that the real value is included in the interval: $(x_i - m, x_i + m)$.

Because the average value does not coincide with the real value, it presents a characteristic deviation

from it, also called the **_MEAN SQUARED ERROR OF AVERAGE:_** $\boxed{\mu = \pm \sqrt{\dfrac{\sum (x_i - \bar{x})^2}{n(n-1)}}}$.

The actual value will be included in the following interval $(\bar{x} - \mu, \bar{x} + \mu)$.

The properties of accidental errors can be expressed using the Gaussian distribution function, if a continuous function will be accepted for accidental errors:

$$P(v) = \frac{1}{\sigma \sqrt{2\pi.}} \exp\left(-\frac{v^2}{2\sigma^2}\right)$$

where σ is a constant that depends on the nature of the measurements and the precision of the executions

and P(v) represents the probability density or the probability that the error of a quantity is included in the interval (v, v+dv).

The probability that the error is included in the interval (- δ, + δ) is:

$$\alpha = \int_{-\delta}^{+\delta} P(v)dv = \frac{1}{\sigma\sqrt{2\pi}} \int_{-\delta}^{+\delta} \exp\left(-\frac{v^2}{2\sigma^2}\right)dv =$$

$$= \frac{1}{\sqrt{2\pi}} \int_{-\eta}^{+\eta} \exp\left(-\frac{t^2}{2}\right)dt = \frac{2}{\sqrt{2\pi}} \int_{0}^{+\eta} \exp\left(-\frac{t^2}{2}\right)dt$$

Where $\eta = \dfrac{\delta}{\sigma}$; $v = \sigma.t$

Performing the integral we arrive at a sum calculated in the tables for different values of η.

The interpretation of σ is as follows: if η=1, then σ= δ.

Thus, 2 σ represents the interval (- σ, + σ), in which approximately 68% of the errors are included, that represents a fraction of 2/3 of the number of errors.

α- represents the probability that the error is included in the interval (-δ, +δ);

α - is called confidence coefficient.

(- δ, + δ) - confidence interval.

Thus, the probability that the real value x is included in the interval (x $_i$ -m , x $_i$ + m) represents 68%.

The mean squared error of average has the following interpretation:

$$\mu = \pm\sqrt{\frac{\sum(x_i - \bar{x})^2}{n(n-1)}}$$: there is a probability of 68% (≈2/3) for the real value of the measured

quantity to be included in the interval $(\bar{x} - \mu, \bar{x} + \mu)$

and the results are expressed in the form: $x = \bar{x} \pm \mu$

Sometimes the aim is to find the interval (- δ, + δ) in which 50% of the errors are included.

In this case, the value obtained for a single measurement is the mean squared error:

$$m = \pm\frac{2}{3}\sqrt{\frac{\sum v_i^2}{n-1}} = \pm\frac{2}{3}\sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}}$$ and the mean squared error of average: $\mu_p = \pm\frac{2}{3}\sqrt{\frac{\sum(x_i - \bar{x})^2}{n(n-1)}}$

which are called probable errors.

In order to obtain a clear overview of the accidental errors, it is useful to use the relative errors defined for each individual measurement by the ratios: v_1/x_1, v_2/x_2, ……., v_n/x_n. And for the arithmetic mean $\pm\dfrac{m}{x}$.

If these two types of relationships are multiplied by 100, we get the relative percentage values.

2. CALCULATION OF ERRORS FOR QUANTITIES RESULTING FROM A CALCULATION

In most cases, the aim is to determine a quantity obtained on the basis of direct measurements. Knowing the errors committed when measuring the quantities that may intervene in obtaining the final result, a method should be found to calculate the error for the result itself. Since the errors are very small, the serial development method can be used.

The theory of errors states that if a large number of measurements are made directly on each quantity that enters a formula, the mean squared error of the averege of the quantity as a result of a calculation is given by the relationship f (x_1, x_2, x_3, … , x_n) = Y the quantity resulting from a calculation made with the help of directly measurable quantities x_1, x_2, …, x_n.

And :

$$\mu = \pm \sqrt{\left(\frac{\partial f}{\partial x_1}\mu_1\right)^2 + \left(\frac{\partial f}{\partial x_2}\mu_{n1}\right)^2 + ... + \left(\frac{\partial f}{\partial x_n}\mu_n\right)^2}$$

it is observed that the relation: $m = \pm\sqrt{\dfrac{\sum v_i^2}{n(n-1)}}$ is a particular case of the above formula for f = x_i = x

and $\mu_1^2 = \dfrac{\sum v_{i1}^2}{n_1(n_1-1)}$; $\mu_2^2 = \dfrac{\sum v_{i2}^2}{n_2(n_2-1)}$; .... ; $\mu_N^2 = \dfrac{\sum v_{iN}^2}{n_N(n_N-1)}$

3. LEAST SQUARES METHOD

There are laboratory works in which the aim is to determine a quantity that constitutes a constant coefficient from a linear relationship of the form: **Y = A.x+B** .

Such a relation is Hooke's law, for example: F=kx, in which the determination of the coefficient k or the acceleration of the center of the cylinder rolling on an inclined plane with rolling friction is required. Depending on $\sin \alpha \approx \alpha$(for α- small : a= A. α+B) where B is required.

By making several measurements for x and y, the constants A and B can be determined from a graphic representation. Usually the representative points are not exactly on a straight line, being affected by accidental errors. The question arises by which methods the constants A and B should be determined so that their values are as close as possible to the real value.

This problem is solved by the "*least squares method* " which is based on the following condition: the most probable value of the constants will be the one for which the sum of the squared errors is minimal.

It can be written accordingly:

$$\bar{x} = \frac{1}{n}\sum_i x_i$$

$$\bar{y} = \frac{1}{n}\sum_i y_i$$

$$\overline{x^2} = \frac{1}{n}\sum_i x_i^2$$

$$\overline{xy} = \frac{1}{n}\sum_i x_i y_i$$

So: $\overline{x^2} A + \bar{x}B - \overline{xy} = 0$

$\bar{x}A + B - \bar{y} = 0$

The solutions of these equations constitute the values sought for A and B:

$$A = \frac{\overline{xy} - \bar{x} . \bar{y}}{\overline{x^2} - (\bar{x})^2}$$

$$B = \frac{\overline{x^2} . \bar{y} - \bar{x} . \overline{xy}}{\overline{x^2} - (\bar{x})^2}$$

The method can also be applied in non-linear relationships obtained on the basis of similar demonstrations.

4. STATISTICAL METHOD OF CALCULATION FOR THE AVERAGE VALUE $\overline{x}$

1. The statistical calculation mode is entered

   Mode → STAT

2. Enter the data into the statistics:

   10.52 DATE

   10.65 DATE

   10.45 DATE   or M+

   10.45 DATE

   10.48 DATE

3. The number of data entered into the statistic should be checked: n=5

   (SHIFT)(n) ⇒n=5

4. The average value is calculated:

   $\overline{x} = 10.51$

Statistical method of calculation for error

$$\mu = \pm \sqrt{\frac{\sum_{i=1}^{n}(x_i - \overline{x})^2}{n(n-1)}}$$

$$\mu = \pm \sqrt{\frac{(10,52-10,51)^2 + (10,65-10,51)^2 + (10,45-10,51)^2 + (10,45-10,51)^2 + (10,48-10,51)^2}{5 \cdot 4}}$$

1. The statistical calculation mode is entered
2. The previous memory should be deleted
3. Enter the differences in memory:

   (10.52-10.51)=DATE

   (10.65-10.51)=DATE

   (10.45-10.51)=DATE

   (10.45-10.51)=DATE

19

(10.48-10.51)=DATE

4. Check no. of data from memory: n=5

(SHIFT)(6) $\Rightarrow$n=5

5. The sum of squares is calculated

$$\sum x^2 = 0,0278$$

6. Afterwards, the following calculation is made $\dfrac{\sum x^2}{5 \cdot 4} = 1,39 \cdot 10^{-3}$

7. It is calculated $\sqrt{\dfrac{\sum x^2}{5 \cdot 4}} = \sqrt{1,39 \cdot 10^{-3}} = 0,0372$

8. The calculated error is $\mu = 0.0372$

Thus, the range of actual values is:

$$x_{real} \in (10,51 - 0,0372; 10,51 + 0,0372)$$
$$x_{real} \in (10,4728; 10,5472)m$$

DETERMINATION OF DENSITY FOR SOLID MATERIALS

INTRODUCTION

The density of a material is an old physical notion since the century. XVII. Émile Littré defined density as the ratio between mass and volume. Laplace uses in 1810 for the notion of density it of volumetric mass, which is still associated in 1960 by the International Bureau of Weights and Measures.

Density is the ratio between mass and its volume.

The relative density of a material is the ratio between its density and the density of a reference material. In the case of liquids, pure water at 4 °C is used as a reference. In the case of liquids, the precise measurement of the density is carried out with the help of the pycnometer. In the case of measuring the density of gases or vapors, the reference gas is air. Density is a quantity that has the following unit of measure: kg/m3, and relative density has no unit of measure.

Densimeters are used for research and development, quality control, commercial transactions, in industrial sectors such as:

- *petrochemicals* : numerous rules define the use of different models of densimeters in this sector.
- *Pharmacy* : according to the methods described in the European Pharmacopoeia.
- *Beverages:* to determine the concentration of sugar of sweet drinks, and for manufacture beer, to determine the level of alcohol in alcoholic beverages;
- *Chemistry:* by measuring the density, numerous chemical products are allowed such as: H_2SO_4, NaOH, HNO_3, etc. ;
- *Cosmetics:* the production of cosmetic items requires numerous checks on raw materials and finished products in compliance with the laws

THE DENSITY

It is a physical quantity that characterizes the mass of the volume unit. It is generally noted with the Greek letter ρ (*rhô*) as it is also used by the International Bureau of Weights and Measures.

Density is by definition the ratio between mass and volume $\rho = \dfrac{m}{V}$

Where:

m- the mass of the studied material

V- the volume of the studied material

Density is synonymous with absolute density and specific density

The unit of measurement in the International System is: kilogram per cubic meter: (kg · m⁻³ or kg/m³): $[\rho]_{SI} = \dfrac{kg}{m^3}$

The unit of measurement in the CGS System is: gram per cubic centimeter: (g · cm⁻³ or g/cm³): $[\rho]_{CGS} = \dfrac{g}{cm^3}$

Apparent density or bulk density is defined as the ratio of the mass of the material and the volume of the grain assembly: $\rho_{apparent} = \dfrac{m_{mat}}{V_{apparent}}$

The real density is the ratio between the mass of the material and the real mass of the grains

$$\rho_{real} = \dfrac{m_{mat}}{V_{real}}$$

Absolute density - is used for porous materials.

This size is used in the case of porous materials. For these, the material must be finely ground and the actual density of the powder obtained is measured. The absolute density of matter is the ratio between the mass of the material and the real volume for which the volume of the pores (open and closed) has been subtracted.

Absolute density is equal to particle density for non-porous materials.

$$\rho_{absolute} = \dfrac{m_{mat}}{V_{absolute}} = \dfrac{m_{mat}}{V_{real} - V_{pore}}$$

Table 1: various values of the density of solid materials

Mineral rocks common materials	density (kg/m^3)
asbestos	2500
clay	1 300 - 1 700
limestone	2 000 - 2 800
compost	550 - 600
chalk	1 700 - 2100
diamond	3 517
granite	1 800 - 2 500
floor tiles	1 600 - 1 900
kaolin	2 260
marble	2 650 - 2 750
cjart	2 650
pumice	910
porcelain	2500
sand	1 600 (sec) - 2 000 (saturated)
silicon	2 330
vegetable soil	1 250
glass range	2 530
cotton	20-60
Metals and alloys	**density (kg/m^3)**
steel	7,500-8,100
high speed steel	8,400 - 9,000
cast iron	6,800 - 7,400
aluminum	2700
silver	10,500
beryllium	1 848
bronze	8,400 - 9,200
Carbon (diamond)	3 508
carbon (graphite)	2 250
constantly	8 910
copper	8 920
duralumin	2900
tin	7 290

Mineral rocks common materials	density (kg/m³)
iron	7,860
iridium	22 560
brass	7 300 - 8 800
lithium	530
magnesium	1 750
Mercury	13 545.88
molybdenum	10,200
nickel	8,900
gold	19,300
osmium	22 610
palladium	12,000
platinum	21 450
lead	11 350
potassium	850
tantalus	16,600
titanium	4500
tungsten	19,300
uranium	18,700
vanadium	6 100
zinc	7 150

MEASUREMENTS WITH BALANCE

The operating principle of electronic balances is based on the variations in the electrical characteristics of some materials when they are subjected to mechanical compression. The electrical variations are measured and recorded on a screen that allows the expression of the mass of the unknown body that compresses the component elements of the balance.

Depending on the masses that can be measured, electronic balances are classified according to divisions and measuring capacity:

Example of analytical balances:

balance (0.1 μg /3g);

balance (0.001 mg / 3 g);

balance (0.01 mg / 30 g);

balance (0.1 mg / 160 g);

precision balance (1 mg / 160 g - 60 kg)

Hand balance

It is used to weigh small amounts of substance: usually 0.06 g – 100-200 g, several weighing models are known of 0.25- 0.5- 1- 2- 5- 10 – 20 g (with the sensitivity decreasing).

Constructively, the hand balance consists of a suspended metal lever, with the arrow pointing upwards, with two equal arms that oscillate around a support point finished with a ring.

At the ends of the arms, 2 anti-corrosive plates, usually made of celluloid or plastic material, are suspended in 3 silk cords.

Hand balance can be simple or with a slider.

With hand balances, weighing is done by balancing the weight of the substance on one of the plates with corresponding weights placed on the opposite platen. On the hand balance with a slider, one of the arms, usually the left one, is divided, the cursor sliding along the lever that indicates the weight of the substance to be weighed (placed on the platen corresponding to the undivided arm.

Sometimes additional weights can be used on the plate of the graduated arm. This operation is not recommended especially for weighing strongly active substances.

Pharmaceutical balance:

Or balance with column:
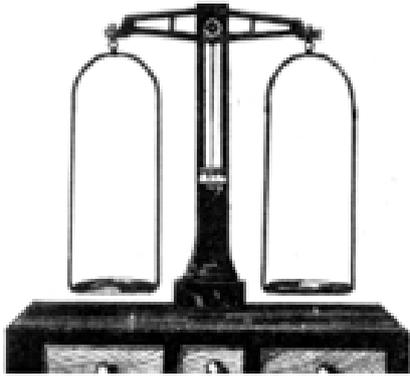
It is used in the pharmacy to weigh from 10 to 1000g or from 5 to 500g with a sensitivity of centigrams.

The balance consists of a metal column, mounted vertically on a box or support, usually covered with a marble plate, with 1-3 drawers. On the upper part of the column is placed on a knife, a horizontal lever with equal arms, on which two plates are suspended on the knives.

The process of balancing of the instrument is signaled by the indicator needle, positioned in the middle of the lever and which oscillates together with it in front of a graduated dial. The process of balancing of the instrument is checked before each weighing, the pharmaceutical balance having adjustment screws at the end of each arm.
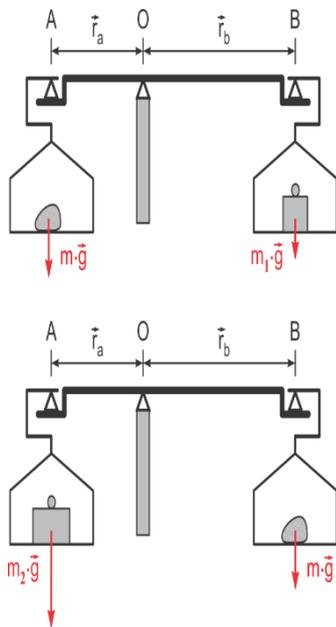
Weighing with a balance with unequal arms

$$m \cdot g \cdot r_a = m_1 \cdot g \cdot r_b$$
$$m_2 \cdot g \cdot r_a = m \cdot g \cdot r_b$$
$$\frac{m}{m_2} = \frac{m_1}{m}$$
$$m = \sqrt{m_1 \cdot m_2}$$

MEASURING USING VERNIER CALIPERS

The caliper is an instrument for measuring lengths whose construction is based on the principle of the linear vernier. The precision of the measurements made with the caliper varies between $\dfrac{1}{10}$ and $\dfrac{1}{50}$ mm.

Instrument description

From the adjacent figure it can be seen that the caliper is made up of the following parts:
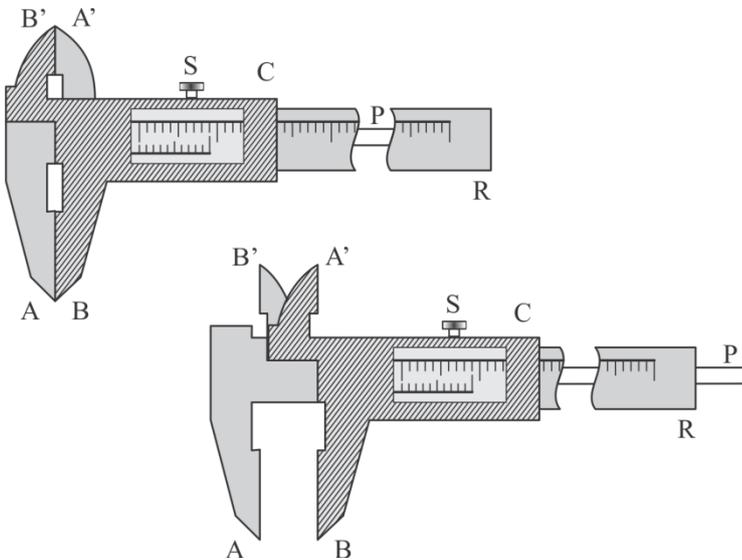
- a metal ruler R, graduated in mm, which ends with a stop device A on one side and another stop device A', on the opposite side;
- a movable cylinder head C;
- a vernier V applied to the cylinder head;
- and cylinder head B' devices B that correspond to the stop devices A and A' that serve to delimit the dimensions to be measured;
- movable blade P, attached to the cylinder head, the blade that moves with the vernier and that serves to measure depths, while it AB serves to delimit thicknesses, external diameters, etc., and $A'B'$ serves to determine internal diameters;
- a screw S for immobilizing the cylinder head.

a) Measuring the inner diameter for cylindrical parts:

It is done in such a way that the stop device is fixed inside the cylinder A' at one end of the inner diameter of the cylinder, and by moving the cylinder head, the mobile device is fixed B' at the other end of the inner diameter. The cylinder head screw is screwed in S and then the reading is taken.

b) **Measurement of the outer diameter for cylindrical parts** :

The measurement of the external diameter for cylindrical parts of the thickness of a bar, or the thickness of a metal plate, etc., is done as follows: the cylinder head of the vernier is moved and the part to be measured is clamped between the branches and so that the part is well fixed, without deforming A it B. Fix the cylinder head bolt so that it does not move and then take the reading according to the indications given as follows.

c) **Measuring the depth of a piece:**

It is done as follows: to accurately measure the depth of the cylinder, the cylinder head of the vernier is moved. The blade moves together with the cylinder head. When the base of the cylinder has been reached, resting the upper edge on the ruler of the caliper, tighten the screw S and read the dimensions on the ruler and on the vernier.

PROCEDURE FOR THE PRACTICAL WORK – METHOD 1:

1. The mass of the material to be studied is determined using the analytical balance from the laboratory

2. Calculate the volume of the solid material considered: a ring with inner diameter Di, external

diameter De and height h, using the following formula: $V = \dfrac{\pi}{4}.h.\left(D_e^2 - D_i^2\right)$

Di, De and h are determined using the caliper.
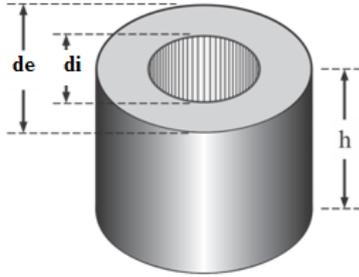
3. The density is calculated with the formula: $\rho = \dfrac{m}{V}$.

4. 5 measurements are made for h, De, Di.

5. 5 calculations are made for V and ρ.

6. Write the values in the table below.

7. The errors and the interval for real values should be calculated.

The average error and the range of real values are calculated

Average value $\rho = \bar{\rho} = \dfrac{\sum\limits_{i=1}^{n} \rho_i}{n}$

THE MEAN SQUARED ERROR OF THE AVERAGE $\mu = \pm\sqrt{\dfrac{\sum(\rho_i - \bar{\rho})^2}{n(n-1)}}$

Interval for real values: $\left(\bar{\rho} - \mu, \bar{\rho} + \mu\right)$

Table 1: determination of the density at the solid ring

No crt	h (cm)	D_{ext} (cm)	D_{int} (cm)	V (cm3)	m (g)	$\rho\left(\dfrac{g}{cm^3}\right)$	$\bar{\rho}\left(\dfrac{g}{cm^3}\right)$	μ	ρ_{real}
1									
2									
3									
4									
5									

PROCEDURE FOR THE PRACTICAL WORK – METHOD 2:

LECITHIN, ESENTIN, AMINO ACID Pills or others may be choosen

1. The mass of the studied material is determined with the help of the balance.

2. The diameter and height are measured using a caliper and based on these values we can calculate the volume of the lecithin tablets that is formed by a cylinder + 2 semispheres at the ends :

$$V = \frac{\pi.D^2}{4}(h-D) + \frac{\pi.D^3}{6}$$

3. With the obtained volume and masses we are able to calculate the density, using the following formula : $\rho = \dfrac{m}{v}$.
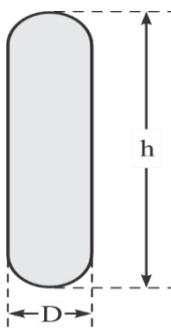
   4. Make 5 measurements for h and D.

   5. 5 calculations should be made for each V and ρ.

   6. The average density value should be calculated using the arithmetic mean

   formula $\bar{\rho} = \dfrac{\sum_{i=1}^{n} \rho_i}{n}$

   7. The mean squared error of the average should be calculated using the

following formula: $\mu = \pm\sqrt{\dfrac{\sum(\rho_i - \bar{\rho})^2}{n(n-1)}}$

8. Calculate the interval of real values $(\bar{\rho} - \mu, \bar{\rho} + \mu)$.

Table 2: determination of the density of lecithin tablets

No. crt.	h	d	V(cm3)	m(g)	$\rho\left(\dfrac{g}{cm^3}\right)$	$\bar{\rho}\left(\dfrac{g}{cm^3}\right)$	μ	ρ$_{real}$
1								
2								
3								
4								
5								

CONCLUSIONS Errors for directly measured quantities can be calculated. Also, the errors of the quantities obtained from a calculation can be determined and the results can be compared. Similar calculations can be made for materials with different shapes.

DETERMINATION OF LIQUID DENSITY USING THE PYCNOMETER

INTRODUCTION

Density (after an older name, "specific gravity") is an intensive property of substances. By definition, absolute density is the mass of the unit volume of the respective substance. If a material (solid, liquid or gas) with the mass "m" occupies the volume "V", then the absolute density (" ρ ") of the body is:

$$\rho = \frac{m}{V} \ (1)$$

In the International System of Units (SI), absolute density is expressed in kg/m^3 . In practice, tolerated measurement units are often used (g/cm^3 , g/liter, etc.).

Due to the presence of the volume "V" in the definition relation (1), the value of the absolute density of a material (solid or liquid) depends on the temperature.

The relative density "d" is often used, and it represents the ratio between the absolute density of the substance of interest (ρ) and the absolute density of a reference material (ρ_{ref}).

$$d = \frac{\rho}{\rho_{ref}} \ (2)$$

From relation (2) results that the relative density is a adimensional quantity. Since both quantities depend on the temperature, the relative density also depends on the temperature. Water density is frequently chosen as a "ρ_{ref}". Regarding the temperature, two expressions of this quantity are used. If one compares the absolute density of the studied medium ("ρ"), measured at a temperature of 20 ºC, with the absolute density ("ρ_{ref} ") of the reference medium, also measured at a temperature of 20 ºC, then the relative density is noted as "d_{20}^{20}". If you compare the absolute density of the studied medium ("ρ"), measured at a temperature of 20 ºC, with the absolute density ("ρ_{ref} ") of water, measured at a temperature of 4 ºC, then the relative density is noted as "d_4^{20}". The relevance of this latter comparison lies in the fact that the density of water is maximum at a temperature of 4 ºC.

Determination of the density of a liquid by means of the pycnometer

Figure 2 represents a simple pycnometer, and Figure 3 represents a pycnometer equipped with a thermometer. The pycnometer shown in Figure 2 consists of a glass flask ("b") and a glass stopper ("d") provided with a thin channel ("c").
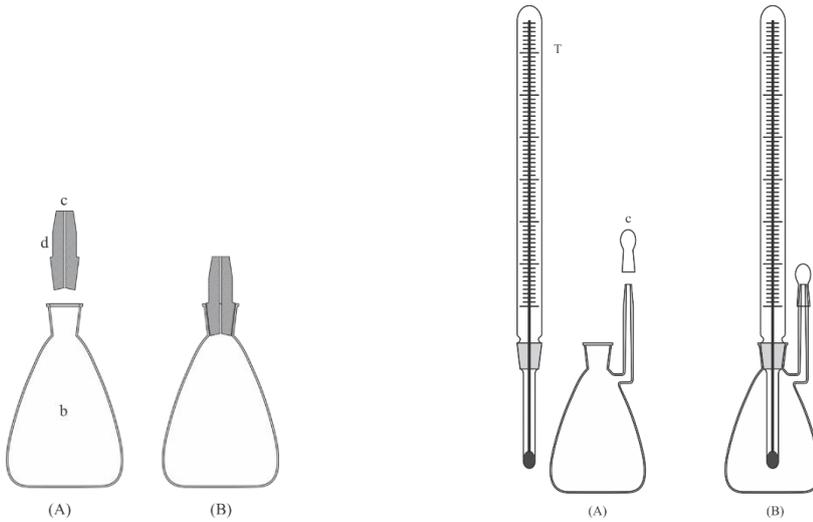
Fig. 2 Simple pycnometer Fig. 3 Pycnometer equipped with thermometer

PROCEDURE FOR THE PRACTICAL WORK – STEPS

1) Weigh the empty and dry pycnometer, together with the stopper "d" (Figure 2-(A), mass "m_o").
2) A reference liquid for which the absolute density "ρ_{ref}" is known is introduced into the balloon "b", so that the balloon "b" is filled to the brim, after which it is closed with the stopper "d" (Figure 2-B). The excess of reference liquid comes out through channel "c", so the volume of reference liquid remaining in the pycnometer is equal to the sum of the volume of balloon "b" and the volume of channel "c" (volume "V").
3) Weigh the pycnometer filled with reference liquid ("m_{ref}").
4) Empty, wash and dry the pycnometer, after which it should be filled with the studied liquid in the manner described at step 2.
5) Weigh the flask filled with the studied liquid ("m").
6) The quantities involved satisfy relation (5).

$$V = \frac{m_{ref} - m_o}{\rho_{ref}} = \frac{m - m_o}{\rho} \quad (5)$$

ρ - the absolute density of the studied liquid can be expressed as follows :

$$\rho = \rho_{ref} \cdot \frac{m - m_o}{m_{ref} - m_o} \quad (6)$$

and also the relative density "d":

$$d = \frac{\rho}{\rho_{ref}} = \frac{m - m_o}{m_{ref} - m_o} \quad (7)$$

The experimental part is performed by using three liquids, ethanol (C_2H_5-OH), carbon tetrachloride (CCl_4) and acetone ($(CH_3)_2CO$), the reference liquid being distilled water each time. The density of water as a function of temperature is shown in Table 2 and Figure 4.

Table 2 Density of water depending on temperature

t (ºC)	ρ (kg/m³)	t(ºC)	ρ (kg/m³)	t(ºC)	ρ (kg/m³)
0	999.87	13	999.40	22	997.80
1	999.93	14	999.27	2. 3	997.56
2	999.97	15	999.13	24	997.32
3	999.99	16	998.97	25	997.07
4	1000.00	17	998.80	26	996.81
5	999.99	18	998.62	27	996.54
6	999.97	19	998.43	28	996.26
7	999.93	20	998.23	29	995.97
8	999.88	21	998.02	30	995.67
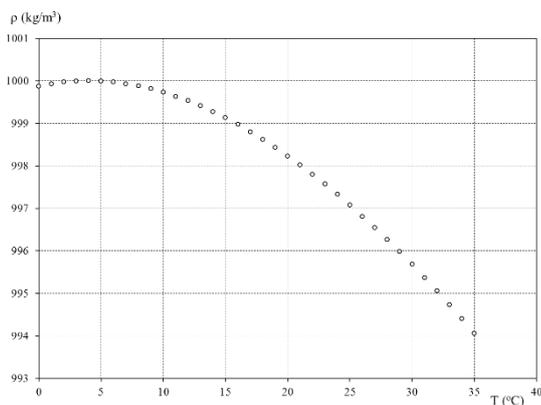
Fig. 4 Density of water depending on temperature

The data obtained form the experimental part should be introduced in Table 3.1 and Table 3.2.

Table 3.1.

Liquid	m(g)	ρ (g/cm^3)
C$_2$H$_5$OH		
CCl$_4$		
(CH$_3$)$_2$CO		

Table 3.2. Determination of liquid density using the pycnometer:

NaCl solution of different concentrations, m_0= .... g

V= 25 ml, m(g) = mass of the pycnometer filled with liquid

C_{NaCl} (%)	M (g)	ρ (g/cm³)
0.9		
1		
5		
6		
8		
10		
15		
20		
25		
30		
50		

DETERMINATION OF THE DENSITY OF A SOLID MATERIAL USING THE PYCNOMETER

If the size of a solid material can be entered inside a pycnometer, then the density of the body can be determined using the pycnometer. This technique is especially useful if the studied sample is a wax or has the consistency of a paste, or consists of several particles, not necessarily identical. In this case, an average (apparent) density of the solid or semi-solid sample can be determined.

PROCEDURE FOR THE PRACTICAL WORK – STEPS

1) Weigh the empty dry pycnometer (together with the stopper, Figure 5-1; mass "m_o").

2) Fill the pycnometer with a reference liquid for which the density "ρ_r" is known (Figure 5-2; mass "m_r").

3) Empty, wash and dry the pycnometer, insert the sample into the pycnometer and weigh it (together with the stopper, Figure 5-3; mass "m_p")

4) Keeping the sample solid in the pycnometer, fill the volume of the pycnometer with the reference liquid taking care not to form air bubbles and close the pycnometer with the stopper (Figure 5-4, mass "m_{pr}").
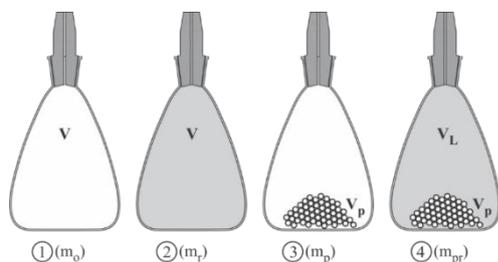
Fig. 5 The stages of determining the density of a solid body with a pycnometer.

If noted:

- " ρ" solid body density;

- " ρ_r " the density of the reference liquid;

- "V" the internal volume (including the volume of the channel in the plug) of the empty pycnometer;

- "V_p" the volume of the solid sample;

- "V_L" the volume of reference liquid that fills the pycnometer containing the solid body;

- "m_o", "m_r", "m_p" and "m_{pr}" the masses weighed in the four stages,

then from the balance of masses and volumes the following relationships result:

$$V_L \cdot \rho_r + V_p \cdot \rho = m_{pr} - m_o \quad (8)$$

$$V_p \cdot \rho = m_p - m_o \quad (9)$$

Substituting the product $V_p \cdot \rho$ from relation (9) into relation (8), the following formula results:

$$V_L \cdot \rho_r + m_p - m_o = m_{pr} - m_o \quad (10)$$

$$V_L = V - V_p = \frac{m_r - m_o}{\rho_r} - \frac{m_p - m_o}{\rho} \quad (11)$$

On the other hand, $\quad V_L = \dfrac{m_{pr} - m_p}{\rho_r} \quad (12)$

From relations (11) and (12) the following formula is obtained, by eliminating the volume "V_L",

$$\frac{m_r - m_o}{\rho_r} - \frac{m_p - m_o}{\rho} = \frac{m_{pr} - m_p}{\rho_r} \quad (13)$$

After explaining the density "ρ" from relation (13), we obtain the expression (14) of the density "ρ" of the solid body depending on the weighed masses "m_o", "m_r", "m_p" and "m_{pr}":

$$\rho = \rho_r \cdot \frac{m_p - m_o}{m_r + m_p - m_{pr} - m_o} \quad (14)$$

In practice, the density of a quantity of small glass balls is determined. For this purpose, the operations described in the sequence 1) - 4) are performed. The solid body is an (arbitrary) amount of small glass balls, and distilled water is used as the reference liquid. It is important to check the temperature of the distilled water and use the "ρ_r" value corresponding to that temperature (from Table 2). Weighings are performed with the semimicro analytical balance. The weighed masses and the result are entered in Table 4.

Table 4 Results of solid body density determination

m_o (g)	m_r (g)	m_p (g)	m_{pr} (g)	t (°C)	ρ_r (g/cm³)	ρ (g/cm³)

DETERMINATION OF THE DENSITY OF A LIQUID USING THE MOHR-WESTPHAL BALANCE

INTRODUCTION

Mohr-Wesrphal balance is also based on Archimedes' principle. Figure 7 shows the construction details of a *Mohr-Wesrphal balance*.

A float is hung on one of the arms of the balance (in some cases a thermometer is included in the float), and a counterweight is found on the other arm. On the arm equipped with a float there are some recesses where different weights can be fixed.

To determine the density of a liquid, the float is immersed in the reference liquid (for which the density is known; this liquid is often water) and the balance is equilibrated. Lock the position of the balance arms, remove the float, wash and dry. After mounting the float in the initial position, it is immersed in the studied liquid and the balance arms are unlocked. The force of ascent being different from that observed for the reference liquid, the balance becomes unbalanced. By changing the values and positions of the weights on the balance arm, the balance is equilibrated again. Basically, the difference between the apparent weights of the volume of the reference liquid and the column of the studied liquid, displaced by the volume of the float, is determined.
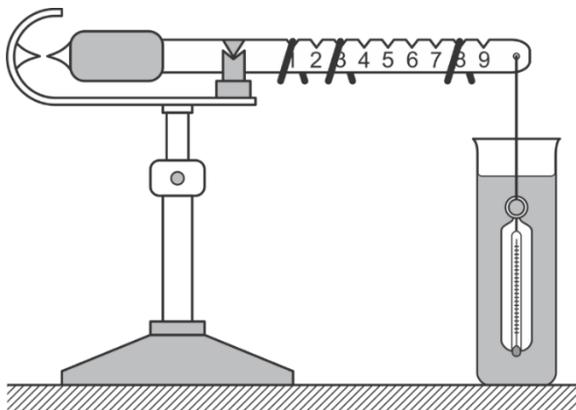
Fig. 1 *Mohr-Westphal balance*

If in the first phase of the measurement (when the float is immersed in the reference liquid) the apparent weight of the float is "Gr" and in the second phase (when the float is immersed in the studied liquid) the apparent weight of the float is "G_p", then, from the law relating to the ascent force (*Archimedes' law*) the following formula results:

$$G_p - G_r = \frac{\rho_p - \rho_r}{\rho_r} (1)$$

In relation (1) "ρ_r" and "ρ_p" respectively represent the density of the reference liquid and the studied liquid (of the sample).

DENSITY OF A WATER-ETHANOL MIXTURE AS A FUNCTION OF COMPOSITION. VOLUME CONTRACTION WHEN MIXING LIQUIDS

When mixing two miscible liquids, it is found (almost always) that the volume resulting from mixing differs from the sum of the initial volumes (the most common finding is a decrease in the total volume compared to the sum of the mixed volumes - volume contraction). For example, if equal volumes of ethanol and water are mixed, the temperature increases when mixed. After the temperature of the mixture is brought back to the initial value, it is found that the volume of the mixture is smaller than the sum of the mixed volumes.

Figure 2 represents the molar volume of the ethanol-water mixture depending on the composition of the mixture (expressed as a molar fraction of ethanol).
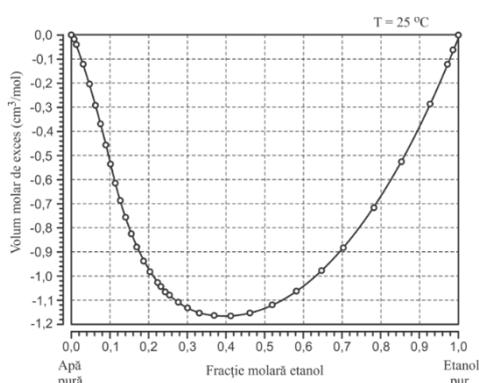
Fig. 2 Molar volume of ethanol-water mixtures according to composition

It is found that for an ethanol-water mixture, in which the molar fraction of ethanol is 0.4, the molar volume is lower by approximately 1.16 cm^3/mol than the molar volume resulting from the summation of the volumes. This phenomenon can be followed by determining the density of ethanol-water mixtures depending on the composition of the mixture.

If when mixing the volume "V_1" of ethanol with the volume "V_2" of water, the two liquids having the densities "ρ_1" and "ρ_2", then theoretically (if no volume contraction would occur), the density of the mixture would be "ρ_t", and the volume of the mixture, "V_t", would be the sum of the mixed volumes.

$$\rho_1 \cdot V_1 + \rho_2 \cdot V_2 = \rho_t \cdot (V_1 + V_2) = \rho_t \cdot V_t \,(16)$$

Practically, due to volume contraction, the volume of the mixture is "V_p" and the density "ρ_p".

$$\rho_1 \cdot V_1 + \rho_2 \cdot V_2 = \rho_p \cdot V_p \,(17)$$

From relations (16) and (17) it follows:

$$\rho_p = \rho_t \cdot \frac{V_t}{V_p} \,(18)$$

Since the volume "V_p" is lower than the theoretical volume "V_t", the real density "ρ_p" is higher than the theoretical density "ρ_t".

This phenomenon can be highlighted by measuring the real density "ρ_p" of the mixture. An alternative way can be based on the use of the semi-micro analytical balance (Figure 3).

PROCEDURE FOR THE PRACTICAL WORK – STEPS

1) A *Berzelius glass*, filled with the reference liquid (distilled water), is placed on the pan of an analytical balance and the displayed "m_{or}" mass is read (Figure 3-A).

2) A body suspended by a thin wire is immersed in the liquid (Figure 3-B) and the indication on the balance display (m_r) is read.

3) Empty, wash and dry both the *Berzelius glass* and the float, after which the operations from point 1) and 2) are repeated, but with the studied liquid in the glass (read the masses m_{op} and m_p, respectively (Figures 3-C and 3-D).

The float must be completely immersed in the liquid and not touch the wall or the bottom of the glass.
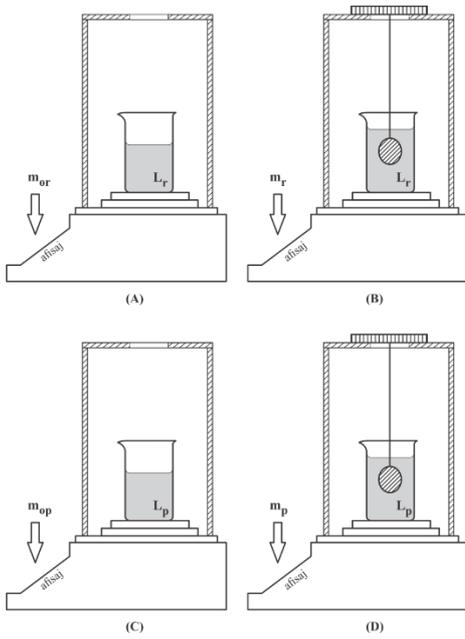
Fig. 3 Highlighting the volume contraction of the ethanol-water mixture

The experiment is, in a way, the opposite configuration to the one presented on the *Mohr-Wesrphal balanc* . Since the float is fixed, the force of ascent manifests itself on the glass and implicitly on the pan of the analytical balance.

If the densities of the reference liquid and the studied liquid (sample) are written with "ρ_r" and "ρ_p", respectively, and with "V" the volume of the float, then, taking into account *Archimedes' law*,

regarding the force of ascent, it can be written:
$$m_r = m_{or} + V \cdot \rho_r$$
$$m_p = m_{op} + V \cdot \rho_p \quad (19)$$

After removing the volume "V" and explaining the density of the sample "ρ_p", it results:

$$\rho_p = \rho_r \cdot \frac{m_p - m_{op}}{m_r - m_{or}} \quad (20)$$

Basically, the density of ethanol-water mixtures is determined, at ambient temperature, for mixtures in which the ethanol:water volumetric ratio is 0:100 (pure water); 20:80; 40:60; 60:40; 80:20; 100:0; (pure ethanol). the data are entered in Table 1.

Table 1 Results

Volumetric ethanol:water ratio	m_{or} (g)	m_r (g)	m_{op} (g)	m_p (g)	ρ_r (g/cm^3)	ρ_p (g/cm^3)
0:100						
20:80						
40:60						
60:40						
80:20						
100:0						

Since in columns II and VI of the Table there are quantities referring to distilled water, in these columns a single value is entered, common to the six compositions.

"ρ_p" is graphically represented as a function of the volumetric percentage composition of the ethanol-water mixture, according to the model in Figure 10. The broken line represents the theoretical plot of the density vs. composition for the case that volume contraction would not occur when preparing the ethanol-water mixture. The graph resulting from the experimental data is located above this line, a sign that when ethanol is mixed with water, the density has higher values than theoretically predicted, so volume contraction occurs.
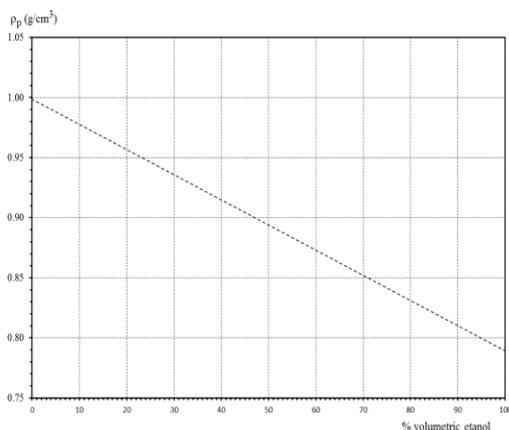
Fig. 4 Model for graphical representation of results

DETERMINATION OF LIQUID DENSITY USING DENSIMETERS

INTRODUCTION

DENSITY

It is a physical quantity that characterizes the mass of the volume unit. It is generally noted with the Greek letter ρ (*rhô*), as it is also used by the International Bureau of Weights and Measures.

Density is by definition the ratio between mass and volume $\rho = \dfrac{m}{V}$

Where:

m- the mass of the studied material

V- the volume of the studied material

Density is synonymous with absolute density and specific density

The unit of measurement in the International System is: kilogram per cubic meter: (kg · m⁻³ or kg/m³): $[\rho]_{SI} = \dfrac{kg}{m^3}$ **The unit of measurement in the CGS System is: gram per cubic centimeter:** (g·cm⁻³ or g/cm³): $[\rho]_{CGS} = \dfrac{g}{cm^3}$

Water is often used as a reference liquid for calculating the density of liquids and solids.

The density of water is 1000 kg/m³ (or 1 kg/dm³ or 1 kg/l or 1 g/cm³). This is the density of water at 3.98 °C and normal atmospheric pressure. Indeed, water has a peculiarity among liquids: its density is maximum, not at the melting temperature (0 °C) like most liquids, but at 3.98 °C. In metrology, taking as a reference a physical property that passes through an extreme it is very interesting what happens in the vicinity of this extreme: the physical property varies very little. Thus, in the vicinity of 3.98 °C, an inaccuracy in determining the exact temperature affects very little the density of water and therefore the result of the density measurement

Relative density: $d = \dfrac{\rho_{solid}}{\rho_{water}}$ or $d = \dfrac{\rho_{liquid}}{\rho_{water}}$

Where $\rho_{material}$ is the density of the considered material (liquid or solid) and ρ_{water} is the density of water (1 000 kg/m³).

To correct the values measured at temperatures other than the reference temperature, it is necessary to use the curve of variation of the density of water as a function of temperature, in order to deduce the density of the materials at the temperature of the measurements.

Liquids	ρ (kg/m³)
Acetone	790
Acetic acid	1 049
liquid nitrogen at -195 °C	810
bromine at 0 °C	3 087
Water to 4 °C	1 000.0
Sea water	1 000 to 1 032
benzine	750
ethanol	789
ether	710
diesel	850
glycerin	1 260
liquid helium at −269 °C	150
olive oil	920
liquid hydrogen at −252 °C	70
liquid oxygen at −184 °C	1 140
milk	1030

ARCHIMEDES' THEOREM

A body immersed in a liquid is pushed from the bottom up with a force equal to the weight of the volume of fluid displaced by the body.

The theorem applies to bodies immersed in liquids at rest.

The theorem applies if the immersion liquid and the immersed body are at rest. It is also necessary to replace the immersed body with immersion liquid without disturbing the balance. A counter-example is the cap of a bathroom filled with water: if it is replaced by water, it is clear that the bathroom is empty and that the fluid is no longer at rest. The theorem does not apply because we are in a case where the plug is not completely wetted by the liquid and does not pass its free surface.

In a uniform gravitational field, the Archimedean force, noted with the symbol F_A, is given by the formula:

$$\vec{F}_A = -M_f \vec{g}$$

Where M_f is the mass of the fluid contained in the displaced volume V and g is the gravitational acceleration.

If the mass of the displaced fluid is expressed as a function of density, the Archimedean force has the form: $\vec{F}_A = -\rho.V.\vec{g}$

In scalar form it is written as follows: $\left\| \vec{F}_A \right\| = -\rho.V.g$
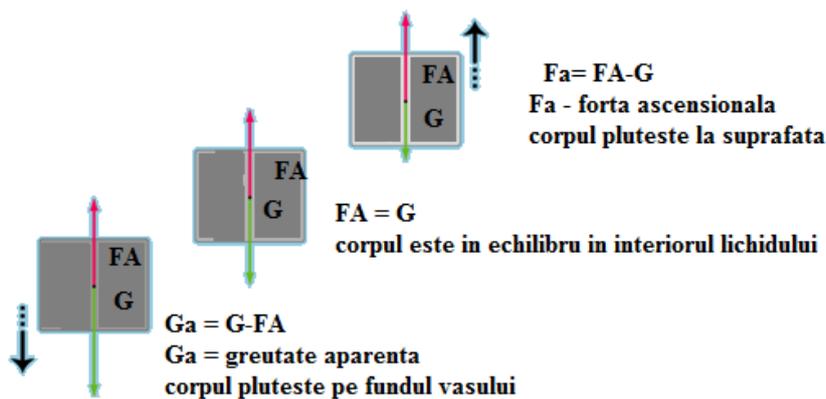
Figure 1: Schematic representation of Archimedes' law

The Archimedean force F_A and the weight G can be in one of the 3 cases presented (from left to right):

Case 1. G > F_A (the weight G is greater than the Archimedean force F_A)

In this case the apparent weight appears: $G_a = G - F_A$

The body falls to the base of the vessel

Case 2. G = F_A the body is in equilibrium inside the liquid.

Case 3. G < F_A (The Archimedean force F_A is greater than the weight G)

In this case the ascension force appears: $F_a = F_A - G$

$F_p = \rho V g$

$F_A = \rho_f V g$

$G / F_A = \rho_s / \rho_f$

The force ratio is equal to that of the densities

- **If the density of the solid material is greater than that of the fluid G > F$_A$, the solid falls to the bottom of the vessel**

- **If the density of the solid material is lower than that of the fluid G< F$_A$, the solid floats on the surface of the liquid from the vessel**

- **If the density of the solid material is equal to that of the fluid G=F$_A$, the solid remains in equilibrium inside the liquid from the vessel.**

MEASURING THE DENSITY OF LIQUIDS USING THE DENSIMETER

The densimeter consists of a glass cylinder filled with air, which has weights at the base and is graduated. It enters into the liquid to be measured more or less, depending on its density.

The density of the liquid in which it is immersed is read directly on the graduation that is in contact with the free surface of the liquid.

The hydrometer is mainly used to measure the density of grape must, barley, sugar syrup or to evaluate the alcohol content. The hydrometer is also used in sedimentometry laboratory tests to calculate the distribution of microscopic particles in a soil sample.

It is also used in the ceramic industry as a means of controlling the density of slips, mainly for the density of glazes or slips that will cover tiles or bricks. This type of measurement has the advantage of being easy to implement and allowing very fast control, but is less accurate than density measurement if a precise volume is weighed using standard 100 ml containers
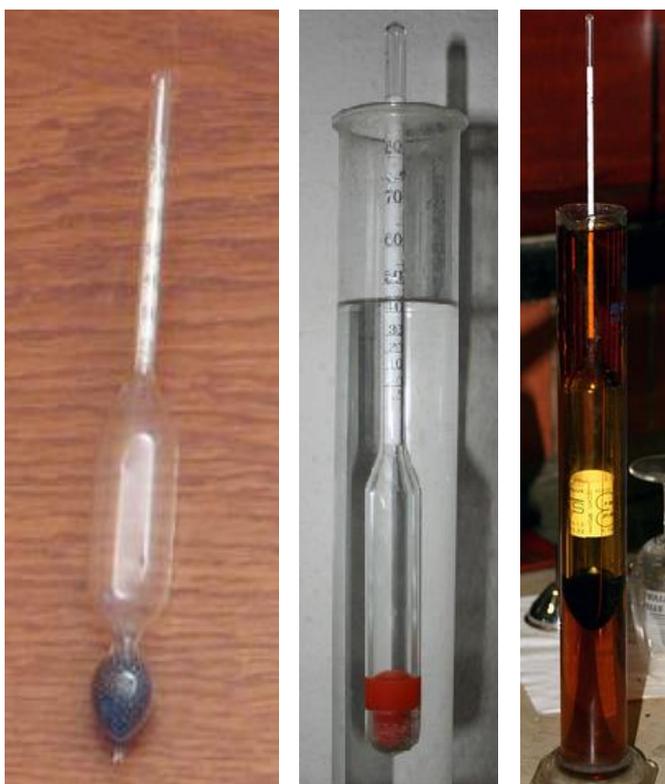
The Fahrenheit hydrometer looks like a glass tube filled with air in the middle, with mercury at the bottom and contains a container at the top. When the hydrometer is immersed in a liquid of unknown density, it floats. The marked masses are then added to the upper container until the center of the hydrometer is completely immersed. The total mass added is the greater Argimedic force imposed on the hydrometer by the liquid,

i.e. the latter's density is greater.

Figure 2. Variants of densimeters, hydrometers, alcohol meters

The alcohol meter is used to measure the degree of alcoholic strength starting from the density of the liquid was defined by Louis Joseph Gay-Lussac in 1824, for the purpose of taxation on alcohol. A hydrometer directly graduated in degrees of alcohol is immersed in the liquid. The measured value is corrected according to the temperature of the liquid. The density tables and their temperature corrections were established experimentally by Gay-Lussac. This technique is accurate only if the liquid contains only water and alcohol in solution, hence the need for previous distillation, if rigorous data is required for commercial or fiscal needs.

Small hydrometers graduated in degrees, alcohol meters or alcohol scales are used by professionals and controllers to roughly and quickly measure the alcoholic strength of a product.

Today, the Malligand Ebulliometer, which appeared in 1875, is used to measure wine strength, which is a miniature still equipped with a precision thermometer. The boiling point of an ethanol-water solution depends on their ratios. The temperature read is converted to alcohol by reading a table. The accuracy of the measurement depends on the concentration of other substances, such as sugars and carbonic acid, which change the boiling point. In the wine industry, the expression "Malligand degree" has long been used for "% vol. at 15 ° C".

Appeared in 1967, an electronic densimeter allows the measurement of TAV (degree of alcohol) from an aqueous alcoholic solution, which requires a distillation before measurement, if the samples have a complex matrix (wine, cognac, Armagnac, liqueurs .. .).

Oscillating tube density measurement (electronic density meter) became the reference standard method in the 1990s for many producers and specialists in wines, spirits and more recently for ethanol as well as precision fuel (TAV +/- 0.01% v / v) and ease of use.

DETERMINATION OF THE DENSITY OF A LIQUID USING A DENSIMETRE

Determination of the density of a liquid with a hydrometer is based on *Archimedes ' law* regarding the upward force exerted on a body immersed in a liquid. Figure 3 represents a densimeter. This is an instrument made of glass in which three portions are distinguished: the weight "G", the volume body "V" and the rod/bar provided with divisions "T" (Figure 3-A). The studied liquid is introduced into a glass and afterwards, the densimeter is introduced into the liquid. The hydrometer floats in the liquid and the depth to which it sinks depends on the density of the liquid. The depth is read on the divisions made on the "T" bar, which correspond to the density values of the liquid (Figure 3-B).

When performing the determination, it is important to control the temperature of the liquid. For this reason, a thermometer is also included in some densimeters.
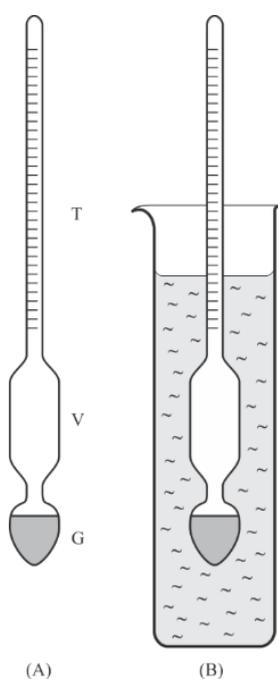
To cover a sufficiently wide range of density values, sets of densimeters are used, each calibrated for a specific density range. While performing the determination of the density of a concrete liquid, choose the densimeter from the set which, inserted in the liquid, floats without touching the bottom of the vessel.

In practice, the density of the following liquids is determined: ethanol (C_2H_5OH), carbon tetrachloride (CCl_4), acetone ((CH_3)$_2CO$). When performing the experiment, it is important that the densimeter does not touch the wall of the vessel in which the studied liquid is placed.

Because the densimeters are calibrated by the manufacturer, determination of the densities is not dependent on any reference liquid.

Figure 3. Simple densimeter

PROCEDURE FOR THE PRACTICAL WORK – STEPS

1. **3 measurements are made for each liquid (NaCl and KCl solutions) with concentrations of 0.9%, 1%, 5%, 6% and 8%**
2. **Average values, errors and actual values will be calculated**
3. **Calculations are made for the relative density - d**
4. **Average values, errors and actual values will be calculated**
5. **The obtained values are entered in the table**
6. **The graphic representation will be made, respecting the function: $\rho = \rho(c)$**

Table: densities of NaCl solutions

No	Sol. used	ρ (g/l)	$\overline{\rho}$ (g/l)	μ_ρ (g/l)	ρ_{real} (g/l)	$d = \dfrac{\rho_{liquid}}{\rho_{water}}$	$\overline{d}$	μ_d	d_{real}
1	H₂O								
2									
3									
1	NaCl 0.9%								
2									
3									
1	NaCl 1%								
2									
3									
1	NaCl 5%								
2									
3									
1	NaCl 6%								
2									
3									
1	NaCl 8%								
2									
3									

Table: densities of KCl solutions

No.crt	Sol. used	ρ (g/l)	$\bar{\rho}$ (g/l)	μ_ρ (g/l)	ρ_{real} (g/l)	$d = \dfrac{\rho_{liquid}}{\rho_{water}}$	$\bar{d}$	μ_d	d_{real}
1	H₂O								
2									
3									
1	**KCl**								
2	0.9%								
3									
1	**KCl** 1%								
2									
3									
1	**KCl** 5%								
2									
3									
1	**KCl** 6%								
2									
3									
1	**KCl** 8%								
2									
3									

DETERMINATION OF LIQUID DENSITY USING THE ABBE METHOD

THEORETICAL INTRODUCTION

In wave physics, refraction means the change in the wave propagation direction when it crosses the separation surface between two media (optical, acoustic or even seismic)

Refraction means a change in orientation:

- Wave front - is the line that describes a light wave (in physical optics or seismology)
- Of the beam: the direction of wave propagation is perpendicular to that of the wave front

The two changes of orientation are equivalent in the case of refraction, however, we prefer the first to explain the phenomenon, and the second to quantify the phenomenon

Light is deflected when it passes from one transparent medium to another (for example, from air to water, or vice versa). This phenomenon is noticed when we look to a straw in a glass and it appears broken. This "division" is possible due to "refraction".

Light is called "refracted", and the property that characterizes different transparent media is "refraction".

Diffuse refraction can be distinguished from perfect refraction.

• in the case of **diffuse refraction**, the incident ray is separated into a multitude of rays in the second medium of propagation;

• in the case of **perfect refraction**, only one ray appears, in the second medium.
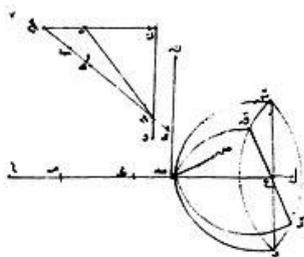
Diffuse refraction generally occurs in nature. For perfect refraction, the optical surface (the separation surface between the circles) must be perfectly smooth, and the second medium must be perfectly transparent and amorphous or monocrystalline.

The first concepts discovered in experimental optics were those related to the phenomena of reflection and refraction.

Refraction was already well known by Ptolemy

The first to mention the law of refraction was **Ibn Sahl.** (c. 940-1000)

Snell-Descartes law
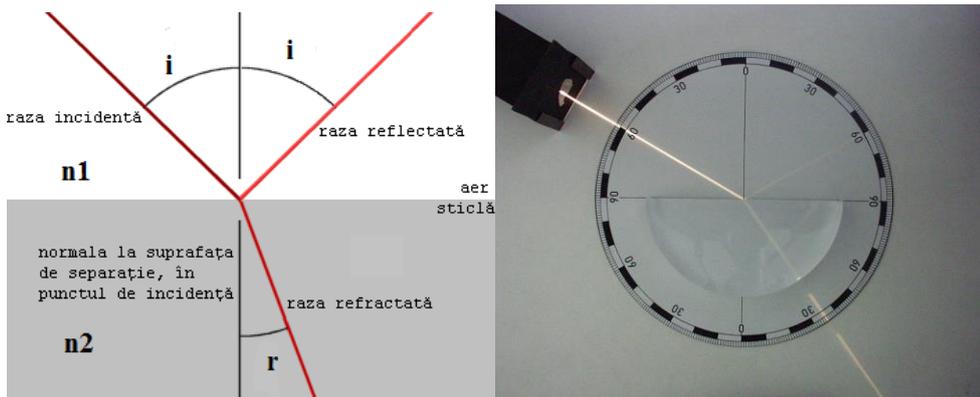
In optics, each transparent medium is characterized by the refractive index ni

Diopter is the surface of separation between two media.

The laws of refraction (the second law), established by Snell and Descartes, can explain the quantitative phenomenon, states that:

- The incident, normal and refracted rays are coplanar.

- The refractive index noted with **n** is the ratio between the sin of the angle of incidence **i** and the sin of the angle of refraction **r**

  $n_1 \cdot \sin i = n_2 \cdot \sin r$, if $n_1 = 1$ and $n_2 = n$ then:

- $$n = \frac{\sin i}{\sin r}$$

Then it is observed that:

• The higher the refractive index n_2, the more the refracted ray approaches the normal, and vice versa;

• If the refractive index n_2 is lower than n_1 (for example, the ray passing from glass to air), the so-called "critical angle" can be exceeded, beyond which a total reflection is observed.

ABBE REFRACTOMETER DESCRIPTION:

The refractometer is a device used to determine the unknown refractive index of some solutions. It has been used since the 19th century.

In principle, all solutions now have a unique refractive index that can be used for its identification.

The refractive index of organic compounds is in the range n $\in (1.08, 1.25)$

The Abbe refractometer is successfully used to determine the refractive index of organic compounds, solutions, food products, pharmaceuticals and serum protein concentration.

The refractive index is measured by aligning the reticle in the telescope with the line corresponding to the total reflection (see the demarcation line between the bright and dark areas of the telescope).

This line is moved by rotating the prism. The reading is carried out at a constant temperature, which is important, so the prisms are often enclosed in a water jacket, which can be connected to a thermostatic bath.

The Carl Zeiss company and the house of Abbe originated the refractometer for much of its history. Ernst Abbe published his book in 1874: »Neue lui APPARATE ....«, in which he discussed the described theory and the instruments that he had developed for measuring the refractive index using prisms and total reflection. He first described the Abbe refractometer invented in 1863 to determine the refractive index of fluids with a refractive index in the range (n = 1.03-1.07). This instrument includes the original Amici prisms and is essentially the same as the modern Abbe refractometer, but without the temperature gain. Initially, Carl Zeiss produced this instrument for internal use and for private customers. Only after 1884 Abbe offered in catalogs for Zeiss microscopes but without illustrations. Carl Zeiss published its first instrument catalog in 1893, following the formation of a new optical instrument department under Dr. C. Pulfrich. The Abbe refractometer was the prominent figure in this catalog, both with and without water jacket prisms.
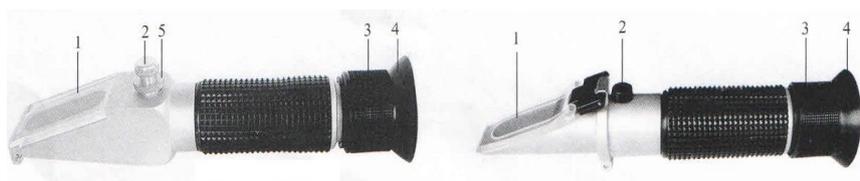
where:

1. plate for lighting - where the incident light falls
2. calibration screw
3. focus adjustment
4. ocular
5. contrary calibration screw

PROCEDURE FOR THE PRACTICAL WORK – STEPS

1. Place the front end of the refractometer in the direction of the light

2. Zero adjustment: Open the refractometer plate towards the bright region

1. Place 2-3 drops of distilled water on the main prism.
2. Close the lid of the prism - close the access to the light and press gently, so that the water spreads over the entire surface of the prism without air bubbles or dry spots.
3. Allow the sample to remain on the prism for approximately 30 seconds.
4. Then the calibration of the refractometer is carried out so that the boundary light coincides with the zero line corresponding to darkness.
5. The setting of the refractometer with the temperature compensation function to be done below the values of 20 °C which is the room temperature. When the temperature of the room or working environment (without sample) changes by more than 5 °C, it is recommended to mention the calibration accuracy.
6. The work procedure is done after calibration and is basically done in the same way as calibration.
7. The refractometer plate is opened.
8. Clean the surface of the prism with a soft cotton cloth.
9. Place 2-3 drops of solution on the main prism.
10. Close the daylight plate and press lightly, then read the value on the appropriate dark limit scale.
11. The reading is the measured value of the density of the solution.
12. After the measurement, immediately clean the test sample from the surface of the prism and the cover plate with a damp cotton cloth. After drying, it must be closed perfectly.

DETERMINATION OF THE CONCENTRATION OF THE SOLUTION

1. Prepare different solutions of propylene glycol $C_3H_8O_2$ with distilled water with concentrations between 10-80%

2. Read the density value on the device (Abbe refractometer) on the scale on the left

3. Using the formula, $c = \dfrac{m(g)}{M.V(l)} = \dfrac{\rho}{M}$ the concentration can be determined. Where M is the molar mass of propylene glycol $C_3H_8O_2$ that is: $M_{C3H8O2} = 3 \cdot 12 + 8 \cdot 1 + 2 \cdot 16 = 76$ g/mol, thus **$M_{C3H8O2} = 76$ g/mol**

4. Enter the data in the table below

5. The graphic representation will be made, respecting the function:

   $\rho = \rho(c)$

6. Enter the data in the table below

7. Read the values for the freezing temperature on the middle scale and write the corresponding data in the table

Table 1: variation of density with concentration and freezing temperature for ethylene glycol solutions

Crt. no.	c_p(%)	c (M)	$\rho\left(\dfrac{kg}{l}\right)$	t °C
1	10			
2	20			
3	30			
4	40			
5	50			
6	60			
7	70			
8	80			

$$c_M = \frac{\rho \cdot c_p \cdot 10}{M}$$

The experiment can be performed with different solutions of clarithromycin, vitamin C solutions, etc.

DETERMINATION OF SURFACE TENSION OF LIQUIDS

THEORETICAL INTRODUCTION

In the case of a liquid in contact with a gaseous medium, a molecule inside it is uniformly stressed in all directions by the other molecules, so that the resultant of these forces is zero, on the other hand, a molecule located at the liquid-gas separation surface will be subjected to an attraction force towards the inside of the liquid, because the gas molecules being less numerous than the liquid ones, the attraction forces exerted by them will be smaller. These molecules constitute the superficial layer of the liquid and the force with which the surface unit is attracted from the superficial layer towards the inside of the liquid is called molecular pressure. So the superficial layer has a higher potential energy than the molecules inside, being proportional to the surface of the upper layer. According to the minimum condition for this surface energy, the surface of a liquid always tends to the shape that gives it a minimum area. So the surface of a liquid behaves like a stretched membrane, and the force that tends to measure the surface is called the surface tension force. If we noted with dL the mechanical work done to increase the surface of the membrane by dS, we write:

$$dL = - \sigma dS \qquad (1)$$

where σ is the SURFACE TENSION COEFFICIENT.

If the process carried out with the film is a reversible and isothermal process (it takes place at the ambient temperature), this mechanical thing represents precisely the free energy of the membrane:

$$- dE = dL \qquad (2)$$

$$dE = \sigma dS \qquad (3)$$

Integrating relation (3) between S=0 and S=S we obtain:

$$E = \sigma S \qquad (4)$$

Consequently, the surface tension force will be of the form:

$$F = \sigma \cdot I \qquad (5)$$

where l represents the length of the contour on which the surface tension force F is applied.

From relation (4) we can deduce that the surface tension coefficient represents the free energy related to the area loss from the surface of the superficial membrane.

Consider a capillary tube open at one end. The detachment of a drop that originates at the end of a capillary tube occurs when its weight overcomes the surface tension force.

In this case we can write:

$$m \cdot g = 2 \cdot \pi \cdot \sigma \tag{6}$$

or
$$V_1 \cdot \rho \cdot g = 2 \cdot \pi \cdot r \cdot \sigma \tag{7}$$

where V_1 is the volume of a drop, r is the radius of the capillary tube, so the surface tension coefficient will be as follows:

$$\sigma = \frac{V_1 \rho \, g}{2\pi \, r} \tag{8}$$

The volume V_1 of a drop can be determined by knowing the volume V of the liquid and the number n of drops that arise from this volume:

$$V_1 = \frac{V}{n} \tag{9}$$

If we have a known liquid characterized by the surface tension coefficient σ_o and the tension ρ_o, we write the relation (10). By dividing relation (8) by (10) we can write relation (11).

$$\sigma_o = \frac{V \rho_o g}{2\pi \, r n_o} \tag{10}$$

$$\sigma = \sigma_o \frac{\rho \, n_o}{\rho_o n}$$

$$\tag{11}$$

The drop method gives us relative measurements. It represents the advantage that with this method, the measurements do not depend on the limit angle of the liquid in relation to the capillary material and the method can also be used for viscous liquids (liquids with higher viscosity). Also these measurements are as simple and precise.

In this paper, we propose to determine the coefficient of surface tension for different liquids, with the help of the stalagmometer.

SODIUM DODECYL SULFATE - SDS

Sodium dodecyl sulfate (SDS or NaDS), sodium lauryl sulfate or sodium lauryl (SLS) is an organic compound with the formula $CH_3(CH_2)_{11}OSO_3Na$.

This is an anionic surfactant used in many cleaning and hygiene products.

The salt is composed of an inorganic sulfate with a chain of 12 carbon atoms attached to a sulfate group, giving the material the properties required for amphiphilic detergents. Derived from coconut and palm oils, it is a common element in many household cleaners.

PRODUCTION: SDS is synthesized by treating lauryl alcohol with sulfur trioxide gas, oils, where a hydrogen atom can produce lauryl sulfate. The method frequently practiced industrially uses sulfur trioxide as gas. The product obtained is then neutralized by adding sodium hydroxide or sodium carbonate. Lauric alcohol is in turn generally derived from hydrolyzed coconut oil and palm oil, releasing the fatty acids, followed by hydrogenation. Because of this method of synthesis, commercial samples of SDS are often a mixture of other alkyl sulfates, with dodecyl sulfate as the main component. SDS is commercially available as powders and granules. It appears that the degranule form dissolves faster than the powder in water.

APPLICATIONS: SDS is primarily used as laundry detergents with many cleaning applications. SDS is an extremely effective surface active agent and is used in a task that requires the removal of stains and oily residues.

For example, it is found in higher concentrations in industrial products, including engine degreasers, floor cleaners and car wash soaps. It is found in toothpastes, shampoos, shaving creams, bath foam solutions.

It can be used to aid in cell lysis during DNA extraction and protein breakdown in SDS-PAGE. Sodium lauryl sulfate, scientifically called sodium dodecyl sulfate (SDS) or Duponol, is frequently used in the preparation of proteins for electrophoresis according to the SDS-PAGE technique. This compound works by disrupting the non-covalent bonds of proteins, denaturing and causing the molecules to lose their native shape (conformation).

This new negative charge is substantially greater than the original charge of this protein. The electrostatic repulsion that is created by binding to SDS causes the proteins to unfold into a rod-like shape, eliminating differences in shape. Electrostatic repulsion acts as a separation factor in the gel.

Sodium lauryl sulfate is probably the most studied anionic surfactant. Like all surfactants in detergents, sodium lauryl sulfate strips skin of oils and can irritate skin and eyes.

The critical micelle concentration (CMC) in pure water at 25 °C is 8.2 mM, and the aggregation number at this concentration is generally considered to be about 62.

The micellar ionization fraction (of α) is approximately 0.3 (or 30%).

Aqueous solutions of SDS are also popular for dispersing or suspending nanotubes such as carbon nanotubes (CNTs). However, sodium dodecylbenzene sulfonate (NaDDBS) and Triton X-100 are reported to be better dispersed on carbon walls.

Sodium lauryl sulfate is also used in hemoglobin analysis. The hydrophobic group of SLS acts on the globin subunit, causing a conformational change. Biological tissues treated with sodium dodecyl sulfate are subjected to quasi-transparent optical microscopy that allows to see through them.

SDS is a potentially effective topical bactericide that can also inhibit and possibly prevent infection with various enveloped and non-encapsulated viruses, such as herpes simplex virus, HIV, and Semliki Forest virus.

Pesticides: Some species of flies, ants and moths are attracted to sodium lauryl sulfate, even in small amounts, and then killed. This is the main active ingredient in most store-bought fruit fly repellants. fruit flies are often attracted to it.

Taste disturbances: Sodium lauryl sulfate temporarily reduces the perception of sweetness, an effect commonly seen after recent use of toothpastes containing this ingredient.

Toxicology studies have shown that SDS is not carcinogenic when applied directly to the skin or consumed. A review of the scientific literature said "SLS [SDS] was negative in an Ames Bacterial Mutation Test, a gene mutation and sister chromatid exchange test in mammalian cells, and an in vivo test on the micronuclei of mice. The negative results of the in vitro and in vivo studies indicate that SDS does not interact with DNA. The only study conducted on the carcinogenicity study said "SDS was not carcinogenic in the Beagle". In the case studied, details were lacking and the data had limited significance "(Agner T (1991)." Susceptibility to atopic dermatitis of patients with irritant dermatitis is caused by sodium lauryl sulfate "Acta Derm Venereol 71 (4): ... 296-300)

Sensitivity : It has been shown to irritate the skin of the face during prolonged and constant exposure (over one hour) in young adults. SDS can worsen skin problems in people with chronic skin hypersensitivity. Some people are more affected than others. In animal studies SDS appears to irritate the skin and eyes.

Canker sores: There have been several studies on how SDS toothpaste affects the recurrence of canker sores, known in some countries as white sores. The results of these studies were in conflict. In 1994, a preliminary central study showed that patients experienced a significantly higher number

of aphthous ulcers after using toothpaste containing SLS than toothpaste without SLS. However, a study published in 1999 failed to find statistically significant differences. A 2012 study found no significant difference in the number of ulcers, but did not find a significant difference in the duration and scores of ulcer-related pain. Only the 2012 Study of patients using a toothpaste without SLS showed faster ulcer healing and less ulcer-related pain, on average, than patients using toothpaste containing SLS.

Interaction with fluoride: Some studies have suggested that SLS in toothpaste may decrease the effectiveness of fluoride in preventing tooth decay (cavities). This may be due to the interaction with SLS deposition of fluoride on tooth enamel.

EXPERIMENTAL ASSEMBLY

THE STALAGMOMETER or BURETTE (figure 1) consists of a reservoir of a determined volume, delimited by two landmarks, finished with a capillary tube, through which the liquid flows, drop by drop.
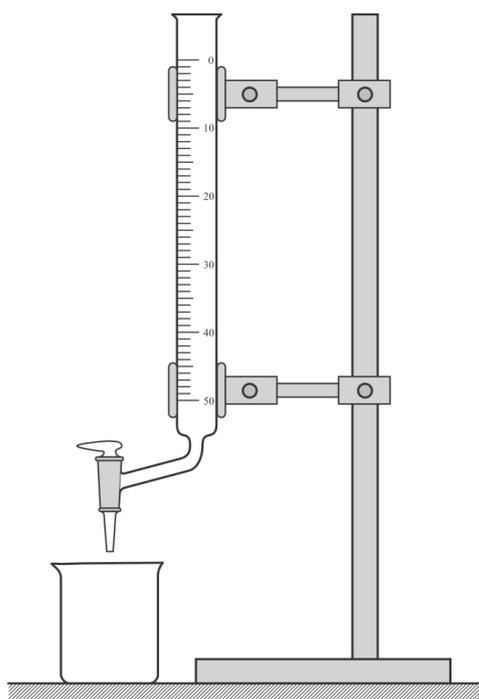
Figure 1. Schematic representation of stalagmometer

Water is introduced into the stalagmometer. Count the water droplets formed while the water flows between the two landmarks (in a given volume). The operations are repeated for the other substances,

which are being studied. 5 determinations are made for each substance, whose density is known and whose surface tension coefficient is determined with relation (11). The results are shown in table 1.

PROCEDURE FOR THE PRACTICAL WORK – STEPS

1. Water is introduced into the stalogmometer
2. The drops that forms from a given volume (between 2 marks) of liquid are counted
3. The operation is repeated for all other substances used
4. 3 measurements are made for each substance
5. The surface tension coefficient is determined with formula (11)
6. The data are entered in table 1 and 2, respectively.

EXPERIMENTAL DATA PROCESSING

Knowing the density of the solutions, the surface tension coefficient of the fluids is determined with

the relation: $\sigma = \sigma_0 \dfrac{\rho n_0}{\rho_0 n}$ (11),

The results will be introduced in table 1.

For each substance, the average value is calculated - $\bar{\sigma}$

Also the error will be calculated with the following formula $\mu = \sqrt{\dfrac{\sum\left(\sigma_i - \bar{\sigma}\right)}{n(n-1)}}$

and the interval of real values $\sigma_{real} \in \left(\bar{\sigma} - \mu, \bar{\sigma} + \mu\right) \ 10^{-3} \dfrac{N}{m}$

Table 1. Variation of surface tension with density

No. crt.	Substance	$\rho \left(kg/m^3\right)$	n (no. drops)	$\sigma \left(10^{-3}\,N/m\right)$	$\overline{\sigma}\left(10^{-3}\,N/m\right)$	μ $\left(10^{-3}\,N/m\right)$
1	water				-	-
2	(H₂O)	$\rho_0 = 1000$		$\sigma_0 = 72.8$		
3						
1	alcohol					
2	iso propyl	786				
3						
1	alcohol					
2	ethyl	789				
3	(C₂H₆O)					
1	acetone					
2	(C₃H₆)	792				
3						
1	TOLUENE					
2	(C₇H₈)	870				
3						
1	methanol					
2	(CH₄O)	1015				
3						
1	aniline					
2	(C₆ H₇H)	1010				
3						
1	acetic acid	1050				
2	C₂H₄O₂					
3						
1	DMSO	1100				
2	Dimethyl sulfur					
3	oxide					
1	ethylene glycol	1110				
2	C₂H₄O₂					
3						
1	hydrogen peroxide	1450				
2	H₂O₂					
3						

Table 2: Variation of surface tension with concentration

No crt	Subst.	ρ (kg/m^3)	n (no. drops)	σ $(10^{-3}\,N/m)$	$\bar{\sigma}\,(10^{-3}\,N/m)$	μ $(10^{-3}\,N/m)$	σ_{real}
1	water						
2	(H$_2$O)	1000		$\sigma_0 = 72.8$	-	-	
3							
1	SDS						
2	0.5%						
3							
1	SDS						
2	1%						
3							
1	SDS						
2	2%						
3							
1	SDS						
2	5%						
3							
1	SDS						
2	6%						
3							
1	SDS						
2	9.7%						
3							

CONCLUSIONS

Conclusions are drawn regarding the variation of the surface tension with the density, respectively with the concentration of the studied substance.

The interval of real values for the studied liquids is calculated according to the formula:

$$\sigma_{real} \in (\bar{\sigma} - \mu, \bar{\sigma} + \mu)\ 10^{-3}\ \frac{N}{m}$$

Table 3: Variation of surface tension with concentration:

MICELLAR SOLUTION

No. crt	C(%)	ρ (kg/m^3)	n (no. drops)	σ $(10^{-3}N/m)$	$\overline{\sigma}$ $(10^{-3}N/m)$	μ $(10^{-3}N/m)$	σ_{real}
1	water (H₂O)	1000		$\sigma_0 = 72.8$	-	-	
2							
3							
1	10	988.4					
2							
3							
1	20	989.2					
2							
3							
1	30	990					
2							
3							
1	40	990.4					
2							
3							

CONCLUSIONS

Conclusions are drawn regarding the variation of the surface tension with the density, respectively with the concentration of the studied substance.

The interval of real values for the studied liquids is calculated according to the formula:

$$\sigma_{real} \in (\overline{\sigma} - \mu, \overline{\sigma} + \mu)\ 10^{-3}\ \frac{N}{m}$$

Table 4: Variation of surface tension with concentration: GLYCERIN

No. crt	C(%)	$\rho \left(kg/m^3 \right)$	n (no drops)	$\sigma \left(10^{-3} N/m \right)$	$\bar{\sigma} \left(10^{-3} N/m \right)$	$\mu \left(10^{-3} N/m \right)$	σ_{real}
1	water						
2	(H_2O)	1000		$\sigma_0 = 72.8$	-	-	
3							
1	10						
2							
3							
1	20						
2							
3							
1	30						
2							
3							
1	40						
2							
3							
1	50						
2							
3							

CONCLUSIONS

Conclusions are drawn regarding the variation of the surface tension with the density, respectively with the concentration of the studied substance.

The interval of real values for the studied liquids is calculated according to the formula:

$$\sigma_{real} \in \left(\bar{\sigma} - \mu, \bar{\sigma} + \mu \right) \ 10^{-3} \ \frac{N}{m}$$

MEASUREMENT OF DYNAMIC AND KINEMATIC VISCOSITY USING THE HOPPLER VISCOSIMETER

THEORETICAL INTRODUCTION

VISCOSITY

At not too high speeds, the fluid flow is <u>linear</u> (in parallel layers), thus, the current lines are well determined and do not intersect anywhere, each fluid particle always remains inside the same current tube. **At high speeds, the movement of the fluid becomes TURBULENT,** irregular, the portions of the fluid mix (the flow of the ideal fluid with vortices). **If the fluid layers slide against each other,** *internal friction or viscosity forces appear between them.* The layer with the lower speed will brake the layer with the higher speed and vice versa the layer with the higher speed will increase the speed of the layer with the lower speed.

The appearance of these forces, located in the working planes, is explained by the variation of the momentum of the layers due to the passage of molecules from one layer to another. We will assume that the fluid flow direction is the same and that the flow speed varies as a mode only in the direction perpendicular (transversal) to the flow direction.

The example shows that *the internal friction force* **that appears in the sliding plane per surface unit is proportional to the degree of speed (Newton's law):**

$$\Im = \frac{dF}{dS} = \eta \frac{dv}{dz} \qquad (1)$$

thus $\quad dF = \eta \frac{dv}{dz} dS \qquad (2)$

where η *is the dynamic viscosity coefficient* depending on the nature of the fluid (and temperature).

The size of the viscosity coefficient is: $[\eta]_{S.I.} = \frac{N \cdot m}{m^2 \cdot \frac{m}{s}} = \frac{Kg \cdot m \cdot s}{s^2 \cdot m^2} = \frac{Kg}{m \cdot s}$ or $[\eta]_{S.I.} = \frac{N \cdot S}{m^2}$

The CGS unit is <u>one poise</u> (P) (after POISEUILLE): $1P = 1\frac{g}{cm \cdot s} = 0{,}1 \frac{Kg}{m \cdot s}$. Thus **the unit of measurement in SI is DECAPOISE (daP).**

For liquids η is 10^{-3} daP and for gases η is two orders of magnitude lower: $\eta = 10^{-5}$ daP.

KINEMATIC VISCOSITY ν **is the ratio between viscosity** η **and density** ρ **of the fluid:** $\nu = \dfrac{\eta}{\rho}$ **and its unit of measure is** $[\nu]_{S.I} = 1\dfrac{Kg}{m \cdot s} \cdot \dfrac{m^3}{Kg} = 1\dfrac{m^2}{s}$ in CGS the unit is STOKES (St)

$$1St = 1\frac{cm^2}{s} = 10^{-4}\frac{m^2}{s}.$$

For liquids $\nu \approx 10^{-6}\dfrac{m^2}{s}$, for gases $10^{-5}\dfrac{m^2}{s}$ (higher than for liquids)

The existence of internal friction (viscosity) can easily be shown experimentally by suspending a disk or a cylinder under which another disk or cylinder rotates by a wire.

The layer of fluid immediately adjacent to the rotating body adheres to it and is driven by it. The other layers are driven at lower and lower speeds until the last layer is glued to the other disc or cylinder, on which a frictional force will be exerted that will rotate it (see fig.1).
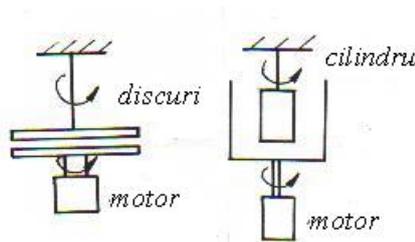

Figure 1

POISEUILLE'S FORMULA

The study **the stationary linear flow** of a viscous fluid through a tube. Linear flow occurs at not too high speeds, or at not too large diameters.
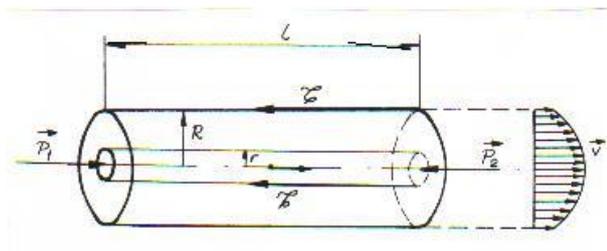

Fig 2.

If we delimit a current tube of radius r (see fig.2). The pressure forces from the extremities act on the fluid in this tube with the resultant $p_1 \pi r^2 - p_2 \pi r^2$ internal friction force on the side surface, exerted by the rest of the fluid due to viscosity $\Im 2\pi r l$.

The flow being <u>stationary</u> (with constant speed), the forces balance: $(p_1 - p_2)\pi r^2 = 2\pi r l \Im$

or $(p_1 - p_2)r = -2l\eta \cdot \dfrac{dv}{dz}$ (3)

($\Im$ is the internal friction force: $\Im = \dfrac{dF}{dS} = \eta \dfrac{dv}{dz}$) The minus sign appears because of the minus sign

of the velocity gradient $\dfrac{dv}{dz} < 0$; the speed on the axis of the tube is maximum and decreases on the

walls of the tube, being zero at the wall, in the adjacent layer.

By integration we get:

$$dv = -\frac{p_1 - p_2}{2l\eta} r dz \qquad (4)$$

$$v = -\frac{p_1 - p_2}{4l\eta} r^2 + C \quad \frac{dv}{dz} \qquad (5)$$

The constant C is determined from the condition that at the wall for r=R, the velocity should be zero.

$$v(r) = \frac{p_1 - p_2}{4l\eta}\left(R^2 - r^2\right) = v_m\left(1 - \frac{r^2}{R^2}\right) \qquad (6)$$

where $v_m = \dfrac{(p_1 - p_2)R^2}{4l\eta}$ \qquad (7)

So $\dfrac{v}{v_m} = 1 - \dfrac{r^2}{R^2}$ - *the speed distribution is parabolic* .   (8)

If we calculate the volume flow rate:

$$Q_v = \int v dS = \int_0^r v \cdot 2\pi r \cdot dr = \int_0^r \frac{2\pi(p_1-p_2)}{4l\eta}(R^2 - r^2)rdr = \frac{2\pi(p_1-p_2)}{4l\eta} \cdot$$
$$\cdot \int_0^r (R^2 - r^2)rdr = \frac{\pi(p_1-p_2)}{8l\eta}R^4 = Sv \qquad (9)$$
$$where \qquad v = \frac{p_1-p_2}{8l\eta}R^2$$

$$Q_v = \frac{\pi(p_1-p_2)}{8l\eta}R^4 = Sv$$
$$where \qquad v = \frac{p_1-p_2}{8l\eta}R^2 \qquad (10)$$

This is **POISEUILLE's formula (1841). The flow rate is proportional to the pressure drop per unit length of the tube and to the power of the 4th of the tube radius.**

This formula can be used to determine the viscosity of fluids (for example in **the OSTWALD viscometer**).

Poiseuille's law explains some aspects of the physiology of blood circulation. The human capillary network totals 10^5 Km. According to the needs of the body, the flow of blood is easily regulated by constriction or dilation of the blood vessels.

BOUNDARY LAYER. STOKES' LAW .

When a body moves in a fluid, a very thin layer of fluid adheres to the surface, driven by the body. In a linear regime, that is, at not too high speeds, in the vicinity of the body there is **a relatively thin layer, called** <u>the boundary layer</u>**, in which the speed drops to zero and in which the friction forces due to viscosity are manifested.**

We can evaluate the thickness of the boundary layer as follows: we write the length and width of the boundary layer with h and b. Then the force of internal friction according to Newton's law is: $F \approx \eta \cdot \dfrac{v}{d} \cdot h \cdot b$ (11)

On the other hand, the internal friction force can be found from the momentum variation of the fluid (from the layer with zero velocity to the one with velocity v) in the unit of time:

$$F \approx Q_m \cdot v = \rho dbv \cdot v = \rho db \cdot v^2 \qquad\qquad (12)$$

From these two expressions it follows: $d \cong \sqrt{\dfrac{h\eta}{\rho v}}$ (13)

If the ratio $\dfrac{hb}{d} = l$ is a characteristic length of the body, then the frictional force becomes:

$$\boxed{F = const. \cdot \eta l v}\ \textbf{Stokes' law} \qquad\qquad \textbf{(14)}$$

STOKES' LAW: *The frictional force F encountered by a body (in flow regime) is proportional to the viscosity of the fluid* η*, to the characteristic linear dimension of the body and to its speed v.*

In the case of the sphere, STOKES' formula $F = 6\pi\eta r v$ is obtained: **(15)**

where r - is the radius of the sphere.

EXPERIMENTAL ASSEMBLY

To determine the dynamic and kinematic viscosity, the Hoppler viscometer is used. The temperature can also be controlled from inside the viscometer in the range (-20, +120 ° C)
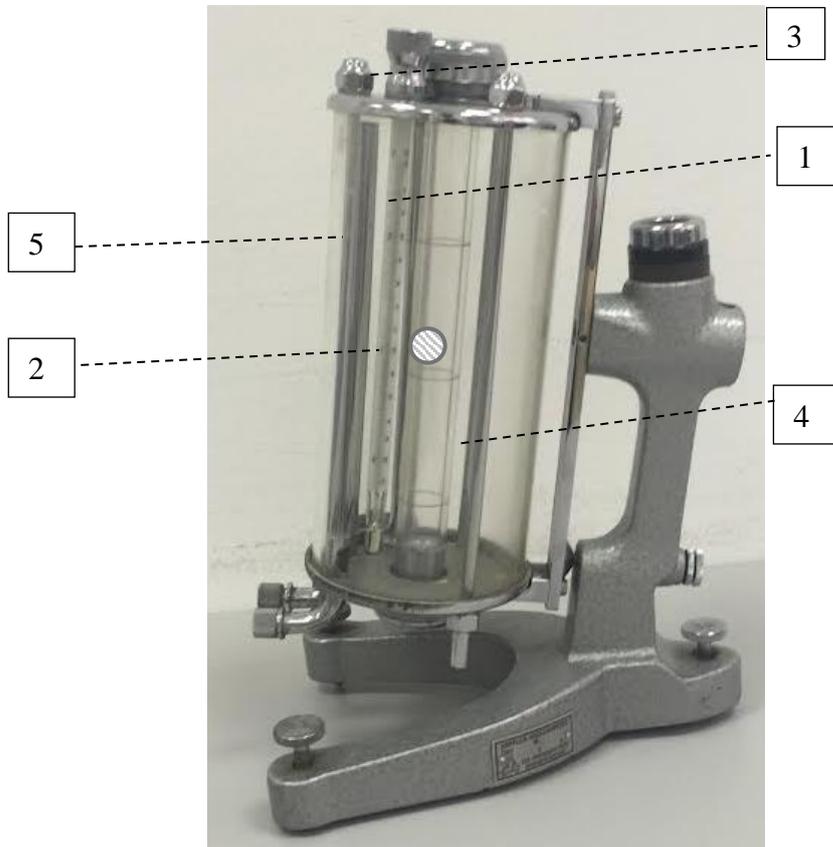
1. the tube where the ball falls
2. ball
3. the closing cap of the tube where the viscous fluid that will be studied is introduced
4. outer tube
5. thermometer
6. The temperature can be controlled inside the viscometer in the range (-20 ; +120) ° C

PROCEDURE FOR THE PRACTICAL WORK – STEPS

MEASUREMENT OF BALL FALLING TIME

Record the time the ball falls between the two marks on the tube. The tube is filled in advance with the viscous liquid to be studied (the distance between the two marks has a value of 4.5 cm = 45 mm)

EXPERIMENTAL DATA PROCESSING
CALCULATION OF DYNAMIC VISCOSITY is done with the formula: $\eta = k.(\rho_1 - \rho_2)t$

where

k is the constant of the ball (having the unit $\dfrac{mPa.s.cm^3}{g.s}$)

ρ_1 – the density of the ball (having the unit: g/cm^3)

ρ_2 - the density of the liquid to be studied (having the unit: g/cm^3)

t - the ball's falling time.

CALCULATION OF KINEMATIC VISCOSITY is done with the formula: $\upsilon = \dfrac{\eta}{\rho_2}$

Unit of measure is $1\dfrac{mm^2}{s} = 1cSt$

The calculation of the density of the falling ball is determined as follows:

$$\rho = \frac{m}{V} = \frac{m}{\dfrac{4.\pi.R^3}{3}} = \frac{6m}{\pi.D^3}$$

Where R- radius of the ball, D- diameter of the ball, m - mass of the ball.

Table 1: Material constants

Article	Ball	Material	Density g/cm^3	Ball diameter mm	Const K mPa·s·cm^3/g·s	The range of values obtained after measuring mPa·s
V91101	1	Glass Borosilicate	2.2	15.81	0.007	0.6...10
V91102	2	Borosilicate glass	2.2	15.6	0.09	7...130
V91103	3	Ni-Fe	8.1	15.6	0.09	30...700
V91104	4	Ni-Fe	8.1	15.2	0.7	200...4800
V91105	5	Steel	7.7-8.1	14.0	4.5	800…10000
V91106	6	Steel	7.7-8.1	11.0	33	6000…75000

Table 2: Determination of dynamic and kinematic viscosity $\eta(mPa.s)$

Bi	M (g)	D(cm)	K $\dfrac{mPa.s.cm^3}{g.s}$	$\rho_1(g/cm^3)$	t(s)	$\eta = k.(\rho_1 - \rho_2)t$	$\upsilon = \dfrac{\eta}{\rho_2}$ (mm^2/s)
1	4.58	1,580	0.01972	2.2212			
2	4.41	1,560	0.12801	2.2199			
3	16.13	1,559	0.13945	8.1380			
4	14.91	1,518	0.78017	8.1480			
5	11.16	1,399	6.32917	7.7925			
6	5.42	1,099	31.15722	7.8147			

Table 3: Determination of dynamic and kinematic viscosity for the plantusin syrup

No. No.	c (%)	ρ_2 g/cm^3	K $\dfrac{mPa.s.cm^3}{g.s}$	ρ_1 (g/cm^3)	t(s)	$\eta = k.(\rho_1 - \rho_2)t$ $\eta(mPa.s)$	$\upsilon = \dfrac{\eta}{\rho_2}$ mm^2/s
1	20	1.06	0.12801	2.21996			
2	40	1.1					
3	60	1.14					
4	80	1.18					
5	100	1.24					

DYNAMIC, KINEMATIC AND RELATIVE VISCOSITY MEASUREMENT USING THE UBELLOHDE VISCOSIMETER

THEORETICAL INTRODUCTION

The forces of intermolecular attraction that oppose the relative displacement of neighboring molecules cause the appearance of the phenomenon of internal friction also called as viscosity The frictional forces between the layers of flowing liquid are given by

NEWTON'S FORMULA: $\boxed{F = \eta.S.\dfrac{\Delta v}{\Delta x}}$

Where η is the viscosity coefficient,

S - contact surface between the liquid layers

$\dfrac{\Delta v}{\Delta x}$ - the speed gradient

POISEUILLE'S FORMULA is used to calculate the viscosity η: $\boxed{Q = \dfrac{p.R^4.\pi}{8.\eta.l}}$

Q - flow; p - pressure; R- radius of the tube; l – tube length.

The laminar flow of liquid is described by Poiseuille's equation: $Q = \dfrac{p.R^4.\pi}{8.\eta.l}$

The definition of flow is: $\boxed{Q = \dfrac{V}{t} \Rightarrow V = Q.t}$

For the unknown liquid we have the following formula: $V = \dfrac{p.R^4\pi.t}{8\eta l}$

For water: $V_0 = \dfrac{p_0.R^4\pi.t_0}{8\eta_0 l}$

The pressure of the unknown liquid is: $p = \rho.g.h$

and the water pressure is: $p_0 = \rho_0.g.h$

if the liquid has: V=V$_0$

$$\frac{p.R^4\pi.t}{8\eta l} = \frac{8.\eta_0 l}{p_0 R^4 \pi.t_0} = 1$$

$$\frac{p.t}{\eta} = \frac{p_0.t_0}{\eta_0} \Rightarrow \frac{\rho.g.h.t}{\eta} = \frac{\rho_0 g.h.t_0}{\eta_0}$$

$$\boxed{\frac{\rho.t}{\eta} = \frac{\rho_0.t_0}{\eta_0}}$$

The viscosity formula is:
$$\boxed{\eta = \eta_0 \frac{\rho.t}{\rho_0.t_0}}$$

And the relative viscosity formula is:
$$\boxed{\eta_{relatif} = \frac{\eta}{\eta_0} = \frac{\rho.t}{\rho_0.t_0}}$$

EXPERIMENTAL ASSEMBLY

The figure below represents the *Ubellohde viscometer* . It is made of glass and has the following constructive parts:

- reservoir R1, R2, R3 and R4;

- communication tubes, open at the upper end, (A), (B) and (C).

- tube with controlled diameter (C) through which R3 and R4 reservoirs communicate.

The determination of the dynamic viscosity coefficient (η) is based on the measurement of the flow time of a controlled volume of liquid through the tube (C). This process is governed by the *Poiseuille* equation according to which the flow rate (Q) of a liquid through a tube with a circular section, of length (L) and inner radius (r), under the action of a pressure difference (Δp) between the ends of the tube:

$$Q = \frac{V}{t} = \frac{\pi \cdot r^4 \cdot \Delta p}{8 \cdot L \cdot \eta} \ (1)$$
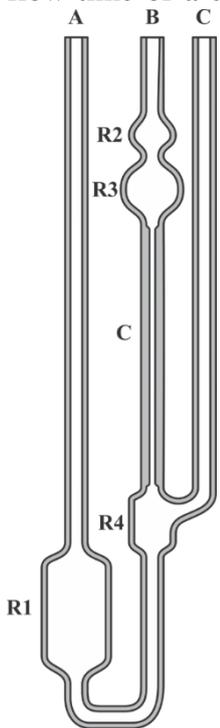
Figure 1. *Ubbelohde* viscometer

Practically, the flow time (t) of a liquid volume (V) is measured, and the dynamic viscosity coefficient is expressed by relation (2).

$$\eta = \frac{\pi \cdot r^r \cdot \Delta p \cdot t}{8 \cdot L \cdot V} \quad (2)$$

If the relation (2) is applied for a reference liquid for which the dynamic viscosity coefficient (η_r) is known, the time (t_r) is required to empty the volume (V). In this case, the equation is written as

follows: $$\eta_r = \frac{\pi \cdot r^r \cdot \Delta p \cdot t_r}{8 \cdot L \cdot V} \quad (3)$$

By dividing member by member the relations (2) and (3), the following formula results:

$$\frac{\eta}{\eta_r} = \frac{t}{t_r} \quad (4)$$

from where the coefficient of dynamic viscosity of the studied liquid (η) is calculated according to the coefficient of dynamic viscosity of the reference liquid (η_r).

$$\eta = \eta_r \cdot \frac{t}{t_r} = d \cdot \frac{t}{t_r} \quad (5)$$

PROCEDURE FOR THE PRACTICAL WORK – STEPS

1. For the practical execution of the measurement, fill the viscometer with the liquid to be studied through the communication tube (A) (a volume of approximately 14-15 ml is recommended).

2. The communication tube (C) is closed and with the help of the air pressure introduced in the tube (B) the liquid is pushed up in the tube (B) until it exceeds the reservoir R2. Both tubes (C) and (B) are released. Liquid begins to flow through tube (B) to reservoir (R4). When the liquid level reaches the narrow part between the tanks (R2) and (R3), the time counting starts (the timer starts). When the tank (R3) is empty, stop the timer and note the recorded time (t).

3. Empty the viscometer, wash and dry it. After that, filled it with the reference liquid for which the dynamic viscosity coefficient (η_r) is known and repeat the procedure described above. The emptying time (t_r) of the reservoir (R3) is also noted this time.

4. The values (t) and (t_r) are entered in relation (5) and the coefficient of dynamic viscosity (η) of the studied liquid is calculated depending on that of the reference liquid (η_r).

Table 1: Determination of relative viscosity for *Glycerin*

No.	C(%)	$d = \dfrac{\rho}{\rho_0}$	t(s)	$\eta = d \cdot \dfrac{t}{t_r}$	η	μ	ηreal
1	water	1					
2							
3							
1		1.0253					
2	10						
3							
1	20	1.0581					
2							
3							
1	30	1.0851					
2							
3							
1	40						
2							
3							

Average values and errors will be calculated and introduced in the table

Table 2: Determination of the viscosity relative to the pine bud syrup depending on the concentration

No.	C(%)	$d = \dfrac{\rho}{\rho_0}$	t(s)	$\eta_{relativ} = d.\dfrac{t}{t_0}$	$\bar{\eta}_{relativ}$	μ	$\eta_{rel\ real}$
1	water	1					
2							
3							
1	10						
2							
3							
1	20						
2							
3							
1	30						
2							
3							
1	40						
2							
3							

Average values and errors will be calculated and introduced in the table

Table 3: Determination of the viscosity relative to Panadol syrup depending on the concentration

No.	C(%)	$d = \dfrac{\rho}{\rho_0}$	t(s)	$\eta_{relativ} = d.\dfrac{t}{t_0}$	$\bar{\eta}_{relativ}$	μ	$\eta_{rel\ real}$
1	water	1					
2							
3							
1	20						
2							
3							
1	40						
2							
3							
1	60						
2							
3							
1	80						
2							
3							
1	100						
2							
3							

Average values and errors will be calculated and introduced in the table

Table 4: Determination of the relative viscosity for the plantusin solution

No.	C(%)	$d = \dfrac{\rho}{\rho_0}$	t(s)	$\eta = d \cdot \dfrac{t}{t_r}$	η	μ	η_{real}
1	water	1					
2							
3							
1	20	1.06					
2							
3							
1	40	1.1					
2							
3							
1	60	1.14					
2							
3							
1	80	1.18					
2							
3							
1	100	1.24					
2							
3							

Average values and errors will be calculated and introduced in the table

Using the following formula from FRX:

$\eta = k \cdot t \cdot \rho$ - the dynamic viscosity using the Ubbelohde viscometer can be calculated

Where $k = 0.005096 \, \frac{m^2}{s^2}$ the constant of the Ubbelohde viscometer

t is the flow time between the two landmarks

ρ - the density of the liquid used in the experiment

Table 5: Determination of the dynamic viscosity of the plantusin solution

No.	C(%)	ρ	t(s)	$\eta = k \cdot t \cdot \rho$	η	μ	η_{real}
1	water	1					
2							
3							
1	20	1.06					
2							
3							
1	40	1.1					
2							
3							
1	60	1.14					
2							
3							
1	80	1.18					
2							
3							
1	100	1.24					
2							
3							

Average values and errors will be calculated and introduced in the table

Using the following formula from FRX:

$\eta = k \cdot t \cdot \rho$ - **the dynamic viscosity using the Ubbelohde viscometer can be calculated**

Where k= 0.005096 – the constant of the Ubbelohde viscometer

t is the flow time between the two landmarks

ρ - the density of the liquid used in the experiment

**Table 6: Determination of the kinematic viscosity for the plantusin solution**

No.	c(%)	ρ	t(s)	$\nu = \eta/c$	η	μ	η_{real}
1	water	1					
2							
3							
1	20	1.06					
2							
3							
1	40	1.1					
2							
3							
1	60	1.14					
2							
3							
1	80	1.18					
2							
3							
1	100	1.24					
2							
3							

Average values and errors will be calculated and introduced in the table

THE LAWS OF THE GRAVITATIONAL PENDULUM

THEORETICAL INTRODUCTION

  The simple gravitational pendulum is a point suspended by an inextensible string of negligible mass, which can oscillate in a vertical plane, around a point of suspension under the action of its weight. Frictional forces are neglected.
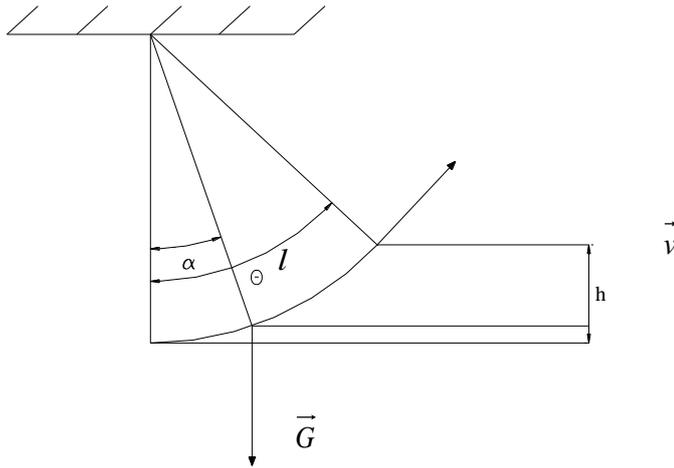
  Choosing for the deviation angle the positive trigonometric sense and the Oz axis perpendicular to the figure towards the reader, the force moment and the kinetic moment relative to the suspension point are written: $M_z = M = -mgl \sin \theta$

$$L_z = L = mvl = m\dot{\theta}\, l^2$$

$$M_z = \dot{L}_z \Rightarrow \ddot{\theta} = \frac{g}{l}\sin\theta = 0$$

$$-mgl\sin\theta = m\ddot{\theta}\, l^2$$

$$-\frac{g}{l}\sin\theta = \ddot{\theta} \Rightarrow \ddot{\theta} + \frac{g}{l}\sin\theta = 0$$

  By simplifying the mass, it follows that the oscillations do not depend on the mass of the material point. The equation can be solved for oscillations under small angles $\theta \ll 1 rad (\theta < 6^0) \Rightarrow \sin\theta \approx \theta$ in radians $\Rightarrow \ddot{\theta} + \frac{g}{l}\theta = 0$.

$$\boxed{\ddot{\theta} + \omega^2\theta = 0} \qquad \omega = \sqrt{\frac{g}{l}} \Rightarrow \text{harmonic oscillator equation}$$

The solution is $\theta = \alpha \cos(\omega t + \varphi)$

$$\omega = \sqrt{\frac{g}{l}} \Rightarrow T = 2\pi\sqrt{\frac{l}{g}}$$

The relationship for the period is obtained by simplifying the following expression:

$$T = 2\pi\sqrt{\frac{l}{g}}\left[1 + \left(\frac{1}{2}\right)^2 \sin^2\frac{\alpha}{2} + \left(\frac{1*3}{2*4}\right)\sin^4\frac{\alpha}{2} + \cdots\right]$$

<u>The laws of the gravitational pendulum:</u>

- **<u>The law of substance or the law of masses</u>**: the period does not depend on the mass and the nature of the substance of the material point.

- **<u>The law of isochronism of small oscillations:</u>** small oscillations ($\theta << 6^0$) do not depend on their angular amplitude.

- **<u>The law of lengths</u>**: the period of oscillations is directly proportional to the square root of the pendulum length and inversely proportional to the square root of the gravitational acceleration.

EXPERIMENTAL ASSEMBLY

The apparatus consists of three gravity pendulums made of different materials (brass, lead, aluminum) and different masses, suspended from a support so that their lengths can be varied.

PROCEDURE FOR THE PRACTICAL WORK – STEPS

- **Law of masses:** The three pendulums of the same length but of different masses are put into oscillation with small amplitude. The time of oscillation $(n \gg 10)$ is measured n, which divided by n gives the period of oscillation.

- **The law of lengths:** it is studied with a pendulum having the same mass but different lengths. The three pendulums of the same mass but different lengths are set to oscillate with small amplitude in turn. The time of oscillation $(n \gg 10)$ is measured n, which divided by n gives the period of oscillation.

PROCESSING OF THE RESULTS

- **The law of masses:** Complete table 1. Calculate the errors using the formula and plot the period T according to the mass $\overline{T} = \overline{T}(m)$. With the method of the smallest, it is demonstrated that the period does not depend on the mass of the pendulum. where:

$$\overline{T} = Am + B \, ; \ A = \frac{\overline{xy} - \overline{x}\,\overline{y}}{\overline{x^2} - \left(\overline{x}\right)^2}, \ B = \frac{\overline{x^2}\,\overline{y} - \overline{x}\,\overline{xy}}{\overline{x^2} - \left(\overline{x}\right)^2}, \ x = m, \ y = \overline{T}$$

Table 1: Verifying the law of masses l= ....cm

	$m(g)$	$t(s)$	$N(oscill.)$	$T(s)$	$\overline{\overline{T}}(s)$	μ	$T_{real}(s)$
1							
2							
3			10				
4							
5							
1							
2							
3			10				
4							
5							
1							
2							
3			10				
4							
5							
1							
2							
3			10				
4							
5							

Mean squared error of the average: $\mu = \pm\sqrt{\dfrac{\sum\limits_{i=1}^{n}\left(T_i - \overline{T}\right)^2}{n(n-1)}}$

n - the number of measurements, $T_{real} \in \left(\overline{T} - \mu, \overline{T} + \mu\right)$, $\overline{T} = \dfrac{\sum\limits_{i=1}^{n}T_i}{n}$.

LEAST SQUARES METHOD

There are laboratory works in which the aim is to determine a quantity that constitutes a constant coefficient from a linear relationship of the form: **Y = A.x+B** .

Such a relation is Hooke's law, for example: F=kx, in which the determination of the coefficient k or the acceleration of the center of the cylinder rolling on an inclined plane with rolling friction is required. Depending on $\sin \alpha \approx \alpha$ (for α- small : $a= A. \alpha+B$) where B is required.

By making several measurements for x and y, the constants A and B can be determined from a graphic representation. Usually the representative points are not exactly on a straight line, being affected by accidental errors. The question arises by which methods the constants A and B should be determined so that their values are as close as possible to the real value.

This problem is solved by the "*least squares method*" which is based on the following condition: the most probable value of the constants will be the one for which the sum of the squared errors is minimal.

It can be written accordingly:

$$\bar{x} = \frac{1}{n} \sum_i x_i$$

$$\bar{y} = \frac{1}{n} \sum_i y_i$$

$$\overline{x^2} = \frac{1}{n} \sum_i x_i^2$$

$$\overline{xy} = \frac{1}{n} \sum_i x_i y_i$$

So: $\overline{x^2} A + \bar{x}B - \overline{xy} = 0$

$\bar{x}A + B - \bar{y} = 0$

The solutions of these equations constitute the values sought for A and B

$$A = \frac{\overline{xy} - \bar{x}.\bar{y}}{\overline{x^2} - (\bar{x})^2}$$

$$B = \frac{\overline{x^2}.\bar{y} - \bar{x}.\overline{xy}}{\overline{x^2} - (\bar{x})^2}$$

The method can also be applied in non-linear relationships obtained on the basis of similar demonstrations.

The law of lengths:

Complete table 2.

The errors are calculated using the formula and the period T is represented graphically according to the length.

Table 2: Verifying the law of lengths m=..............g

	$l(cm)$	$t(s)$	$T(s)$	$\overline{T}(s)$	μ	$T_{real}(s)$	$T_C = 2\pi\sqrt{\dfrac{l}{g}}(s)$
1							
2							
3							
4							
5							
1							
2							
3							
4							
5							
1							
2							
3							
4							
5							
1							
2							
3							
4							
5							

The mean squared error of the average: $\mu = \pm \sqrt{\dfrac{\sum\limits_{i=1}^{n} (T_i - \overline{T})^2}{n(n-1)}}$

n - the number of measurements, $T_{real} \in (\overline{T} - \mu, \overline{T} + \mu)$, $\overline{T} = \dfrac{\sum\limits_{i=1}^{n} T_i}{n}$.

5. Conclusions: The period does not depend on the mass, it depends on the length of the pendulum.

DETERMINATION OF THE MOMENT OF INERTIA OF A RIGID BODY USING THE TRIFILAR TORSION PENDULUM

THEORETICAL INTRODUCTION

The trifilar torsion pendulum consists of two equal disks connected by three thin wires (of negligible mass), each of length "L". The assembly is positioned vertically (Figure 1-1)

Let the radius of the discs be "R". The upper disc is fixed while the lower disc can rotate around the vertical axis "OQ". After rotating the lower disk around the "OQ" axis with the angle " α_O " compared to the initial equilibrium position (Fig 1-2), the movable disk rises from the initial position, so the potential energy of the system increases.
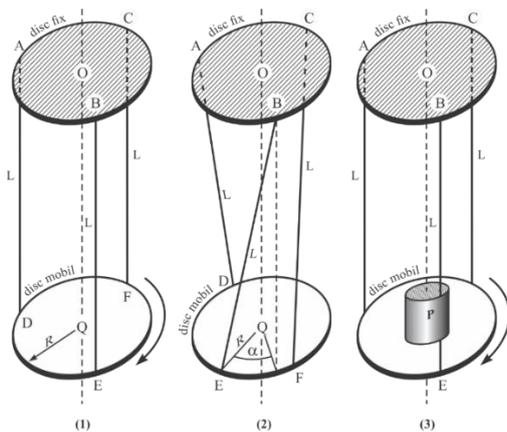
Fig. 1 Construction details of the trifilar torsion pendulum

Left free, the system returns to its initial position and engages in a circular oscillating motion. The oscillation of the mobile disk has a period "T_o", dependent on the length "L" of the supporting wires, the radius "R" of the disks, the initial angle of rotation "α_0" and the moment of inertia of the mobile disk, "I_o", in relation to the axis of rotation "OQ". During the oscillation the elongation [instantaneous value at time "t" of the angle, "$\alpha(t)$"] changes periodically in time. The tension "F", which acts in each supporting wire, is determined by the weight of the movable disc "M_o". The oscillation period is T_o. The relationship between these quantities is expressed by the differential equation (1).

$$I_o \cdot \frac{d^2\alpha(t)}{dt^2} + \frac{R^2 \cdot F(t)}{L} \cdot \sin\alpha(t) = 0 \quad (1)$$

In relation (1) the tension in the wire, "$F(t)$", is dependent on the momentary value of the elongation "$\alpha(t)$", thus implicitly on time. In the case of small initial deviation ($\alpha_o < 5^o$), the acceptance of a few simplifications is justified:

(a) $\sin\alpha(t) \approx \alpha(t)$ [$\alpha(t)$ being expressed in radians]

(b) The tension in the wire is approximately constant and determined, at each moment of the movement, by the weight of the moving disk: $F \approx M_o \cdot g$ ("g" is the gravitational acceleration).

(c) The oscillation is approximately aronic, that is, the period "T_o" can be considered constant in time, independent of the angle "α_o".

In the light of these simplifications, equation (1) can be transcribed as follows:

$$\frac{d^2\alpha(t)}{dt^2} + \frac{R^2 \cdot M_o \cdot g}{L \cdot I_o} \cdot \alpha(t) = 0 \quad (2)$$

A differential equation of the type

$$\frac{d^2\alpha(t)}{dt^2} + \omega_0^2 \cdot \alpha(t) = 0 \quad (3)$$

has, as a solution, a function of the form: $\alpha(t) = A \cdot \sin\alpha_0 t$ where "α_0" represents the pulsation, and "A" is the amplitude of the oscillation. The relationship between the pulsation "α_0" and the period "T_o" of the oscillation is:

$$\omega_o = \frac{2 \cdot \pi}{T_o} \quad (4)$$

Comparing equations (2), (3) and (4), it follows:

$$\omega_o^2 = \frac{4 \cdot \pi^2}{T^2} = \frac{R^2 \cdot M_o \cdot g}{L \cdot I_o} \quad (5)$$

$$I_o = \frac{T_o^2 \cdot R^2 \cdot g \cdot M_o}{4 \cdot \pi \cdot L} \quad (6)$$

Relation (6) expresses the moment of inertia "I_o" of the mobile disc. If a rigid object (denoted by "P" in Figure 1-3) is deposited on the moving disk, having the moment of inertia "I_P" relative to the axis of rotation "OQ", then the period of oscillation ("T_o") is changed becomes "T"). In this case, the

total mass that generates the tension in the wire is $M = M_o + M_P$, "M_P" being the mass of the object "P". The total moment of inertia, "I" is the sum of the moments of inertia "M_o" and "M_P".

$$I = I_O + I_P = \frac{T^2 \cdot R^2 \cdot g}{4 \cdot \pi \cdot L} \cdot (M_O + M_P) \qquad (7)$$

From this formula, the moment of inertia "IP" of the object "P" in relation to the axis of rotation "OQ"

is obtained: $I_P = \dfrac{R^2 \cdot g}{4 \cdot \pi \cdot L} \cdot \left[T^2 \cdot (M_O + M_P) - T_O^2 \cdot M_O \right] \qquad (8)$

PROCEDURE FOR THE PRACTICAL WORK – STEPS

(1) The mass Mo of the movable disk is determined.

(2) The torsional oscillation of the pendulum is initiated by deflecting the mobile disk with a small angle ($\alpha_o < 5°$).

(3) The duration "T_N" of a number of "N" complete oscillations is determined. For greater precision, choose as many complete oscillations as possible. If the oscillations amortize quickly, repeat the experience several times.

(4) The "T_o" period is calculated by dividing the "T_N" period by the number "N".

(5) The mass "Mp" of the studied body is determined.

(6) The studied body settles in the center of the mobile disc.

(7) System oscillation is initiated ($\alpha_o < 5°$).

(8) Follow the duration of "N" complete oscillations and obtain the period "T" by dividing the duration by the number of "N" complete oscillations.

(9) The data obtained are replaced in relation (8) to obtain the value of the moment of inertia "I_P" of the object in relation to the axis of rotation "OQ" of the system.

The moment of inertia in relation to parallel axes of rotation (verification of the *Huygens-Steiner theorem*)

Huygens - Steiner theorem refers to the moment of inertia of a body in relation to parallel axes of rotation (Figure 2). If the body has the moment of inertia "I_G" with respect to an axis of rotation passing through the center of gravity of the body ("G"), then the moment of inertia of the body ("I_P")

with respect to an axis of rotation parallel to the first axis, which passes through the point "P" located at the distance "d" from the center of gravity "G", is

$$I_P = I_G + M \cdot d^2 \quad (9)$$

where "M" represents the mass of the body.
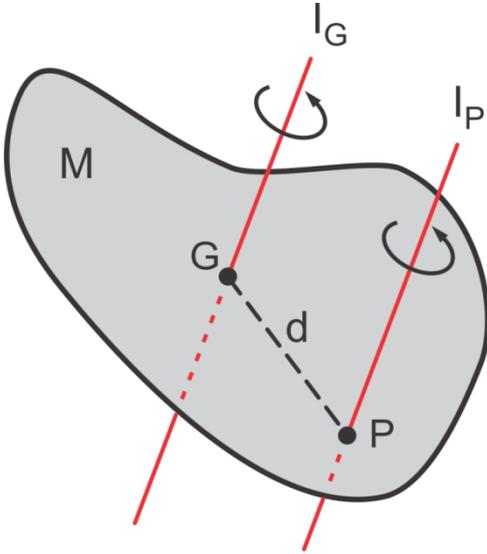
Fig. 2 The essence *of the Huygens - Steiner theorem*

Huygens-Steiner theorem can be verified if two identical bodies, each of mass "m", are placed on the moving disk, symmetrically in the hood with the center of the moving disk, the distance between the two bodies being "2·d". In this case, the moment of inertia of the assembly thus formed is with the relation:

$$I = \frac{R^2 \cdot g}{4 \cdot \pi \cdot L} \cdot \left[T^2 \cdot \left(M_o + 2 \cdot M_p \right) - T_o^2 \cdot M_o \right] \quad (10)$$

It is checked if the moment of inertia "I", thus determined, satisfies the relation (11).

$$\frac{I}{2} = I_o + m \cdot \left(\frac{d}{2} \right)^2 \quad (11)$$

EXPERIMENTAL DATA PROCESSING

To determine the moments of inertia with the above relationships, the following tables of values will be drawn up:

Table 1: Determination of the moment of inertia with the help

No. crt.	M_o(kg)	R(cm)	L(cm)	m_2 (kg)	to(s)	N (Osk)	T_o(s)	Yo (kg.m^2)
1								
2								
3								
4								
5								

Table 2:

No. crt.	m (kg)	R(cm)	r(cm)	l(cm)	m (kg)	t_o(s)	N (Osk)	T(s)	I(kg.m^2)
1									
2									
3									
4									
5									

5. Conclusions:

conclusions are drawn regarding the values of the moments of inertia thus obtained and their values

THE STUDY OF BERNOULLI'S LAW

THEORETICAL INTRODUCTION

BERNOULLI'S EQUATION

An incompressible fluid without viscosity is called IDEAL FLUID.

With fairly good accuracy, ideal liquids can be considered incompressible. Although gases are easily compressible, their compressibility is manifested only in flows with speeds close to the speed of sound. Experience shows that a large number of liquids and even gases, if their velocities are much lower than the speed of sound and the velocity gradients are small, correspond satisfactorily to the ideal fluid. We will study in this paragraph the flow of an ideal fluid.
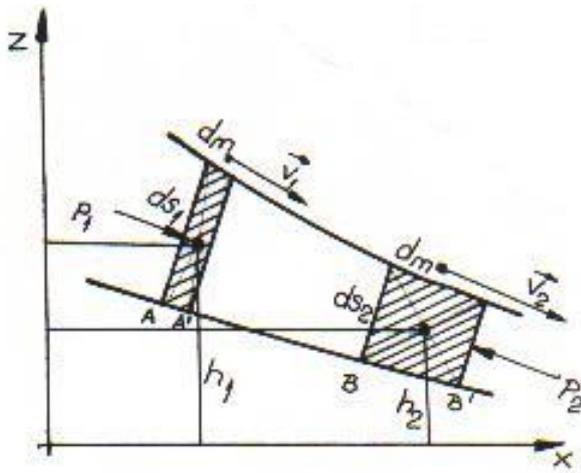
Figure 1: Helpful schematic representation for Bernoulli's law

Let's consider the ideal fluid and an infinitely thin current tube, delimited at the ends by two sections dS_1, dS_2 and apply the fluid quantities thus delimited by the mechanical energy variation theorem. During dt the system moves along the tube from position AB to A'B'. Everything happens as if the mass disappears from the portion AA'

$$dm = \rho dS_1 v_1 dl = \rho dV \qquad (1)$$

with the kinetic energy $\dfrac{dm \cdot v_1^{\,2}}{2}$ and the potential energy $dm \cdot g \cdot h_1$, and in the portion BB' there would appear a mass equal (due to the incompressibility of the ideal fluid) $dm = \rho dS_2 \cdot v_2 \cdot dt = \rho dV$ with the kinetic energy $\dfrac{dm \cdot v_2^{\,2}}{2}$ and the potential energy $dm \cdot g \cdot h_2$. The variation of the mechanical energy (kinetic and potential) of the system is therefore:

$$dE = \frac{1}{2} dm\left(v_2^{\,2} - v_1^{\,2}\right) + dm \cdot g\left(h_2 - h_1\right) \qquad (2)$$

and must be equal to the mechanical work of the pressure forces exerted on the considered system:

$$dw = F_1 \cdot dS_1 - F_2 \cdot dS_2$$
$$= p_1 dS_1 v_1 dt - p_2 dS_2 v_2 dt \qquad (3)$$
$$= p_1 dV - p_2 dV$$

and $\quad dV = \dfrac{dm}{\rho}$

The lateral pressure forces do not perform mechanical work and we have no tangential frictional forces, the fluid being assumed to be ideal (without viscosity) dE=dw

So: $\quad p_1 + \dfrac{1}{2}\rho v_1^{\,2} + \rho g h_1 = p_2 + \dfrac{1}{2}\rho v_2^{\,2} + \rho g h_2 \qquad (4)$

or $\quad \boxed{p + \dfrac{1}{2}\rho v^2 + \rho g h = const.} \qquad (5)$

(5) is the BERNOULLI equation

The constant generally differs from one current line to another (it is the same for flow without eddies).

The pressure p is *the static pressure*

$\boxed{pd = \dfrac{1}{2}\rho v^2}$ - *dynamic pressure* (due to the kinetic energy of the fluid, being equal to the kinetic

energy of the volume unit)

$\boxed{p = \rho g h}$ - *positional pressure* (or potential due to the potential energy being equal to the potential

energy of the volume unit)

BERNOULLI'S LAW

The total pressure in a fluid is constant along a streamline .

Static pressure is exerted on a surface element placed parallel to the current lines, for example on the walls of the tube (that's why it is sometimes called pressure on the walls) or exerted on an arbitrarily oriented surface element but moved in solidarity with the fluid. **The static pressure is measured with the pressure probe.**

The dynamic pressure is measured with the PRANDTL tube.

The total pressure is exerted on a surface element placed perpendicular to the current lines and **is measured with the PITOT tube** having the opening placed perpendicular to the current lines.

For the horizontal pipe, the BERNOULLI equation becomes:

$$p_1 + \frac{1}{2}\rho v_1{}^2 = p_2 + \frac{1}{2}\rho v_2{}^2 = p + \frac{1}{2}\rho v^2 = const. \qquad (6)$$

THE HYDRODYNAMIC PARADOX

Entering a narrow portion of a current tube, the speed of the particles increases (the flow rate being constant), that is, they move faster, from which it follows that the pressure in the fluid in the wide portion of the tube must be higher than in the narrow portion.
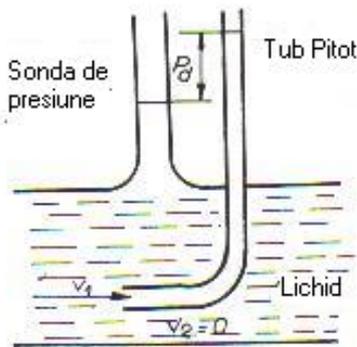
Figure 2

Indeed, because in the narrow portions of the tube the speed of the fluid increases (according to the continuity equation), the dynamic pressure also increases, therefore the static pressure, i.e. the pressure on the walls, must decrease so that their sum remains constant, according to Bernoulli's equation (HYDRODYNAMIC PARADOX)
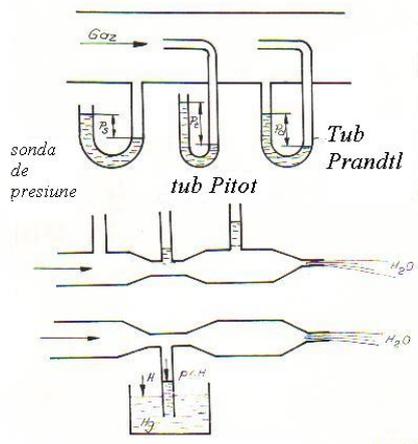
Fig3:

the phenomenon of suction can appear, on which the name of the practical application is based, such as SPRAYER, WATER PIPE, BUNSEN LAMP

EXPERIMENTAL ASSEMBLY

The device for verifying Bernoulli's law is a device **Type: DVLB-1**

The experiences that can be carried out with the help of this device, as well as the relative errors, listed in parentheses, are the following:

1.Measurement of total pressure using a pitot tube (2%);

2. Partial pressure measurement (2%);

3. Verification of Bernoulli's law, total pressure =ct .(2%);

4. Highlighting the turbulent flow;

5. Determination of dynamic pressure using the Prandtl tube. 3%);

6.Measuring the flow rate of a fluid through a pipe (3%);

7. Verification of the law of continuity, Sv=ct (3%);

8. Highlighting the ascension force-qualitative.
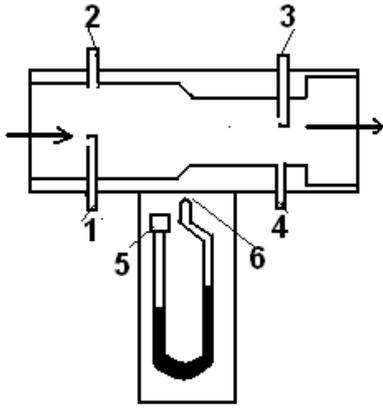
Fig.1.Schema principială
a dispozitivului de verificare
a legii lui Bernoulli.
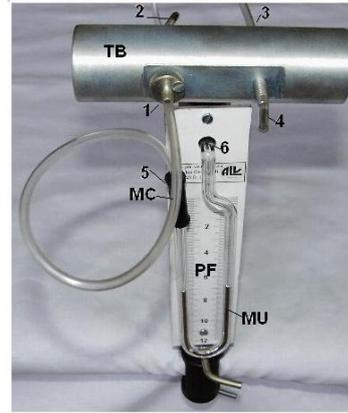
Fig.2.Vedere de ansamblu a dispozitivului
de verificare a legii lui Bernoulli.
Vedere frontală.

Fig.3.Elemente suplimentare utilizate în efectuarea
experiențelor legate de dinamica fluidelor.

Fig.4.Vedere de ansamblu a aranjării
elementelor suplimentare la dispozitivul
de verificare a legii lui Bernoulli pentru
evidențierea forței ascensională.

Apart from the verification of Bernoulli's law, the apparatus allows the experimental realization of other laws and phenomena. This device can also be used as a Pitot tube or a Prandtl tube. It is designed to be used together with a regular vacuum cleaner.

DESCRIPTION

Fig. 1 shows very simply the constructive principle of operation of the Bernoulli's law verification device. In a tube, TB, of variable section, from 20mm to 16.5mm in diameter, a jet of air is allowed to circulate, which is sucked in the direction of the arrow in fig.1, with the help of a vacuum cleaner, which is not shown in this figure and which connects to the right end, as we look at the image.

The device is equipped with two pairs of pressure measuring probes, as follows: 1 and 3 are the total pressure measuring probes, and 2 and 4 are the static (wall) pressure measuring probes. On the two sections, the two pairs of probes are arranged in a cross, as can be seen in fig.2. On the front side, PF, of the device there is a measuring ruler in front of which a mercury manometer, MU, is positioned.

The mercury manometer, MU, will be used to measure static, dynamic, total pressures relative to atmospheric pressure or differentially. The coupling of this manometer, to the two pairs of probes, is done by means of polyethylene tubes. At the end 5 visible on the front panel PF, the coupling is made by means of a rubber sleeve, MC, and at the second end, 6, the one that enters through the front panel, the coupling is made through the back, the coupling piece being provided with a spigot appropriate output.

PROCEDURE FOR THE PRACTICAL WORK – STEPS

Mounting the device is as simple as possible, 90% is already done by the manufacturing company. The corresponding steps are as follows:

1- carefully read the instructions, as well as the CD with the experimental procedures;

2-remove the manometric tube, from the appropriate packaging, remove the safety rubber sleeves during transport, from the two ends. Unwrapping them is done starting with the longer end and then the shorter;

3-at the short end, 5, connect a rubber sleeve, MC;

4-insert the end 6 of the mercury manometer, MC, in the upper part of the front panel, as shown in fig.2. The insertion is done carefully, with a rotation of 30^0 to the right and left of the vertical position. A rotation at a greater angle is forbidden, there is a risk that the mercury will come out of the capillary tube of the manometer.

5-moderately tighten the M5 screws on the back of the device. Tightening is carried out until the capillary tube can no longer be rotated in the rubber gasket, from the device support.

The operations from 2-5 are done, either with the pressure tube inserted 75% in a plastic bag or on top of a bowl of water. These precautions are mandatory in order to avoid accidental spillage of mercury in the laboratory.

6- the capillary tube is inserted into a small transparent plastic bag, bag delivered together with the device and which is attached with adhesive tape to the front of the device. The role of this bag is to avoid spilling the mercury in the laboratory when the capillary tube accidentally breaks.

VERIFICATION OF BERNOULLI'S LAW, $P_T = CT$.

The calculation formulas are:

$$p_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

If h1=h2

$$p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2 = p + \frac{1}{2}\rho v^2 = const.$$

$$\Delta p = p_1 - p_2 = \frac{\rho}{2}\left(v_1^2 - v_2^2\right) = \frac{\rho}{2} . v_1^2 . \left[\left(\frac{S_1}{S_2}\right)^2 - 1\right]$$

At the same time $\Delta p = \rho_{lichid} . g . h$

So the flow speed of the liquid in the pipe is: $v_1 = \sqrt{\dfrac{2\rho_{lichid} . g . h}{\rho_{aer}\left[\left(\dfrac{S_1}{S_2}\right)^2 - 1\right]}}$

And the surface of the pipe is: $S_1 = \dfrac{\pi . D_1^2}{4}$ respectively: $S_2 = \dfrac{\pi . D_2^2}{4}$

So the speed of the fluid flow through the pipe is:

$$v_1 = \sqrt{\dfrac{2\rho_{lichid} . g . h}{\rho_{aer}\left[\left(\dfrac{D_1}{D_2}\right)^4 - 1\right]}}$$

And the speed in section S $_2$ is: $v_2 = v_1 \dfrac{S_1}{S_2} = v_1\left(\dfrac{D_1}{D_2}\right)^2$

The data are entered in **table 1.** for the following cases:

1. Small closure with closed valves
2. Small closure with open valves
3. InLarge shutoff with open valves
4. Large closure with closed valves
5. With total opening

In tables 2, 3, 4, the values of the pressure variation, of the flow speed through the pipe v1 and v2 are entered.

6. Experimental data processing

Table 1.

No. crt	d1 (mm)	d2 mm	ρ_{air} kg/m^3	ρ liquid (kg/m^3)	h (mm)	Δp (N/m^2)	v1 (m/s^2)	v2 (m/s^2)
1	20	18	1.20	800				
2				Technical				
3				alcohol				
4								
5								

Table 2 Pressure Calculation

	$\Delta p \left(\dfrac{N}{m^2} \right)$	$\Delta \bar{p} \left(\dfrac{N}{m^2} \right)$	$\mu_{\Delta p} \left(\dfrac{N}{m^2} \right)$	$\Delta p_{real} \left(\dfrac{N}{m^2} \right)$	$\Delta p = \rho_{lichid} \cdot g \cdot h$ Average value: $$\Delta \bar{p} = \frac{\sum_{i=1}^{n} \Delta p_i}{n}$$ Error: $$\mu_{\Delta p} = \pm \sqrt{\frac{\sum_{i=1}^{n} \left(\Delta p_i - \Delta \bar{p} \right)^2}{n(n-1)}}$$ Range of actual values: $\Delta p_{real} \in \left(\Delta \bar{p} - \mu_{\Delta p}, \Delta \bar{p} + \mu_{\Delta p} \right)$
1					
2					
3					
4					
5					

Table 3: calculation of flow velocity v1

No. crt	$v_1\left(\frac{m}{s}\right)$	$\bar{v}_1\left(\frac{m}{s}\right)$	$\mu_{v_1}\left(\frac{m}{s}\right)$	$v_{1real}\left(\frac{m}{s}\right)$	$v_1 = \sqrt{\dfrac{2\rho_{lichid}\cdot g\cdot h}{\rho_{aer}\left[\left(\dfrac{D_1}{D_2}\right)^4 - 1\right]}}$
1					Average value: $\bar{v}_1 = \dfrac{\sum\limits_{i=1}^{n} v_{1i}}{n}$
2					
3					
4					Error: $\mu_{v1} = \pm\sqrt{\dfrac{\sum\limits_{i=1}^{n}\left(v_{1i} - \bar{v}_1\right)^2}{n(n-1)}}$
5					Range of actual values: $v1_{real} \in \left(\bar{v}_1 - \mu_{v1}, \bar{v}_1 + \mu_{v1}\right)$

Table 4: calculation of the flow speed v2

No. crt	$v_2\left(\frac{m}{s}\right)$	$\bar{v}2\left(\frac{m}{s}\right)$	$\mu v2\left(\frac{m}{s}\right)$	$v_{2real}\left(\frac{m}{s}\right)$	$v_2 = v_1\dfrac{S_!}{S_2} = v_1\left(\dfrac{D_!}{D_2}\right)^2$
1					Average value: $\bar{v}2 = \dfrac{\sum\limits_{i=1}^{n} v_{2i}}{n}$
2					
3					
4					Error: $\mu_{v2} = \pm\sqrt{\dfrac{\sum\limits_{i=1}^{n}\left(v2_i - \bar{v}2\right)^2}{n(n-1)}}$
5					Range of actual values: $v2_{real} \in \left(\bar{v}2 - \mu_{v2}, \bar{v}2 + \mu_{v2}\right)$

STUDY OF GAS LAW

BOYLE-MARIOTTE LAW

INTRODUCTION

The Boyle-Mariotte law (also called **Boyle's law** by Anglophones, or **Mariotte's law** or **Boyle-Mariotte law** by Francophones) is one of the thermodynamic laws of real gases

Mariotte and Boyle found with a difference of a few percent that the curve was close to an equilateral hyperbola given by Clapeyron 's coordinates (p,V), that is:

pV = constant for a given constant temperature

Or it can be written $p_1.V_1 = p_2.V_2$

That is, maintaining a constant temperature during an increase in pressure, there is a decrease in volume

The law was discovered by the Irishman Robert Boyle in 1662 and by the French Français Edme Mariotte in 1676 .

Guillaume Amontons stated in 1702 that this law is valid only at constant temperature and low pressure.

This relationship between pressure and volume was noted by 2 scientists Richard Towneley and Henry Power. Robert Boyle confirmed and experimentally discovered this law. Robert Hook built the apparatus for the experiment. Boyle's law is based on experiments carried out with air, which he considers to be composed of fluid particles at rest between two invisible springs.

Boyle was interested in air as an important element of life.

Boyle used a J-shaped tube in the experiment where he introduced mercury into a branch and forced the air to contract under the pressure of the mercury. He performed the experiment several times under different conditions: different amounts of mercury in the installation and concluded that the gas pressure varies inversely proportional to the volume of the occupied gas. The French physicist Edme Mariotte (1620-1684) discovered

The same law with Boyle independently of him in 1676, but Boyle published the results already in 1662. However, this law is called the Boyle-Mariotte law

Later in 1867 in Philosophiæ Naturalis Principia Mathematica, Newton

He demonstrated mathematically that an elastic fluid contains particles at rest, that repulsive forces are exerted between them that are inversely proportional to the distance

Density is inversely proportional to pressure, but this mathematical reality is not the physical explanation for the observed relationship.

The kinetic-molecular theory introduced by Maxwell and Boltzmann two centuries later is needed to explain this law.

This law is the first physical law expressed in the form of an equation that describes the dependence of two variable quantities.

The mathematical equation for Boyle's law is the following:

$PV = k$ or $P_1V_1 = p_2V_2 = ... = p_nV_n$

P represents the pressure in the system

V represents the volume of the gas

k is a constant that depends on the pressure and volume in the system

TRANSFORMATION (T=CONST.) – BOYLE-MARIOTTE LAW

$PV = k$ or $P_1V_1 = p_2V_2 = ... = p_nV_n$

(A) →(B) Isothermal expansion (with T_1 = const)

(C) →(D) Isothermal compression (T_2 = const) and $T_1 > T_2$

$p_1 \quad V_1 \quad T$

$p_2 \quad V_2 \quad T$

$p_3 \quad V_3 \quad T$
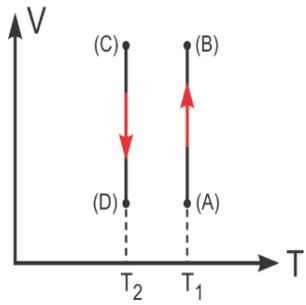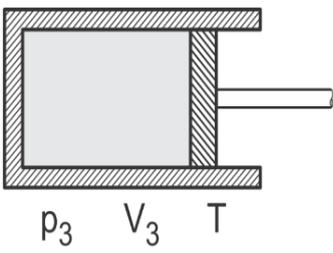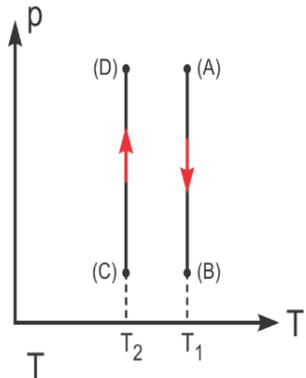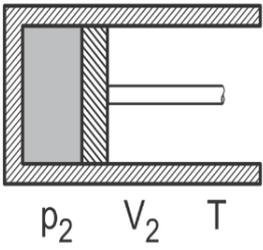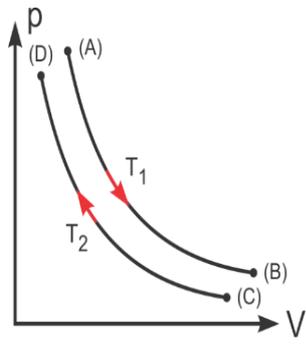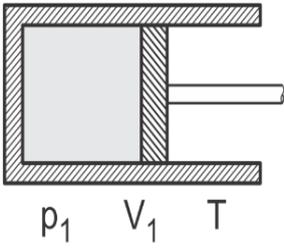
PART I: VERIFICATION OF BOYLE MARIOTTE'S GAS LAW

EXPERIMENTAL DEVICE

The instrument consists of burette 1 where the gas volumes V1, V2, ..., Vn can be determined. By modifying the height of the reservoir 3, the volume of the gas in the burette changes, but in the same time the pressure also changes, which can be read on the manometer 2.
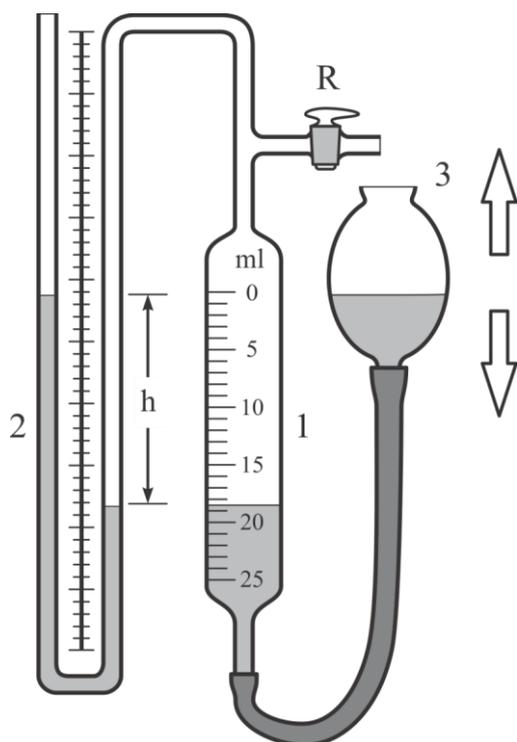
Figure 1. Schematic representation of the device used to verify Boyle Mariotte's gas law

PROCEDURE FOR THE PRACTICAL WORK – STEPS

  1. determine the pressure to be studied using the manometer 2. You can write p_1, p_2, ... p_n

  2. determine the corresponding volume from burette 1. It can be written: V_1, V_2, V_3, ...V_n

  3. 5 measurements are made for p, respectively for V

  4. 5 appropriate calculations are made to check $p_1V_1 = p_2V_2 = ...= p_nV_n$

  5. Introduce the experimental data in the table below

Table 1. Gas law verification

No. crt.	V_{read} cm³	$V = V_{read} + V_0$ cm³	P_{read} mm H₂O	$P = P_{read} + p_0$ mmH₂O	pV=K $\frac{N}{m^2}.m^3 = N.m$	$\bar{K}$ N.m	$\mu = \pm\sqrt{\frac{\sum(K_i - \bar{K})^2}{n(n-1)}}$	K_{real}
1								
2								
3								
4								
5								

where

P_0 = 760 mm Hg= 10336 mm H₂O= 101325 N/m² – is the normal atmospheric pressure

And **V_0 = 123.88 cm³** is the constant of the device or it is also called "dead volume" - it is the volume of the manometer with liquid measured from division 0 to the liquid in the manometer.

To determine the volume V_0, the isothermal transformation formula is used:

pV = constant as follows: $p_1.(V_1 + V_0) = p_2(V_2 + V_0)$

$$V_0 = \frac{p_2 V_2 - p_1 V_1}{p_1 - p_2}$$

or
$$p_1 = p_0 + \rho.g.h_1$$
$$p_2 = p_0 + \rho.g.h_2$$

After making the calculations, we obtain: V_0 = 123.88 cm³ = 123.88 mL

The following conversions can be made:

for pressure p: $1 mmH_2O = 9.8 N/m^2$

for volume V: $1 cm^3 = 1 \cdot 10^{-6} m^3$

Average values, errors and interval of real values can be calculated:

Average value for pV=K: $\bar{K} = \frac{\sum_{i=1}^{n} K_i}{n}$ and

The mean squared error of the average: $\mu = \pm\sqrt{\frac{\sum(K_i - \bar{K})^2}{n(n-1)}}$

FINAL CONCLUSIONS

Errors can be calculated for the values obtained by direct measurements of p and V

The graphs can be represented by respecting the function: p = p (V)

PART 2: CALCULATION OF THE UNIVERSAL CONSTANT OF GASES (R):

The universal perfect gas constant denoted by R is the product of Avogadro's number Na and Boltzman's constant kB

This product is **R = 8.3144621 J · mol^{-1} · K^{-1}** with an accuracy of

7.5×10^{-6} J · mol^{-1} · K^{-1}[1]

In the CGS system it can also have the following values:

R = 0.0821 L·atm/(mol.K)

R = 8.2057×10^{-5} m^3 atm/(mol K)

R = 62.3637 L·Torr/(mol·K) or L·mmHg/(mol·K) [2]

R = 1.987 cal K^{-1} mol^{-1} [3]

Conversions of measurement units:

$\qquad$ 1 Pa $\simeq$ 7,500 615×10^{-3} mmHg (millimeters of mercury column)

$\qquad$ 1 Pa $\simeq$ 9.869 233×10^{-6} atm (normal atmosphere)

$\qquad$ 1 Pa = 10^{-5} bar

$\qquad$ 1 hPa = 10^{-3} bar = 1 mbar or millibar

$\qquad$ 1 Pa $\simeq$ 1.42×10^{-4} PSI

$\qquad$ 1Pa = 1N/ m^2

either: 10^5 Pa = 1 bar = 1 000 mbar = 10.2 m H$_2$O column (water column meters) = 0.987 atm

1 psi = 6894.76 Pa (N/m²) = 0.069 bar = 0.069 kgf/cm² = 51.7 mmHg = 689.7 mm H$_2$O = 0.068 atmospheres

By using the equation of state: pV = nRT

$$R = \frac{p.V}{n.T}$$

Where: T$_0$ = 273 K and the molar volume of air is: V = 22.4 L = 22,4 ·10^{-3} m^3

In n = 1 mole of air there is: V = 22.4 L (liters)

Table 2. Determination of the universal gas constant - R

No. crt.	p $\dfrac{N}{m^2}$	V m³ 10^{-6}	T (K)	n (mol) 10^{-3}	$R = \dfrac{p.V}{n.T}$ $\dfrac{J}{mol.K}$	$\overline{R}$ $\dfrac{J}{mol.K}$	$\mu = \pm\sqrt{\dfrac{\sum(R_i - \overline{R})^2}{n(n-1)}}$	$\mathbf{R_{real}}$
1								
2								
3								
4								
5								

Average values, errors and interval of real values can be calculated:

Average value for $\overline{R} = \dfrac{\sum\limits_{i=1}^{n} R_i}{n}$

The mean squared error of the average: $\mu = \pm\sqrt{\dfrac{\sum(R_i - \overline{R})^2}{n(n-1)}}$

DETERMINATION OF SPECIFIC HEAT FOR SOLID AND LIQUID MATERIALS

INTRODUCTION

In order to determine the temperature of different materials we should know the amount of heat given off or absorbed by each material within the system. This depends on the mass of the material, the nature of the material from which the body is made and the degree of heating. The heating of a material can be achieved by radiation, convection currents and thermal conductivity.

The thermal capacity of a material is equal to the heat required by that material to increase or decrease its temperature by one degree Kelvin $C = \dfrac{Q}{T}$

The unit of measurement is: $[C]_{S.I.} = \dfrac{[Q]_{S.I.}}{[T]_{S.I.}} = \dfrac{J}{K}$ or $[C]_{S.I.} = \dfrac{kcal}{K}$

THERMAL CAPACITY of the mass unit is called specific heat.

$c = \dfrac{C}{m}$ whose unit of measurement is: $[c]_{S.I.} = \dfrac{J}{kgK}$ or $[c]_{S.I.} = \dfrac{kcal}{kgK}$

SPECIFIC HEAT is the heat required by the mass unit of the material increase or decrease its temperature by 1 degree $c = \dfrac{Q}{m.\Delta T}$

And the **THERMAL CAPACITY** of a mole of substance is called molar heat and is the amount of heat needed by a mole of substance to increase or decrease its temperature by 1 degree Kelvin.

$c_\mu = \dfrac{Q}{\upsilon.\Delta T}$ the unit of measurement is: $[c_\mu]_{S.I.} = \dfrac{J}{kmolK}$ or $[c_\mu]_{S.I.} = \dfrac{kcal}{kmolK}$

Between the international system of units and the tolerated system the following relationship exists: $1\dfrac{kcal}{K} = 4.186\dfrac{J}{K}$

The specific heat is a variable quantity with the temperature generally increasing with its raise, therefore its definition must specify the temperature to which it refers. For solid bodies heated in the temperature range between $273K$ and $373K$ the specific heat is measured by the mixture method

based on the thermal balance with the help of the calorimeter. The mixture method is based on two calorimetric principles:

1. **The principle of heat exchange equality:**

When there is an exchange of heat and only heat between the two systems of bodies, until thermal equilibrium is established, the sum of the heat received by the system initially at the lower temperature is equal to the sum of the heat lost by the system of bodies initially at a higher temperature raised.

2. **Principle of inverse transformations:**

The amount of heat required for a system of bodies to go from a state 1 to a state 2 is that given by the system passing from state 2 to state 1. The method of mixtures consists in heating the considered body to a known temperature and introducing it inside the vessel with water, measuring the increase in its temperature. If it is noted with C the thermal capacity of the calorimeter, with M_a and c_a - the mass, respectively the specific heat of the water in the calorimeter, T_0 - its initial temperature, T_f - the final temperature of the mixture.

After the body to be studied has been introduced into the calorimeter considering that:

$$Q = Mc\Delta T \ (1)$$

the calorimetric equation is written: $(c_a M_a + C)(T_f - T_0) = Mc(T - T_f) \ (2)$

where the specific heat of the body to be studied is obtained: $c = \dfrac{(C + M_a c_a)(T_f - T_0)}{M(T - T_f)}$ (3)

The thermal capacity of the calorimeter is given by the relation: $C = \sum\limits_{i=1}^{n} M_i c_i$

M_i, c_i - represent the masses and the specific heats respectively and the indexes have the following specification: 1 – refers to the calorimetric vessel, 2 – stirrer, 3 – thermometer.

The purpose of this paper is to determine the specific heat for a metallic body using the Berthelot calorimeter.

EXPERIMENTAL ASSEMBLY:
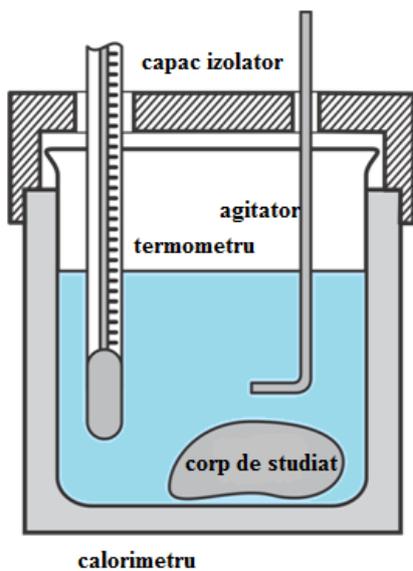
The necessary equipment consists of a Berthelot calorimeter, an electric hob and a vessel for heating the bodies that will be studied. The Berthelot calorimeter has the following components: isolating cover, thermometer, stirrer, calorimetric vessel.

Figure 1. Schematic representation of the experimental assembly for determination of specific heat

DETERMINATION OF HEAT CAPACITY OF THE CALORIMETER

PROCEDURE FOR THE PRACTICAL WORK – STEPS AND EXPERIMENTAL DATA PROCESSING

The calorific capacity of the calorimeter is determined as follows:

- A known amount of water M_{a1} is introduced in the calorimeter, the temperature of the water should be in thermal equilibrium with the ambient temperature - noted as temperature t_0
- Afterwards a known amount of heated water M_{a2} is added in the calorimeter, noted as temperature t
- The final temperature of the mixture (t_e) is determined by using a thermometer
- The obtained data will be inserted in table 1.
- Calculations are made for the heat capacity of the calorimeter
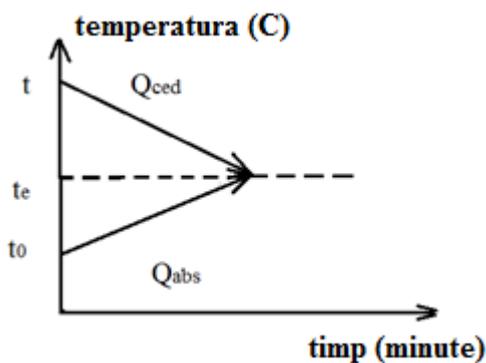
M_{a1} – mass of cold water introduced in calorimeter

M_{a2} - mass of hot water introduced in calorimeter

$c_a = 4182.61 \dfrac{J}{kgK}$ - specific heat of water

The calorimetric equation is as follows: $\left| Q_{ced} \right| = Q_{abs}$ **(1)**

$Q_{abs} = M_{a1} c_a \left(t_e - t_0 \right) + C\left(t_e - t_0 \right) > 0$ **(2)**

$Q_{ced} = M_{a2} c_a \left(t_e - t \right) < 0$

$\left| Q_{ced} \right| = M_{a2} c_a \left(t - t_e \right) > 0$ **(3)**

$M_{a1} c_a \left(t_e - t_0 \right) + C\left(t_e - t_0 \right) = M_{a2} c_a \left(t - t_e \right)$ **(4)**

$$C = \frac{M_{a2}c_a(t - t_e)}{(t_e - t_0)} - M_{a1}c_a$$

(5)

Table 1: Determination of the heat capacity of the calorimeter

n	M_{a1} (kg)	M_{a2} (kg)	c_a $\left(\dfrac{J}{kgK}\right)$	t_0 (^0C)	t (^0C)	t_e (^0C)	C $\left(\dfrac{J}{K}\right)$	$\overline{C}$ $\left(\dfrac{J}{K}\right)$	μ $\left(\dfrac{J}{K}\right)$	C_{real} $\left(\dfrac{J}{K}\right)$
1										
2										
3			4182.61							
4										
5										

Average values, errors and the interval of actual values will be calculated

The average value of the caloric capacity is $\overline{C} = \dfrac{\sum\limits_{i=1}^{n} C_i}{n}$

The mean squared error of the average: $\mu = \pm\sqrt{\dfrac{\sum(C_i - \overline{C})^2}{n(n-1)}}$

The interval of real values is: $C_{real} \in (\overline{C} - \mu, \overline{C} + \mu)$

DETERMINATION OF THE SPECIFIC HEAT FOR SOLIDS

The specific heat for solid materials is determined as follows:

- A known quantity of water M_a that is in thermal equilibrium with the ambient temperature, at temperature t_0, is introduced into the calorimeter

- After that a solid material of known mass-m (whose mass is determined with a balance before), is introduced in the calorimeter at a specific temperature (t)

- The final temperature (t_e) of the mixture (water-solid material) is determined

- The obtained data will be entered in table 1.

- Calculations are made for the specific heat of the solid material that will be studied.
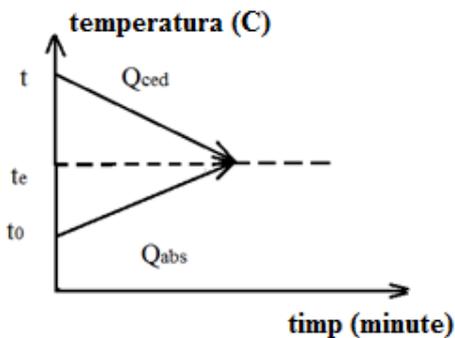
$M_{a1} + M_{a2} = M_a$ is the mass of cold water in the calorimeter

m – is the mass of the solid material whose specific heat (c) will be determined. This solid material (a body made from teflon) is heated to a specific temperature (t)

The calorimetric equation is: $\left|Q_{ced}\right| = Q_{abs}$ **(1)**

$$Q_{abs} = M_a c_a (t_e - t_0) + C(t_e - t_0) > 0 \qquad \textbf{(2)}$$

$$Q_{ced} = m.c.(t_e - t) < 0$$
$$\left|Q_{ced}\right| = m.c.(t - t_e) > 0 \qquad \textbf{(3)}$$

$$M_a c_a (t_e - t_0) + C(t_e - t_0) = m.c\ (t - t_e) \qquad \textbf{(4)}$$

$$\boxed{.c = \frac{M_a c_a (t_e - t_0) + C(t_e - t_0)}{m.(t - t_e)}} \qquad \textbf{(5)}$$

Table 2: Determination of the specific heat for solid materials

n	M_a (kg)	m (kg)	c_a $\left(\dfrac{J}{kgK}\right)$	t_0 (^0C)	t (^0C)	t_e (^0C)	c $\left(\dfrac{J}{Kg.K}\right)$	$\bar{c}$ $\left(\dfrac{J}{Kg.K}\right)$	μ $\left(\dfrac{J}{Kg.K}\right)$	c_{real} $\left(\dfrac{J}{Kg.K}\right)$
1										
2										
3			4182.61							
4										
5										

Average values, errors and the interval of actual values will be calculated

Average values of c : $\bar{c} = \dfrac{\sum\limits_{i=1}^{n} c_i}{n}$ and

The mean squared error of the average: $\mu = \pm\sqrt{\dfrac{\sum(c_i - \bar{c})^2}{n(n-1)}}$

The real value will be in the following interval : $c_{real} \in (\bar{c} - \mu, \bar{c} + \mu)$

DETERMINATION OF THE SPECIFIC HEAT OF LIQUIDS

The specific heat of liquids is determined as follows:

- A known amount of lichd M_1 is introduced into the calorimeter in thermal equilibrium with the ambient temperature, at temperature t_0
- Afterwards a known quantity of the same heated liquid (M_2) at temperature t is added into the calorimeter
- The final temperature of the mixture t is determined.
- The obtained data will be entered in table 1.
- Calculations are made for the specific heat of the studied liquid c_L
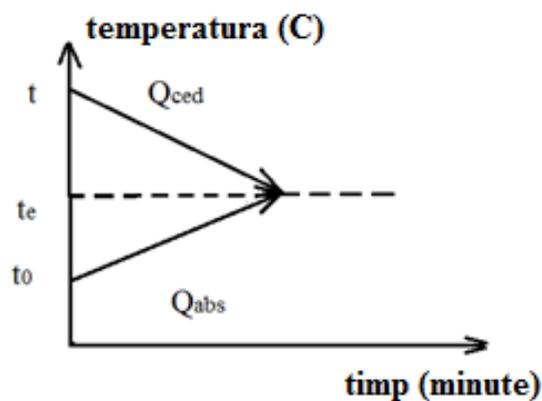
M_1 – mass of cold liquid in the calorimeter

M_2 - mass of hot liquid in the calorimeter

c_L - specific heat of the liquid that will be studied

The calorimetric equation is: $|Q_{ced}| = Q_{abs}$ **(1)**

$$Q_{abs} = M_1 c_L (t_e - t_0) + C(t_e - t_0) > 0 \qquad \textbf{(2)}$$

$$Q_{ced} = M_2 c_L (t_e - t) < 0$$
$$|Q_{ced}| = M_2 c_L (t - t_e) > 0 \qquad \textbf{(3)}$$

$$M_1 c_L (t_e - t_0) + C(t_e - t_0) = M_2 c_L (t - t_e) \qquad \textbf{(4)}$$

$$\boxed{.c_L = \frac{C(t_e - t_0)}{M_2.(t - t_e) - M_2(t_e - t_0)}} \qquad \textbf{(5)}$$

Table 3: Determination of the specific heat of a liquid

n	M_1 (kg)	M_2 (kg)	C (J/K)	t_0 (^0C)	t (^0C)	t_e (^0C)	c_L $\left(\dfrac{J}{Kg.K}\right)$	$\bar{c}_L$ $\left(\dfrac{J}{Kg.K}\right)$	μ $\left(\dfrac{J}{Kg.K}\right)$	$c_{L\,real}$ $\left(\dfrac{J}{Kg.K}\right)$
1										
2										
3										
4										
5										

Average values, errors and the interval of actual values will be calculated

Average value of c_L: $\bar{c}_L = \dfrac{\sum\limits_{i=1}^{n} c_i}{n}$ and

The mean squared error of the average: $\mu = \pm\sqrt{\dfrac{\sum (c_i - \bar{c})^2}{n(n-1)}}$

The real value will be in the interval : $c_{L\,real} \in (\bar{c}_L - \mu, \bar{c}_L + \mu)$

THE STUDY OF FREE DIFFUSION

INTRODUCTION

Dilute solutions present similar characteristics with gas mixtures.
The molecules of the dissolved substance diffuse, meaning that, they spread throughout the mass of the solvent liquid.

By dissolving a solid in a liquid, the ordered structure is lost, and its molecules get a supplement of kinetic energy, being hit by the molecules of the solvent.

In turn, the solvent molecules lose part of their kinetic energy, which is expressed by the decrease in the temperature of the solution. In order to restore the initial temperature, heat must be supplied.

Diffusion transports molecules (or ions) from a higher concentration to a lower concentration.

The spontaneous variation in time of the concentrations of the components of a system due to the relative movement of their particles, consists of a transport of mass or electric charge.

Diffusion in gases or in liquids consists in the spreading of the molecules of a gas (liquid) among the molecules of another gas (liquid), when the substances come into contact, resulting in a mass transport in the sense of decreasing the concentration of the molecules of each of the considered components.

According to ***Fick's law***: $\dfrac{dn}{dt.S} = -D\dfrac{dC}{dx}$ or $\dfrac{\Delta n}{\Delta t.S} = -D\dfrac{\Delta C}{\Delta x}$

Where J is the material flow

- On the one hand, the flow of material is equal to the concentration gradient $\dfrac{dC}{dx}$ or concentration variation Δc in a given direction x, i.e. Δx

$$J = -D\dfrac{dC}{dx} \text{ or } J = -D\dfrac{\Delta C}{\Delta x}$$

- However, the Material Flow is the number of moles of solute Δn transported due to diffusion through an area S of 1 m^2 in a time interval of $\Delta t = 1$ s.

$$J = \dfrac{\Delta n}{\Delta t.S}$$

$$[J]_{S.I.} = 1\dfrac{mol}{m^2 s}$$

D is the diffusion coefficient which is a characteristic of the dissolved substance but also of the environment in which the diffusion takes place. The scientific literature provides tabulated data for the diffusion coefficient D.

Taking into account the formula: $J = -D\dfrac{\Delta C}{\Delta x}$, the unit of measurement for the concentration gradient

$\dfrac{dC}{dx}$ is: $\left[\dfrac{\Delta C}{\Delta x}\right]_{S.I.} = 1\dfrac{mol}{m^3.m}$

where $\dfrac{mol}{m^3}$ is the unit of measure for the concentration

Starting from the equation $J = -D\dfrac{\Delta C}{\Delta x}$, from the point of view of the unit of measurement, the following unit was obtained:

$$\dfrac{mol}{m^2.s.} = [D]_{S.I.}\cdot\dfrac{mol}{m^4} \Rightarrow [D]_{S.I.} = 1\dfrac{m^2}{s}$$

Fick's law is valid only for stationary conditions! (meaning that, for boundary conditions in which it can be considered that a very small value of the flow - in a very small time interval - does not significantly change the concentration gradient).

Let's consider 2 vessels of infinite size that communicate with each other through a channel, through which there is no tendency for the solute to flow from the region with higher concentration to the one with lower concentration. If the liquid level in the two compartments are equal then, from the point of view of the law of communicating vessels, there is no mechanical flow tendency from one compartment to another.

To measure the concentration variation in the studied solution, we measure the electrical conductivity.

Electrical conductivity is the inverse of resistance: $G = \dfrac{1}{R}$

The unit of measurement for conductivity is $[G]_{S.I.} = \dfrac{1}{\Omega} = S(SIEMENS)$
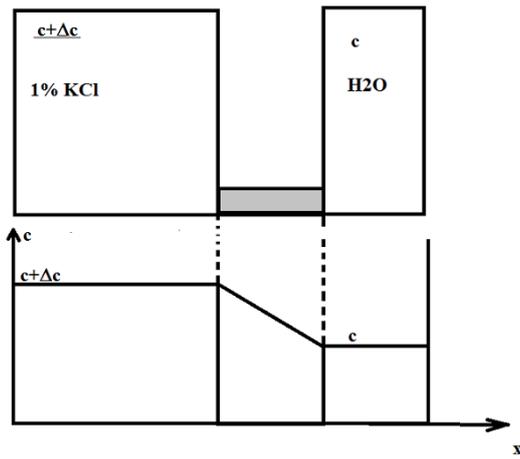
For a resistor of length l, section S and resistivity ρ, the expression of electrical resistance can be written: $R = \dfrac{\rho.l}{S}$.
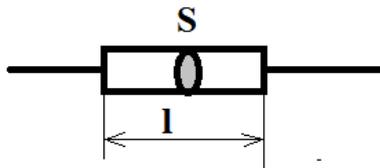
The unit of measurement for resistivity is: $[\rho]_{S.I.} = 1\Omega.m$.

We can also talk about specific conductivity: $\lambda = \dfrac{1}{\rho}$

EXPERIMENTAL PART

An aqueous solution of KCl is used.

Electrolytes can be classified as "strong" or "weak". Strong electrolytes dissociate completely into ions upon dissolution, while weak electrolytes dissociate only partially upon dissolution.

KCl is an electrolyte that dissociates as follows: KCl $\rightarrow$ K$^+$ + Cl$^-$

Electrolytes are ionic forms that dissolve in water

All salts are weak electrolytes: KCl, NaCl, CH$_3$COONa

Non-electrolytes are substances that dissolve in water and do not dissociate, such as: glucose - C$_6$H$_{12}$O$_6$, urea - NH$_2$CONH$_2$

Examples of strong and weak electrolytes

ACID		BASES	
Strong acids	**Weak acids**	**Strong bases**	**Weak bases**
SOLID INORGANIC ACIDS nitric acid, HNO_3 hydrobromic acid, HBr hydrochloric acid, HCl hydrochloric acid, $HClO_3$ hydroiodic acid, HI perchloric acid, $HClO_4$ sulfuric acid, H_2SO_4	**WEAK AND MEDIUM STRENGTH INORGANIC ACIDS** boric acid, H_3BO_3 carbonic acid, H_2CO_3 (simply called "acid" when included in mineral waters or soft drinks such as Fanta) hydrofluoric acid, HF **WEAK ORGANIC ACIDS** acetic acid, CH_3COOH butyric acid, $CH_3CH_2CH_2COOH$ benzoic acid, C_6H_5COOH citric acid, $(C_6O_7H_8)$ formic acid, HCOOH lactic acid, $CH_3CHOHCOOH$ malic acid, $HOOCCH_2CHOHCOOH$ oxalic acid, HOOCCOOH pyruvic acid, $CH_3COCOOH$ propionic acid, CH_3CH_2COOH valerianic acid, $CH_3(CH_2)_3COOH$	NaOH KOH LiOH $Ca(OH)_2$ $Ba(OH)_2$	Ammonia NH_3 H_2O $Mg(OH)_2$ $Zn(OH)_2$ $Al(OH)_3$

DESCRIPTION OF THE WORKING INSTRUMENT: MULTIMETER WTW 340I (CONDUCTOMETER / PH METER):
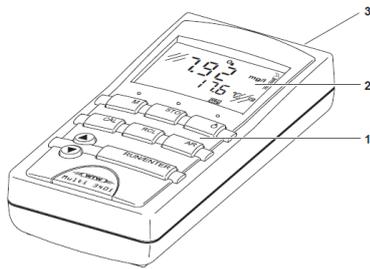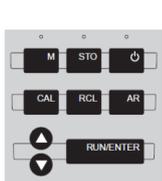
1- the keyboard

2- display

3- current connection

Affichage

affichage de l'état

symbole de senseur / l'électrode

affichage de la valeur mesurée

fonction et affichage de la température

Touche	Fonction
M	sélectionner la variable mesurée pH / potentiel Redox D.O. concentration _ / D.O. saturation conductivité / salinité
STO	enregistrer (sauver) une valeur mesurée
⏻	ouvert / fermé (ON/OFF)
CAL	calibrer la variable mesurée actuellement fixé
RCL	Afficher / transmettre les valeurs mesurées
AR	activer / désactiver la fonction de lecture automatique (AutoRead)
▲	sélectionner le mode de mesure, augmenter les valeurs, rouleau
▼	sélectionner le mode de mesure, diminuer les valeurs, rouleau
RUN/ENTER	confirmer un enregistrement, activer la fonction lecture automatique (AutoRead) valeurs de sortie mesurée

domaine de prise
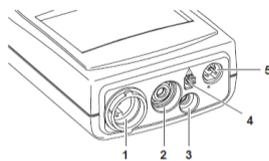
1	D.O. sonde ou la conductivité du cellule
2	Electrode de pH
3	Sonde de température de pH
4	Branchez - dans l'unité d'alimentation
5	RS232 interface série

PROCEDURE FOR THE PRACTICAL WORK – STEPS
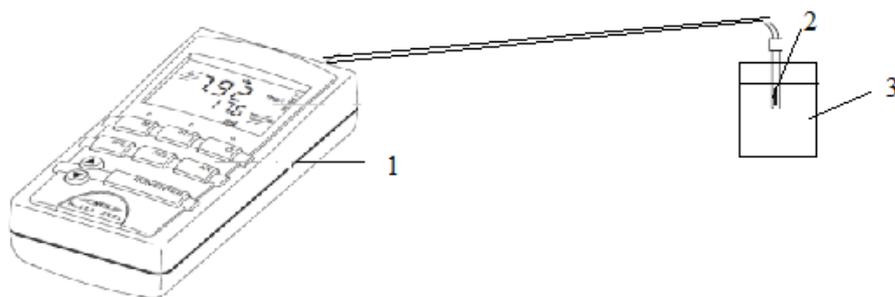
1. Put distilled water (AD) in glass 3

Distilled water dissociates as follows: $2\,H_2O \Leftrightarrow H_3O^+ + OH^-$

Where H_3O^+ - is called the hydronium ion and OH^- the hydroxyl ion.

Water does not dissociate well because it is not a strong electrolyte

2. Within the space created (2) by the two conductivity probes, a porous material is inserted - for example cotton (wadding)

3. The conductivity of the distilled water is measured

The conductance is read $G\left(\dfrac{\mu S}{cm}\right)$ every 30 seconds until 5 minutes when the value of G stabilizes

4. The recorded data will be entered in table 1.

5. Change the aqueous solution: distilled water from glass (3) with 1% KCl aqueous solution.

6. Measurements are made every 30 seconds up to 30 minutes.

7. Do not stir the solution to observe only the phenomenon of diffusion

Table 1

t(s)	G(μS/cm)	c(mol/m³)	G/c
0			
30			
60			
90			
120			
150			
180			
210			
240			
270			
300			
330			
360			
390			
420			
450			
480			
510			
540			
570			
600			
630			
660			
690			
720			
750			
780			
810			
840			
870			
900			
930			
960			
990			

1020			
1050			
1080			
1110			
1140			
1170			
1200			
1230			
1260			
1290			
1320			
1350			
1380			
1410			
1440			
1470			
1500			
1530			
1560			
1590			
1620			
1650			
1680			
1710			
1740			
1770			
1800			

8. Open an Excel file and fill in table 1, enter the conductance G measured at every 30 s.

9. draw the graph $G = G(t)$. It is a graph that after a period of instability of approx. 3 minutes shows a linear variation of conductivity depending on time. The linear part of the curve is selected and the equation corresponding to this part is determined: $G = A_1.t + B_1$. The value of the coefficient R^2 should be close to the value 1. If the value of R^2 is closest to 1, this means that this is the line that best represents the phenomenon.

A_1 is the slope of the equation line: $G = A_1.t + B_1$.

So we represented the variation of the conductance as a function of time: G=G(t)

10. To determine the variation in the concentration of ions recorded in the region where the probe was inserted, do not remove the porous layer of cotton between the two conductometric sensors and measure the conductivity of a 0.1% KCl solution. The correlation between conductivity and concentration is made.

For the calibration solution (KCl 0.1%) the following value is used $G = 1923 \dfrac{\mu S}{cm}$

The molar mass of KCl is: $M_{KCl} = 74{,}5 \dfrac{g}{mol}$

For the concentration of 0.1% KCl we have the measured value of $G = 1923 \dfrac{\mu S}{cm}$

For the concentration of $1000 \dfrac{g}{m^3}$ KCl the measured value of G is as follows $G = 1923 \dfrac{\mu S}{cm}$

For the concentration of $\dfrac{1000}{74.5} \dfrac{mol}{m^3}$ KCl the measured value of G is as follows $G = 1923 \dfrac{\mu S}{cm}$

Then for the unknown concentration $c\left(\dfrac{mol}{m^3}\right) KCl$ we have the measured value of $G\left(\dfrac{\mu S}{cm}\right)$

so $c\left(\dfrac{mol}{m^3}\right) = G . \dfrac{1000 \dfrac{mol}{m^3}}{74{,}5 \dfrac{g}{mol} . 1923 \dfrac{\mu S}{cm}} = G.0{,}006980145$

$$\boxed{c = G . \dfrac{1000}{74{,}5 . 1923} = G.0{,}006980145}$$ 　　　　　　　　　　　　(5)

This represents the formula to calculate the concentration

For the values obtained in this formula, enter the values obtained in the second column of table 1.

11. Draw the graph c = c (t) as a function of time.

The line is obtained: c = A $_2$. t + B $_2$ with the R^2 coefficient also very close to 1.

12. The flow of ions is calculated using Fick's law: $J = \dfrac{\Delta n}{\Delta t.S} = \dfrac{\Delta n.v}{v \, \Delta t.S}$.

but $\dfrac{\Delta n.}{v} = \Delta C$ - it is the variation of the concentration, that is, the variation of the number of moles in the volume unit.

then the particle flow can be written: $J = \dfrac{\Delta n}{\Delta t.S} = \dfrac{\Delta c.}{\Delta t.} \cdot \dfrac{v}{S}$

$\dfrac{\Delta c.}{\Delta t.} = A_2$ represents the slope of the line c = A $_2$. t + B $_2$ which is the variation concentration as a function of time c = c (t).

In the flow expression $J = \dfrac{\Delta n}{\Delta t.S} = \dfrac{\Delta c.}{\Delta t.} \cdot \dfrac{v}{S}$, the ratio between volume and surface is:

$\dfrac{v}{S} = \Delta x = 1cm = 10^{-2}\, m$.

It is considered S = 1 cm^2 the surface of the conductor which is S = 1 cm^2 is subject to the diffusion phenomenon and the corresponding volume V = 1 cm^3

Remember: the volume of the probe is used here, which is V = 1 cm^3

Thus the flux corresponding to the porous material is J = A $_2$ .10 $^{-2}$

It is worth noting here the significance of the notation A$_2$

$\dfrac{\Delta c.}{\Delta t.} = A_2$ represents the slope of the line c = A $_2$. t + B $_2$ which represents concentration as a function of time c = c (t)

According to Fick's equation, the ion flux that diffuses is $J = -D.\dfrac{\Delta c}{\Delta x}$

But here we have a concentration difference from 1% to 0%.

Then:. $\dfrac{\Delta c}{\Delta x} = 134,2\dfrac{mol}{m^3} \cdot \dfrac{1}{10^{-2}\,m} = 134,2.10^2\dfrac{mol}{m^4}$

It can be said that the concentration equivalent of 1% corresponds to a value of $134,2\dfrac{mol}{m^3}$

$$1\% --- \frac{1g}{100ml} --- 10\frac{g}{l} --- 10000\frac{g}{m^3} --- \frac{10000}{74,5}\frac{mol}{m^3} --- 134,2\frac{mol}{m^3}$$

It can be written as follows: A_2 corresponds to the slope of the concentration line c = c (t)

$$A_2.10^{-2} = -D.134,2\frac{mol}{m^3}$$

$$\boxed{D = \frac{A_2.10^{-2}}{134,2.10^2} = A_2\frac{10^4}{134,2}\frac{m^2}{s}}$$ - **THE FORMULA FOR CALCULATING THE DIFFUSION**

COEFFICIENT

Where A_2 is the slope of the line obtained from the graphic representation

c = c (t)

The experiment can be realized with rehydration salts with the composition: NaKCl

The molar mass of NaKCl is: $M_{KNaCl} = 97.5\frac{g}{mol}$

For rehydration salts, the concentration is calculated with the formula:

$$c = G.\frac{1000}{97.5.1923} \qquad\qquad\qquad \textbf{(5)}$$

To determine the diffusion coefficient D

The concentration equivalent of 1% corresponds to a value of

$$1\%............ \frac{1g}{100\ ml}................................ ....\frac{10000\ mol}{97.5\ m^3} = 102.564\frac{mol}{m^3}$$

It can be written: A_2 corresponds to the slope of the concentration line

c = c (t)

$$A_2.10^{-2}=-D.102.564\frac{mol}{m^3}$$

$$D = \frac{A_2.10^{-2}}{102.546.10^2} = A_2.\frac{10^4}{102.564}\frac{m^2}{s}$$

THE FORMULA FOR CALCULATING THE DIFFUSION COEFFICIENT

Where A2 is the slope of the line obtained from the graphic representation

c = c (t)

The experiment can be realized with DISTILLED WATER:

The molar mass of H_2O is: $M_{H2O} = 18 \frac{g}{mol}$

For rehydration salts, the concentration is calculated with the formula:

$$c = G.\frac{1000}{18.1923} \qquad\qquad (5)$$

To determine the diffusion coefficient D

The concentration equivalent of 1% corresponds to a value of

$1\%\dots\dots\dots \frac{1g}{100\,ml}\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \frac{10000\,mol}{18\,m^3} = 555.555 \frac{mol}{m^3}$

It can be written: A_2 corresponds to the slope of the concentration line

$c = c\,(t)$

$A_2.10^{-2} = -D.555,555\frac{mol}{m^3}$

$$D = \frac{A_2.10^{-2}}{555.555.10^2} = A_2.\frac{10^4}{555.555}\frac{m^2}{s}$$

THE FORMULA FOR CALCULATING THE DIFFUSION COEFFICIENT

Where A2 is the slope of the line obtained from the graphic representation

$c = c\,(t)$

The rule of determination in the category is the different solutions used, using the Diffusion Coefficient

For MICROMOLECULES:

$M < 10^3$ Da et $D \sim 10^{-5}$ cm^2/s $\sim 10^{-9}$ m^2/s

For MACROMOLECULES:

10^3 Da $< M < 10^8$ Da et $D \sim 10^{-8}$ cm^2/s $D \sim 10^{-12}$ m^2/s

STUDY OF VARIATION OF CONDUCTANCE WITH CONCENTRATION FOR STRONG AND WEAK ELECTROLYTES

THEORETICAL INTRODUCTION

The chemical transformations accompanied by the passage of an electric current through the considered system are known as electrochemical reactions. Many chemical reactions take place by the transfer of electric charges, such as proton transfer reactions between an acid (AH or BH^+) and solvent SH, or between a base (B or A^-) and a solvent S:

$AH + SH = A^- + SH_2^+$ $\qquad\qquad$ $A^- + SH = AH + SB^+$

$SH = S^- + BH^+$ $\qquad\qquad$ $BH + + SH = B + SH_2^+$

In solution, the reactant components are usually in ionic form, but they can also be neutral molecules.

An important role in electrochemical processes is played by the state of ionic species in the liquid phase (for example, in the solution). As electrically charged particles, they interact strongly both with the solvent (an interaction called *solvation*) and with the other ionic particles (which constitute *the ionic atmosphere*). Their transition into other forms, following electrochemical reactions, is dependent on the value of the free energy of the process. Both the solvation process (ion – molecule interactions) and the interaction with the ionic atmosphere (ion – ion interactions) present great difficulties in a quantitative approach at the microscopic level.

Electronic conductors are generally solid or molten metals, alloys and some metallic compounds. Electronic conduction occurs through the orderly movement of electrons, while the positive ions from which they came occupy fixed positions. Electronic conduction can be characterized quantitatively with the help of specific conductance, also called conductivity. According to Ohm's law, electrical resistance, R , represents the ratio between the applied potential difference, U , and the resulting current, I : $R = \dfrac{\Delta U}{I}$ and is measured in ohms (Ω)

The electrical resistance of a body depends on its length, x, and its cross-sectional area S (when the section is constant). The proportionality constant, depending on the nature of the material, is called specific resistance or resistivity: $R = \dfrac{\rho.l}{S}$

The inverse value of resistance is called conductance, and the inverse value of resistivity $G = \dfrac{1}{\rho}$ is called conductivity or specific conductance: $\dfrac{1}{R} = G.\dfrac{S}{l}$

The dimensions of resistivity and conductivity result from the analysis of the definition relations:

$[\rho]_{S.I.} = 1\Omega.m \quad ; [G]_{S.I.} = 1\Omega^{-1}.m^{-1}$

The unit $\Omega^{\square\square\square}$ is sometimes referred to as mho (inverse of ohm) or siemens.

Electronic conductors have resistivities between 10^{-8} and 10^{-5} Ωm, compared to insulators that have resistivities **G** $>10^6$ Ωm.

The increase in temperature leads to a decrease in the conductivity of the electronic conductors due to the increase in the agitation of the "electronic gas".

Ionic conductors (also called conductors of the second kind), in the form of electrolyte solutions or melts, are formed either by the electrolytic dissociation of some polar substances (ionic substances such as HCl, CH$_3$COOH, etc.) upon dissolution in polar solvents (for example water), either by dissolving solid substances with an ionic structure (ionophores such as NaCl, KNO$_3$, etc.) or by melting them. Electrolytes are considered strong when they are completely dissociated, or weak when they are only partially dissociated. The division of electrolytes into the two categories has a relative character since even the dissociated species interact with each other. At higher concentrations, "ion pairs" or even higher aggregates are formed.

Unlike electronic conductors, in which the density of charge carriers (electrons) is an intrinsic characteristic of the material, for ionic conductors in the form of solutions the density of charge carriers can be modified by changing the concentration.

In addition, the transport of electric current through an electrolyte solution is provided by both positive and negative ions. The transport of ions in an electrolyte solution occurs either due to the existence of a concentration gradient, or due to the application of a potential difference, or both stresses.

In order to highlight the conductive characteristics of the solutions of the different electrolytes, a standardization of the concentration is first necessary. Conductivity measured at different

concentrations must be converted to a quantity related to a unit concentration. The ratio between conductivity and molar concentration, called molar conductivity, allows the comparison between the conductivities of solutions of different electrolytes at the same concentration. Molar conductivity is defined as: $G_m = \dfrac{1000.G}{C_m}$.

where C_m is the molar concentration of the electrolyte, and the factor 1000 converts the molar concentration from mol/L to SI units (mol/m^3).

Since the conductive properties of an electrolyte solution are dependent on both the concentrations of the ions and their charges, a standardized property also from the point of view of the valence of the ions is the ***equivalent conductivity,*** defined as: $G_e = \dfrac{1000.G}{C_e}$.

where C_e represents the normal concentration (in gram equivalents per liter of solution).

In the absence of interactions between ions, the equivalent conductivity should be a constant characteristic of each system. It was found experimentally that, for dilute solutions of strong electrolytes, the equivalent conductivity decreases with increasing concentration, according to a law of the form: $G_C = G_0 - A.\sqrt{C}$. By extrapolating the values of G_C at zero concentration (when the interionic interactions cancel), the equivalent conductivities at infinite dilution, G_0, are obtained. These are intrinsic properties of charge carriers and are tabulated for individual ions in aqueous solutions at a temperature of 25 ^{0}C. They are used in the calculation of other transport properties of electrolyte solutions.

The temperature dependence of the conductivity of electrolyte solutions is also different from that of electronic conductors: an increase in temperature leads to an increase in the conductivity of diluted electrolyte solutions according to an empirical law of the form:

$$G_t = G_{25}\left[1 + \alpha(t - 25) - \beta(t - 25)^2\right]$$

The transport of ions in solutions can occur both due to the application of an electric field and due to the existence of a concentration gradient. In the first case, the transport is called migration, and in the second case, diffusion. The diffusion of neutral particles is described by Fick's laws. For ions, these laws must be modified to take into account the electric field gradient induced by a concentration gradient. The two transport mechanisms can occur separately or together.

Electronic and ionic conduction are two extreme mechanisms that can be found together, cooperating in the transport of electric current.

PROCEDURE FOR THE PRACTICAL WORK – STEPS

An aqueous solution of KCl is used.

Electrolytes can be "strong" or "weak". Strong electrolytes dissociate completely into ions upon dissolution, while weak electrolytes dissociate only partially upon dissolution.

KCl is an electrolyte that dissociates as follows: $KCl \rightarrow K^+ + Cl^-$

Electrolytes are substances that, in a molten state or in solution, are electrical conductors. The electrical conductivity of electrolyte solutions is very different (whether they are ionic or covalent combinations) and consequently they have been classified according to this criterion into **strong electrolytes** and **weak electrolytes** .

Strong electrolytes are the following:

- salts: $NaCl$, KNO_3, Na_2SO_4 , $Pb(NO_3)_2$, $CaCl_2$, $CuSO_4$, CH_3COONa;

- soluble hydroxides: $NaOH$, KOH, $Ba(OH)_2$;

- mineral acids: HBr, HCl, H_2SO_4, HNO_3, H_3PO_4;

Weak electrolytes are the following:

- organic acids: CH_3COOH, C_6H_5COOH;

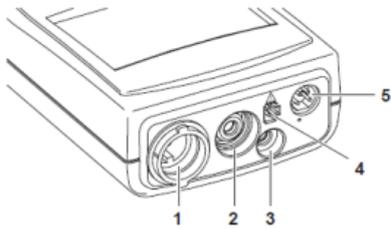- inorganic acids: H_2S, H_2CO_3 , HCN;

- bases: NH_3, amines.

DEVICE DESCRIPTION: WTW 340I MULTIMETER (CONDUCTOMETER / pH METER):
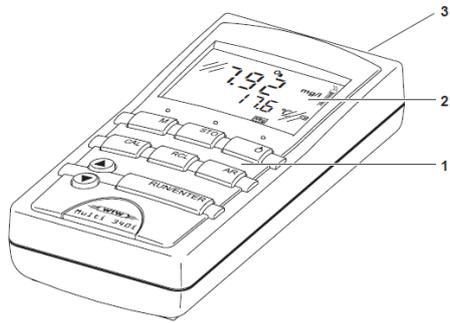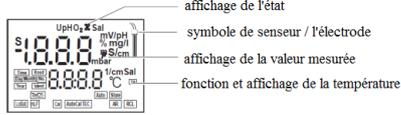

1- keyboard (Keypad)

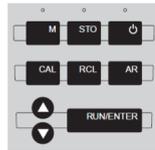2- display

3- connection region (Jack field)

domaine de prise

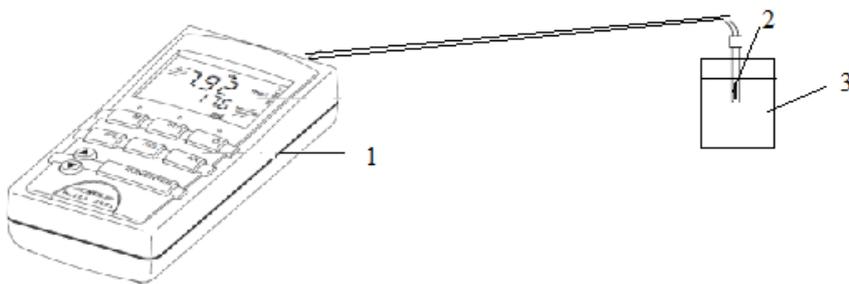| 1 | D.O. sonde ou la conductivité du cellule |
2	Electrode de pH
3	Sonde de température de pH
4	Branchez - dans l'unité d'alimentation
5	RS232 interface série

Affichage

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symbole de senseur / l'électrode
affichage de la valeur mesurée
fonction et affichage de la température

M	sélectionner la variable mesurée pH / potentiel Redox D.O. concentration _ / D.O. saturation conductivité / salinité
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▼	sélectionner le mode de mesure, diminuer les valeurs, rouleau
RUN/ENTER	confirmer un enregistrement, activer la fonction lecture automatique (AutoRead) valeurs de sortie mesurée

1. Prepare solutions of acetic acid CH_3COOH of different concentrations as follows:

2. A stock solution of acetic acid of concentration $c_1=0.4M$ is made as follows: 12 g of acetic acid in 500 ml of water.

3. From the stock solution of acetic acid with $c_1=0.4M$, prepare the other solutions needed in the experiment and whose conductance is measured $G\left(\dfrac{\mu S}{cm}\right)$ as presented in Table 1.

Table 1

Soil no	The volume in ml of acetic acid CH_3COOH of concentration $c_1=0.4M$ needed to be poured into the a graduated flask. From this value, add water up to the volume of 50 ml of the graduated flask.	The concentration obtained in molars (M)
1	45	0.36
2	40	0.32
3	35	0.28
4	30	0.24
5	25	0.20
6	20	0.16
7	15	0.12
8	10	0.08
9	5	0.04
10	2	0.016
11	1	0.008

4. Thus, 12 working solutions are obtained, having concentrations between 0.4 M and 0.008 M, which are introduced into the Berzelius glass and afterwards their conductance will be measured $G\left(\dfrac{\mu S}{cm}\right)$.

The results are shown in table 2 in column 4.

5. Calculate G/c and enter the results in table 2 in column 5.

6. A solution of KCl - a strong electrolyte - of concentration $c_1 = 0.4$ M is obtained as follows:

dissolve 14.9 g KCl - in 500 ml water

the molar concentration formula is used $\quad c = \dfrac{m(g)}{M.V(l)}$

where m= 14.9 g is the mass of KCl used

V= 500 ml= 0.5L is the volume of water used to obtain the aqueous solution
and M = 74.5 g/mol is the molar mass of KCl

7. From the KCl stock solution with $c_1 = 0.4$ M, prepare the other solutions needed in the experiment and afterwards their conductance will be measured $G\left(\dfrac{\mu S}{cm}\right)$ (see table 3)

Table 2:

No. Sol.	C(M)	$G\left(\dfrac{\mu S}{cm}\right)$ CH$_3$COOH	G/C CH$_3$COOH	$G\left(\dfrac{\mu S}{cm}\right)$ KCl	G/C KCl
1	0.4				
2	0.36				
3	0.32				
4	0.28				
5	0.24				
6	0.20				
7	0.16				
8	0.12				
9	0.08				
10	0.04				

8. Open an Excel file and fill in the data from table 2:

9. The data will be graphically represented for both CH$_3$COOH (weak electrolyte) and KCl (strong electrolyte) as the following function G=G(c)

10. Afterwards represent graphically $\dfrac{G}{c} = \dfrac{G}{c}(c)$ for CH$_3$COOH (weak electrolyte) and KCl (strong electrolyte)

11. Compare the graphs obtained for weak and strong electrolytes.

Table 3:

No. Sol.	Mass of KCl expressed in grams m(g) required to achieve the concentration	The concentration obtained in molars (M)
1	14.9	0.4
2	13.41	0.36
3	11.92	0.32
4	10.43	0.28
5	8.94	0.24
6	7.45	0.20
7	5.96	0.16
8	4.47	0.12
9	2.98	0.08
10	1.49	0.04

VARIATION OF ELECTRICAL CONDUCTIVITY OF WATER WITH TEMPERATURE

INTRODUCTION

The electric current passing through a conductive medium encounters a resistance on its part that manifests itself as a difficulty in the passage of the current. To ensure a current intensity ("I") through the conductor, it is necessary to apply a potential difference (electrical voltage, "U") between the ends of the conductive medium. The more a potential difference is needed to ensure a current intensity, the greater is the electrical resistance ("R") of the conductive medium.
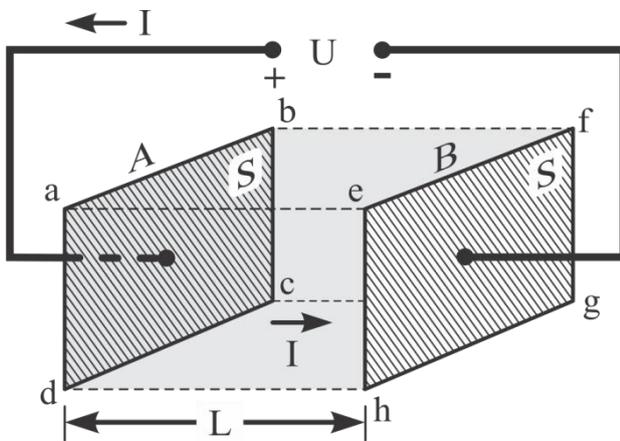
Figure 1. Electrical resistance of an environment

Figure 1 shows an imaginary montage for defining the electrical resistance of an environment. The medium of interest is found between planar electrodes "A" and "B" and uniformly fills the parallelepiped a, b, c, d, e, f, g, h limited by these electrodes. If the difference of the potential between electrodes "A" and "B" is "U_{AB}" (expressed in *volts*), and the intensity of the electric current is "I" (expressed in *amperes*), then the electrical resistance "R_{AB}" of the medium (expressed in *ohms*) is calculated according to relation (1).

$$R_{AB} = \frac{U_{AB}}{I} \quad (1)$$

The electrical resistance of an environment, in addition to the particularity of the environment, depends on its geometric factors according to relation (2).

$$R_{AB} = \rho \cdot \frac{L}{S} \quad (2)$$

In relation (2), "L" represents the length and "S" is the area of the section of the path traversed by the electric current between electrodes "A" and "B". The "□" coefficient is characteristic of the material of the environment; is *the resistivity* of the environment (in the International System of Units it is expressed in *ohms • meter* , □•m).

The value of the resistivity of an environment depends on the temperature: in the case of metallic conductors, the resistivity increases with temperature; in the case of semiconductors and electrolyte solutions, the resistivity decreases with temperature. Figure 2 illustrates the temperature dependence of the resistivity of pure water (expressed in the tolerated unit *mega-ohm•centimeter* , M□•cm).
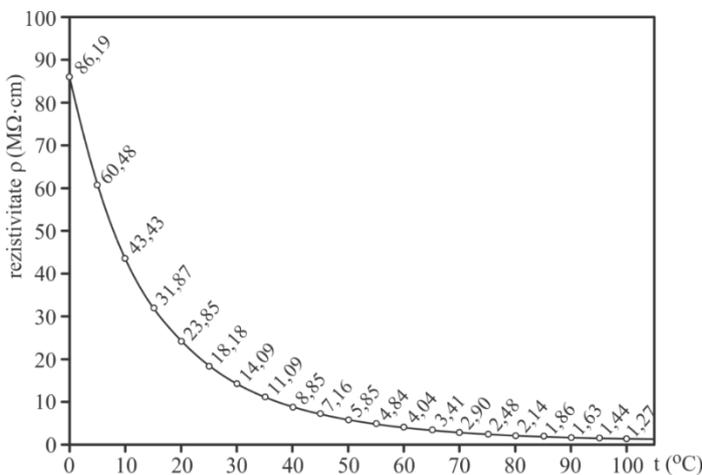

Fig. 2 Dependence of pure water resistivity on temperature

The reciprocal value of resistance "R" is expressed in (*ohm*)$^{-1}$, (□)$^{-1}$; this unit of measurement is called " *Siemens* ", " *S* ".

The reciprocal of resistivity is electrical conductivity, "K".

$$\kappa = \frac{1}{\rho} \quad (3)$$

If for the electrical resistivity "ρ" the tolerated measurement unit *ohm • centimeter* , Ω•cm is accepted, the electrical conductivity "K" is expressed in " *Siemens / cm* ", " *S / cm* ". Figure 3 represents the conductivity "G" of pure water as a function of temperature.
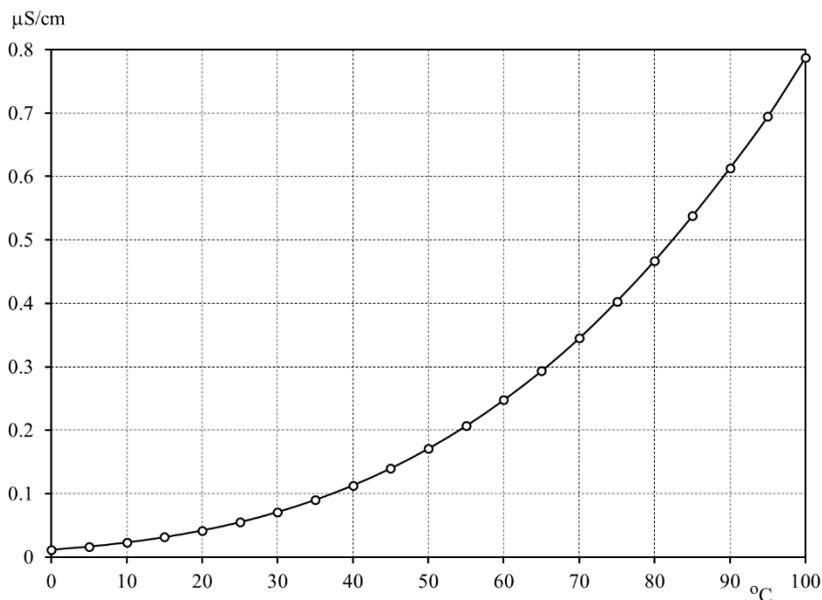
Fig. 3 Dependence of pure water conductivity on temperature

PROCEDURE FOR THE PRACTICAL WORK – STEPS

In a 100 ml *Berzelius* beaker put 50 ml of double-distilled water, a thermometer ("T"), a magnetic stirring bar ("A") and the electrode assembly ("E") of the probe of a conductometer (Fig. 4). The glass is placed on a heating plate with the possibility of magnetic stirring. The temperature indicated by the thermometer and the conductivity displayed by the measuring instrument are recorded. Water heating is started and the change in water conductivity is monitored. The temperature vs. value pairs are recorded. conductivity for every 5 $^{\circ}$C temperature change. The monitoring of the process is continued until the temperature of 75 $^{\circ}$C.

Stop heating the water and record, every 5 $^{\circ}$C, the conductivity vs. temperature during water cooling. The water conductivity is graphically represented as a function of temperature for both heating and cooling.

Compare the graph obtained with the one shown in Figure 4.
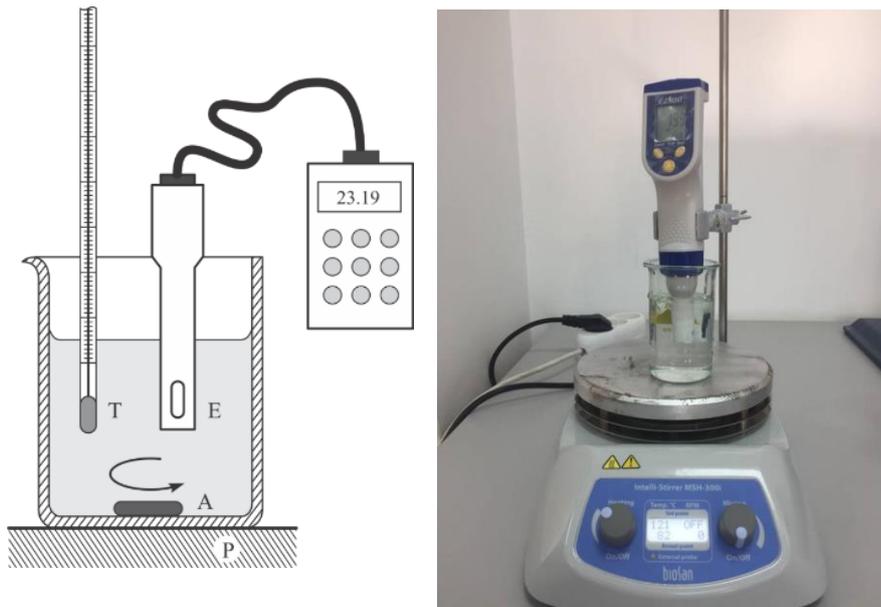
How can the observed difference be explained?

Figure 4. Experimental assembly

Table 1: Variation of Conductance with temperature for water

No. crt	T(oC)	G(µS/cm)
1	20	
2	25	
3	30	
4	35	
5	40	
6	45	
7	50	
8	55	
9	60	
10	65	
11	70	
12	75	

Table 2: Variation of Conductance with temperature

No. crt	t(ºC)	Solution of NaCl 0.9% G(μS/cm)	Rehydration salts G(μS/cm)
1	25		
2	30		
3	31		
4	32		
5	33		
6	34		
7	35		
8	36		
9	37		
10	38		
11	39		
12	40		
14	41		
15	42		
16	43		
17	44		
18	45		

Graphs are represented: G=G(t) for tap water (table 1) and for solution of NaCl 0.9% and rehydration salts (table 2).

Conclusions are formulated.

DETERMINATION OF TDS

THEORETICAL INTRODUCTION

TDS - total dissolved solids is a measure of the dissolved content of all combined inorganic and organic substances that are present in a liquid in the form of a molecular, ionized or micro-granular suspension (colloidal soil). In general, the definition of such sizes is that the solids must be small enough to pass through micrometer size (normal size or smaller) filters. TDS are normally discussed only for freshwater systems because salinity includes some of the ions that make up the definition of TDS.

The main application of TDS is the study of water quality. Although TDS is not generally considered a primary pollutant (ie, it is not considered to be associated with health effects), it is used as an indication of aesthetic characteristics in drinking water and as an aggregate indicator of the presence of a wide range of chemical contaminants.

The primary sources for TDS in receiving waters are agricultural and residential runoff, clay-rich mountain waters, soil contamination leaching, and water pollution discharges from industrial or sewage treatment plants.

The most common chemical components are calcium, phosphates, nitrates, sodium, potassium, and chloride, which are found in nutrient runoff, general stormwater runoff, and snow runoff where road deicing salts are applied. **Chemicals can be cations, anions, molecules, or aggregates of a thousand or fewer molecules,** as long as soluble micro-granules are formed.

Exotic and harmful elements of TDS are pesticides resulting from surface runoff. Some naturally occurring dissolved solids occur due to the weathering and dissolution of rocks and soils. Water quality standards have been established, for example the USA has values of 500 mg/L to ensure the taste of drinking water.

The TDS value suitable for consumption is in the range of 50-100 ppm. A good classification in this sense is the following:

- Good taste: 30 – 60 ppm.
- Suitable taste: 60-200 ppm.
- Acceptable taste: 200 – 250 ppm.
- Unacceptable taste: over 250 ppm.

Total dissolved solids TDS is differentiated from total suspended solids (TSS) in that the latter cannot pass through a two micrometer sieve and yet remains suspended indefinitely in solution. The term "settleable solids" refers to material of any size that does not remain suspended or dissolved in a storage tank that is not subject to movement and excludes both TDS and TSS. Soluble solids can include larger particles or insoluble molecules.

TDS can be measured using two methods such as: Gravimetric analysis and conductometry (measurement of electrical conductivity).

Gravimetric methods are the most accurate and involve evaporating the liquid solvent and measuring the mass of residue left. This method is generally the best, although it is time consuming. If inorganic salts comprise the vast majority of TDS, gravimetric methods are appropriate.

The electrical conductivity of water is directly related to the concentration of ionized solids dissolved in the water. Ions from solids dissolved in water create the ability of that water to conduct an electrical current that can be measured using a conventional counter meter or a TDS meter. When correlated with laboratory TDS measurements, conductivity provides an approximate value for TDS concentration, usually to within ten percent.

The relationship between TDS and the specific electrical conductance of water follows the following equation: $TDS = k_e EC$

Where TDS is measured in mg/L and EC (electrical conductance is measured in microSiemens/cm at 25°C.

k_e is the correlation factor between the two quantities and has values between 0.55 and 0.8.

From the point of view of TDS values, water is classified into:

• Fresh water: TDS = 500 ppm

• Brackish water: TDS = 500 - 30,000 ppm

• Saline water: TDS = 30,000 - 40,000 ppm

• Hypersaline: TDS greater than 40,000 ppm

Dissolved ionized solids such as salts and minerals increase the electrical conductivity (EC) of a solution. Because it is a measure of the volume of ionized solids, EC can be used to estimate TDS. Solid organic solids such as sugar and microscopic solid particles, or those such as colloids, do not significantly affect the conductivity of a solution and are not considered.

A TDS meter indicates the total dissolved solids (TDS) of a solution, i.e. the concentration of dissolved solid particles.

The best method for measuring the TDS of water in the laboratory is to evaporate the water and solvents and then weigh the remaining residue.

Many TDS meters display TDS values in parts per million (ppm);

1 ppm indicates 1 milligram of dissolved solids per kilogram of water.

The terms EC and TDS are often used to quantify the amount of dissolved solids in water. Pure H_2O has practically zero conductivity. The conductivity is usually about 100 times greater than the cation or anion values expressed as equivalents. TDS is calculated by converting EC by a factor of 0.5 to 1.0 times EC, depending on the levels studied.

The only accurate way to measure TDS is to evaporate the water and weigh the solid residue obtained. The TDS level can be estimated by measuring the EC (electrical conductivity) of the water with a conductometer and converting. A TDS meter is actually an EC meter calibrated in TDS, estimating TDS from EC. Some meters can be set to display either one value.

All elements dissolved in water have an electrical charge. It is therefore possible to estimate TDS values by determining the electrical conductivity of water by passing a small current through it. A similar measurement is made with an ohmmeter which measures the resulting voltage and current and calculates the conductivity.

Converting from CE to TDS can create significant errors because the conversion factor is different for different dissolved solids.

For example, for potassium chloride, to convert EC to TDS, the conversion factor is 0.50-0.57. Sodium chloride has a factor of 0.47-0.50 and some commonly found dissolved minerals can be as high as 0.85.

The conversion factor also varies with temperature and only more sophisticated measurements measure solution temperature and compensate.

Experimental assembly:

It consists of the TDS-meter, which measures the TDS values of different solutions

PROCEDURE FOR THE PRACTICAL WORK – STEPS

1.Introduce into a Berzelius glass, the experimental solution

2. Introduce the TDS-meter into the Berzelius glass filled with solution

3. The TDS value for each solution to be studied is read on the TDS-meter display

3. Enter the obtained values in the table below

Table 1. Experimental data for TDS analysis

No. crt	The solution	TDS (ppm)	Remark
1			
2			
3			
4			
5			

DETERMINATION OF SALINITY OF SOLUTIONS

Theoretical introduction

Salinity is the amount of salt dissolved in an aqueous medium, called salt water.

This is usually measured in $\frac{g\ salt}{kg\ sea\ water}$ (it is technically a dimensionless quantity).

Salinity is an important factor in determining many chemical quantities of natural waters and the biological processes within them.

Salinity is a thermodynamic state variable that, together with temperature and pressure, governs physical characteristics such as density and heat transfer capacity of water.

Salinity in the medical field

Saline is a mixture of sodium chloride in water and has a number of uses in medicine. Applied to the affected area, it is used to clean wounds, help remove contact lenses and improve eye moisture. By injection into a vein it is used to treat dehydration, such as in cases of gastroenteritis and diabetic ketoacidosis. It is also used to dilute other drugs that must be given by injection.

Large amounts can lead to congestion, swelling, acidosis, and sodium in the blood. In those with long-term blood sodium, excessive use can cause osmotic demyelination syndrome.

Saline is part of the crystalloid family of medications. It is most commonly used as a sterile solution of 9 g of salt per liter (0.9%), known as normal saline. Higher and lower concentrations may also occasionally be used.

Saline has a pH of 5.5, which makes it acidic

The medical use of saline began around 1831.

It is on the World Health Organization's list of essential medicines, the most effective and safest medicines needed in a health system. The wholesale cost in developing countries is about $0.60-$4.20 per liter of normal saline.

Normal saline (NSS, NS, or N/S) is the usual name for a solution of 0.90% w/v NaCl, 308 mOsm/L or 9.0 g per liter. Less commonly, this solution is referred to as physiological saline or isotonic saline (as it closely approximates isotonic, i.e., physiologically normal); although neither of these names is technically accurate (since normal saline is not exactly like blood serum), they convey

the commonly observed practical effect: good fluid balance with a minimum of hypotonicity or hypertonicity.

Normal saline is frequently used as an intravenous (IV) drip for people who cannot take fluids by mouth and have developed or are at risk of developing dehydration or hypovolemia. NS is also used for aseptic purpose. NS is typically the first fluid used when hypovolemia is severe enough to threaten the adequacy of blood circulation and has long been thought to be the safest fluid to give rapidly in large volumes.

However, it is now known that rapid infusion of NS can cause metabolic acidosis.

Saline solution is the solution of 9 grams of sodium chloride (NaCl) dissolved in water, up to a total volume of 1000 ml (weight per unit volume (weight / volume)). The mass of 1 milliliter of normal saline is 1.0046 grams at 22 °C. The molecular weight of sodium chloride is about 58.5 grams per mole, so 58.5 grams of sodium chloride equals 1 mole . Since normal saline contains 9 grams of NaCl, the concentration is 9 grams per liter divided by 58.5 grams per mole or 0.154 moles per liter. Because NaCl dissociates into two types of ions, sodium and chloride ions - 1 molar is 2 osmolar of NaCl.

Thus, **saline solution** contains 154 mEq / l Na + and Cl-. It has a slightly higher degree of osmolarity (ie more dissolved per liter) than blood. However, if you take into account the osmotic coefficient, a correction for non-ideal solutions, then saline is much closer to isotonic. NaCl is about 0.93, so $0.154 \times 1000 \times 2 \times .93 = 286.44$. However, the osmolarity of normal saline is close to the osmolarity of NaCl in the blood.

1 liter of 0.9% saline solution contains:

- 154 mEq of sodium ion = 154 mmol
- 154 mEq of chloride ion = 154 mmol

For medical purposes, saline is often used to clean wounds and skin abrasions. Normal saline will not burn or sting when applied.

Saline is also used in intravenous therapy, the intravenous supply of supplemental water to rehydrate people or to supply the daily water and salt needs ("maintenance" needs) of a person who cannot take them orally . Because infusing a low-osmolality solution can cause problems such as hemolysis, low-concentration intravenous saline solutions typically have dextrose (glucose) added to maintain a safe osmolality while delivering less sodium chloride. The amount of normal saline infused depends largely on the person's needs (eg, diarrhea or heart failure).

Saline is often used as a nasal wash to relieve some of the symptoms of the common cold. The solution exerts a softening and loosening influence on the mucus to facilitate the washing and cleaning of the nasal passages for both babies and adults. In this case "household saline" can be used: this is done by dissolving about half a teaspoon of table salt in 240 ml of clean tap water. In very rare cases, Naegleria fowleri amoeba infection can occur if the amoeba enters the body through the nose, therefore the water used for nasal irrigation must be sterile. Note that clean tap water is not necessarily sterile liquid.

Eye drops are drops containing saline solution, used in the eye. Depending on the condition being treated, they may contain steroids, antihistamines, sympathomimetics, beta-blockers, parasympathomimetics, parasympatholytics, prostaglandins, nonsteroidal anti-inflammatory drugs (NSAIDs), antibiotics, or topical anesthetics.
Eye drops sometimes have no medicine in them and are just lubricating and tear replacement solutions.

Saline drop systems designed for syringes (eg, Wallace Cameron Ultra Saline Minipod) are distributed in modern needle exchange programs because drugs can be effectively administered either by injection or ophthalmically, which is comparable to intravenous use.

It has been shown that the elimination of latanoprost acid from plasma is rapid (half-life of 17 minutes) after ophthalmic or intravenous administration. However, ophthalmic use is done with filtered sterile drugs that are potent in fairly small doses and with pH adjusted acidity of 7.0-7.5 after drug addition to avoid eye damage. The human eye has a pH of about 7.5, water has a pH of 7.0. Hypertonic saline solutions of 7% NaCl are considered mucoactive agents and are therefore used to hydrate thick secretions (mucus) to facilitate coughing and expectoration.
hypertonic saline solutions of 3% NaCl are also used in cases of critical care, acutely raised intracranial pressure, or severe hyponatremia.

Inhaling hypertonic saline has been shown to help with other respiratory problems, especially bronchiolitis. Hypertonic saline is currently recommended by the Cystic Fibrosis Foundation as a primary part of a treatment regimen for cystic fibrosis.

An 11% xylitol solution with 0.65% saline stimulates nasopharyngeal lavage and has an effect on nasal pathogenic bacteria. This has been used in complementary and alternative medicine.

Other commonly used concentrations include:

- Semi-normal saline (0.45% NaCl), often with "D5" (5% dextrose), contains 77 mEq/L Na and Cl and 50 g/L dextrose.
- ¼ normal saline (0.22% NaCl) has 39 mEq/L of Na and Cl and almost always contains 5% dextrose for osmolality reasons. It can be used alone in neonatal intensive care units.

Saline can be used in perioperative fluid administration protocols to reduce excessive intravenous fluid infusions and decrease pulmonary complications.

Hypertonic saline is used to treat hyponatremia and cerebral edema. Rapid correction of hyponatremia by means of hypertonic saline or any saline infusion > 40 mmol/L (Na + having a valency of 1.40 mmol/L = 40 mEq/L) central pontine myelinolysis (CPM) and requires constant monitoring of the person's answer. Removal of water in combination with diuretic block does not produce the risk of CPM as high as saline administration; however, it does not correct hyponatremia as rapidly as administration of hypertonic saline. Due to hypertonicity, administration may lead to phlebitis and tissue necrosis. As such, concentrations greater than 3% NaCl must normally be administered via a central venous catheter, also known as a "central line".

Such hypertonic saline is normally available in two concentrations, the first of which is more commonly administered:

3% NaCl has 513 mEq/L of Na and Cl.

5% NaCl has 856 mEq/l Na and Cl.

Less commonly used NaCl solutions are 7% (1200 mEq/L) and 23.4% (about 4000 mEq/L), both of which are used (also via central line), often with additional diuretics, in the treatment of traumatic brain injuries.

Dextrose (glucose) 4% in 0.18% saline is sometimes used for maintenance.

In the medical field, the most common types of saline solutions are the soup as follows:

- Lactated Ringer's solution
- Acetate Ringer's solution
- Intravenous sugar solution
  - 5% dextrose in normal saline (D5NS)
  - 10% dextrose in normal saline solution (D10NS)
  - 5% dextrose in semi-normal saline solution (D5HNS)
  - 10% dextrose in semi-normal saline solution (D10HNS)

In cell biology, the following saline solutions are used:

- buffered saline (PBS) (Dulbecco recipe = D-PBS, Galfre, Kuchler, Ausubel, etc.)

- TRIS - buffered saline solution (TBS) (Goldsmith recipe, Ausubel, etc.)
- Hank's balanced salt solution (HBSS)
- Earle's balanced saline solution (EBSS)
- Standard Saline Citrate (SSC)
- HEPES - buffered saline solution (HBS) (recipes from Dittmar, Liu, Ausubel, etc.)
- Gey's balanced saline solution (GBSS)

- **Lactated Ringer's solution** (also known as sodium lactate solution or Hartmann's solution, is a mixture of sodium chloride, sodium lactate, potassium chloride and calcium chloride in water)

1 liter of lactated Ringer solution contains:
- 130–131 mEq sodium ions = 130 mmol L^{-1}
- 109–111 mEq chlorine ions = 109 mmol L^{-1}
- 28–29 mEq of lactate ions = 28 mmol L^{-1}
- 4–5 mEq potassium ions = 4 mmol L^{-1}
- 2–3 mEq of calcium ions = 1.5 mmol L^{-1}

Intravenous sugar solution is also called dextrose solution and is a mixture of dextrose and water that includes:

D5W (5% dextrose in water), which consists of 278 mmol/L dextrose

D5NS (5% dextrose in normal saline solution), which in addition, contains normal saline solution (0.9% w/v NaCl).

D5 1/2NS 5% dextrose in half normal saline solution), (0.45% w/v of NaCl).

D5LR (5% dextrose in Lactated Ringer's solution)

D50 - 50% dextrose in water

The percentage is here considered a mass percentage, so 5% glucose / dextrose solution contains 50g/L of glucose / dextrose (5g/ 100ml)

Glucose provides 4 kcal/gram of energy, so a 5% glucose solution provides 0.2 kcal/ml. If prepared from dextrose monohydrate, which provides 3.4 kcal/gram, a 5% solution provides 0.17 kcal/ml

A salinometer is a device designed to measure the salinity or dissolved salt content of a solution.

Because salinity affects both the electrical conductivity and specific gravity of a solution, a salinometer often consists of an ec meter (conductometer) or hydrometer and some method of converting these readings into a salinity reading.

A salinometer can be calibrated either in micro-ohms, in a unit of electrical conductivity (typically 0-22), or directly calibrated in units for salinity in "grains per gallon" (0-0.5).

A typical reading will be 2 micro-Ohms or 0.05 grains per gallon.

Fresh water generators (evaporators) use salinometers for water distillation in order to measure water quality. Evaporator water can be used for drinking water supply, salt water is not desirable for human consumption.

In some cases, higher distillation is required for use in water boilers, where salt water would be disastrous. In these cases, a salinometer is also installed on the supply system where it would alert the engineer to any salt contamination. The salinometer can automatically switch the evaporator output from the fresh water tanks to the feed water tanks depending on the water quality. Superior quality (low salinity) is required for boiler feed water, not for drinking.

A contour line of constant salinity is called an isohaline, or sometimes an isohaline.

Salinity in rivers, lakes, and the ocean is conceptually simple, but technically challenging to accurately define and measure.

Conceptually, salinity is the amount of salt dissolved in water . Salts are compounds such as sodium chloride, magnesium sulfate, potassium nitrate, and sodium bicarbonate that dissociate into ions. The concentration of dissolved chloride ions is sometimes referred to as chlorinity. Operationally, solute is defined as that which can pass through a very fine filter (a filter with a pore size of 0.45 μm, but nowadays usually 0.2 μm).

Salinity can be expressed as a mass fraction, that is, the mass of dissolved material in a unit mass of solution.

Seawater typically has a salinity value of about 35 g/kg, although lower values are typical near coasts where rivers enter the ocean.

Rivers and lakes can have a wide range of salinities, from less than 0.01 g/kg to several g/kg, although there are many places where higher salinity values are found.

The Dead Sea has a salinity greater than 200 g/kg.

Rainwater, before it hits the ground, has a TDS of 20 mg/l or less.

Regardless of the pore size used for the filters, the resulting salinity value of a given sample of natural water will not vary by more than a few percent (%). However, physical oceanographers working in the abyssal ocean are often concerned about the accuracy and intercomparability of measurements made by different researchers at different times to close to five significant figures. A bottled seawater product known as IAPSO Standard Seawater is used by oceanographers to standardize their measurements with sufficient accuracy to meet this requirement.

Classification of aqueous environments according to salinity levels			
Fresh water	Brackish water	Salt water	Brine
< 0.05%	0.05 – 3%	3 – 5%	> 5%
< 0.5‰	0.5 – 30 ‰	30 – 50‰	> 50‰

Another name for marine waters is euhaline seas. The salinity of euhaline seas is from 30 to 35. Seas or poor waters have salinities in the range of 0.5 to 29 and metahaline seas from 36 to 40. These waters are considered thalassic because their ocean salinity is derived and defined as homoiohaline if salinity does not vary much over time (essentially constant). The table below modified from Por (1972), follows the "Venetia" (1959) system.

Thalassic water series
>300
hyperhaline
60–80
metahalines
40
myxoeuhalines
30
polyhaline
18
mesohaline
5
oligohalines
0.5
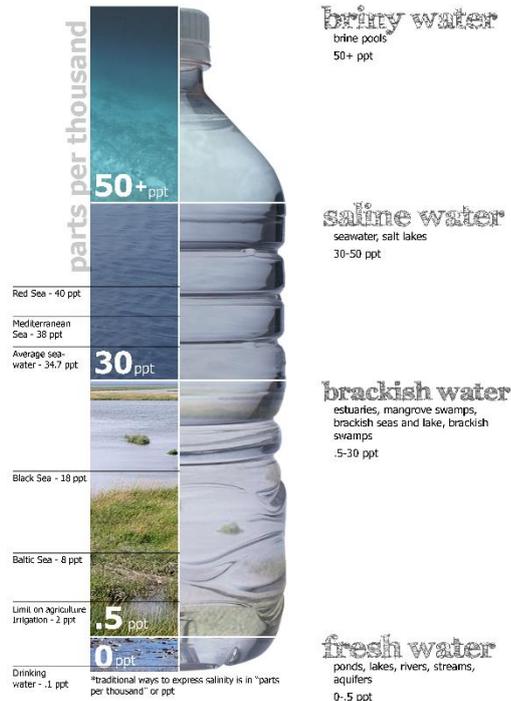
Very salty seawater, for which the salts crystallize, is also called saline solution.

Salinity is an ecological factor of considerable importance, influencing the types of organisms that live in a watery environment. Salinity also influences the types of plants that will grow either in a watery environment or on land fed by water (or groundwater). 11 A plant adapted to saline conditions is called a halophyte. A halophyte that is tolerant of residual sodium carbonate salinity is called a glass or salt or barrel plant. Organisms (mostly bacteria) that can live in very salty conditions are specifically classified as extremophiles or halophiles. An organism that can withstand a wide range of salinities is called euryhaline.

Ocean salinity is a driver of the world's ocean circulation, where density changes due to both salinity changes and ocean surface temperature changes produce changes in buoyancy, causing the water mass to sink and rise. Changes in ocean salinity are thought to contribute to global changes in carbon dioxide because more saline water is less soluble in carbon dioxide. Additionally, during glacial periods, the hydrography is such that a possible cause of reduced circulation is the production of stratified oceans. In such cases, it is more difficult to clean water through thermohaline circulation.

Experimental assembly:

It consists of a salinometer, which measures the salinity values of different solutions

PROCEDURE FOR THE PRACTICAL WORK – STEPS

1.Introduce into a Berzelius glass, the experimental solution

2. Introduce the salinometer into the Berzelius glass filled with solution

3. The salinity value for each solution to be studied is read on the salinometer display

3. Introduce the obtained values in the table below

Table 1. Experimental data for salinity measurement

No. crt	The solution	salinity (ppt)	Remark
1			
2			
3			
4			
5			

THE STUDY OF PH

INTRODUCTION

SOLID ELECTROLYTES completely dissociate in aqueous solution.

Examples of strong electrolytes:

all salts,

strong acids (H_2SO_4, HCl, HNO_3)

strong bases (NaOH, KOH)

Weak electrolytes dissociate to a small extent. Most molecules are undissociated in aqueous solution.

Examples of weak electrolytes:

Weak acids (H_2CO_3, CH_3COOH)

Weak bases: ammonia (NH_3) and water (H_2O).

Non-polar solvents can be lipids in the body, phospholipids of membranes.

They preferentially dissolve non-polar substances and not ions.

Reactions between ions in aqueous solution, at 37 ^oC, are fast reactions.

The acid-base systems and the systems corresponding to other ionic reactions in the body are in a state of equilibrium. This state of equilibrium may differ from one compartment to another.

The law of mass action is used to treat chemical and physical balances.

The acidity or basicity of an aqueous solution is measured by pH or pOH

The dissociation of water takes place according to the stoichiometric equation: $H_2O \leftrightarrows H^+ + OH^-$

Or more correctly: $2H_2O \leftrightarrows H_3O^+ + OH^-$

For simplification it is considered

H^+ the hydronium ion of the formula H_3O^+

Water dissociates very little , its dissociation constant or **the ionic product of water** is:

H^+ and OH $^-$ ions come only from the dissociation of water and will be in equal amounts:

$$P_{H_2O} = 10^{-14}(mol/l)^2$$

In reality, water also dissolves some CO_2 from the air, and some silicate from the glass, so it is not pure.

If a strong, completely dissociated acid is dissolved, practically all H$^+$ ions come from the dissociation of the acid dissolved in water. The product of the concentration of the 2 ions remains constant: [H$^+$]·[OH$^-$] = constant, thus the concentration [OH$^-$] decreases.

If a strong, completely dissociated base is dissolved, the concentration of OH$^-$ ions will be equal to the concentration of the dissolved base and the concentration of H$^+$ ions will decrease

Acidic aqueous solution = is an aqueous solution where [H$^+$]>[OH$^-$] and pH < 7

Basic aqueous solution = is an aqueous solution where [H$^+$]<[OH$^-$] and pH > 7

Neutral aqueous solution = is an aqueous solution where [H$^+$]=[OH$^-$] and pH = 7

DISSOCIATION OF ACIDS AND WEAK BASES

THE NOTION OF pH

Electrolytic dissociation is a phenomenon by which some substances in solution break down into positive ions and negative ions.

By dissociating an acid, hydrogen ions and acid radical ions appear, as follows: AH $\Leftrightarrow$ A$^-$ + H$^+$

By dissociating a base, oxidryl ions and basic radical ions are obtained, as follows: BOH $\Leftrightarrow$ B$^+$ + OH$^-$

Water behaves like an electrolyte and dissociates into hydrogen ions and oxydryl ions: H$_2$O $\Leftrightarrow$ H$^+$ + OH$^-$

In reality **the hydrogen ion H$^+$** obtained after dissociation **hydrates and the equilibrium relationship will be written: 2HOH $\Leftrightarrow$ H$_3$O$^+$ + HO$^-$**

The ion H$_3$O$^+$ - is called hydronium

The double-headed arrow shows that the water molecules ionize and are permanently regenerated from ions. If the temperature is constant, the speed of ionization and restoration of the molecules remains constant, achieving a stationary concentration of H$^+$ equal to the concentration of OH$^-$.

If a strong acid is dissolved in water, the concentration of hydronium ions H$^+$ increases and that of hydroxyl ions OH$^-$ decreases, because the ionic product of water remains constant at a given temperature. If a strong base is dissolved in water, the concentration of OH$^-$ increases and that of H$^+$ decreases.

At constant temperature the concentrations of H$^+$ and OH$^-$ will oscillate as follows:

H$^+$	10^0	10^{-1}	10^{-2}	.	10^{-7}	.	10^{-12}	10^{-13}	10^{-14}
OH$^-$	10^{-14}	10^{-13}	10^{-12}	.	10^{-7}	.	10^2	10^1	10^0
Character	ACID				NEUTRAL		ALKALINE		

To simplify the calculations, it was agreed to express this concentration

by **pH- which represents the logarithm with changed sign of the hydrogen ion concentration:**

pH = - log H $^+$

or in general, according to SORENSEN: pX=-log X=log (1/X)

also, it can be written as follows: pH + pOH = pK, where pK is the ionic product of water

pH	0	1	2	.	7	.	12	13	14
pOH	14	13	12	.	7	.	2	1	0
Character	ACIDITY				NEUTRALITY	ALKALINE			

The acid or basic character of a solution can be described quantitatively in terms of the concentration of hydrogen ions. In some situations, the concentration has a very low value, thus it is more convenient to use the notion of pH.

The pH is by definition the decimal logarithm with changed sign of the molar concentration of hydronium ions:

$$pH = -\log\left[H^+\right]$$

The pOH of a solution is:

$$pOH = -\log\left[OH^-\right]$$

The relationship between them is: pH + pOH = 14

pH and pOH are complementary

It is enough to indicate the pH to know if a solution is acidic or alkaline:

- if pH < 7 - the solution is acidic

- if pH = 7 - the solution is neutral

- if pH > 7 – the solution is alkaline (or basic)

pH SCALE

H+	10^0	-	10^{-7}	-	10^{-14}
pH	0	-	7	-	14
pOH	14	-	7	-	0
Character	ACID		NEUTRAL	BASIC	

The neutral solution is the solution in which the concentration of H^+ and OH^- ions are equal and consequently the value of **pH is 7**.

When a strong acid is dissolved in water, it completely dissociates into ions, the H^+ ions practically only come from the ionization of the acid. The ionic product of water remains constant, the increase in the concentration of H^+ ions remains constant, it will cause the decrease in the concentration of OH^- ions,

the acid range is the one in which pH < 7.

If a strong base is dissolved in water, OH^- ions will come exclusively from this ionization, the concentration of OH^- ions will prevail.

The basic domain is the one in which the OH^- concentration is higher, thus: pH > 7.

ELECTROLYTES AND NON-ELECTROLYTES

ACID		BASES	
Strong acids	**Weak acids**	**Strong bases**	**Weak bases**
SOLID INORGANIC ACIDS nitric acid, HNO_3 hydrobromic acid, HBr hydrochloric acid, HCl hydrochloric acid, $HClO_3$ hydroiodic acid, HI perchloric acid, $HClO_4$ sulfuric acid, H_2SO_4	**WEAK AND MEDIUM STRENGTH INORGANIC ACIDS** boric acid, H_3BO_3 carbonic acid, H_2CO_3 (simply called "acid" when included in mineral waters or soft drinks such as Fanta) hydrofluoric acid, HF phosphoric acid H_3PO_4 **WEAK ORGANIC ACIDS** acetic acid, CH_3COOH butyric acid, $CH_3CH_2CH_2COOH$ benzoic acid, C_6H_5COOH citric acid, $(C_6O_7H_8)$ formic acid, $HCOOH$ lactic acid, $CH_3CHOHCOOH$ malic acid, $HOOCCH_2CHOHCOOH$ oxalic acid, $HOOCCOOH$ pyruvic acid, $CHCOCOOH$ propionic acid, CH_3CH_2COOH valerianic acid, $CH_3(CH_2)_3COOH$	NaOH KOH LiOH $Ca(OH)_2$ $Ba(OH)_2$	Ammonia NH_3 H_2O $Mg(OH)_2$ $Zn(OH)_2$ $Al(OH)_3$

ELECTROLYTES AND NON-ELECTROLYTES

calculation formulas for pH

▶ For **STRONG ACIDS** :
$$pH = -\lg\left[H^+\right] = -\lg[HA] = -\lg c$$

▶ For **WEAK ACIDS** :
$$pH = pK_{HA} + \lg\frac{[D]}{[P]}$$

(**Henderson Hasselbach formula**)

D-form deprotonated, P- form protonated

▶ For **STRONG BASES:**
$$pH = 14 - pOH = 14 + \lg\left[OH^-\right]$$

The pH of SOLUTIONS OF WEAK ACIDS AND BASES

- ○ **When only the initial concentration of the weak acid is known, taking into account that the H$^+$ and A^{-ions} resulting from the dissociation are in the solution in equal concentrations, the equilibrium constant becomes:**

$$K_{HA} = \frac{\left[H^+\right]^2}{[HA]}$$

- ○ **After the logarithm, we get:**

$$-\lg K_{HA} = -\lg\left[H^+\right]^2 + \lg[HA]$$

- ○ **Similar to the definition of pH: pH = - lgK**

- ○ **The formula for calculating pH is:**

$$pH = \frac{pK_{HA} - \lg[HA]}{2}$$

When the concentration of the protonated form is known

[P]= [HA] – the molar concentration of the weak acid

as **well as the concentration of the deprotonated form [D]= [A$^-$]** – the molar concentration of the conjugate base

- ▸ **The HENDERSON HASSELBACH FORMULA** $pH = pK_{HA} + \lg\dfrac{[D]}{[P]}$ is used :

EXPERIMENTAL ASSEMBLY: pH - meter
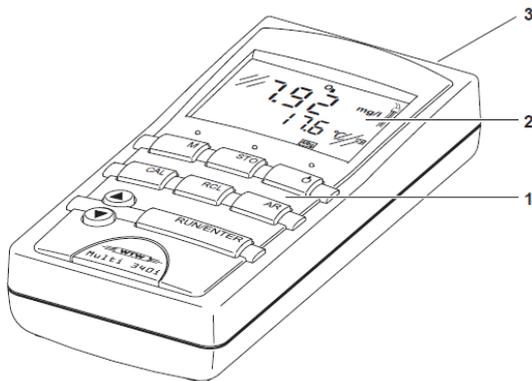
1- keyboard (Keypad)

2- display

3- the socket system (Jack field)

M	sélectionner la variable mesurée pH / potentiel Redox D.O. concentration _ / D.O. saturation conductivité / salinité
STO	enregistrer (sauver) une valeur mesurée
⏻	ouvert / fermé (ON/OFF)
CAL	calibrer la variable mesurée actuellement fixé
RCL	Afficher / transmettre les valeurs mesurées
AR	activer / désactiver la fonction de lecture automatique (AutoRead)
▲	sélectionner le mode de mesure, augmenter les valeurs, rouleau
▼	sélectionner le mode de mesure, diminuer les valeurs, rouleau
RUN/ENTER	confirmer un enregistrement, activer la fonction lecture automatique (AutoRead) valeurs de sortie mesurée

Affichage
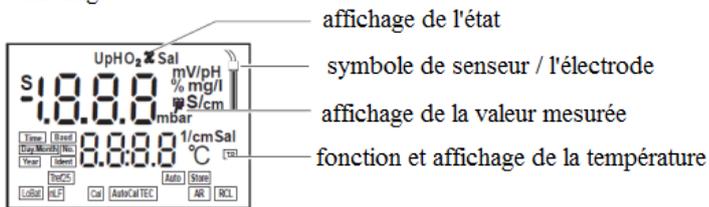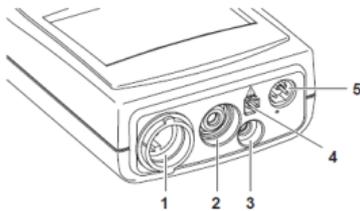
affichage de l'état

symbole de senseur / l'électrode

affichage de la valeur mesurée

fonction et affichage de la température

domaine de prise

1	D.O. sonde ou la conductivité du cellule
2	Electrode de pH
3	Sonde de température de pH
4	Branchez - dans l'unité d'alimentation
5	RS232 interface série

PROCEDURE FOR THE PRACTICAL WORK – STEPS
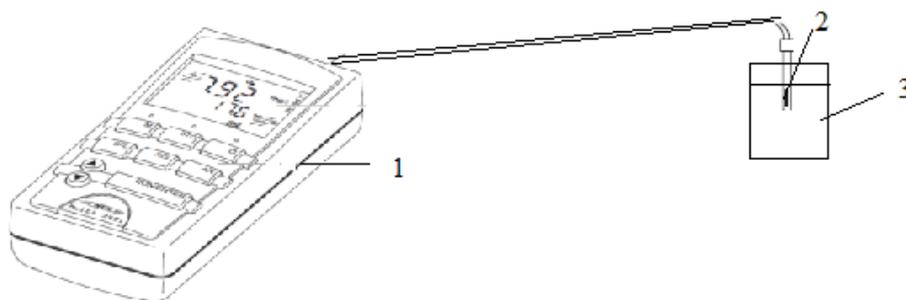
DETERMINATION IN THE ACID MEDIUM:

1. Firstly, the calibration is performed in the acid range by using a buffered solution with pH = 4

2. Insert the electrode into the calibration solution and read the pH. If the device does not indicate correctly, calibrate the device.

3. Unbuffered solution (tap water) is introduced into a Berzelius glass (V=20 mL)

4. Add 0.5 mL of 0.1 M HCl 5 times, by using a pipette

5. The solution is stirred until the pH-meter does not indicate any variation of pH value

6. Read the pH values and introduce them in the table

7. Repeat steps 3-6 with an unbuffered solution of pH = 4

DETERMINATION IN THE BASIC MEDIUM:

1. Firstly, the calibration is made in the basic range using the buffered solution with pH = 7

2. Insert the electrode into the calibration solution and read the pH. If the device does not indicate correctly, calibrate the device.

3. Unbuffered solution (tap water) is introduced into a Berzelius glass (V = 20 mL)

4. Add 5 times 0.5 mL of KOH 0.1 M, by using a pipette

5. The solution is stirred until the pH-meter does not indicate any variation

6. Read the pH values and introduce them in the table

7. Repeat steps 3-6 with an unbuffered solution of pH = 7

Preparation of buffered solution with pH = 4.0

7.71 mL of Na_2HPO_4 solution of 0.2 M + 12.29 mL of citric acid solution ($C_6H_8O_7$) with 0.1 M results in 20 mL of buffered solution with pH = 4

Preparation of buffered solution with pH = 5.0

10.30 mL Na_2HPO_4 solution of concentration 0.2 M + 9.70 mL citric acid solution ($C_6H_8O_7$) with 0.1 M we obtain 20 mL buffered solution with pH=7.

We have a buffered solution with pH=4 in which we introduce 5x0.2 mL of 0.1 M HCl and in the buffered solution with pH=7 we introduce 5x 0.2 mL of KOH 0.1M.

Table 1: pH values for the basic and acid medium V= 20 mL

No.	V (ml)	pH acid domain		pH basic domain	
		0.1 M HCl Solution unbuffered	0.1 M HCl Solution buffered	KOH 0.1M Solution unbuffered	KOH 0.1M Solution buffered
1	0				
2	0.5				
3	1.0				
4	1.5				
5	2.0				
6	2.5				

CALCULATIONS AND GRAPHICS

1. For all 4 cases, the following calculations are made:

The pH variation for the case of a solution without HCl or KOH

The pH variation for the case of a solution with HCl or KOH

ΔpH = pH (after 25 ml) - pH (0)

ΔpH = final pH - initial pH

2. It is calculated $i = \dfrac{\Delta V}{|\Delta pH|}$ - **the buffering capacity that characterizes the effectiveness of the buffer system to resist pH variations**

3. It is also calculated for all 4 situations:
        1. acid domain – unbuffered solution
        2. acid domain - buffered solution
        3. basic domain - unbuffered solution
        4. basic domain - buffered solution

4. Plot the graphs pH=pH(V): for the 4 situations:
        1. acid domain – unbuffered solution
        2. acid domain - buffered solution
        3. basic domain - unbuffered solution
        4. basic domain - buffered solution

Table 2: quantities required to obtain buffer solutions with different pH

pH	Na_2HPO_4 (c= 0.2M) (mL)	$C_6H_8O_7$ (c=0.1M) (citric acid) (mL)
3.0	20.55	79.45
4.0	38.55	61.45
5.0	51.5	48.5
6.0	63.15	36.85
7.0	82.35	17.65
8.0	97.25	2.75

Table 3: quantities required to obtain buffer solutions with different pH

pH	CH_3COOH (c=0.2M) (mL)	CH_3COONa (c=0.2M) (mL)
3.47	95	5
3.80	90	10
4.15	80	20
4.38	70	30
4.57	60	40
4.75	50	50
4.93	40	60
5.12	30	70
5.70	10	90
6.03	5	95

PHYSICAL TITRATION OF SOME SALTS - CONDUCTOMETRICAL TITRATION

THEORETICAL INTRODUCTION

According to the following sources: <u>DEX '98 (1998)</u> ; <u>DOOM 2 (2005)</u> ; <u>NODEX (2002)</u>

TITRATION has the following meaning: To determine by volumetric analysis the concentration of a solution. - From brother **titer.** To subject to special analysis (to determine concentration). /<fr. *titer*   To determine the proportion of components in a substance. [< bro. *title*].

<u>**TITRATION**</u> **represents the quantitative analytical determination of a sample.**

TITRATION - THE GENERAL CASE

Classification of electroanalytical methods

Electrochemical methods can be classified according to several criteria:

- according to the way in which the studied system is disturbed, they can be stationary and non-stationary;

- according to the monitored variable: current (chronoamperometry, voltammetry), potential (chronopotentiometry), load (chronocoulometry), impedance.

- according to the disturbed variable there can be: controlled potential (potentiostatic), controlled current (galvanostatic) and coulostatic methods;

- A separate category is the hydrodynamic methods (voltammetry on disk electrode or rotating ring), in which the working electrode and the electrolyte are in relative motion to each other. In these methods, forced convection works.

Conductometric titration - principle

☐ the presence of ions in a solution allows the passage of electric current

☐ conductivity

☐ varies proportionally with the concentration of the analyte

☐ is the inverse of electrical resistance

$$G = \frac{1}{R}; \quad R = \frac{\rho.l}{S}; \quad G_s = \frac{1}{\rho}; \quad G = \frac{1}{R} = G_s.\frac{S}{l}$$
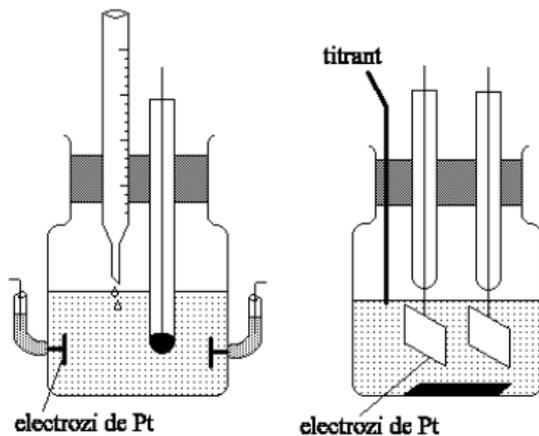
G = conductivity

ρ = resistivity

l = column length

S = cross-sectional area of the column

G s = specific conductivity

CONDUCTOMETRICAL TITRATION – TITRATION CELL – THEORY

electrozi de Pt   electrozi de Pt

☐ the glass cell, closed or not, into which the platinum or silver electrodes and the solution to be analyzed are inserted;

☐ a constant voltage is applied between the two electrodes, determining the passing current

by solution as a result of a chemical reaction;

☐ the potential difference between the electrodes depends on the processes that take place at the electrodes and

current transport phenomena.

CONDUCTOMETRICAL TITRATION - PRINCIPLE SCHEME
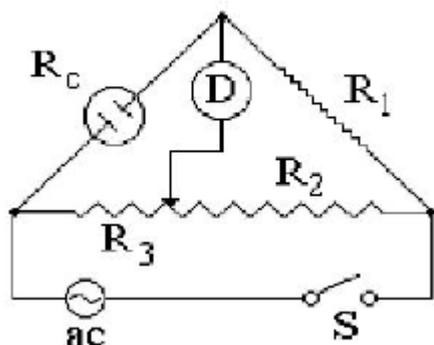
☐ **measuring the resistivity of the solution with a Wheatstone bridge**

☐ **cell constant** l/s ratio

☐**conductivity specifies** the ratio$\chi = C/R$

☐ **conductivity measurement unit – Siemens (S)**

CONDUCTOMETRICAL TITRATION - APPLICATIONS

- **MONITORING THE PURITY OF DISTILLED WATER IT WAS THE BASIS OF THE DETERMINATION OF THE IONIC PRODUCT OF WATER**
- **DETERMINATION OF EQUIVALENCE POINTS IN TITRATIONS**
- **TITRATION OF STRONG ACIDS WITH STRONG BASES**

A- Conductometric titration curve of 0.1M HCl with 0.1M NaOH

A - they have a decrease in the conductivity of the solution up to the equivalence, as a result of the formation of water molecules and the replacement of the hydrogen ion with sodium with a lower mobility. After the equivalence point, there is an increase in the conductivity of the solution as a result of the excess sodium hydroxide added and the high mobility of the hydroxyl ion.

B- Titration curve of 0.001M pnitrophenol with 0.1 M NaOH

B - a different shape of the titration curve, which is explained by the slow increase in conductivity of the solution by the formation of ionized sodium p-nitrophenoxide, and after equivalence, a more pronounced increase in the conductivity of the solution is observed, as a result of the excess sodium hydroxide added, which is a strong electrolyte.

- **TITRATION OF WEAK ACIDS WITH WEAK BASES**

In the case of the conductometric titration of a 0.01M ammonia solution with a 0.5M acetic acid solution in methanol (both electrolytes being weak), a curve with a totally different appearance is obtained from the other two .

Up to equivalence, the conductivity of the solution increases a lot due to the formation of ionized ammonium acetate (hard electrolyte), and after equivalence the conductivity created very

slightly due to the small excess of added acetic acid solution, which is a weak electrolyte.

The method based on following the variation of the conductivity of a solution as a result of a chemical reaction;

☐ It uses a specific cell provided with two Pt electrodes, through them a constant voltage is applied determining the current passing through the solution as a result of a chemical reaction;

☐ Through the graphic representation of the conductivity of the solution at different moments of the titration depending on the volume of titrant added, the titration curve is obtained consisting of two right segments whose intersection indicates the equivalence point.

- **POTENTIOMETRIC TITRATION**

The variation of the potential of the solution to be analyzed determined by a certain chemical reaction is monitored;

☐ From this variation determined with the help of an indicator electrode (in relation to a reference electrode), the analyte concentration can be determined, respectively the titrant volume (from which the analyte concentration can be calculated);

POTENTIOMETRIC TITRATION – INDICATOR ELECTRODES

TYPE I ELECTRODES:

☐ **Metal in contact with its cation or a non-metal in contact with its anion**

☐ **Examples:**

- ☐Cu^{2+} /Cu(s)
- ☐Zn^{2+}/Zn(s)
- ☐SHE
- ☐Ag^+/Ag
- ☐Cl^-/Cl_2(g)/Pt
- ☐ **The response of the electrode is Nernstian**
- $E = E^0 + (RT/nF) \ln a(M^{2+})$

Type II electrodes:

- Metal in contact with a sparingly soluble metal salt
- Examples:
- Ag/AgCl(s)
- Hg/Hg_2Cl_2(s)/Cl^- (saturated calomel electrode; SCE)
- The response of the electrode is Nernstian
- $E = E^0 - (RT/F) \ln a(Cl^-)$

Type III electrodes:

Electrodes that serve as a source of electrons (redox, inert electrodes)

Examples:

- metals: Pt, Au, graphite, Hg
- semiconductors: Si, GaAs, In-SnO_2/glass
- Answer:
- for Pt in contact with Fe^{2+}, Fe^{3+} in solution:
- $E = E^0 - 0.059 \log ([Fe^{2+}]/[Fe^{3+}])$

Potentiometric titration - applications

Example of potentiometric titration of a chloride with AgNO3:

- the determination of the equivalence point can be done by the graphic representation of

of the potential of the solution during the titration depending on the volume of added nitrate (a);

received

the derivative of the potential

(b) or the second derivative of the potential

(c) depending on the volume of titrant added.

The equivalence volume can be determined from

- graphic method

- calculations **based on the Hosteller – Roberts relationship.** Constant volumes of titrant of 0.1 or 0.2 ml are added around the equivalence point, therefore ΔV and ΔV^2 are constant and E or ΔE^2 can be graphically represented Δ as a function of V.

- $$V_e = V_1 + 0.1 \left(\frac{\dfrac{\Delta^2 E_1}{\Delta V^2}}{\dfrac{\Delta^2 E_1}{\Delta V^2} - \dfrac{\Delta^2 E_{21}}{\Delta V^2}} \right) = V_1 + 0.1 \left(\frac{\Delta^2 E_1}{\Delta^2 E_1 - \Delta^2 E_2} \right)$$

Old - vol of equivalence

V1 vol of titrant before equivalence

0.1 - volume of titrant around the equivalence point

$\Delta E_2{}^2 / \Delta V^2$ – second derivative after equivalence

$\Delta E^2{}_1 / \Delta V^2$ – second derivative before equivalence

EXPERIMENTAL ASSEMBLY
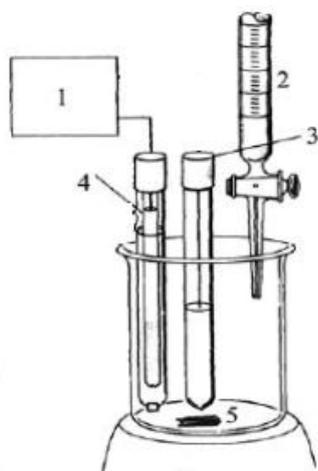
- 1 – conductometer
- 2 – burette
- 3 – thermometer
- 4 – indicator electrode - conductometric sensor
- 5 – magnetic stirrer

PROCEDURE FOR THE PRACTICAL WORK – STEPS

A sample is introduced into a vessel whose quantity is unknow. A solvent is introduced over the sample - in our case it can also be water, after which a titration reagent is introduced under control conditions and in small portions.

During this time, properties of the contents of the vessel are monitored, such as:

- Chemical properties: chemical titration
- Physical properties: physical titration: conductivity, concentration, or optical properties such as the transparency of the solution used or not

If the titration is continued above a certain limit value, a drastic change takes place.

We want to determine the amount of $AgNO_3$ in a sample.

The reaction takes place: $AgNO_3 \Longrightarrow Ag^+ + NO_3^-$

The titration solution used is KCl 0.1 M which is added in small and controlled portions

The reaction takes place: $Ag^+ + Cl^- \Longrightarrow AgCl$ (white precipitate - very difficult to dissolve solution)

The titrated sample is approximately 220 mg of $AgNO_3$ in H_2O

The titration reagent is: 0.1 M KCl solution.

The titration takes place in a titration vessel (with 3 inlets) into which:

- the conductivity electrode
- the tip of the burette through which the titration reagent is added
- thermometer for temperature control.

WORKING STEPS

1. The sample of AgNO3 - a crystalline solid - is introduced into the titration vessel

2. An appropriate volume of water is added to bring the level of the liquid in the titration vessel to the appropriate height so that the electrode can perform the measurement.

3. The contents of the titration vessel are stirred using a magnetic stirrer.

4. The buret with the nominal volume of 25 ml is filled with the titration solution (KCl 0.1 M), up to division 0 (top).

5. While the contents of the titration vessel are being stirred, the titration solution is added in portions of 0.5 ml.

6. After each added amount, read the conductance of the solution in the titration vessel.

7. The data are entered in the table below.

8. If in the titration vessel at the end of the experiment the color of the solution obtained in the vessel is milky white, upon the introduction of ammonia the solution becomes transparent.

Table 1. The conductance of the solution in the titration vessel

No.	V(ml)	G(μS/cm)
1	0	
2	0.5	
3	1	
4	1.5	
5	2	
...	....	
36	17	

EXPERIMENTAL DATA PROCESSING

At the beginning of the titration, the electrical conductivity shows a

decrease with the addition of the titration reagent because in this phase the conductivity is controlled by the very weak solubility and dissociation of AgCl. From a certain added volume, an increase in conductivity is found. **Explication** it consists in the fact that when the entire amount of Ag+ is precipitated, when the titration solution is added, the total concentration of ions progressively increases (K+ and Cl-: both types of ions contribute to electrical conductivity)

The conductivity measured according to the volume of added solution is represented graphically.

The volume of the solution at which the sudden variation of the slope of the titration curve occurs is called the equivalence volume from which the amount of AgNO3 in the sample can be calculated.

If we know the molar mass of $AgNO_3$: $M_{AgNO3} = 169.86$ g/mol.

($M_{Ag} = 107.87$ g/mol, $M_N = 14$ g/mol, $M_O = 16$ g/mol)

KCl solution ....0.1 M

1000 ml soil .....(contains) .... 0.1 mol KCl

V (ml) .... n mol KCl ……… …… n mol AgNO3

$$n = \left(.V. \frac{0.1}{1000} \right) \ mol \ KCl$$

$$n = \left(.V. \frac{0.1}{1000} \right) \ mol \ AgNO_3$$

$M_{AgNO3} = 169.86$ g/mol

$M_{AgNO3} = 169.86$ g/mol……………………………. 1 mole of AgNO3

m_{AgNO3} …………………………………………………….. $\left(.V. \frac{0.1}{1000} \right) \ mol \ AgNO_3$

$$m = \left(M_{AgNO3}.V. \frac{0.1}{1000} \right) \ g \ AgNO_3$$

$$m = \left(M_{AgNO3}.V. \frac{0.1}{1000} \right) \ g \ Ag^+$$

The conductivity measured as a function of the added solution volume is graphically represented:

G=G(V)

It is obtained: G= A.V+B

Where A represents the slope of the line.

But we are dealing with two rights:

First right up to Ve : G= A_1.V+B_1

Second right from Ve up: G= A_2.V+B_2

A_1 and A_2 are the slopes of the graphed lines.

To find the equivalent volume, the equations of the two lines are equal:

A_1.Ve+B_1 = A_2.Ve+B_2

Ve (A_1 -A_2) = B_2 - B_1

$$V_e = \frac{B_2 - B_1}{A_1 - A_2}$$

RESISTANCES STUDY

THEORETICAL INTRODUCTION

OHM'S LAW FOR A CIRCUIT PORTION

Considering an electric circuit composed of several consumers and a power generator, we can easily appreciate that the electric potential between points A and B decreases when the electric current passes. Carrying out the ratio of the electrical voltages U and the currents I passing through each consumer, it is found that they are constant.

$$\frac{U_1}{I_1} = \frac{U_2}{I_{21}} = \frac{U_3}{I_3} = ... = \frac{U_n}{I_n} = const.$$

ou

$$\frac{U}{I} = R$$
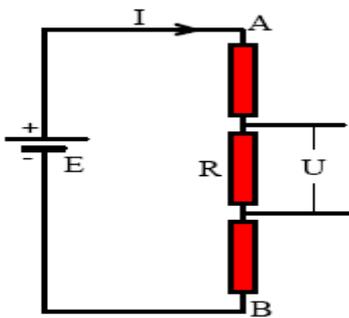
The ohmic conductor is an electronic component also called resistance that verifies Ohm's law:

$U = I.R$

Where I is the intensity of the current, in amperes, that crosses the resistance R, and U is the voltage at the terminals.
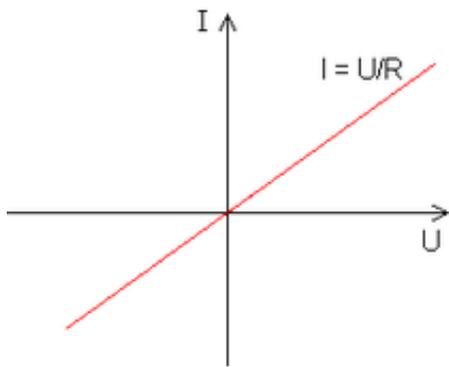
The characteristic curve of the intensity of the electric current I depending on the voltage at the terminals U is a straight line that passes through the origin

The characteristic of an ideal resistance is the curve: $I = f(U) = U/R$

Sometimes the term pure resistance or ideal resistance is used.

For example, the resistance of a metal conductor that depends on the temperature θis given by the relation:

$R = R_0(1 + a\theta + b\theta^2)$ with R_0a hypothetical ohmic conductor that perfectly models a thermostated conductor at a temperature of 0K. θis expressed in K

The voltage drop U on a portion of the circuit is proportional to the intensity of the current I that crosses the portion of the circuit $U = RI$

The proportionality constant between voltage and electric current is called electrical resistance and is denoted by R. The unit of measure for electrical resistance is derived as follows.

$$\frac{U}{I} = R$$

$$[R]_{SI} = \frac{[U]_{SI}}{[I]_{SI}} = \frac{1V}{1A} = 1\Omega$$

Electrical resistance is characteristic of an electrical consumer and depends on its constructive elements: $R = \frac{\rho.l}{S}$

Where ρis a characteristic of the material from which the consumers are made.

Electrical resistivity depends on the temperature of the conductor $\rho = \rho_0(1 + \alpha.t)$

Where ρo is the resistivity at 0oC and αis the thermal coefficient of resistivity

The electrical resistance depends on the temperature $R = R_0(1 + \alpha.t)$

Table with the electrical characteristics of some materials

(http://msabau.xhost.ro/?Fizic%E3:Electrokinetics:Ohm's_Law)

the substance	ρ_0 (Ω.m). 10^{-8}	ρ(Ω.m) (20^0C).10^{-8}	α(degree $^{-1}$). 10^{-4}
nickel	30	42	1
gold	1.92	2.24	83
copper	1.48	1.68	68
iron	8.59	9.71	65
silver	1.42	1.59	61
tungsten	5.02	5.47	45
platinum	9.83	10.6	39
aluminum	2.44	2.65	43
Mercury	94.1	95.8	9

OHM'S LAW FOR AN INTEGRATED CIRCUIT

Let there be a simple electric circuit consisting of a generator that has electromotive voltage E and internal resistance r, which generates an electric current of intensity I in the circuit formed by the generator and an electric resistor of resistance R, it can be written

- **Ohm's law for the whole circuit** : $I = \dfrac{E}{R + r}$

- **Ohm's law for a portion of a circuit is written:**

  U = RI , u = RI

So we can write the intensity of the electric current that crosses a closed electric circuit is directly proportional to the electromotive voltage E of the source and inversely proportional to the total electric resistance of the circuit.

The voltage at the terminals of the closed circuit is: U = E – RI

The voltage at the terminals of the open circuit is: U = E, because I=0

For a zero external resistance, the intensity of the short-circuit current can be written as Icc = E / r. The short-circuit current is the maximum current that an electric generator can supply

KIRCHHOFF'S LAWS

Kirchhoff's laws express the conservation of energy and charge in an electrical circuit. They are named after the German physicist who introduced them in 1845: Gustav Kirchhoff.

In a complex circuit, it is possible to calculate the potential differences across each resistor and the forward current in each circuit branch by applying Kirchhoff's two laws: the node law and the loop law.

THE LAW OF KNOTS

The sum of the intensities of the currents entering through a node is equal to the sum of the intensities of the currents leaving the same node.

The figure shows the direction of orientation of each wire (chosen arbitrarily), which enters or leaves node A. The intensity of a current is an algebraic quantity (positive or negative) defined according to the orientation of the wire. For example, if the intensity of an input wire is 3 A, it means that in this wire at the output there will be an intensity of - 3 A.

According to the law of knots, it can be written: i1 + i2 = i3 + i4.
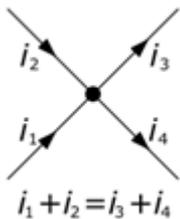
The diagram illustrating the law of knots

This law derives directly from the law of conservation of electric charge, taking into account the fact that, in stationary mode, these charges cannot accumulate at any point in the circuit. Tasks arriving at a node offset those leaving. This law allows the solution of the "electrical equations" with the help of the knot method.

THE LAW OF MESHES

In any EYE of a network, near the quasi-steady regimes and provided that the variations of the magnetic flux through the meshes are negligible, the algebraic sum of the potential differences along the mesh is constantly zero.

This law results from the additivity of potential differences between two points.

The potential difference between a and b is Uab = Va - Vb.

Va and Vb being the respective potentials from points a and b.

By adding all these differences on a closed eye, we get a null result.
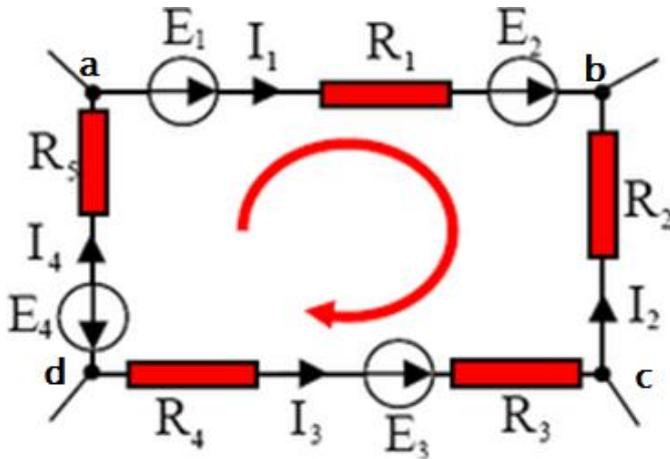
This law allows solving the electrical equations using the mesh method

$$E_1 + E_2 - E_3 - E_4 = R_1 I_1 - R_2 I_2 - R_3 I_3 - R_4 I_3 + R_5 I_4$$

The knot law is valid only if the flux of the electric field surrounding each knot remains zero or constant. Therefore, it is not valid in electrostatics.

In a semiconductor, two types of mobile charges coexist, electrons and holes. The total current, the sum of the electron current and the hole current strictly obeys the knot law. To describe with an excellent approximation the behavior of a bipolar transistor, we can limit ourselves to the transport of only one type of charge: the minority carriers in the base. The node equation for these carriers must take into account their storage as well as their disappearance by recombination. This equation, also improperly called Kirchhoff's equation, has been improved to describe transistor lasers.

METHODS OF CONNECTING THE RESISTORS

Any part of an electrical circuit communicates with the rest of the circuit through a number of terminals. The simplest situation is where the circuit part is a dipole. If the dipole is passive (does not contain generators) consisting only of resistors, then it can be replaced by a single resistor, called an equivalent resistor, so that the rest of the circuit does not "feel" the replacement.

A resistor is equivalent to a group of resistors if when the same voltage is applied to the resistance as the equivalent group, an electric current flows with the same intensity.

The laws of connection of resistances apply strictly to ohmic conductors:

- connecting resistors in series: $R_s = R_1 + R_2 + R_3$

- connecting resistors in parallel: $\dfrac{1}{R_p} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3}$

CONNECTION OF RESISTORS IN SERIES
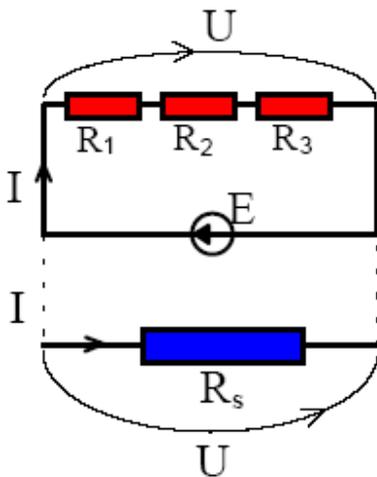
If two or more resistors are connected in series they are part of the same branch of an electrical network.

Grouping resistors in series achieves the same power.

Considering a group of three resistors connected in series on each resistor is a voltage U1; U2 and U3 we can write:

U = U1 + U2 + U3

Using resistors, Ohm's law is written:

U = IR1 + IR2 + IR3

or U = I (R1 + R2 + R3)

We apply the same law for the equivalent circuit:

U = IRS

This results in the following relationship: R = R1 + R2 + R3

In the general case, when connecting resistors in series, it is written:

$$R_s = R_1 + R_2 + R_3 \text{ or} : R_s = \sum_{k=1}^{n} R_k .$$

The equivalent resistance is always greater than any of the component resistances Rk.

CONNECTING RESISTORS IN PARALLEL
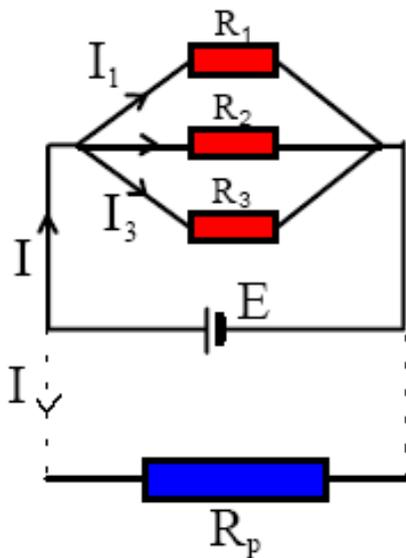
Two or more resistors connected in parallel are connected between the same two nodes

The equivalent resistance when connected in parallel is subjected to the same voltage U at the terminals

According to Kirchhoff's first law

I = I1 + I2 + I3 and

$$I = \frac{U}{R_1} + \frac{U}{R_2} + \frac{U}{R_3} \text{ or}$$

$$I = U\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

and $I = \dfrac{U}{R_p}$

For the equivalent circuit $\dfrac{1}{R_p} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3}$

so: $\dfrac{1}{R_p} = \sum_{k=1}^{n} \dfrac{1}{R_k}$ if we have n resistors connected in parallel

the equivalent resistance Rp of the parallel connection is always lower than any resistance Rk

If we have 2 resistances connected in parallel, the equivalent resistance is calculated with the relation:

$$R_p = \frac{R_1.R_2}{R_1. + R_2}$$

PROCEDURE FOR THE PRACTICAL WORK – STEPS

1. **Read the values of the voltage U on the voltmeter and the values of the resistors R**
2. **The intensity of the electric current I_read is determined**
3. **The calculation is performed using the following formula:** $I_{calculated} = \frac{U}{R}$

EXPERIMENTAL PART
VERIFICATION OF OHM'S LAW FOR A SIMPLE CIRCUIT
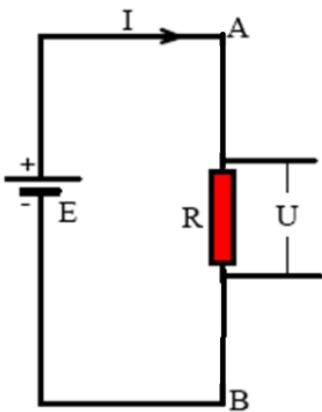
1. Read the value of the electric voltage U on the voltmeter and the value of the resistance R

For a resistance of R= 1000Ω

R = 1000Ω

U=10V

Enter the read values in the following table:

	U(V)	R(Ω)	I read (A)	I calculated (A)
1				
2				
3				
4				
5				
6				
7				

CONNECTION OF RESISTORS IN SERIES

R = 1000Ω

U=10V
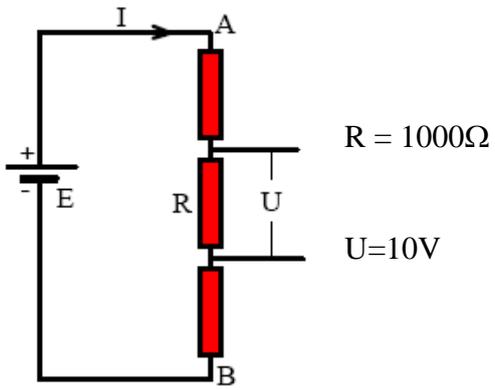
2. Enter the values read in the following table:

	u (T)	R (Ω)	I took (A)	$R_{total}=U/I_{mon}$ (Ω)	$R_{total\ calculated}$ (Ω)	I calculated (A)
1						
2						
3						
4						
5						

CONNECTING RESISTORS IN PARALLEL

R1 = R2 = R3 = R = 1000Ω

U=10V

2. Enter the data in the following table:

	u (T)	R (Ω)	I_{read} (A)	$R_{total} = U/I_{read}$ (Ω)	$R_{total\ calculated}$ (Ω)	$I_{calculated}$ (A)
1						
2						
3						
4						
5						

MIXED RESISTANCE ASSOCIATIONS

$R = 1000\Omega$

$U=10V$

2. Enter the data in the following table:

	u (T)	R (Ω)	I took (A)	$R_{total}=U/I_{mon}$ (Ω)	$R_{total\ calculated}$ (Ω)	I calculated (A)
1						
2						
3						
4						
5						

LIGHTING MEASUREMENTS

NOTIONS OF PHOTOMETRY

Considering that the radiation field of light radiation is an integral part of the radiation field of optical radiation, we can make the following observations:

a) the photometric quantities must have their correspondent between the radiometric quantities

b) the units used for measuring radiometric quantities are based on the fundamental units used for measuring radiometric quantities are based on the fundamental units used for measuring length, mass and time, to which is added the complementary unit for measuring the solid angle.

c) the units we will use to measure the photometric quantities must have the same fundamental units as the radiometric quantities to which the fundamental unit called CANDELA must be added.

d) the CIE notations lead to the following conclusions: the size definition, the size symbol and the unit of measurement of photometric quantities were recommended and accepted by the international commission for lighting.

LIGHT from the point of view of the illuminator's technique is the radiant energy (or radiation) evaluated according to its ability to produce the visual sensation in people.

The assessment of radiant energy as light is done with the help of the eye, the primary optical instrument compared to which all other optical instruments are only self-adjoint.

If different spectral distributions are involved, the basic norms used to evaluate the radiant flux as luminous flux are given by a set of sensitivity factors of the eye. In order to distinguish between the mechanisms of the normal eye depending on the values of the radiation flow, we will call the vision during a clear day daytime **vision,** and the vision during evening **twilight view.** Daytime vision corresponds to relatively high radiation fluxes and twilight vision corresponds to relatively low radiation fluxes.

LIGHT SPECTRAL YIELD

The sensation of vision varies a lot depending on the frequency of the radiation or the wavelength of the radiation in the light spectral range. The eye as a standard observer (CIE) adapted for daytime vision presents the maximum sensitivity for λ= 555 nm. The visibility of the eye decreases relatively quickly on either side of this value, reaching the value 0 for: λ= 380 nm and λ= 780 nm. When it is normalized in relation to its maximum value corresponding to the value λ= 555 nm the visibility corresponding to a given wavelength λ- we thus define **the luminous spectral efficiency K$_\lambda$ (or relative brightness).** K$_\lambda$ is the standard visibility factor of the human eye adapted for daytime vision and with the trichromatic component y (y$_\lambda$) of the standard observer within the trichromatic system (CIE).

The values of the luminous spectral yield have been accepted both by the International Commission for Illumination and by the International Union of Pure and Applied Physics and by the Weights and Measures Committee. They were used as the basis for establishing different types of photometric standards.

LUMINOUS FLUX **F (CIE)** is defined as the temporal rate of variation of light through a given surface

$$\Phi = K\int_{0}^{\lambda} K_{\lambda}\Phi_{e\lambda}d\lambda$$

where Φ$_{is\ it\lambda}$ - is the spectral radiant flux

The integration must be considered for the wavelength domains where the integral is non-zero. Beyond the visible range the integrand is zero because K$_\lambda$ is null. Choosing the value of the proportionality constant k = 683 and expressing the radiant flux Φ$_{e\lambda}$ in watts, **the unit of measurement for luminous flux Φis the lumen (lm)**

The lumen is the luminous flux in the solid angle unit of 1 steradian created by a point light source with the intensity of 1 candela. The lumen is the luminous flux through the surface unit whose points are located at a distance of 1 m from a light source of 1 candela.

The **LUMINOUS EFFICIENCY** of a light source is defined as the ratio between the luminous fluxΦ_λ and the radiant flux $\Phi_{e\lambda}$. The old name of luminous efficiency is **LIGHT EFFICIENCY FACTOR** . The unit of measurement of luminous efficiency is lm/W. The luminous efficiency is not the same as the efficiency of a radiation source, which is also expressed in lm/W, but which refers to the supply power of the radiation source and not to the radiant flux of the source.

THE QUANTITY OF LIGHT $\boxed{Q = \int_0^t \Phi \, dt \qquad (C.I.E)}$

The amount of light Q is given by the time integral of the luminous flux

If the luminous flux is a constant quantity over time, the amount of light is given by the product of the luminous flux and the operating time of the light source. The unit of measure for the amount of light is **lm.h.** In the case of light sources that have a short operating time, such as those used in photography, **the unit of measurement is lm.s.**

THE LUMINOUS INTENSITY $I = \dfrac{d\Phi}{d\Omega} \qquad (C.I.E.)$

The luminous intensity of a light source in a given direction is defined as the density of the solid angle of the luminous flux from that direction.

The luminous intensity is equal to the ratio between the luminous flux through an area element perpendicular to the direction of the luminous flux and the solid angle element that the area element subtends in relation to the light source, considered point-shaped. Since the solid angle must have a peak, the definition given for the luminous intensity applies only to point sources. In many cases, the dimensions of the light sources are negligible compared to the distance at which they are observed, so that it can be considered that the light comes from a point source.

The unit of measurement of luminous intensity I is the fundamental unit of measurement in photometry and bears the name of candella -cd - (CIE)

LIGHTING $\boxed{E = \dfrac{d\Phi}{dS} \qquad (C.I.E)}$

The surface density of the luminous flux Φthrough a surface S, given is called illumination E. When quantitative values are not applied instead of lighting, **the amount of lighting** or **illuminance is used. The unit of measure (CIE) used to measure illumination is lux (lx) and is defined as the**

illumination of a surface with an area of 1 m^2 on which there is a uniform distribution of a luminous flux equal to 1 lm. If the unit of area is $1cm^2$, **the unit of illumination is (CIE) is the photo(ph)**

BRIGHTNESS
$$B = \frac{d\,I}{d\,S_n} = \frac{d^2\Phi}{d\,S_n d\,\Omega} = \frac{d\,\Phi}{d\,\Omega}$$

or luminance or brightness is defined as light intensity corresponding to the surface area unit of a light source viewed from a given direction.

The term brightness usually used refers to the color attribute of the surfaces from which light usually comes to the eye. With the help of brightness, visual perceptions can be classified from unclear (dark) to very bright.

The internationally recognized unit of measurement of brightness is cd.m^{-2}

The brightness of a surface in a given direction can also be expressed in lm.m^{-2} provided that the respective surface is illuminated uniformly and perfectly diffused. A perfectly diffused surface must satisfy exactly the cosine law for both emission and reflection, which is difficult to achieve from a practical point of view. The unit of measure creates ambiguities of similarity between brightness and luminous intensity, while brightness is only the surface density of luminous intensity.

The luminous flux Φcorresponds to the area unit of a perfectly diffused surface whose light intensity in the direction normal to the surface is equal to **I** candela will be equal to π**.I** lumens.
The brightness measurement unit accepted by (CIE) is **the nit** : 1 nt = 1 cd/m^2. The stilt is also used as a tolerated unit **:** 1sb = 1 cd/1cm^2 .
The lambert is also used as a unit of brightness measurement : **1L = 1/ π.cd/cm^2. Lambert is the uniform brightness of a perfectly diffused surface that emits or reflects light at a temporal rate equal to 1 lm/1cm^2**
Mediation must to take into account both the variation of brightness from one point to another as well as the variation of brightness with the observation angle. The lambert is a unit of measure for intense light sources such as the Sun.
 For less intense light sources, the submultiple called the millilambert can be used: mL.

LIGHT DENSITY $\boxed{U = \dfrac{d\,Q}{d\,V}}$

The amount of light corresponding to the volume unit is called light density u and is measured in (lm.h)/(m^3) or (lm.s)/m^3

Among **the photometric coefficients,** the most important and most frequently used are:

a) LIGHT TRANSMISSION t is defined as the fraction of incident light transmitted by a certain medium.

b) LIGHT TRANSMISSION r is defined as the fraction of the incident light reflected by a certain medium.

c) LIGHT ABSORBANCEα is defined as the fraction of the incident light absorbed by a certain medium.

MEASUREMENT STANDARDS. THE FUNDAMENTAL UNIT OF PHOTOMETRY

The standards used in photometry are **primary standards** and **secondary standards.**

CANDELLA (LUMINOUS INTENSITY MEASUREMENT UNIT) is used as the primary standard in photometry, although even the luminous flux unit could be more appropriate.

The first standards of light intensity were candles. At the beginning of this century, the proposal was made to use the black body radiator as a preliminary standard, but due to experimental difficulties, it was only in 1931 that the first established standard of this kind was achieved. The temperature used was that of platinum solidification. After several national laboratories made this black body standard and it was found that the result agreed satisfactorily, it was agreed in 1948 that it should be universally accepted as the primary light standard.

At the 13th General Conference of Weights and Measures in 1967, the **definition of the candle was adopted:**

CANDELLA is the luminous intensity in the perpendicular direction of a surface of 1 / 600000 m^2 of the black body at the solidification temperature of platinum under a pressure of 101325 N/m^2 .

Between the international illuminance used in 1948 as a unit of measurement of luminous intensity and the candella there is a relationship:

1 international lighting = 1.005 candelas

The definition of the candle according to the black body was kept between the years 1948 - 1979 and the corresponding standard proved to be much more stable than its predecessors. Using Planck's law and the thermodynamic solidification temperature of platinum, the spectral power distribution could be calculated.

Two things led to the redefinition of the candle, the first referring to difficulties in the practical realization of the integral black body standard and the second referring to the rapid increase in the application of radiometric techniques in photometry. The redefinition of the candle in relation to the watt offers the possibility for several laboratories to build their own standards.

Candella is the luminous intensity in a given direction of a source that emits monochromatic radiation with frequency $\nu = 540.10^{12}$ Hz and has a radiant intensity of (1/683) W/sr.

The value $\nu = 540.10^{12}$ Hz corresponds to a wavelength (= 555 nm)

Thus, the candle represents the fundamental unit in SI

Luminous spectral efficiency

$$K(\lambda) = \frac{F_\lambda}{\Phi_{e\lambda}}$$

$$[K]_{S.I.} = \frac{lm}{W}$$

The maximum value for K(λ) is obtained for λ= 555 nm and is

K(λ) = 683 lm/W. The luminous spectral yield V(λ) of the radiant flux

(photopic vision) is equal to the luminous efficiency corresponding to a certain given wavelength and the luminous efficiency equal to 683 lm/W corresponds to a wavelength λ= 555 nm.

So we can write: $V(\lambda) = \dfrac{K(\lambda)}{683}$

Any photometric quantity X_f (corresponding to daytime vision) can be obtained from a radiometric quantity X_e using the relation:

$$X_f = \int_{380nm}^{780nm} X_{e,\kappa}.V(\lambda).d\lambda$$

2. Lighting measurements.

The following values are recommended for lighting measurements

The location		illumination E (lx)
OFFICE	Conference rooms, reception rooms	200-700
	Church premises	700-1500
factories (Companies)	Entrance passages, goods packaging departments	150-300
	Production department (production line)	300-750
	Quality department (verification)	750-1500
	Department of assembly of electronic components	1500-3000
Hotels	The waiting halls	100-200
	Reception	200-1000
shops Supermarkets	Corridors, stairs,	150-200
	Table for sale	750-1500
	Showcases	1500-3000
HOSPITALS	Salons for patients	100-200
	Examination room	200-750
	Operating room	750-1500
	Room for emergency treatments	750-1500
schools, universities	amphitheatres	100-300
	Classrooms	300-750
	laboratory	750-1500

EXPERIMENTAL ASSEMBLY:

The measurements are made using the digital luxmeter BF06 TROTEC with photodetector

Figure 1. Digital luxmeter BF06 TROTEC with fotodetector

PROCEDURE FOR THE PRACTICAL WORK – STEPS

Using the digital luxmeter BF06 device, light intensity measurements will be performed.

The practical work is done using the Digital Luxmeter BF06 device and a lamp

	E(lx)	d(x)
1		
2		
3		
4		
5		
6		
7		
8		
9		

Light intensity determinations will be made depending on the distance from the light source, according to the following function: E=E(x)

MEASUREMENT OF SOUND INTENSITY

THEORETICAL INTRODUCTION

Acoustics is the science of sound, considered to be that part of physics that deals with the study of phenomena regarding the production, propagation, reception of sounds as well as their effects. In current usage, the term "sound" refers not only to the phenomenon in the air responsible for the sensation of hearing, but also to humans or animals. Disturbances with low frequencies (infrasounds) or high frequencies (ultrasounds) that are received by a human or animal auditory organ are also considered "sound"; we can talk about underwater sound, sound in solids or sound in structures.

The wide field of acoustics and the area of interest are attributed to multiple applications such as:

a) the existence of the ubiquitous nature of mechanical disturbances generated by natural causes and human activity;

b) the existence of the sensation of hearing, of the human vocal ability, of communication through sound together with the variety of psychological influences that sound has on the auditory organ.

Fields such as speech, music, sound recording and reproduction, telephony, audiology, architectural acoustics and noise control have a strong association with the auditory sensation.

Sound is a means of transmitting information, independent of our natural ability to hear, it is a significant factor especially in underwater acoustics. The physical effects of sound on substances and bodies with which it interacts represent other areas of interest and application.

Figure 1 shows the fields of acoustics and the disciplines with which it is associated. The first ring shows the traditional subdivisions of acoustics and the outer one presents the technical and artistic fields in which acoustics are applied.
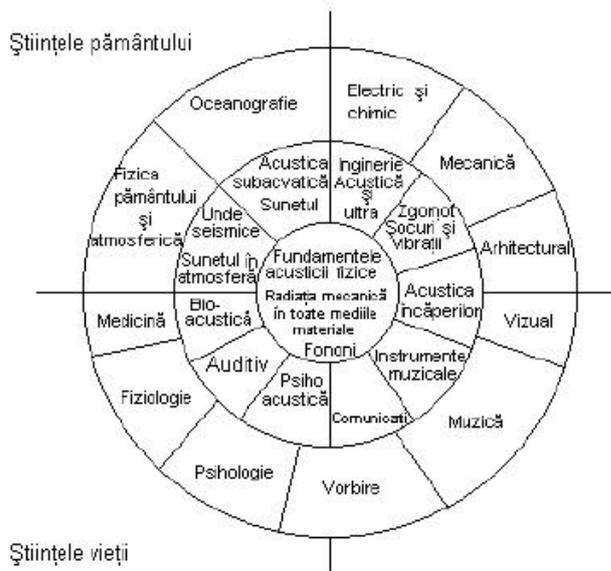
Figure 1. Schematic representation of fields of acoustics

Historic

The idea that sound is a wave phenomenon was born from observations about water waves. The notion of a wave means an oscillatory disturbance that moves far from the source and does not transport any amount of matter at long propagation distances. The wave interpretation was also compatible with Aristotle's (384 - 322 B.H.) statement that air motion is generated by a source that pushes the surrounding air forward in such a way that sound propagates unaltered over long distances until the air disturbance is extinguished. A pertinent experimental result with antecedents from the time of Pythagoras (550Î.H) shows that the air movement generated by a body (source) that oscillates with a single musical note is also an oscillatory movement and has the same frequency as the body (source); historically this is related to the development of laws for the natural frequencies of vibrating strings and for the physical interpretation of musical consonants. The main authors of these interpretations were the French philosopher Marin Mersenne (1588 - 1648) who was called *the father of acoustics* and Galileo Galilei (1564 - 1642) whose book "Mathematical Discourses Concerning Two New Sciences" (1638) contains the most credible statement, given until then, regarding frequency equivalence. Mersenne's description in the book "Harmonic universelle" (1636) of the first absolute determination of the frequency of an audible tone (at 84 Hz) indicates that he had already demonstrated that the ratio of the absolute frequencies of two oscillating strings radiating in space (air) a tone musical and its octaves is 1:2; the ratio of the oscillation frequencies is also 1:2, which is

compatible with the hypothesis of equivalence between the source in the air and the air movement frequency.

The analogy with water waves was strengthened by the belief that the air motion associated with musical sounds is oscillatory and by the observation that sound propagates with a finite speed.

Another known problem was that sound "bends" at corners, suggesting diffraction, a phenomenon often observed in water waves. Also, the classic experiment of Robert Boyle (1640) on the radiation of sound with the help of an alarm clock inserted in a partially empty glass vessel, ensures that air is necessary for the production and propagation of sound.

A special point of view on the wave was held by Gassendi (contemporary with Marsenne and Galileo) who argued that sound is due to a "storm of atoms" emitted by the body that emits sound, the speed of sound is the speed of atoms and the frequency represents the number of atoms emitted in time unit.

The apparent conflict between the ray and wave theories played an important role in the history of the sister science, optics, but the theory of sound developed from the beginning as a wave theory. When ray concepts were used to explain acoustic phenomena, as Reynolds and Rayleigh did in the 19th century, they were seen as mathematical approximations of wave theory. The successful incorporation of geometric optics into wave theory demonstrated that approximate, viable models of the wave phenomenon could be experienced in terms of ray concepts. (This recognition strongly influenced twentieth-century developments in architectural acoustics, underwater acoustics, and noise control.)

The mathematical theory of sound propagation shown in Isaac Newton's (1642 - 1727) work entitled "Principia" (1686) included a mathematical interpretation of sound as pressure pulses transmitted by *surrounding* fluid particles. The diagrams in figure 2 show the divergence of the wavefronts after they pass through a slit. The mathematical analysis was limited to waves of constant frequency because it required a number of devices, circuits and approximations that could influence the frequency variability. A substantial advance in the development of a viable theory of sound propagation

to be based on mathematical and physical concepts was produced in the 18th century by Euler (1707 - 1783), Lagrange (1736 - 1813) and d'Alembert (1717 - 1783) when field theory began to receive a defined mathematical structure ; modern theories can be seen as improvements of the theory developed by Euler and his contemporaries.
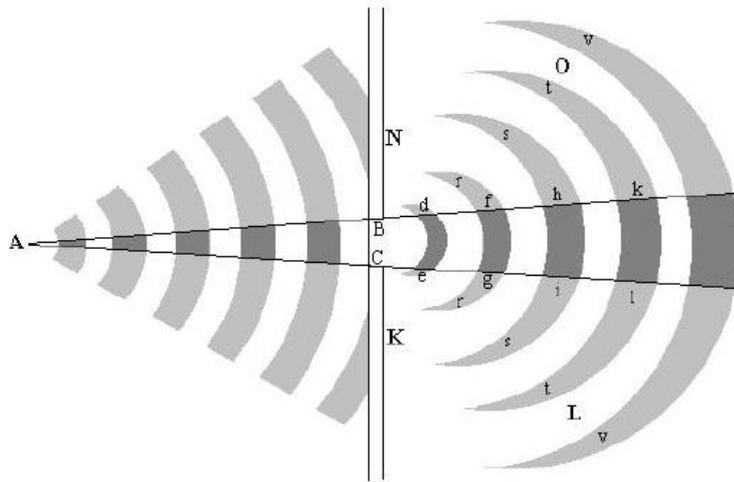
Figure 2. Sound qualities

The sound qualities designate the types of subjective effects corresponding to the characteristics quantities of the incident wave.

The sound has the following qualities:

- *the height* corresponding *to the frequency* ;
- *the strength* corresponding to *the intensity;*
- *the timbre* corresponding to *the harmonic content* of a compound sound.

2.1 *Sound pitch*

This quality of sound was studied for the first time by Galileo Galilei and represents the quality of the auditory sensation determined by frequency. Due to this quality, two or more sounds of the same loudness can be differentiated through a subjective scale so that it may appear to the auditory organ higher (acute) or deeper (grave), that is, from high sounds to low sounds; however, corresponding to an objective scale
of frequencies, results in high (high) and low (low) frequencies, respectively. In this case, two sounds are considered to have equal pitches if they have the same frequency.

Due to the frequency dependence of the height, the three types of sounds could be defined:

- infrasound (1Hz -16Hz);

- sounds (16Hz - 16KHz) and ultrasound (16KHz - 200MHz);

- hypersound (> 200 MHz).

Theoretically, this frequency dependence leads to the application of the expression of the frequency of an acoustic source and in the case of this sound quality, being of the form:

$$f = \frac{\omega}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$ **(1)**

where **m** is the mass of the oscillating source that stores kinetic energy and **k** is the elasticity constant of the connecting element that stores potential energy.

Thus the production of a higher sound leads to a higher frequency of the wave process.

A solid body (material) possesses a series of own oscillation frequencies, one of which we can consider as fundamental, which determines the pitch of the sound and corresponds to a pure tone.

The human auditory organ can appreciate if two sounds are of the same pitch even though they are produced by different instruments and intensities. The causal correspondence between frequency and height is stable, so that at the same height, that is, the same sound as sensation. This property of fidelity of the human auditory organ to frequency made possible the existence of the musical scale and even music.

Thus, the pitch of the sound reflects the sensitivity of the human auditory organ to variations in frequency; with pure tones there is a difference of 0.2% in the frequency range 400Hz □□ 4000Hz which manifests itself in the form of a change in height. Outside the considered frequency range, the sensitivity decreases with the frequency variation. This frequency-dependent sensitivity implies certain restrictions on the calibration and frequency adjustment of radios, musical or electronic instruments. The reception of the sound height is done logarithmically, and the height difference according to the frequency is determined according to the frequency ratio. According to the pitch scale, this frequency between the pitches of two tones with different frequencies is called an *interval* , and in music, a *musical interval* .

Experimentally, the pitch of the sound is determined by different methods, among which we mention *the recording method* and *the beating method* .

Method of registration . The oscillogram of the sound whose height we want so is recorded

we determine and on the same tape the oscillogram of a pendulum that beats the second is also recorded. In this way, the number of periods per second of the researched sound can be determined on the graph.

The method of beating . The phenomenon of "beating" is known, explained in the "Oscillations" chapter. The beat frequency **fb** is equal to the difference in the frequencies of the two compared sounds, i.e. fb = f2 - f1

where the sound of frequency f1 is known, that of frequency f2 must be determined and the frequency of beats fb is determined auditorily.

2.2 ***Intensity*** (*loudness)* ***of the sound***

The sound intensity at a point of the sound field is defined as the amount of sound energy that traverses the unit of flat surface located at that point and oriented perpendicular to the direction of sound propagation in the unit of time.

The expression of intensity **I** is: $I = 2\pi^2 f^2 A^2 \rho v$

for a unitary surface, being proportional to the square of the local frequency and amplitude that characterizes the oscillatory system (source) and to two quantities that characterize the propagation medium, namely the density $\square\square$ and the speed of sound v.

Sound intensity is an objective physical quantity having a physical dimension

$$[I] = \frac{[F] \cdot [L]}{[L]^2 \cdot [T]}$$

and as a unit of measure:

$$I_{SI} = \frac{W}{m^2}$$

that is, it represents a power relative to the surface.

To define the acoustic pressure, we consider a continuous elastic medium for sound propagation.

If the wave phenomenon in this environment is null (there is no sound) then the local pressure is given only by the static pressure **pst** ; if longitudinal acoustic (sound) waves propagate through the

elastic medium, then at a point of the medium the total pressure **pt** will oscillate harmonically and the wave phenomenon appears. In this case, the dynamic pressure **pdin** , which would be due only to the wave effect, has the following expression: pdin = pt - pst

and depending on the propagation distance x and the wavelength λ of the sound, the relation is obtained:

$$p_{din} = p_{max} \cos 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right)$$
(3)

for a period T of the oscillations at a given time t and where p

$$p_{max} = \frac{2\pi A E_{ac}}{\lambda}$$

The above expression (3) represents the momentary acoustic pressure at a certain distance x from the source of longitudinal acoustic waves and which acts on the auditory organ (tympanum) giving rise to the auditory *sensation* .

Depending on the maximum acoustic pressure (pmax), the acoustic intensity has the expression:

$$I = \frac{p_{max}^2}{2\rho v}$$

(4)

and depending on the maximum speed of the material particles that make up the elastic medium vmax, there is the relationship:

$$I = \frac{1}{2} v_{max}^2 \rho v$$
(5)

These relations are important in practice, because they allow the determination of acoustic intensity based on measurements of acoustic pressure or the speed of material particles. Making the report

$$\frac{p_{max}}{v_{max}} = \rho v$$
(6)

a law is obtained acoustically analogous to Ohm's law in electricity, if it is considered that the maximum acoustic pressure corresponds to the electric voltage, and the speed corresponds to the current intensity; therefore, an impedance, but acoustic, of the form appears:

Z = $\square$ v **(7)**

which represents the specific *acoustic impedance* of the elastic medium of propagation **.**

2.3 *Sound timbre*

Timbre has different definitions, but they all refer to the spectral content of the composite sound. Thus, according to STAS 1957-66, timbre is a characteristic of the auditory sensation that allows to distinguish different compound sounds having the same fundamental frequency and intensity but different spectral compositions and according to STAS 1957-74, timbre represents the quality of compound sounds of sensibly equal intensities to could be differentiated according to their spectral composition. From these definitions it follows that the timbre is a unique, structural characteristic of a sound that allows the identification and tracking of a certain source from a group of sound sources. The objective explanation of this sound quality, the timbre, can be achieved by studying the classification
sounds according to the result of their harmonic analysis or indirectly according to the auditory sensation it produces.

Thus, it can be defined as follows:
a) *the pure sound* (tone) characterized by a single frequency and amplitude and which corresponds the oscillation of the simplest material body (source). In the elongation-time graphic representation, the pure sound is a sinusoid and in the intensity-frequency representation, the pure sound is a vertical line drawn towards the respective frequency (Fig. 3)
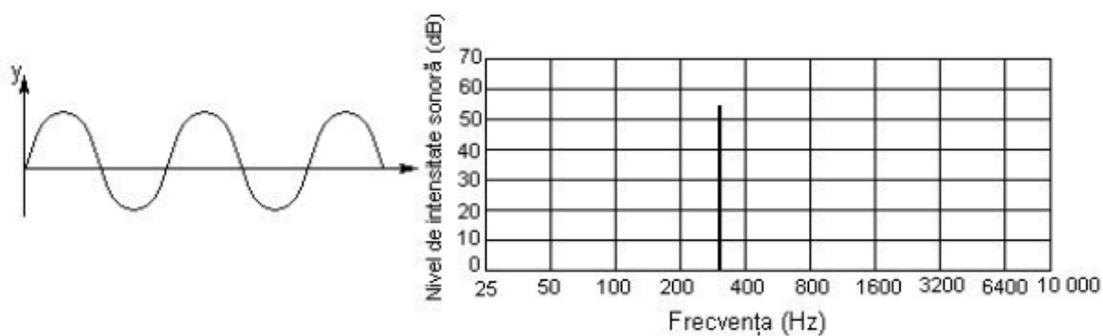
Figure 3

In nature, pure sounds can be obtained very rarely; most often they can be obtained in the laboratory with

the help of tone generators and used in acoustic measurements and audiometry;

b) *the musical sound* - is produced by the periodic oscillation of a certain body. This sound is composed of a pure, fundamental sound followed by a certain number of harmonics that represent a multiple of the fundamental sound. So, the musical sound is a complex sound consisting of a fundamental and several harmonics obtained from a material body of a certain geometric shape (musical instruments). Thanks to the timbre, a musical note produced by a musical instrument can be distinguished from the same note produced by another instrument (violin and flute).

c) *noise* - it is an excellently complex sound, made up of very numerous but chaotically distributed components on the frequency band. The oscillogram of a noise does not present periodicity and its components are non-harmonic. As a physiological effect, noise produces an unpleasant auditory sensation.

In conclusion, all these three qualities of sound, pitch, intensity, timbre are defined only in the presence of the human auditory organ. Experimental studies have highlighted the fact that there are also secondary influences between loudness and frequency, between pitch and intensity, and timbre is influenced by intensity and

frequency.

3 **Introduction to physiological acoustics**

The production and propagation of elastic waves from a source together with their reception in the form of sounds represents a continuous, linked, indissoluble process. All this received information is taken in real time by the human brain which also creates the sensation of sound. Thus, in order for an elastic wave (objective quantity) to be transformed into the sensation of sound (subjective quantity), frequency and sensitivity conditions must be met.

3.1 *The human auditory organ*

The human auditory organ (the ear) is a specialized organ that analyzes the excitations, sorts and classifies them according to frequency, giving the sensation of height, according to intensity, giving the sensation of loudness and according to the spectral composition giving the sensation of timbre. That is why the human ear is also a spectroscope or selective sensory analyzer because through a process of analysis and synthesis of external stimuli (elastic waves) it creates the sensation of sound.

Simply, the ear is an intermediate auditory organ that transforms elastic waves into the sensation of sound. Figure 4 explains the fact that the excitation (objective element) represented by the sound intensity Is, which corresponds to a certain sound pressure, is transforms through the ear, U, into a subjective element (perception) represented by the auditory intensity at.
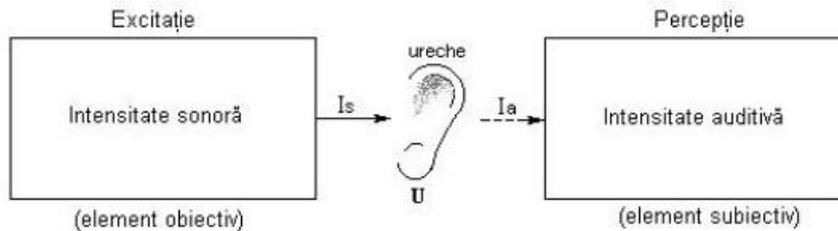

Figure 4. Schematic representation between excitation and perception

As a psycho-physical system for sound reception and processing, the human auditory organ, the ear, has three main regions:

- *external ear* - Ue,
- *middle ear* - Um,
- *inner ear* - Ui

regions that are the seat of physical processes that justify their shape and dimensions.

AUDIBILITY LIMITS

The human ear can perceive sounds if the elastic waves fall within certain limits of *frequency* , *intensity* and *duration* .

Frequency limits . The human auditory organ has an audibility range of 16Hz (20Hz) - 16KHz (20KHz) because it largely depends on the individual; with age the upper limit begins to decrease.

Intensity limits . These depend mainly on the frequency but also on the individual. for a certain frequency there is a lower limit of sound intensity, but also an upper limit when the sounds produce a painful and harmful sensation. The highest sensitivity of the human ear is for normal sounds (1000Hz frequency sounds), because the difference between the upper and lower limits is maximum. For these normal sounds, the amplitude of the acoustic pressure on the eardrum is p min = **2.84.10** -

5N $^/$ m2 and the minimum sound intensity Ismin = 10 $^{-12}$ W/m2. In air, the amplitude of air oscillations for a plane wave is Amin = 0.123Å for the frequency of 1000Hz and an air density of 1.29Kg /m ^{3} .

This lower limit Ismin = 10 -12 W/m2 represents **the threshold of audibility** which is the minimum value of acoustic pressure or sound intensity that the human ear still receives in the form of sound. Depending on the frequency, the audibility threshold has the minimum value (maximum sensitivity) in the range 1000Hz □□ 3000Hz, which is practically a constant value. Recent measurements have shown that the sensitivity of the human ear is maximum around the frequency of 2500Hz and at neighboring frequencies the audibility threshold increases considerably.

Statistically, we can show that at f = 50Hz, PA (audibility threshold) increases by 5 . 10^5 times and at f = 20Hz PA increases 108 times compared to the minimum value. Also, the sensitivity of the human ear decreases 104 times compared to the maximum value, for f = 100Hz and at f = 400Hz it decreases only 10 times.

The upper threshold of audibility is defined as the maximum value of the pressure or

Ismax sound intensities corresponding to normal sound (f = 1000Hz);

that is, pmax = 2 . 10 ^{2} N/m2 again

Ismax = 10 ^{2} W/m2.

At higher values, the person feels a strong and unpleasant pressure on the eardrum that turns into pain (pain threshold). The ratio between the sound intensity values for the two upper and lower thresholds is:

$$\frac{Is_{max}}{Is_{min}} = \frac{10^2}{10^{-12}} = 10^{14}$$

and that of the pressures is:

$$\frac{p_{max}}{p_{min}} = \frac{2 \cdot 10^2}{2 \cdot 10^{-5}} = 10^7$$

which shows that the field of auditory intensity is very wide. The curves that delimit the two thresholds of audibility (upper and lower) depending on the frequency are represented in figure 5, which delimits **the surface** (domain) **of audibility** inside them . The size of this surface (domain) is an indicator of a person's hearing capacity (the surface decreases in people with hearing defects).
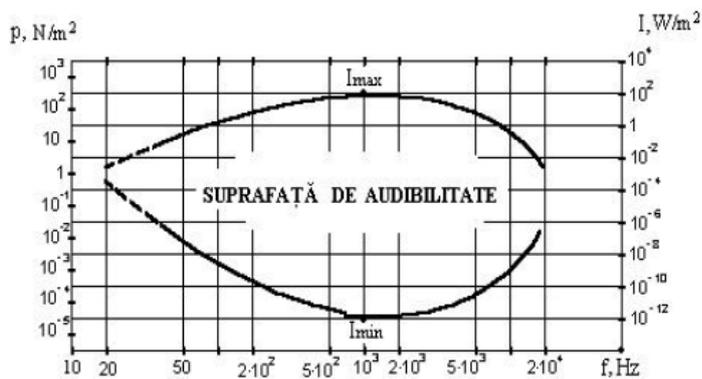
Figure 5. Schematic representation of the audibility domain

Duration limits

For the sound to be heard, the oscillation that produces the elastic waves must have a certain minimum duration. This is estimated at 60ms, which means for a normal sound (f = 1000Hz) a persistence on the eardrum of 60 periods. The human ear can perceive differences in duration between two sounds of up to 10ms. If the incident elastic waves have a shorter duration then this one

it is interpreted by the ear as a click with undefined characteristics.

WEBER - FECHNER LAW

This law represents a link between sound intensity Is (objective element) and auditory intensity Ia (subjective element). Weber and Fechner showed that the variation of hearing intensity Ia is proportional to the relative variation of sound intensity Is and has the relation:

$$dIa = k \frac{dIs}{Is} \qquad (8)$$

Integrating the relation above, we get: $Ia = k \ln Is + C$

To determine the value of the constant C, write the relation for the sound intensity corresponding to the lower threshold of audibility (Ismin), i.e.: Ia0 = k ln Ismin + C

but, as Ia0 = 0, the value of the integration constant C is found as: C = - k ln Ismin

By entering the value of the constant C in the initial relationship, we obtain:

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$$Ia = k \ln Is - k \ln Is_{min} = k \ln \frac{Is}{Is_{min}}$$

(9)

which represents the Weber - Fechner law, which is a logarithmic law specific to the sound intensity measurement system.

The Weber - Fechner law shows that **if the sound intensity increases in geometric progression, then the auditory intensity increases in arithmetic progression.**

ACOUSTIC LEVELS

Sound intensity level

Experiments in electroacoustics led to the establishment of a quantitative link between the intensity of objective excitation and the intensity of subjective excitation. Thus, *the sound intensity level* **Ns** was defined as the sound intensity related to the lower threshold of audibility (Ismin). But, as the expression of this ratio presents very large numbers, up to 10^{14}, it was agreed that the linear scale should be replaced by a logarithmic scale, so that the relation for the sound intensity level is:

$$Ns = \log \frac{Is}{Is_{min}}$$

(10)

where we recall that Ismin represents the minimum sound intensity (the lower threshold of audibility) and has the value of $Ismin = 10^{-12}$ W/m2 for a frequency of 1000Hz. The unit of measure for the sound intensity level is *the Bell* (B), after Graham Bell, the inventor of the telephone. Since the Bel is considered to be a unit of measurement that is too large, another unit is used which is the tenth part of the Bel, i.e. deciBel (dB) which represents the minimum level difference that can be perceived by the ear. In this case, the sound intensity level has the expression:

$$Ns = 10 \log \frac{Is}{Is_{min}} \approx 20 \log \frac{p_{max}}{p_{min}} (dB)$$

(11)

The level of sound intensity corresponding to the threshold of painful sensation is:

$$Ns = 10 \log \frac{Is_{max}}{Is_{min}} = 10 \log 10^{14} = 140 dB$$

(12)

The level of auditory intensity

Since the intensity of the auditory sensation depends on the sound intensity and the frequency of the sound, the *auditory intensity level* **Na** of a sound is defined as the sound intensity level of a normal sound (f = 1000Hz) which produces the same intensity of auditory sensation as the sound considered. This level of hearing intensity has the relationship:

$$Na = 10\log\frac{Isn}{Is_{min}} \approx 20\log\frac{(p_{max})_n}{p_{min}}$$ **(13)**

where Isn and (pmax)n represent the sound intensity and respectively the sound pressure amplitude of a normal sound of 1000Hz. The unit of measure is the *phon* . A phon roughly corresponds to the resolving power of the ear relative to the loudness of the sound. The loudness of the sound expressed in phons is equal to the sound intensity level expressed in decibels of the normal sound of 1000Hz which produces the same intensity of the auditory sensation.
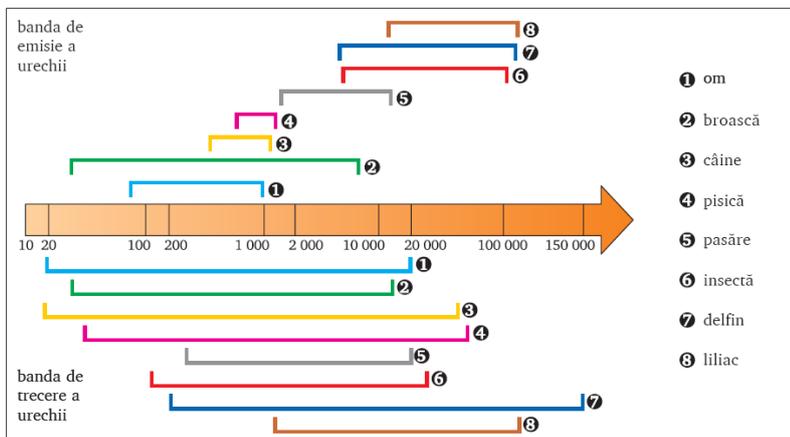

Figure: the passing bands of the human ear and of some animal species.

EXPERIMENTAL ASSEMBLY

A sound intensity measuring instrument is used in the montage, which records the sound intensity from second to second

PROCEDURE FOR THE PRACTICAL WORK

Sound intensity determinations will be recorded and the data will be processed Sound intensity (dB) as a function of time (s)

The maps obtained for each registration will be presented

No. crt.	I(dB)	T(s)
1		
2		
3		
4		
5		
6		

The values of the maximum and minimum intensities and the average values recorded will be determined.

Data will be taken every 10 seconds with the device and graphed: I=I(t)

With the digital device for recording the intensity of the sound, automatic recordings are made from second to second. The data are processed in Excel and the graphs I=I(t) are obtained.

DETERMINATION OF THE REFRACTIVE INDEX OF TRANSPARENT SOLID AND LIQUID MEDIA USING THE MICROSCOPE

INTRODUCTION

From the point of view of operation, the microscope is like a magnifying glass in the sense that the final image of an object is virtual and magnified, the only significant difference between the operation of a microscope and a magnifying glass is that in the case of the microscope the image is inverted from the real orientation of the object (as opposed to the magnifying glass).

Figure 1 represents the L lens in the position of the objective lens closest to the object. In order for the image of the object (source S_1) created by the microscope to be clear in the field of view of the microscope, the object (source S_1) must be located at a distance x_1 determined by the characteristics of the objective lens. If a plane-parallel plate (medium with refractive index "n" greater than that of the medium) of thickness "d" is interposed between the object and the objective lens, the clarity of the image is compromised. To obtain a clear image again, the distance between the objective and the objective lens must be changed (reduced by "Δx"), that is, the object from point S_1 must be brought to point S_2. The displacement "Δx" imposed on the object, to restore the clear image, depends on the thickness "d" of the plane-parallel plate and its refractive index "n". By determining the displacement "Δx" and having the thickness "d", the refractive index of the plate can be calculated. The method is known as the "*Chaulnes method*" (Michel-Ferdinand d'Albert d'Ailly, duc de Chaulnes, 1712 – 1777; the method was proposed and described in 1768).
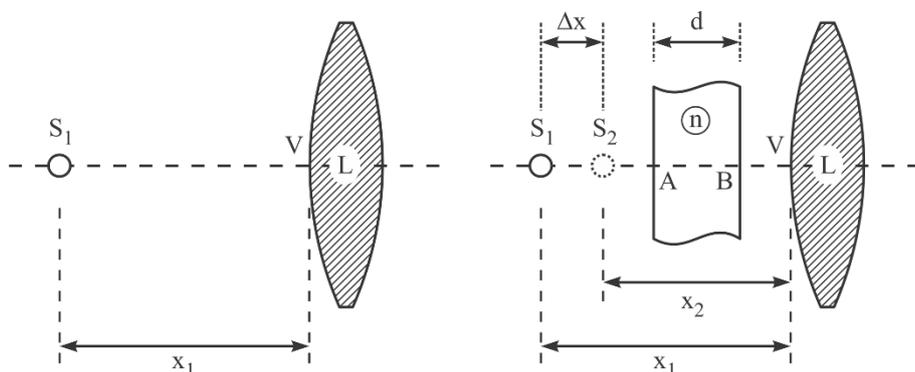

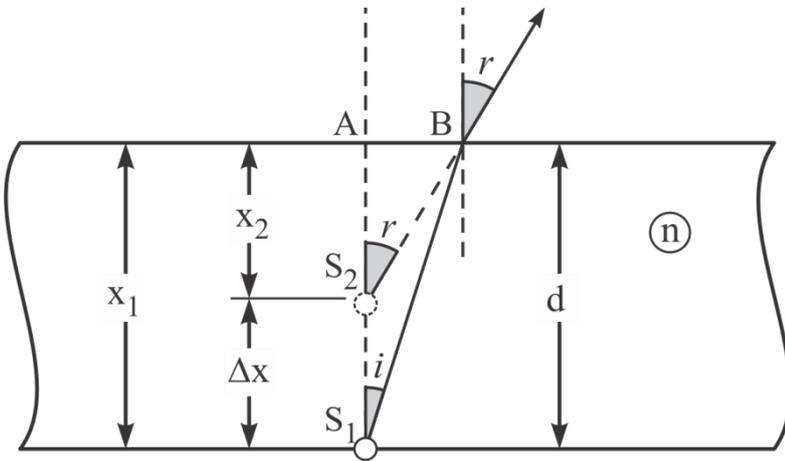Figure 1. The influence of a plane-parallel plate positioned between the object and the objective lens

Figure 2. The apparent displacement of the image of an object due to a layer of refracting medium

Figure 2 illustrates the relationship between the object-lens distance ("d") for a clear image in the absence and presence of a homogeneous medium, of plane-parallel shape, thickness "d" and refractive index "n". If in the absence of the plate the image of an object located at the point "x_1" is clear, then, in the presence of the plane-parallel plate, the object must be moved to the position "x_2", with " Δx " closer to the lens, to obtain again a clear picture. With the help of the micrometer screw of the microscope, the "x" displacement can be measured Δ.

The length of the segment "AB" can be expressed from the right triangle "ABS_1": AB = d•tg i

$$(1)$$

and from the right triangle "ABS_2" : AB = (d- Δx)•tg r (2)

By dividing, member by member, the two relations, it results:

$$\frac{\text{tg}r}{\text{tg}i} = \frac{d}{d - \Delta x} (3)$$

If the observation of the emergent ray is performed close to the S1S2A direction, the angles " i " and " r " are small; in this case the approximation is accepted: tg $r \approx \sin r$ and tg $i \approx \sin i$.

$$\frac{\text{tg}r}{\text{tg}i} = \frac{d}{d - \Delta x} \approx \frac{\sin r}{\sin i} = n\,(4)$$

The refractive index "n" is expressed from relation (4):

$$n = \frac{d}{d - \Delta x}\,(5)$$

PROCEDURE FOR THE PRACTICAL WORK – STEPS

I. CALIBRATION OF THE MICROMETRIC SCREW OF THE MICROSCOPE

To measure the change in the distance ("D") between the objective lens and the sample table of the microscope, the micrometer screw located on the right side of the microscope is actuated. The wheel of the micrometric screw is divided into 200 parts (Figure 3).
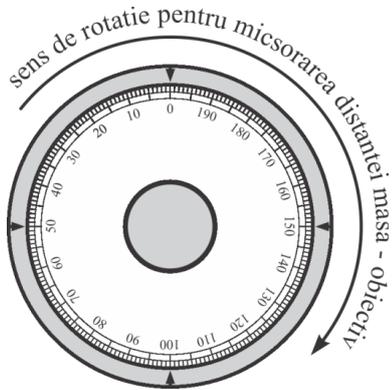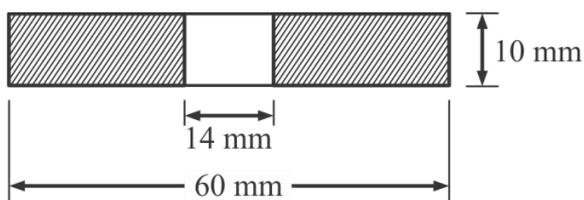
Figure 3. Schematic representation of the disc divided into 200 parts of the micrometric screw

In order to be able to correlate the change in the distance "D" with the measure of the rotation of the split disc, a body of known thickness (10 mm) fitted with a thin wire "MN" is placed on the microscope table, Figure 4. The first time the body is placed on the microscope table like this so that the "MN" wire is in the upper part of the body. Rotate the divided disk until a clear image of the object is obtained in the visual field. The position of the split disc is noted.

The object in Figure 4 is inverted so that the "MN" thread ends up at the bottom. Thus, the object-lens distance was changed with the thickness of the object (10 mm). Rotate the split disc of the micrometer screw to obtain a clear image again. The number of divisions between the two positions of the divided disk is noted. If between the two observations the disk has rotated with "N" complete rotations and with another "n" divisions, then (200•N + n) divisions correspond to the change of 10 mm in the distance between the sample table and the objective. It means that a division on the divided disk corresponds to a displacement "δ" expressed in millimeters by relation (6).

$$\delta = \frac{10}{200 \cdot N + n} \quad (mm) \, (6)$$

Figure 4. Disk for calibrating the micrometer screw of the microscope
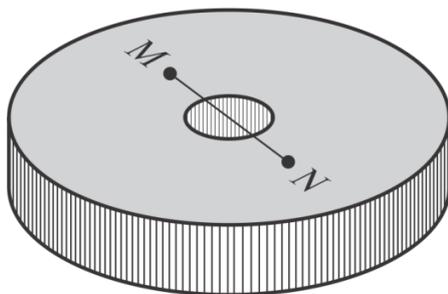
II. DETERMINATION OF THE REFRACTIVE INDEX OF A PLANE-PARALLEL GLASS PLATE

For reasons of convenience regarding the readings of the divisions of the divided disk of the micrometric screw, the operations are performed in the following sequence:

1) Measure the thickness of the glass plate, "d". On one of the faces of the plate is marked an "S_1" sign. Place the studied glass plate on the microscope table with the "S_1" sign on the lower surface. Actuate the micrometric screw until the clear virtual image "S_2" of the sign "S_1" is obtained (Figure 5-a). In this situation, the real distance between the sign "S_1" and the objective of the microscope is "x_1". The distance between the apparent image "S_2" and the objective of the microscope is "x_2".

2) Turn the glass plate so that the "S_1" mark reaches the upper surface of the glass plate. The real distance between the sign "S_1" and the objective of the microscope becomes "x_1'". The image of the sign "S_1" is now blurred (Figure 5-b).

3) Turn the micrometer screw to increase the distance between the "S_1" mark and the microscope objective. For the real distance "x_2" between the sign "S_1" and the objective of the microscope, the clear image of the sign "S_1" is obtained again (Figure 5-c).

4) Read the difference between the divisions of the disc divided between configurations 1) and 2) and applying relation (6) calculate the displacement "D" of the sample table of the microscope.

It can be seen from Figure 5-c that the displacement "D" of the microscope table is

$D = d - \Delta x$; from here: $\Delta x = d - D$ (7)

5) Refractive index "n" is calculated based on relation (5):

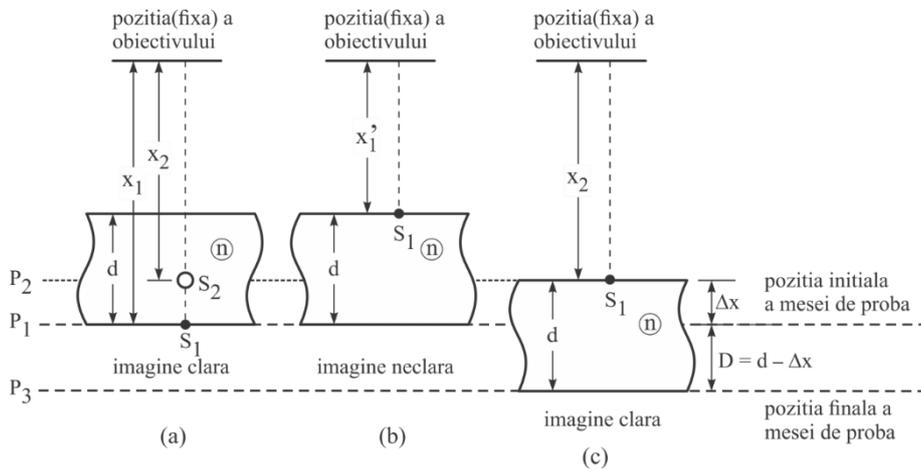$$n = \frac{d}{d - \Delta x} = \frac{d}{d - (d - D)} = \frac{d}{D} \ (8)$$

Figure 5. Sequence of operations for determining the refractive index of a plane-parallel glass plate

III. DETERMINATION OF THE REFRACTIVE INDEX OF A LIQUID USING THE MICROSCOPE

The refractive index of liquids can also be determined with the *Chaulnes method.* For this purpose, a glass vessel with internal thickness $d = 1$ cm can be used, a known accessory for spectrophotometric measurements (Figure 6-a). The tank can be closed tightly with the help of a plug made of Teflon.

The stages of determination are as follows:

1) Fill the vessel with the studied liquid (having the refractive index "n") and close it with the Teflon plug (Figure 6-b). It is important that the liquid enclosed in the tank does not contain air bubbles.

2) Create a mark on one of the outer faces of the cuvette and place the cuvette, in the lying position, on the sample stage of the microscope (Figure 6-c).

clear virtual image S_2 of the sign S_1 appears in the visual field of the observer. Note the position of the graduated disc of the micrometer screw.

4) Empty the tub, wash and dry. The empty cuvette is placed on the stage of the microscope. In the field of view of the observer the image is blurred.

5) Turn the graduated disc of the micrometric screw, in the direction indicated in Figure 3, until the image in the observer's visual field becomes clear (Figure 7-b). Note the complete number of rotations "D" and the number of divisions "y" with which the graduated disc was rotated.

6) The displacement " Δx " is, this time, equal to the displacement "D" of the sample table:

$\Delta x = D = 200 \cdot K + y$ (9)

To calculate the refractive index "n" of the liquid in the tank due to the displacement " Δx ", a more general analysis of the system from an optical point of view is required.
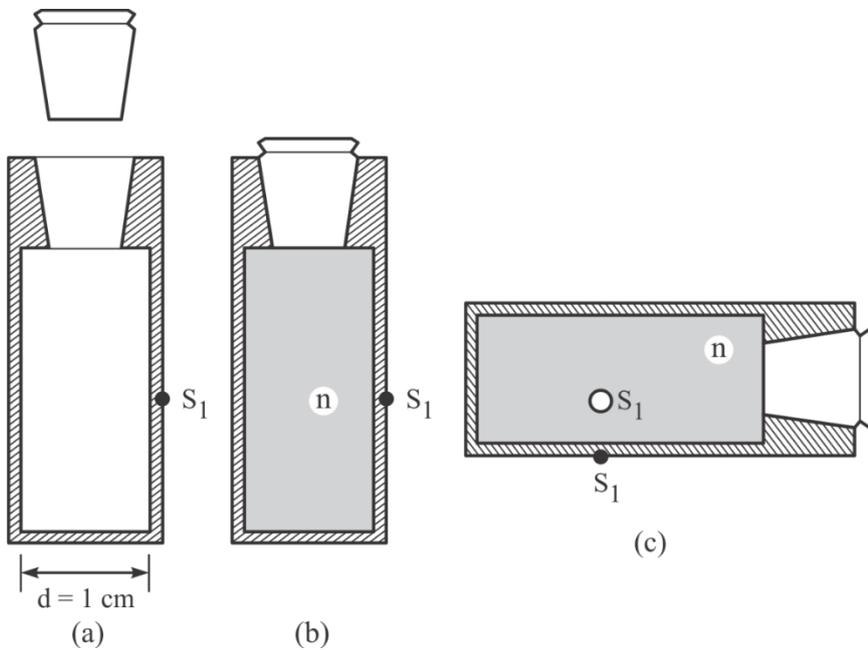

Figure 6. Quartz vessel used for determining the refractive index of liquids
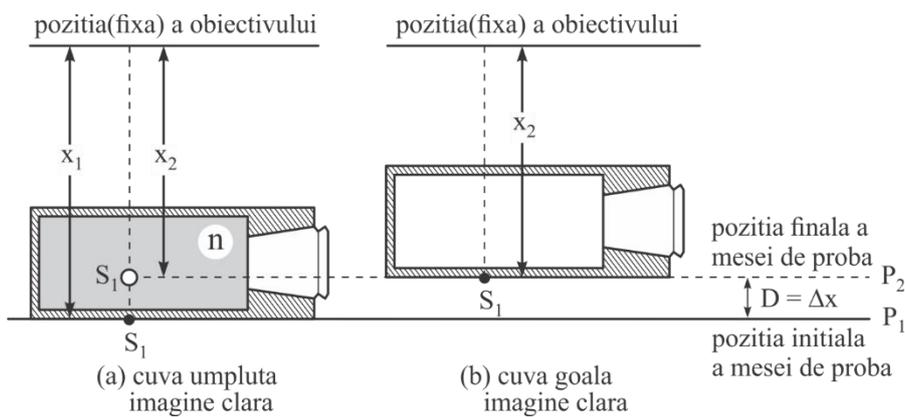

Figure 7. Determination of the refractive index of a liquid

Figure 8 represents the path of a light ray starting from the source "S" (the real object) and crossing three separation surfaces (the surfaces of the segments "AB", "CD" and "EF"). When crossing each surface, the limina undergoes refraction. The system models the two glass walls of the tank with the thickness "d_1" and "d_2" as well as with the refractive index "n_1" and "n_2". Also, Figure 8 models the environment in the space between the two glass walls (thickness "d" and refractive index "n"). Refractive index of air "n_o" is considered equal to 1.

Following the crossing of the layers and the multiple refraction of light, the observer (microscope lens) sees the virtual image "S_2" of the real object "S_1" displaced by the distance "Δx".

Next, we aim to express the distance "Δx" according to the thicknesses "d_1", "d", "d_2", refractive indices "n_1", "n", "n_2", "n_o" and the angles "i_1", "i_2", "r_1", "r_2".

From the triangle "ABS_1" the length of the segment "AB" is expressed, from the triangle "BCD" the length of the segment "CD" is expressed, and from the triangle "DEF" the length of the segment "EF" is expressed:

$$AB = d_1 \cdot \mathrm{tg} i_1 \quad ; \quad CD = d \cdot \mathrm{tg} r_1 \quad ; \quad EF = d_2 \cdot \mathrm{tg} i_2 \ (10)$$

The distance "p" is the sum of the lengths of the segments "AB", "CD" and "EF":

$$p = AB + CD + EF (11)$$

On the other hand, $p = $ "q"$\bullet \mathrm{tg}\, r_2$ (12)

From facts (11) and (11) it follows:

$$p = d_1 \cdot \mathrm{tg} i_1 + d \cdot \mathrm{tg} r_1 + d_2 \cdot \mathrm{tg} i_2 \ (13)$$
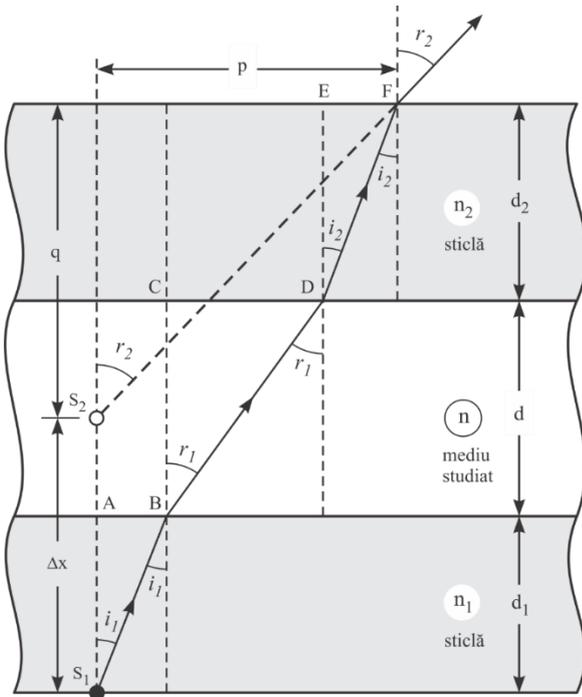
Figure 8. Generation of the Virtual image "S$_2$" of the object "S$_1$" as a result of the consecutive refraction of light on three separating surfaces

If the observation direction is very close to the direction of the straight line "S$_1$A", then all the angles "i_1", "r_1", "i_2" and "r_2" tend to zero and it can be assumed that:

$$AB \approx d_1 \cdot \sin i_1 \quad ; \quad CD \approx d \cdot \sin r_1 \quad ; \quad EF \approx d_2 \cdot \sin i_2 \ (14)$$

Accepting this approximation, relations (12) and (13) become:

$$p \approx q \cdot \sin r_2 \text{ and } p = d_1 \cdot \sin i_1 + d \cdot \sin r_1 + d_2 \cdot \sin i_2 \ (15)$$

Applying in turn the *Willebrord Snel van Roijen relation* , related to refraction, to the surfaces "AB", "CD" and "EF", it results:

$$\left. \begin{cases} n_1 \cdot \sin i_1 = n \cdot \sin r_1 \\ n \cdot \sin r_1 = n_2 \cdot \sin i_2 \\ n_2 \cdot \sin i_2 = n_o \cdot \sin r_2 \end{cases} \right\} \Rightarrow n_1 \cdot \sin i_1 = n_o \cdot \sin r_2 \ (16)$$

From relations (6) it follows:

$$\sin i_1 = \frac{n_o}{n_1} \cdot \sin r_2 \ ; \ \sin r_1 = \frac{n_o}{n} \cdot \sin r_2 \ ; \ \sin i_2 = \frac{n_o}{n_2} \cdot \sin r_2 \qquad (17)$$

Substituting relations (17) into relations (15), we obtain:

$$p \approx q \cdot \sin r_2 \;\; ; \;\; p \approx n_o \cdot \sin r_2 \cdot \left(\frac{d_1}{n_1} + \frac{d}{n} + \frac{d_2}{n_2} \right) \tag{18}$$

From the two relations (8) it follows:

$$p \approx n_o \cdot \left(\frac{d_1}{n_1} + \frac{d}{n} + \frac{d_2}{n_2} \right) \tag{19}$$

Since $\Box x = d_1 + d + d_2 - q$, we obtain:

$$\Delta x \approx d_1 + d + d_2 - n_o \cdot \left(\frac{d_1}{n_1} + \frac{d}{n} + \frac{d_2}{n_2} \right) \tag{20}$$

and after rearranging relation (2), the expression of displacement "$\Box$x" results:

$$\Delta x \approx d_1 \cdot \left(1 - \frac{n_o}{n_1} \right) + d \cdot \left(1 - \frac{n_o}{n} \right) + d_2 \cdot \left(1 - \frac{n_o}{n_2} \right) \tag{21}$$

By specifying relation (21) for the conditions of the experiment:

$$n_1 = n_2 = n_{bottle} \; ; \; d_1 = d_2 = d_{glass} \; ; \; n_o = n_{air} = 1$$

the general relation (21) is simplified.

For the case where the vessel is filled with the liquid sample (refractive index "n"), relation (21) reduces to form (22).

$$\Delta x_{filled} \approx 2 \cdot d_{glass} \cdot \left(1 - \frac{1}{n_{glass}} \right) + d \cdot \left(1 - \frac{1}{n} \right) \tag{22}$$

For the case when the cuvette is empty ($n_{air} = 1$), it follows:

$$\Delta x_{empty} \approx 2 \cdot d_{glass} \cdot \left(1 - \frac{1}{n_{glass}} \right) \tag{2.3}$$

Changing the position of the virtual image "S_2" ("$\Delta\Delta x$") for the measurement performed with a filled cuvette and an empty cuvette,

$$\Delta\Delta x = d \cdot \left(1 - \frac{1}{n} \right) \tag{24}$$

where "d" is the thickness of the space between the two glass walls (for the cuvette used in the experiment d = 1cm). Explaining from relation (24) the refractive index of the liquid contained in the cuvette, we obtain:

$$n = \frac{d}{d - \Delta\Delta x} \qquad (25)$$

that is, a relation of similar form to the first equality in expression (8). It is noted that it is not necessary to know the thickness of the glass walls (d_1 and d_2).

If in the system represented in Figure 8, the thicknesses "d" and "d_2" tend to zero, then the situation created corresponds to the one represented in Figure 2. In this case, the general relationship (21) takes the particular form
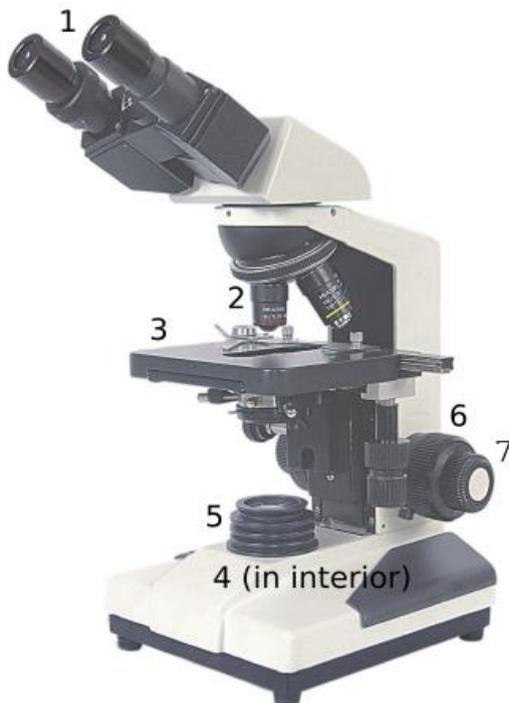
$$\Delta x \approx d_1 \cdot \left(1 - \frac{1}{n_1}\right) \qquad (26)$$

and from here the index of refraction of the glass plate ("n_1") is expressed

$$n_1 = \frac{d_1}{d_1 - \Delta x} \qquad (27)$$

through a relationship similar to (5).

EXPERIMENTAL ASSEMBLY

Ocular (1) – contains the lenses ocular; typical magnification values: 5x, 10x and 2x

☐ **Objective** (2); typical values of magnifications: 4x, 5x, 10x, 20x, 40x, 50x and 100x; interchangeable

☐ **Table** (3) – supports the test of examination

☐ **Light source** (4) – located under the table

☐ **Condenser** (5) – system of lenses and diaphragms which controls the amount of light by focusing the light

☐ **Macrovisa** (6) and **microvisa** (7) used to clarify image

EXPERIMENTAL DATA PROCESSING

pozitia(fixa) a obiectivului	pozitia(fixa) a obiectivului	pozitia(fixa) a obiectivului

(a)   (b)   (c)

imagine clara   imagine neclara   imagine clara

pozitia initiala a mesei de proba

pozitia finala a mesei de proba
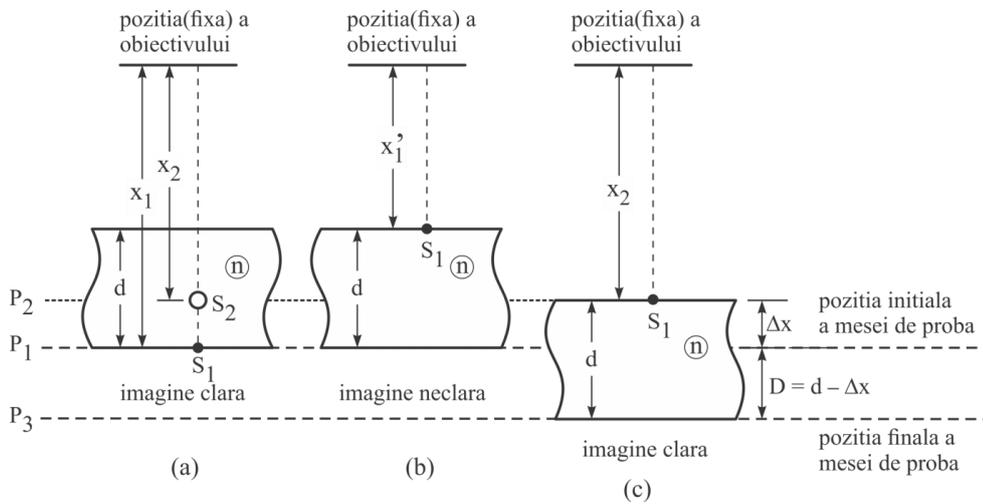
$$x' = x - d + dx$$

$$x' = x + d(n-1)$$

$$x' - x = \Delta x = d(n-1)$$

$$n = 1 + \frac{\Delta x}{d}$$

$$n = 1 + \frac{\Delta x}{d}$$

$$\Delta x = 200K + y$$

K - the number of complete rotations again

y - the number of divisions

d= 1 cm – the side of the cuvette where the liquid is introduced

1. DETERMINATION OF THE REFRACTIVE INDEX IN *TRANSPARENT SOLID MEDIUMS*

PROCEDURE FOR THE PRACTICAL WORK - STEPS

1. Calibrate the microscope

2. The conversion factor of the microscope can be determined by superimposing the image formed by the ocular microscope and the objective microscope.

3. A transparent plate with refractive index n and thickness d is placed on the microscope table. The value of d is determined and entered in the table of values.

4. An image is created on the surface of the plate

5. Read the value $\Delta x = 200 K + y$ from the microscope,

6. where K are the number of complete rotations and y are the number of divisions

7. The data are entered in the table

8. Calculations are made for the refractive index n with the following formula:

$$n = 1 + \frac{\Delta x}{d}$$

$$\Delta x = 200K + y$$

K - the number of complete rotations again

y - the number of divisions

d = 10 mm

Table 1: determination of the refractive index n for different blades of dimensions d

No.	d (mm)	K (wheel)	Y (div)	Δx (μm)	n
1					
2					
3					
4					
5					

Plot n=n(d) graphically

2. DETERMINATION OF THE REFRACTIVE INDEX IN *TRANSPARENT LIQUID MEDIUMS*

2.2 VARIATION OF REFRACTORY INDEX WITH CONCENTRATION
PROCEDURE FOR THE PRACTICAL WORK – STEPS

1. Calibrate the microscope
2. The conversion factor of the microscope can be determined by superimposing the image formed by the ocular microscope and the objective microscope.
3. A transparent plate with refractive index n and thickness d is placed on the microscope table. The value of d= 1 cm is known and entered in the table of values.
4. An image is created on the surface of the plate
5. Read the value $\Delta x = 200 \, K + y$ from the microscope,
6. where K are the number of complete rotations and y are the number of divisions, d= 1 cm – the side of the tank where the liquid is introduced
7. The data are entered in the table
8. Calculations are made for the refractive index n with the following formula:

$$n = 1 + \frac{\Delta x}{d}$$
$$\Delta x = 200K + y$$

K - the number of complete rotations again

y - the number of divisions

d= 1 cm – the side of the tank where the liquid is introduced

TABLE 2: determination of the refractive index n for the ethylene glycol solution of different concentrations

C(%)	K (wheel)	Y (div)	Δx (μm)	n
100				
90				
80				
70				
60				
50				
40				
30				
20				
10				

Plot n=n(c) graphically

2.3 VARIATION OF REFRACTIVE INDEX WITH DENSITY

PROCEDURE FOR THE PRACTICAL WORK

1. Calibrate the microscope
2. The conversion factor of the microscope can be determined by superimposing the image formed by the ocular microscope and the objective microscope.
3. A transparent plate with refractive index n and thickness d is placed on the microscope table. The value of d is known and entered in the table of values.
4. An image is created on the surface of the plate
5. value is read Δfrom the microscope.
6. The data are entered in the table
7. Calculations are made for the refractive index n with the following formula:

$$n = 1 + \frac{\Delta x}{d}$$

$$\Delta x = 200K + y$$

K - the number of complete rotations again

y - the number of divisions

d = 1 cm – the side of the tank where the liquid is introduced

TABLE 2: Determination of the refractive index for solvents of different densities

No. crt	Substance	ρ (kg/m³)	K (rotate)	y (div)	$\Delta x = 200\ K + y$ (μm)	n
1	Water (H_2O)	1000				
2	isopropyl alcohol	786				
3	ethyl alcohol (C_2H_6O)	789				
4	methanol (CH_4O)	1015				
5	aniline (C_6H_7H)	1010				
6	acetic acid $C_2H_4O_2$	1050				
7	DMSO	1100				
8	ethylene glycol $C_2H_4O_2$	1110				
9	Glycerin	1260				

It is drawn graphically n=n(ρ)

DETERMINATION OF THE FOCAL LENGTH OF LENSES USING THE BESSEL METHOD

THEORETICAL INTRODUCTION

The optical behavior of thin lenses (where the thickness is much smaller than the diameter) can be characterized by the value of the focal length "f". If it is limited to the incident rays close to the main optical axis (paraxial rays), then it can be admitted that the focal length (the distance from the optical center of the lens to the point where the emerging ray intersects the main optical axis) does not depend on the distance between the emerging ray and the main optical axis of the lens.

The optical behavior of a lens is realized by its ability to create the image of an object. If the image is formed at the intersection of the real emergent rays, then the image is "real". If the image created by the lens is formed at the intersection of the extension of the real emergent rays, then the image is "virtual". Only a real image can be projected on a screen.

In the case of a real object, the distance at which the image is formed, as well as the nature of the image (real or virtual) depends on the focal length of the lens.

The location of the object and image relative to the lens is indicated by the "coordinates" of the object and image in relation to a reference system that has, as one of the coordinate axes ("x" axis), the main optical axis of the lens. The positive direction of the "x" axis is determined by the direction of the light ray starting from the real object. The origin of the "x" axis is chosen in the optical center of the lens. Figure 1 illustrates the sign of the "x_o" and "x_i" coordinates of the respective object and image.
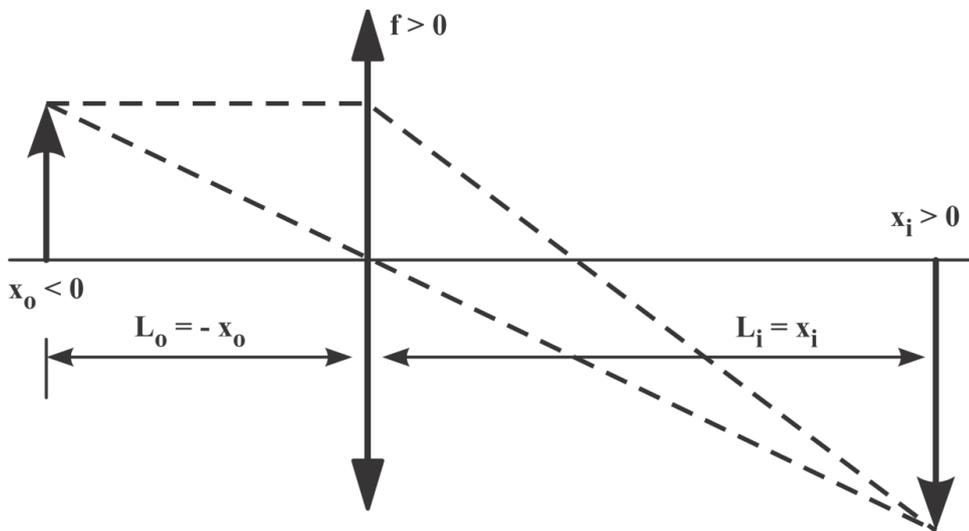
Fig.   1   Sign   convention   regarding object and image coordinates in the case of a converging lens

The focal length of a converging lens is considered positive, while the focal length of a diverging lens is negative. In the example illustrated in Figure 1, the "x_o" coordinate of the object is negative ($x_o < 0$), and that of the place where the real image is formed, "x_i", is positive ($x_i > 0$). If reference is made to the lens-object ("L_o") and lens-image ("L_o") "distances", these quantities are defined as positive, so $L_o = -x_o$ while $L_i = x_i$. (it is important to distinguish the notions of "coordinate" and "distance").

For a position of the lens, for which the clear image of an object (located at the "x_o" coordinate) is formed on a screen (located at the "x_i" coordinate), the relation of conjugate points (1) is respected.

$$\frac{1}{f} = \frac{1}{x_i} - \frac{1}{x_o} \, (1)$$

If the distance between the object and the screen (where the image of the object is formed) is "D", this can be expressed by relation (2).

$$D = L_o + L_i = (-x_o) + x_i \, (3)$$

"x_o" and "x_i" can be expressed as follows:

$$x_i \cdot (-x_o) = D \cdot f \, (4)$$

Relations (3) and (4) respectively express the sum and the product of two quantities ("$-x_o$" and "x_i") depending on the distance "D" and the focal distance "f". It is possible to write an equation of

the second degree in relation to the unknown "x", which has, as roots, precisely the quantities "$-x_o$" and "x_i":

$$x^2 - D \cdot x + D \cdot f = 0 \qquad (5)$$

If a certain relationship is observed between the quantities "D" and "f" (relation (8)), then the second degree equation has two distinct roots, "x_A" and "x_B":

$$x_A = \frac{D + \sqrt{D^2 - 4 \cdot D \cdot f}}{2}$$
$$\qquad (6)$$
$$x_B = \frac{D - \sqrt{D^2 - 4 \cdot D \cdot f}}{2}$$

The condition for the roots (6) to be real and disjoint is for the discriminant to be positive, so

$$\sqrt{D^2 - 4 \cdot D \cdot f} > 0 \qquad (7)$$

The relation (7) is equivalent to the relation (8)

$$D > 4 \cdot f \qquad (8)$$

which expresses the condition that there are two different positions of the lens for which a clear image of the object is formed at the distance "D" from the object.

Numerous methods are known for experimentally determining the focal length of a lens. An ingenious method is known as " *Bessel 's method* ". To understand the essence of this method, we will consider an optical assembly consisting of a thin converging lens, a real object and the real image of the object projected on a screen. If the object-screen distance is kept constant, two positions of the lens can be found, between the object and the screen, for which the clear image of the object is formed on the screen (Figure 2). In one of the positions of the lens, the enlarged image of the object is formed on the screen (Figure 2-A), and in the other position of the lens, the actual reduced image of the object is obtained (Figure 2-B). The coordinate of the object in the first case is "x_{o1}" ($x_{o1} < 0$), and that of the image is "x_{i1}" ($x_{i1} > 0$). The coordinate of the object in the second case is "x_{o2}" ($x_{o2} < 0$), and that of the image is "x_{i2}" ($x_{i2} > 0$). In the first case, the lens-object distance is $L_{o1} = -x_o$, and the lens-image distance is $L_{i1} = x_{i1}$. For the second position of the lens (Figure 2-B) we have $L_{o2} = -x_{o2}$ and $L_{i2} = x_{i2}$.
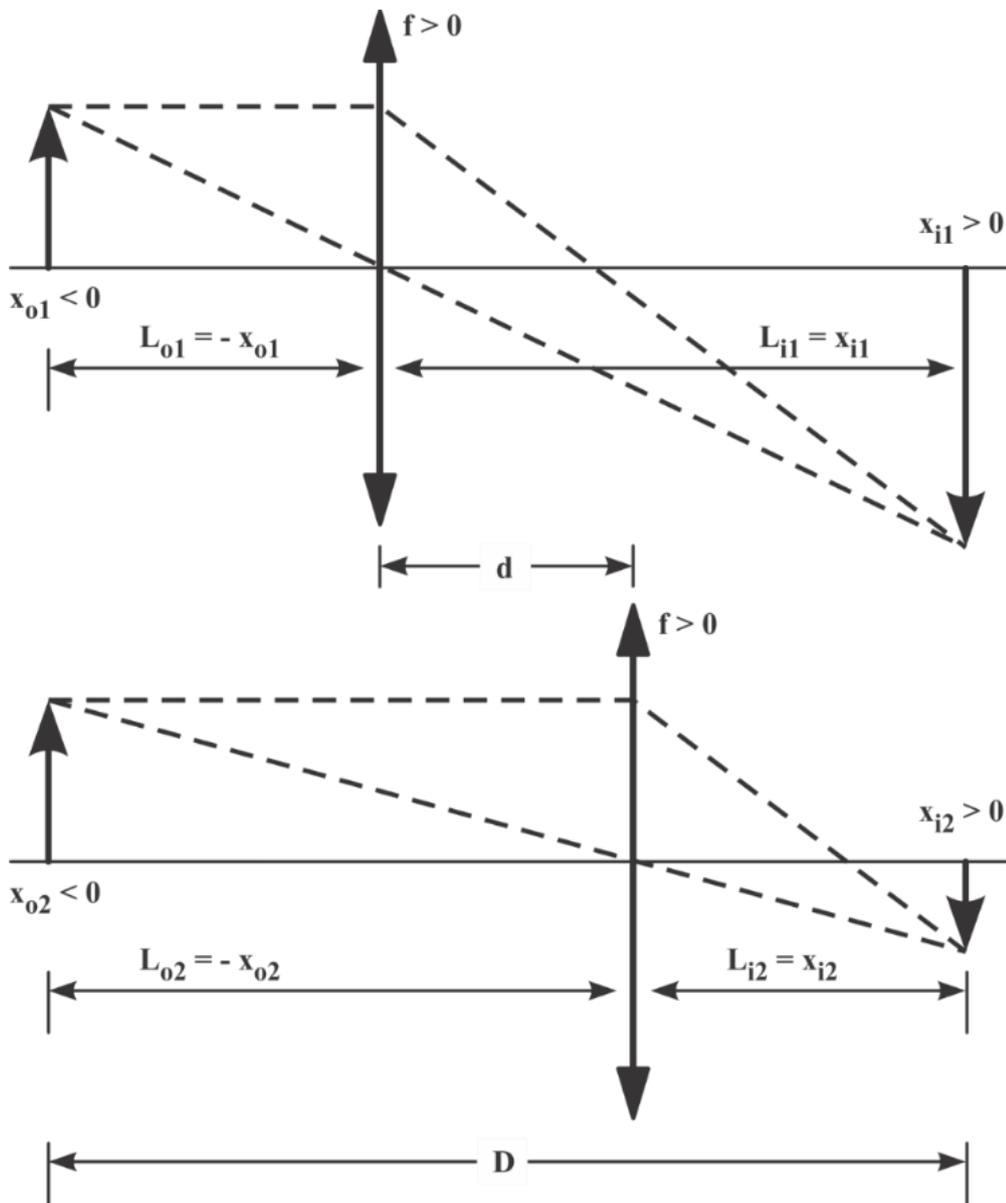
Fig. 2 *Bessel's* **method for determining the focal length of a lens**

The coordinates of the location of the object and the image for the two positions of the lens, at which the clear image of the object is obtained, are:

$$-x_{o1} = \frac{D - \sqrt{D^2 - 4 \cdot D \cdot f}}{2} \quad ; \quad -x_{o2} = \frac{D + \sqrt{D^2 - 4 \cdot D \cdot f}}{2}$$

$$x_{i1} = \frac{D + \sqrt{D^2 - 4 \cdot D \cdot f}}{2} \quad ; \quad x_{i2} = \frac{D - \sqrt{D^2 - 4 \cdot D \cdot f}}{2} \qquad (9)$$

The distance "d" between the positions of the lens for which the real and clear image of the object is obtained, is (Figure 2):

$$d = D - L_{o1} - L_{i2} = D - (-x_{o1}) - x_{i2} \quad (10)$$

Substituting in relation (1) the expressions found for the coordinates "x_{o1}", "x_{i1}", "x_{o2}" and "x_{i2}", we obtain:

$$d = D - \frac{D - \sqrt{D^2 - 4 \cdot D \cdot f}}{2} - \frac{D - \sqrt{D^2 - 4 \cdot D \cdot f}}{2} \quad (11)$$

from which it follows, for the distance "d":

$$d = \sqrt{D^2 - 4 \cdot D \cdot f} \quad (12)$$

The focal length of the lens can be explained from relation (12):

$$f = \frac{D^2 - d^2}{4 \cdot D} \quad (13)$$

Practically, the distance between the two positions of the lens for which the clear image of the object is formed is determined and the focal distance is calculated with relation (13).

PROCEDURE

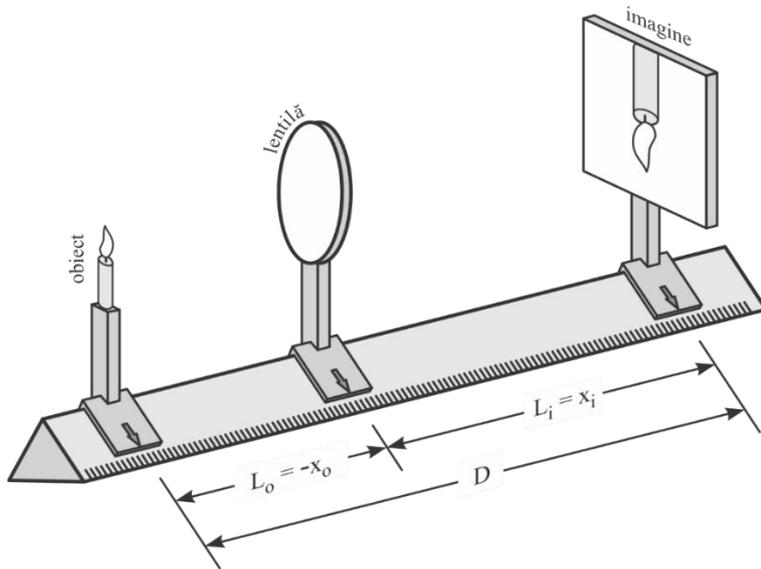Figure 3 represents a setup for performing measurements.

Fig. 3 The optical assembly for determining the focal distance

Five determinations are performed, each with a different value of the distance "D" and - implicitly - resulting in other "d" values. For each pair of "D" and "d" values, the focal distance is calculated with relation (13). The average of the "f" values and the standard deviation of the individual values around the average value are determined.

The data goes into a table according to the following model.

Table 1 Results

no.	D (mm)	L_{o1} (mm)	L_{i1} (mm)	L_{o2} (mm)	L_{i3} (mm)	d (mm)	f (mm)
1							
2							
3							
4							
5							

BIBLIOGRAPHY

1. Nicolov M, Szabadai Z., *Physique Pharmaceutique Travaux Pratiques*, Ed. V.Babes, **2016.,**

2. ****, Physics Compendium, Scientific and Encyclopedic Ed., Bucharest, 1988.*

3. ****, Romanian Pharmacopoeia, 10th edition* , Bucharest Medical Publishing House, 2012

4. Aczel O., M. Erdei, *Guide to practical works on mechanics and acoustics* , Timisoara University Press, 1987.

5. Agner T, *Susceptibility of atopic dermatitis patients to irritant dermatitis caused by sodium lauryl sulphate".* Acta Derm. Venereol. , (1991), 71 (4): 296–300

6. *Anati, DA (1999). "The salinity of hypersaline brines: concepts and misconceptions". International J. Salt Lake. Res. 8 : 55–70. doi:10.1007/bf02442137.*

7. Atekwanaa, Eliot A.; Atekwanaa, Estella A.; Roweb, Rebecca S.; Werkema Jr., D. Dale; Legalld, Franklyn D , *"The relationship of total dissolved solids measurements to bulk electrical conductivity in an aquifer contaminated with hydrocarbon" (PDF) . Journal of Applied Geophysics. Elsevier. . (2004), 56 (4): 281–294. two : 10.1016/j.jappgeo.2004.08.003*

8. Birau O., D.Andru Vangheli, *Molecular Physics and heat – practical works* , Timisoara University Press, 1985

9. Britannica Educational Publishing 2012 , p. 94, p. 95.

10. International Bureau of Weights and Measures 2006 , pp. 29-30

11. Civera David, *« Les transistors-lasers et la loi de Kirchhoff »* [archive], tom's HARDWARE, 06.02.2015.

12. Cretu T., *Physics - Theory and Problems,* Technical Ed. Bucharest, 1991.

13. Dahl, E. *(1956). "Ecological salinity boundaries in poikilohaline waters". Oikos. 7 (1): 1–21. doi:10.2307/3564981.*

14. DeZuane, John , *Handbook of Drinking Water Quality (2nd ed.). (1997). John Wiley and Sons.*

15. Eilers, JM; Sullivan, TJ; Hurley, KC The most dilute lake in the world? . *Hydrobiology. (1990). 199 : 1–6.*

16. Gibney E. How many yottabytes in a quettabyte? Extreme numbers get new names. Nature News. 18 Nov 2022.

17. Greiner, Walter; Neise, Ludwig; Stöcker Horst , 1997, *Thermodynamics and Statistical Mechanics* , 2nd printing ed.. Springer. p. 9.

18. Holton Gerald James, *Physics, the Human Adventure: From Copernicus to Einstein and Beyond* . Rutgers University Press., 2001, pp. 270

19. Homemade Saline Nose Drops Archived 2012-11-27 at the Wayback Machine at Food.com

20. Hopes To Hold The Salt, And Instead Break Out Beet Juice And Beer To Keep Roads Clear . www.wbur.org .

21. Hrianca I., I. Muscutariu, N. Ohanovici, M. Prosteanu, I.Pintea, *Guide for practical laboratory works in electricity, magnetism and electrotechnics* , Typografia Univ. from Timisoara, 1985.

22. Hristev A., *Mechanics and Acoustics* , Bucharest Didactic Publishing House, 1984.

23. *IOC, SCOR, and IAPSO (2010). The international thermodynamic equation of seawater – 2010: Calculation and use of thermodynamic properties. Intergovernmental Oceanographic Commission, UNESCO (English). pp. 196 pp.*

24. Jones, Alonzo . *"Intranasal Xylitol, Recurrent Otitis Media, and Asthma: Report of Three Cases*" . Nasal xylitol, from Clinical Practice of Alternative Medicine. Alonzo H. Jones, DO. Archived from the original on May 8, 2014 . Retrieved 7 May 2014 .*

25. Kalcic, Maria, Turowski, Mark; Hall, *Callie (2010-12-22). Stennis Space Center Salinity Drifter Project. A Collaborative Project with Hancock High School, Kiln, MS. Stennis Space Center Salinity Drifter Project. NTRS . Retrieved 2011-06-16 .*

26. Kwan A., JM Dudley, E. Lantz, Who really discovered Snell's law?, *Physics World,* 15 (2002): p.64-84.

27. Ledeti AV, Axente C., *Qualitative Analytical Chemistry* , Course Notes, Ed. Mirton, 2018

28. Levine IN, *Physical Chemistry,* University of Brooklyn: McGraw-Hill., 1978, p12 gives the original definition., p400 – Historical background of Boyle's law relation to Kinetic Theory, p11 notes that deviations occur with high pressures and temperatures, J. Appl Physiol 98: 31-39, 2005.

29. Marincu BN, Neagu M., Neagu A., *Laboratory Works in Biophysics* , second edition, Ed. Eurobit, Timisoara, 2013.

30. Nagy I., *Guide to practical biophysics works for students of the Faculty of Dentistry* , lito IMT, 1982.

31. Nanfang Yu, Patrice Genevet, Mikhail Kats, Francesco Aieta, Jean-Philippe Tetienne, Federico Capasso, Zeno Gaburro, *Light Propagation with Phase Discontinuities: Generalized Laws of Reflection and Refraction* , Science, (2011), 334, p.333.

32. Nicoara I, A.Lucaci, A. Greuceanu, E. Preda, *Laboratory instructor - optics* , Timisoara University Press, 1990.

33. Nicolov M., *Physics–Experimental Applications,* Ed. Gutemberg, Arad, 2002.

34. O'Connell OJ, O'Farrell C, Harrison MJ, Eustace JA, Henry MT, Plant BJ *(2011). "Nebulized hypertonic saline via positive expiratory pressure versus via jet nebulizer in patients with severe cystic fibrosis". I breathe Which.* **56** *(6): 771–5. two : 10.4187/respcare.00866* .

35. Pawlowicz, R., Key Physical Variables in the Ocean: Temperature, Salinity, and Density. *Nature Education Knowledge. (2013). 4 (4): 13.*

36. Plăcințeanu I., *Theory of measurement errors and the method of least squares* , Bucharest Technical Publishing House, 1957.

37. Principi T, Komar L , A critical review of "a randomized trial of nebulized 3% hypertonic saline with epinephrine in the treatment of acute bronchiolitis in the emergency department .. *J Popul Ther Clin Pharmacol. (2011).* **18** *(2): e273 -4. PMID 21633141* .

38. Prough, DS; Bidani, A *(1999). "Hyperchloremic metabolic acidosis is a predictable consequence of intraoperative infusion of 0.9% saline". Anesthesiology.* **90** *(5): 1247–1249. two : 10.1097/00000542-199905000-00003* .

39. Rashed R. "A Pioneer in Anaclastics: Ibn Sahl on Burning Mirrors and Lenses", *Isis* 81 (1990): pp. 464–91.

40. Reeves EP *et al* (2011). " Nebulized hypertonic saline decreases IL-8 in sputum of patients with cystic fibrosis. " Am J Respir Crit Care Med. 2011 Jun 1; **183** (11):1517-23. two: 10.1164/rccm.201101-0072OC .

41. *Total Dissolved Solids (TDS): EPA Method 160.1 (Gravimetric, Dried at 180 deg. C) , Washington, DC: US Environmental Protection Agency (EPA). 1999-11-16.*

42. Vivian McAlister, Karen EA Burns, Tammy Znajda, and Brian Church. "Hypertonic Saline for Peri-operative Fluid Management" Cochrane Database of Systematic Reviews.1 (2010): CD005576 Available at: *"Archived copy"* . *Archived from the original on 2011-07-06* . *Retrieved 2019-04-14* .

43. West John B. *Robert Boyle's landmark book of 1660 with the first experiments on rarified air* , Journal of Applied Physiology, 2005, Vol. 98 no. 1, pp. 31-39.

44. Venice system (1959). The final resolution of the symposium on the classification of brackish waters. *Archo Oceanogr. Limnol.* , 11 (suppl): 243–248.

45. Agnieszka Kolodziejczak-Radzimska, Marlena Samuel, Dominik Paukszta , Adam Piasecki, Teofil Jesionowski Synthesis Of Hydroxyapatite In The Presence Of Anionic Surfactant, Physicochem. Probl. Miner. Process. 50(1), 2014, 225−236

46. J L Oulton, Systems of measurement: their development and use in medicine, Can Anaesth Soc J, 1976 Jul;23(4):345-56., doi: 10.1007/BF03005914.

47. https://www.cuemath.com/measurement/system-of-measurement/

48. https://www.britannica.com/science/measurement-system