Theme 3. Physics principles of characteristics quantification and classification of human body fluids in accordance with real fluids Hydrodynamics basics. Hydrodynamics model describing and quantifying blood circulation in human cardiovascular system

Problem
Objective identification and quantitative evaluation of factors influence extents on the functional state of the human cardiovascular system

Attendance prerequisite checklist. Note! Answer in writing to perform

1. Define: pressure ________________________________ ____________
definition formula

2. Draw diagram to illustrate statements:
2.1. U-tube manometer can be used to compare pressures
2.2. A mercury barometer balances a column of mercury against the atmosphere
3. Explain and support by formula phenomenon: fluid pressure variation with depth when fluid density and gravitational field strength are constant
4. List simplifications identifying Physics model: an ideal fluid
5. Define and support by illustration: streamlines, lines of motion
6. Derive: the equation of continuity for an ideal fluid flowing through a frictionless pipe that becomes narrower and narrower
7. What is the Bernoulli effect?
8. Derive: the Bernoulli equation for fluid horizontal streamline
9. Derive: the Bernoulli equation for fluid not horizontal streamline
10. Define: a fluid viscosity________________________________ ____________;
definition symbol, measuring unit

a fluid kinematic viscosity________________________________ ____________;
definition formula, measuring unit

the Reynolds number ________________________________ ____________
definition formula, measuring unit

Information resources
1. https://slideplayer.com/slide/4179880/
2. http://aplusphysics.com/courses/honors/fluids/fluids_intro.html

Introduction

Hemodynamics is the study of the factors determining blood flow and blood pressure in the circulatory system.

Pressure. Pressure is the force per unit area and is usually expressed in terms of the height of a column of fluid that the pressure will support. The common units of pressure are mm Hg. Pressure gradient (ΔP) is the difference in total energy (or pressure) between two locations within the system. Fluid always flows from an area of higher pressure to one of the lower pressure; in other words, water, or blood, always flows downhill.

The total energy at any point equals the sum of the potential energy (pressure) and the kinetic energy. Kinetic energy is the momentum that blood gains because its mass (m) and velocity (v): kinetic energy = $mv^2/2$.Potential energy includes both **hydrostatic** and **lateral** pressure components.

Hydrostatic pressure (P_h) is caused by the effects of gravity on a fluid-filled system. Because of gravity, fluid has weight that generates force. The force is proportional to the vertical height of the column of the fluid exposed to gravitational conditions, for example the pressure at the bottom of a lake is higher than it is at the surface: $\mathbf{P_h = \rho \cdot h \cdot g}$, where **ρ** is density of the fluid **h** is the height of the fluid column above or below a reference level **g** is the gravitational constant.

In the human vascular system, hydrostatic pressure occurs as a result of the weight of the blood in the vessels. Assuming that in upright person the foot is 150cm below the heart, the pressure in the vessels of the foot would be 150 cm H_2O or 110 mm Hg higher than the pressure at the root of the aorta. In a supine subject, the hydrostatic effect is eliminated because the entire cardiovascular system is at essentially the same horizontal level. Therefore, it is important to eliminate the hydrostatic effect by measuring vascular pressures at the zero reference level, which is equivalent to the level of the right atrium.

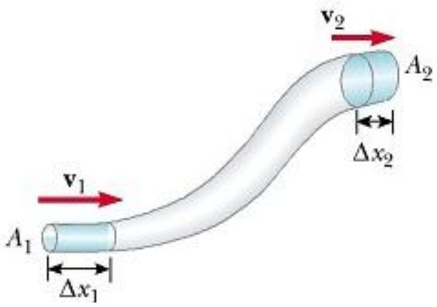
Both arteries and veins are affected equally by the hydrostatic column of blood so that the pressure gradient between arteries and veins is not altered.

Lateral (static) pressure represents the pressure in the cardiovascular system that is usually measured with a gauge after eliminating the hydrostatic pressure effect. It does not include kinetic energy.

There is a progressive loss in the total energy as the fluid flows through the pipe. The progressive loss of energy along the pipe when there is flow is a result of frictional or resistive factors. The narrowed section of the pipe is a high-resistance segment. The greater resistance leads to a greater loss of total energy per unit length of the pipe.

Flow. Consider a situation where an incompressible fluid completely fills a channel such as a pipe or an artery. Then if more fluid enters one end of the channel, an equal amount must leave the other end. This principle, which can be put into various mathematical forms, is called the **equation of continuity**. It will be quite useful in many of our discussions. Quantitative statements about fluid flow are made in terms of the **flow rate Q, the volume of fluid flowing past a point in channel per unit time: $Q = \Delta V/\Delta t$**

The **S.I. units** of flow rate are **cubic meters per second (m^3/s)**. If an incompressible fluid enters one end of a channel at a rate $\mathbf{Q_1}$, it must leave the other end at a rate $\mathbf{Q_2}$, which is the same. Thus the **equation of continuity** can be written as $\mathbf{Q_1 = Q_2}$.



This can be put in more useful form if all the fluid in the channel is moving with a uniform velocity **v**. Consider a section of a tube with a constant cross-sectional area **A**. In a time $\mathbf{\Delta t}$, the fluid moves a distance $\mathbf{\Delta x = v \cdot \Delta t}$, and a volume of fluid leaving the tube is $\mathbf{\Delta V = A \cdot \Delta x = A \cdot v \cdot \Delta t}$. Alternatively, $\mathbf{\Delta V}$ equals the flow rate **Q** times the time interval $\mathbf{\Delta t}$, or $\mathbf{\Delta V = Q \cdot \Delta t}$. Comparing these expressions for $\mathbf{\Delta V}$, gives $\mathbf{Q = A \cdot v}$.

Figure 1

Flow rate Q equals the cross-sectional area of the channel A times the velocity of the fluid v.

For a channel whose cross section changes from $\mathbf{A_1}$ to $\mathbf{A_2}$, this result together with $\mathbf{Q_1 = Q_2}$ gives another form of the equation of continuity, $\mathbf{A_1 \cdot v_1 = A_2 \cdot v_2}$.

The product of the cross-sectional area and the velocity of the fluid are constant.

Usually the flow velocity is not uniform in a channel. For example, the fluid near the walls of the channel is moving at a lower speed than the fluid near its center. The equation of continuity still holds for such cases if it is written in terms of the average flow velocity v. In any system arranged in series, the flow though each vascular component must be equal to the flow through every other, unless one segment becomes progressively distended. The cross-sectional are of various vascular segments varies in the body. To keep the flow rate equal the velocity of flow must vary inversely with the cross-sectional area for each vascular segment.

Viscosity. Viscosity is readily defined by considering a simple experiment. The figure 2 shows two flat plates separated by a thin fluid layer. If a lower plate is held fixed, a force is required to move the upper plate at a constant speed. This force is needed to overcome the viscous forces due to the liquid and is greater for a highly viscous fluid, such as molasses, than for a less viscous fluid, such as water.

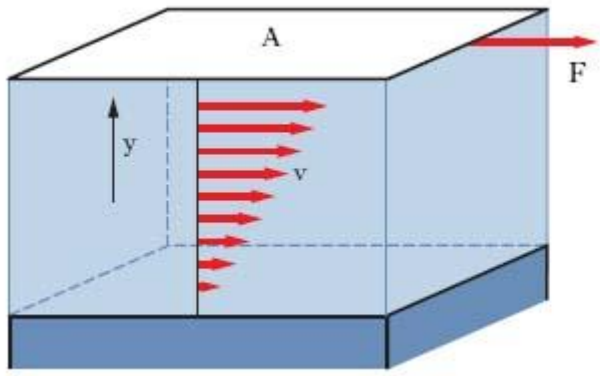


Figure 2

The force **F** is observed to be proportional to the area of the plates **A** and to the velocity change in the fluid layer **Δv** and inversely proportional to the fluid layers separation **Δy**: $F = \eta \cdot A \cdot \Delta v/\Delta y$

The ratio **Δv/Δy** is the **velocity gradient**, and the proportionality constant **η** is the fluid **viscosity**. The larger the viscosity, the larger the force needed to move the plate at a constant speed.

Because viscous forces are usually small, fluids are often used as lubricants to reduce friction.

Viscosity is the internal friction to the flow in a fluid. Blood is a complex fluid because of the presence of the cells and proteins, and its viscosity varies as a function of the flow rate and the vessel size.

Hematocrit is percentage of the blood that is occupied by red blood cells. Hematocrit is the major factor that changes the viscosity. The normal hematocrit for men is 40 - 45,whereas normal hematocrit for women is 35 - 40. Blood with a hematocrit of 40 has a viscosity that is approximately three times that of water. Blood with a hematocrit of 60 has approximately twice the viscosity of blood with a hematocrit of 40.

An increase in hematocrit requires a greater pressure to produce a given flow rate because of the increased viscosity.

Laminar flow. The fluid in contact with the moving plate has the same velocity as the plate. The fluid layer just below moves slightly more slowly, and each successive layer lags a bit more. The layer next to the stationary plate is at rest. This layered structure or **laminar flow** is the kind of streamline flow characteristic of viscous fluids at low velocities.

Many interesting applications of the physics of fluids involve laminar flow in cylindrical tubes such as human arteries. In this section, we consider a formula for the flow rate called **Poisuille's law**. It was first discovered experimentally by a physician, Jean Louis Marie Poisuille (1799-1869), who was investigating the flow in blood vessels. **Poisuille's law** relates the flow rate to the viscosity of the fluid, the pressure drop, and the radius and length of the tube.

Consider a fluid moving through a tube slowly enough so that the flow is laminar. Just as in the case of the two flat surfaces discussed, the fluid in contact with the wall of the tube clings to it and is at rest. The thin, cylindrical layer of fluid adjacent to this stationary layer moves very slowly, and successive thin layer move at increasing velocities. Hence the fluid at the center has the maximum velocity, $\mathbf{v_{max}}$. It is found that the average velocity $\bar{v}$ is half this, so $\bar{v} = 1/2\, v_{max}$, and from continuity equation the flow rate is $Q = A \cdot \bar{v} = 1/2\, v_{max}$.

In a horizontal tube with a constant cross section, the equation of continuity implies that the average velocity $\bar{v}$ remains the same, since $A\,\bar{v}$ must be constant. Nevertheless, the pressure drops as the fluid moves along the tube. This is because work is done against the viscous forces.

The pressure drop $\Delta P = P_1 - P_2$ along the horizontal tube of constant cross section is proportional to the viscous forces and hence to the average velocity of the fluid. Also, the pressure drop is proportional to the length **l** of the tube, since the work done against the viscous forces is proportional to the displacement. Thus, $\Delta P \propto \bar{v} \cdot l$ or $\bar{v} \propto \Delta P/l$. The **average velocity** $\bar{v}$ **and the flow rate** $Q = A \cdot \bar{v}$ **of the fluid are proportional to the pressure gradient ΔP/l.**

The average velocity depends on other factors in addition to the pressure gradient. It is easier to pump fluid through a wide tube than through a narrow one, and it is easier to pump a relatively nonviscous fluid than a highly viscous fluid. Thus, $\bar{v}$ must also depend on the tube radius **R** and the viscosity **η**. An exact expression for $\bar{v}$ can be found by considering the forces acting on each thin cylindrical fluid layer. However, this approach requires mathematics beyond the level of this course. Accordingly, we obtain the main features of the result using a technique called **dimensional analysis**. The analysis shows that the average velocity and the flow rate can be written as

$$\bar{v} = \Delta P R^2 / 8\eta l$$

$$Q = \Delta P \pi r^4 / 8\eta L$$

The formula for **Q** is called **Poisuille's law.** Poisuille's law is valid for straight rigid tubes that contain a fluid with constant flow rate and constant viscosity. Therefore, it is not strictly accurate in regard to vascular system. Nevertheless, important principles relating flow, pressure gradient and resistance remain applicable. **Resistance** is defined as $R = 8\eta L/\pi r^4$. Poisuille's law may be simplified to a relationship analogous to Ohm's law: $Q = \Delta P/R$. An increase in pressure gradient causes an increase in blood flow, whereas an increase in resistance causes a decrease in blood flow.

The major factors that determine the resistance to blood flow are the radius of the vessels and viscosity of the blood. Because the radius (**r**) is raised to the fourth power, any change in the radius produces a change in resistance that markedly alters the flow.

Turbulent flow. Poisuille's law hold true only for laminar flow. However, often the flow is not laminar, but **turbulent**. It is much harder to analyze turbulent flow than laminar flow. For example, Poisuille's law for the laminar flow rate in a tube has no analog for turbulent flow. In practice turbulent flow is treated using a variety of empirical rules and relationships developed from extensive experimental studies.

In order to determine whether the flow is laminar and thus whether Poisuille's law can be applied, we can make use of these empirical rules. It states that the value of a dimensionless quantity called the **Reynolds number,** N_R, determines whether the flow is turbulent, or laminar. Consider a fluid of viscosity η and density ρ. If it is flowing in a tube of radius **r** and has an average velocity $\bar{v}$, then the Reynolds number is defined by $N_R = 2\cdot\rho\cdot\bar{v}\cdot r/\eta$. In tubes it is found experimentally that if $N_R < 2000$, flow is **laminar**; if $N_R > 3000$, flow is **turbulent**, if $2000 < N_R < 3000$, flow is **unstable**, that is, may change from laminar to turbulent, or vice versa. In turbulent flow, some energy is dissipated as sound and some as heat. The noise associated with turbulent flow in arteries facilitates blood pressure measurements and it makes possible the detection of some heart abnormalities.

Pressure is defined as the force per unit area, so its unit in SI is $N\ m^2$**,** which is given the name **pascal (Pa)**. In discussions of the circulatory system, it is convenient to measure pressures in **kilopascals, kPa,** where 1 kPa = 10^3 Pa. The **torr** or the **millimeter of mercury (mm Hg)** is used in medicine and physiology.
1 atmosphere = 1 atm = 1.013×10^5 Pa = 760 torr = 760 mm Hg.

Since the upper arm of a human is at about the same level as the heart, blood pressure measurements made there give values close to those near the heart. Also, the fact that the upper arm contains a single bone makes the brachial artery located there easy to compress. The pressure needed to do this is measured with the familiar instrument called the **sphygmomanometer**, which is convenient and painless.

During a complete pumping cycle, the pressure in the heart and circulatory system goes though both a maximum (as a blood is pumped from the heart) and a minimum (as a heart relaxes and fills with blood returned from the veins). The sphygmomanometer is used to measure these extreme pressures. Its use relies on the fact that blood flow in the arteries is not always streamline. When the arteries are constricted and the blood flow rate is large, the flow becomes turbulent. This turbulent flow is noisy and can be heard with a stethoscope.

The sphygmomanometer consists of inflatable cuff and a manometer. The cuff is strapped round in the arm at heart height. Air is pumped in manually until a pressure of 200 mm Hg is applied to the brachial artery, so that it obstructs the blood flow. When a stethoscope is placed on the artery below this point no sound is heard. The pressure is slowly reduced by releasing air until the blood begins to spurt through a small opening in the artery, when it is at maximum pressure. This causes turbulence and the sound, called **Korotkoff sound**, can be heard in the stethoscope. This highest, systolic pressure can than be read on the manometer. These sounds continue as the pressure falls, until the blood vessel remains open throughout the pulse period. This means that the applied pressure has now fallen as low as the lowest, diastolic pressure. So a second manometer reading is taken when the Korotkoff sounds cease. The technique of listening for the sound is called **auscultation** (fig. 3)**.**

Blood pressure is usually presented as systolic/diastolic ratios. Typical readings for a resting healthy adult are about 120/80 in torr and 16/11 in kPa. The borderline for high blood pressure (hypertension) is usually defined to be 140/90 in torr and 19/12 in kPa. Pressures appreciably above that level require medical attention, because prolonged high blood pressure can lead to serious damage of the heart or other organs before a person is aware of any problem. Increasing emphasis has been placed in recent years on mass screenings to discover people with undetected high blood pressure.

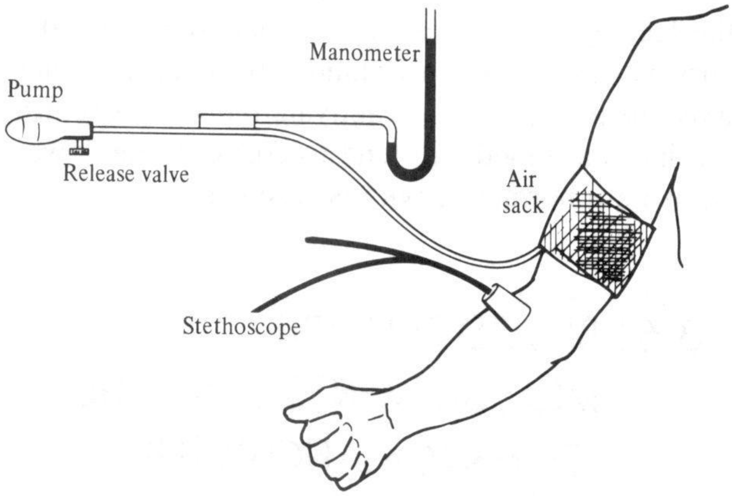


Figure 3

Invasive measurements. Because of the shortcomings of the indirect methods it is often necessary to introduce a transducer directly into the bloodstream to measure pressure. This is done by inserting a catheter into the appropriate vessel percutaneously, that is through the skin (fig. 4). The catheter is a plastic tube of a suitable diameter to fit into the vessel and to carry the transducer. It can be passed via the superficial (near the surface) veins or arteries, throughout the circulatory system and into the heart. The transducer can either be ready mounted at the end of the catheter or introduced while it is in place. An alternative method which is used when monitoring over a long period, or at a distance is required is to implant the transducer surgically at the site to be measured.

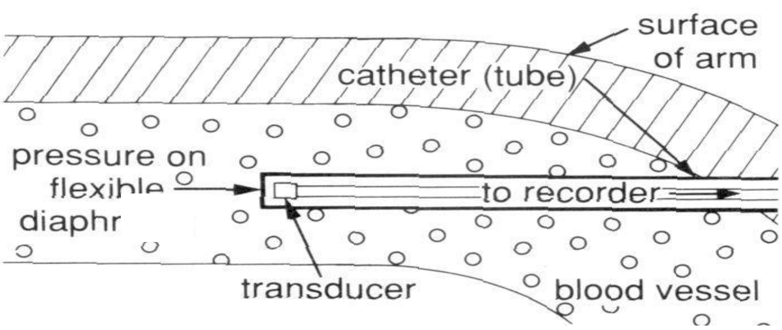


Figure 4

Lab test

Investigation and quantitative estimation of fluids compositional structures influence on fluids hydrodynamic parameters via capillary viscometry

Problem

Compositional structures determinate main biological fluids function as substances transport and consequently functional states of human organs

Equipment

Capillary viscometer ВПЖ-2, water solutions, stopwatch, calculator

Attendance prerequisite checklist. Note! Answer in writing to perform

1. Define liquids kinds of hydrodynamics classification.
2. Explain physical phenomena of liquid viscosity.
3. Formulate and explain Newton's law of viscous liquids movement.
4. Define types of viscous liquids movement into cylindrical tubes. How does Reynolds number rating that types?
5. Define Poiseuille law. What type of liquid flow does Poiseuille law describe?
6. List liquids viscometry methods.
7. List human liquids.
8. What is main blood function?
9. What are human blood structures?

Information resources

1. http://www.physics-help.info/physicsguide/mechanics/fluid_mechanics.shtml
2. http://www.wikilectures.eu/w/Ideal_fluid
3. https://www.quora.com/Are-ideal-fluids-viscous-in-nature
4. http://hyperphysics.phy-astr.gsu.edu/hbase/ppois.html
5. http://www.qclabequipment.com/VISCOSITY.html
6. https://opentextbc.ca/anatomyandphysiology/chapter/26-1-body-fluids-and-fluid-compartments/

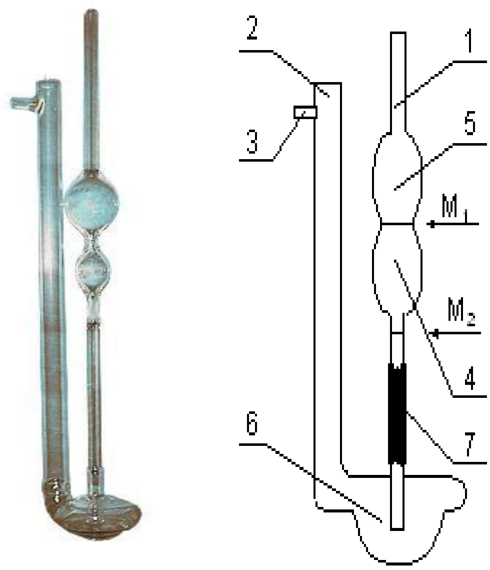
Introduction

Key concept and equipment of capillary viscometry

Viscosity is an important fluid property when analyzing liquid behavior and fluid motion near solid boundaries. Viscosity of a fluid is a measure of its resistance to gradual deformation by shear stress or tensile stress. The shear resistance in a fluid is caused by inter molecular friction exerted when layers of fluid attempt to slide by one another.

The viscometer ВПЖ-2 is used for transparent liquids kinematic viscosity coefficient measurements at positive ambient temperature. The arrangement of vertical liquid flow avoiding hydrostatics pressure influence determines this viscometer type greater accuracy.

The key concept of capillary viscometry is the time measurement of liquid flow through thin capillary at constant pressure and temperature.



a b

Figure 5

The viscometer ВПЖ-2 is a glass U-tube (fig. 5a). The capillary of 0.39 mm diameter (7 fig. 5b) is built in U-tube part 1 (fig. 5b). To determinate a kinematic viscosity coefficient the time t of liquid flow from reservoir 4 (fig.5b) between marks M_1 and M_2 through the capillary 7 (fig.5b) is measured. The time t, s taken for the fluid to flow through the capillary tube can be converted directly to a kinematic viscosity coefficient ν using a simple calibration constant K, mm^2/s^2 provided for each tube via formula: $\nu = Kt$, mm^2/s (1).

The SI unit for kinematic viscosity coefficient is square meters per second (m^2/s). However, due to the viscosity values of most common fluids, square centimeters per second (cm^2/s) is used more often. Kinematic viscosity coefficient is often measured in the CGS unit centistokes (cSt), which is equivalent to 0.01 stokes (St). Note that 1 cm^2/s is equivalent to 100 cSt.

The ВПЖ-2 kinematic viscosity coefficients measurement range is of (1.0 – 5.0) mm^2/s.

A kinematic viscosity coefficient is the ratio of absolute/dynamic viscosity coefficient η to a liquid density ρ: $\nu = \eta/\rho$. The formula for a dynamic viscosity coefficient including results of direct measurements is: $\eta = K\,t\,\rho$ (2).

In the SI system the dynamic viscosity units are N s/m^2, Pa s *or* kg/(m s) where
1 Pa s = 1 N s/m^2 = 1 kg/(m s).

Dynamic viscosity may also be expressed in the metric CGS (centimeter-gram-second) system as g/(cm s), dyne s/cm^2 or poise (p) where
1 poise = 1 dyne s/cm^2 = 1 g/(cm s) = 1/10 Pa s = 1/10 N s/m^2.

For practical use the Poise is normally too large and the unit is often divided by 100 - into the smaller unit centipoise (cP**)** where 1 P = 100 cP; 1 cP = 0.01 poise = 0.01 gram per cm second = 0.001 Pascal second = = 1 milli Pascal second = 0.001 N s/m^2.

The viscometer ВПЖ-2 dynamic viscosity coefficients measurement range is of (10^{-3} – 10^3) Pa s.

Before to start measurements check that the viscometer is fixed properly at the clamp of the laboratory stand. Use a plumb weight bob to control strong vertical position of the viscometer the laboratory stand that is required to maintain liquid flow through a capillary at constant hydrostatic pressure.

The investigation is carried out at (20 – 25) ^{0}C room temperature avoiding an air circulation that may change investigated liquids temperature. The liquids are kept at the laboratory before investigation up to their temperatures become equal to ambient temperature of (20 – 25) ^{0}C. At this condition it is correct to use densities of the investigated liquids measured within temperatures range (20 – 25) ^{0}C (table 1) to calculate these liquids dynamic viscosity coefficients.

Lab test protocol NOTE! Copy Table 1, Table 2.

NOTE! Take note of the going gently on the glass viscometer

Close by thumb a viscometer tube 2 and start to pump air by rubber squeeze bulb through an inlet branch pipe 3 (fig.1a). Under air pressure a solution will go from a reservoir 6 (fig. 1b) and fill a reservoir 4. Pump air until a solution go up a mark M_1 about (2 - 3) mm. Then stop to pump air and open a tube 2. After a solution becomes at a level of a mark M_1 switch on a stopwatch and gauge time of a solution flow between marks M_1 and M_2.

1. Investigation of watery glycerol solution concentration bringing influence to bear on a solution dynamic viscosity coefficient

Four watery glycerol solutions of different concentrations $C_{gc1,\ 2,\ 3,\ 4}$ poured at four viscometers are under investigations. Use instruction above and measure time of each solution flow through the viscometer capillary,. Repeat measurements two times again and write down three results obtained $t_{gc1,\ 2,\ 3}$ at the table 1. Identify the viscometers by their simple calibration constant $K_{1,\ 2,\ 3,\ 4}$ and reflect these at the table 1 in correspondence with the solutions.

Use arithmetic formulas from the table 1 columns in tern and compute the watery glycerol solutions dynamic viscosity coefficients $\eta_{gc1,\ 2,\ 3,\ 4}$.

NOTE! Use parameters of the same measuring units system while compute!

Plot the graph to reveal functional dependence of the watery glycerol solution dynamic viscosity coefficient on the solution concentration: $\eta_{gc} = f(C_{gc})$.

Determinate from the graph the rates of the change of the watery glycerol solution dynamic viscosity coefficient $d\eta_{gc}/dC_{gc}$ within two glycerol concentrations ranges (40.0 – 20.0) % (mass) and (20.0- 5.0) % (mass).

Table 1

Concentrations, C_{gc} % (mass)	**Solutions flows through viscometers capillaries times t_{gc}, s**			**$\bar{t}_{gc} = (t_{gc1}+t_{gc2}+t_{gc3})/3$, s**	**$\eta_{gc} = K\ \bar{t}_{gc}\ \rho_{gc}$, Pa·s**
	t_{gc1}	**t_{gc2}**	**t_{gc3}**		
C_{gc1} = 39,1					K_1 =___; ρ_{gc1}=1,097 rg/ml; η_{gc1}=
C_{gc2} = 28,7					K_2 =___; ρ_{gc2}=1,070 g/ml; η_{gc2}=
$C_{gc\ 3}$ = 20,5					K_3 =___; ρ_{gc3}=1,048 g/ml; η_{gc3}=
$C_{gc\ 4}$ = 6,6					K_4 =___; ρ_{gc4}=1,014 g/ml; η_{gc4}=

2. Investigation of a watery glucose solution concentration bringing influence to bear on a solution dynamic viscosity coefficient.

Four watery glucose solutions of different concentrations $C_{gl1,\ 2,\ 3,\ 4}$ poured at four viscometers are under investigations. Use instruction above and measure time of each solution flow through the viscometer capillary,. Repeat measurements two times again and write down three results obtained $t_{gl1,\ 2,\ 3}$ at the table 2. Identify the viscometers by their simple calibration constant $K_{1,\ 2,\ 3,\ 4}$ and reflect these at the table 2 in correspondence with the solutions.

Use arithmetic formulas from the table 2 columns in tern and compute the watery glucose solutions dynamic viscosity coefficients $\eta_{gl1,\ 2,\ 3,\ 4}$.

Plot the graph to reveal functional dependence of the watery glucose solution dynamic viscosity coefficient on the solution concentration: $\eta_{gl} = f(C_{gl})$.

Determinate from the graph the rates of the change of the watery glucose solution dynamic viscosity coefficient $d\eta_{gl} = dC_{gl}$ within two glucose concentrations ranges (40.0 – 20.0) % (mass) and (20.0- 5.0) % (mass).

Table 2

Concentrations, C_{gl} % (mass)	**Solutions flows through viscometers capillaries times t_{gl}, s**			**$\bar{t}_{gl} = (t_{gl1}+t_{gl2}+t_{gl3})/3$, s**	**$\eta_{gl} = K\ \bar{t}_{gl}\ \rho_{gl}$, Pa·s**
	t_{gl1}	**t_{gl2}**	**t_{gl3}**		
C_{gl1} = 39,1					K_1 =___; ρ_{gl1}=1,097 rg/ml; η_{gl1}=
C_{gl2} = 28,7					K_2 =___; ρ_{gl2}=1,070 g/ml; η_{gl2}=
$C_{gl\ 3}$ = 20,5					K_3 =___; ρ_{gl3}=1,048 g/ml; η_{gl3}=
$C_{gl\ 4}$ = 6,6					K_4 =___; ρ_{gl4}=1,014 g/ml; η_{gl4}=

3. Analyse tow graphs $\eta_{gc}(C_{gc})$ and $\eta_{gl}(C_{gl})$ progresses and formulate conclusion about the watery glycerol solution concentration and watery glucose solution concentration bringing influence to bear on the solutions dynamic viscosity coefficients.

Compare the rate of the change of the watery glycerol solution dynamic viscosity coefficient $d\eta_{gc}/dC_{gc}$ and the rate of the change of the watery glucose solution dynamic viscosity coefficient $d\eta_{gl} = dC_{gl}$ within these solutions concentrations ranges (40.0 – 20.0) % (mass) and (20.0- 5.0) % (mass). Formulate conclusion about the different or same degree of the compositional structures affects on the solutions viscosities. Create an idea explaining this conclusion.