

Laboratory Experiment in the Context of Distance Learning

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Abstract

A number of problems arose during the implementation of the educational process in the context of the Covid-19 pandemic and the transition of universities to distance learning. Some of them are the implementation of the practical part of the physics program and the organization of students' independent work. For a partial solution of these problems, we offer a developed computer simulation on the topic "Studying Stokes's Law". As the development of professional competencies by future programmers, the students were offered the idea of creating this program. The simulation is broken up with the help of C++ programming and the .Net Core framework in the Visual Studio IDE. The program interface is quite simple and user-friendly, contains 10 options. The theoretical data for the variants are selected in such a way as not to violate the logic of the physical process. Also, the program provides for safety conditions if a student enters incorrect data. In addition, a real laboratory setup was created. With its help, we checked the correctness of the results that the computer simulation gives. A separate task was to master the skills of processing experimental data using the Microsoft Excel environment. We found that the values of the viscosity of the liquid, which were obtained experimentally and with the help of computer simulation, practically coincide, the calculation error was 5-10%.

Keywords

Distance learning, computer simulation, Stokes' law, viscosity, analytical method.

1. Introduction

Today, the world is facing the problem of organizing training during a pandemic. Due to restrictions imposed by states to prevent the spread of infection, there has been a problem with full-time education for students. Almost all Ukrainian universities have switched to distance learning. In such conditions, the problem is the implementation of the practical part of the program, namely, the implementation of laboratory work.

Also, in modern conditions, the practical orientation of education acts as a means of deepening the theoretical knowledge of university students, which contributes to the use of productive teaching methods. It is very difficult to include in the curriculum all the knowledge, skills, abilities that are needed by a highly qualified specialist in his practice, given that in today's world there is a very rapid development of technology, updating information [1].

In the conditions of considerable reduction of hours for classroom work of participants of educational process the important component of didactic work of the teacher is the organization and management of independent work of students of high school. Reducing their classroom load involves a significant increase in educational activities in the independent work of students. In these conditions, the teacher largely needs to think about different types, forms of practical orientation of independent work, use the whole arsenal of didactic teaching aids: both traditional and innovative, to avoid detrimental consequences in education [2]. For the future high-level specialist, a physics teacher should

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strive to create educational conditions during the educational process in physics to understand the demand for physical knowledge, physical research to study the disciplines of professional and practical training according to special activities.

The actual didactic task facing the technical university in the process of training specialists in the technical university is the formation of competencies, in particular, information and digital competence of future engineering and technical personnel [2,3]. Information and digital competence implies that having mastered it, a person in the XXI century must be critical and confident in the use of information and communication technologies in various spheres of their lives, and in education, and in personal, and in household, and in professional and etc.

2. Purpose and objectives

In this paper, we touched on this problem:

– first, the integration of physical knowledge on the topics "Dynamics of fluid motion", "Kinematics" and knowledge of disciplines of professional and practical training of future specialists, for example, specialties 141 "Electricity. Electrical Engineering and Electromechanics", 121 "Software Engineering", 192 "Construction", 136 "Metallurgy"[4];

– secondly, the creation of an intellectual product, such as a computer program to perform the work of the physical workshop "Study of the law of Stokes" by students majoring in 121 "Software Engineering" [5-7];

– thirdly, the use of an intellectual product for the formation of physical knowledge during the practical part of the program in laboratory classes by other students of the university [8-10];

– fourth, the organization of independent work of university students.

Thus, the purpose of this work is to create a computer simulation to perform laboratory work "Study of Stokes' law" and a description of the features of its code.

The task of the work is, first, the analysis of theoretical material related to the topic of the work; second, the creation of a computer simulation; third, the comparison of the results obtained as a result of the simulation and real measurements.

3. Computer simulation

3.1. Tasks for computer simulation

According to the standard of higher education in the specialty 121 "Software Engineering" for I level [11], one of the professional competencies that should be possessed by future software engineers is "The ability to participate in software design, including modeling (formal description) of its structure, behavior and functioning processes (K 14) ", " Ability to formulate and ensure requirements for software quality in accordance with customer requirements, specifications and standards (K 16) ", " Ability to apply fundamental and interdisciplinary knowledge for the successful solution of software engineering problems (K 20) ". To form these competencies by means of a physics course, students of this specialty were offered as an independent work to create a computer simulation for laboratory work "Study of Stokes' law" in the section "Mechanics". This work, on the one hand, allows to determine the coefficient of dynamic viscosity and the Reynolds number experimentally, on the other - to determine these physical quantities by theoretical formulas. To complete the task, students were offered data for options (Table 1.2, Form 1.2) and the appearance of the finished simulation.

Table 1

Theoretical data for options.

	Version				
	1	2	3	4	5
$\eta, 10^{-3},$ Pa·s	1480	390	1,002	10000	865
$\rho_p, \text{kg/m}^3$	1260	900	1000	1350	864
$\rho_r, \text{kg/m}^3$	7800	2500	1850	8900	2700

	Version				
	6	7	8	9	10
$\eta, 10^{-3}, \text{Pa}\cdot\text{s}$	1480	987	1,54	10000	865
$\rho_p, \text{kg/m}^3$	1260	950	13600	1350	864
$\rho_T, \text{kg/m}^3$	11300	2000	19300	10500	1650

Table 2
The length of the path

№ experience	1	2	3	4	5	6
The length of the path, ℓ, m	0	0,1	0,15	0,2	0,25	0,3
№ experience	7	8	9	10	11	12
The length of the path, ℓ, m	0,35	0,4	0,45	0,5	0,55	0,6

Formulas for calculations:

Task 1 (excluding tube diameter)

$$t = 18 * \eta * 10^{-3} * 1 / [(d * 10^{-3})^2 * 9,81 * (\rho_T - \rho_p)] \quad (1)$$

Task 2 (consider the diameter of the tube)

$$t = 18 * \eta * 10^{-3} * 1 / [(d * 10^{-3})^2 * 9,81 * (\rho_T - \rho_p) * (1 + 2,4 * d/D)] \quad (2)$$

where: t – the time of movement in the liquid, η – the viscosity coefficient of the liquid, d – the diameter of the ball, D – the diameter of the tube, ρ_p – the density of the liquid, ρ_T – the density of the material.

Mandatory check: $d < D!!!$ When calculating the time, make an error from 0 to ± 0.005 randomly.

3.2. Creating a computer simulation

The simulation of laboratory work was developed using the C++ programming language and the .Net Core framework in the Visual Studio compiler. The program window has three main blocks: "Task 1", "Task 2" and the field where the result of calculations will be displayed (with the button "Calculate") (Fig.1). The parameters for which calculations are performed are presented in the methods of the class `calc_task_1()` and `calc_task_2()` (Table 3, example). In addition, the program has a toolbar with 2 function buttons - "Shut down (exit)" and a link to GitHub, where you can find this project.

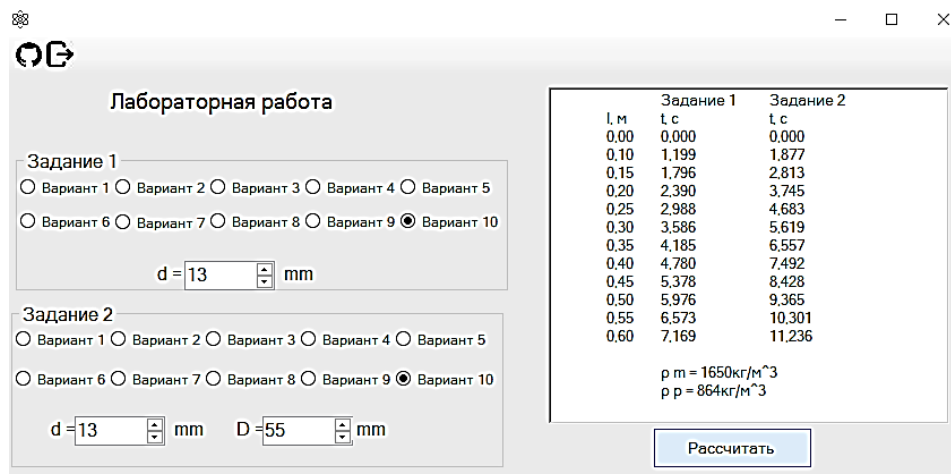


Figure 1: Example of program output

Table 2
Simulation data entry

Task 1	Task 2
void calc_task_1() {	void calc_task_2() {
switch (task_1) {	switch (task_2) {
case 1:	case 1:
N_1 = 1480;	N_2 = 1480;
Ro_p_1 = 1260;	Ro_p_2 = 1260;
Ro_m_1 = 7800;	Ro_m_2 = 7800;
break;	break;
and so on	and so on

The program asks for input:

- select option (1 option by default);
- d for the first task and d and D for the second.

After entering the data, you need to click on the "Calculate" button to see the result (Fig. 1). The program provides several safety conditions if the student (user) keeps invalid data (Fig.2a). If you do not specify a value to calculate the result, an error message will be issued. If you enter a value that violates the logic - the user will also see an error message (Fig. 2b)

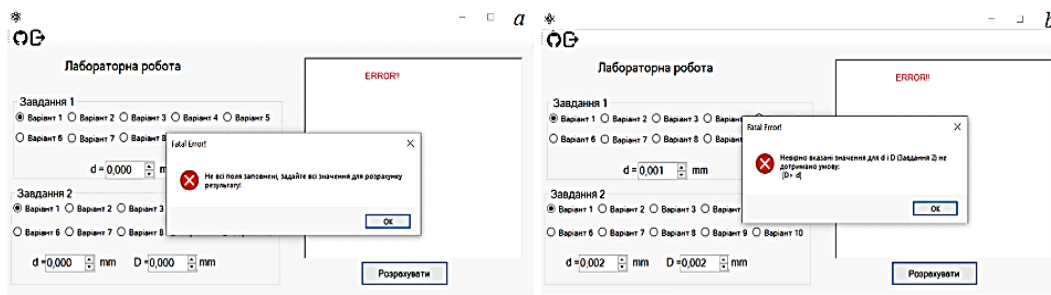


Figure 2: Example of one of the errors (a) and invalid data (b)

Thus, the program has a small cascade of checks, only after which we proceed to perform calculations of the code snippet. 4.1. The code snippet 4.1 shows the three conditions under which the check takes place, first, all input parameters cannot be 0, if all values are 0 - then the information is displayed. About the error "Not all fields are filled, set all values to calculate the result!" (Fig. 3).

```

if(d_1 == 0 || d_2 == 0 || D == 0) { //check for filled data
    richTextBox1->ForeColor = Color.Red;
    richTextBox1->Text = ("\n\t\tERROR!!");

    MessageBox.Show("Не всі поля заповнені, задайте всі значення для
    розрахунку результату!", "Fatal Error!", MessageBoxButtons.OK,
    MessageBoxIcon.Error); }
else if (d_2 >= D) { //check for [D > d]
    richTextBox1->ForeColor = Color.Red;
    richTextBox1->Text = ("\n\t\tERROR!!");

    MessageBox.Show("Невірно вказані значення для d і D
    (Завдання 2) не дотримано умову: \n [D > d]", "Fatal Error!",
    MessageBoxButtons.OK, MessageBoxIcon.Error); }
else if (task_1 != task_2) { //check for one option for 2th tasks
    richTextBox1->ForeColor = Color.Red;
    richTextBox1->Text = ("\n\t\tERROR!!");

    MessageBox.Show("Варіанти 1 і 2 Завдання повинні
    збігатися!", "Fatal Error!", MessageBoxButtons.OK, MessageBoxIcon.Error); }

```

Figure 3: Fragment of the code 4.1

different sites in a glass tube with liquid.

The disadvantages of this device are: the presence of a glass cylinder of the same size; a set of usually five balls of the same size, the movement time of which is alternately measured with a stopwatch at different sections in a glass tube with liquid, and this can be considered as a single measurement to determine the coefficient of dynamic viscosity of the liquid.

Common features with the device for determining the viscosity of the liquid are the presence of: a cylinder with liquid, balls, stopwatch.

A device for determining the viscosity coefficient of a liquid [12] is known, which includes: an open cylinder with the test liquid, a funnel for directing a ball in the liquid, a set of balls for obtaining a spectrum of values of the liquid viscosity coefficient.

The disadvantages of this device are the inability to observe the dependence of the motion of different radii of the ball on the size of the cylinder with the test fluid.

Common features with the device for determining the viscosity of the liquid are the presence of an open cylinder with the test liquid with a funnel inserted from above to direct the ball in the liquid, a set of balls to obtain a range of values of the studied liquid characteristics, estimation of relaxation path and time. using the Reynolds number of the nature of the flow around the ball.

When designing the device for determining the viscosity of the liquid was the task: to develop a device for determining the quality at home according to the coefficient of dynamic viscosity, which is stated by the manufacturer, as well as to expand the range of training laboratory equipment.

The essential features of the device for determining the viscosity of the liquid is the presence of three glass cylindrical tubes of different diameters, which provides a study of the influence of vessel walls on the movement of balls of different diameters in them, the study of laminar, turbulent ball flow.

Distinctive features of the previous device are the presence of: three cylindrical glass tubes of different diameters, LED lighting, the choice of method for measuring the time of movement of the ball in the liquid.

Example of a specific implementation; in the laboratory during the study of the motion of the ball in the liquid, determining the coefficient of dynamic viscosity of the oil at home.

To determine the coefficient of dynamic viscosity of the oil at home, we used the installation shown in Figure 5.

The installation includes the following elements, namely:

- vertical base t - similar in shape to particleboard;
- three glass pipes of different diameters ($d_1 = 55$ mm, $d_2 = 40$ mm, $d_3 = 15$ mm), based on drain taps with a diameter of 5 mm;
- power supply of the illuminating element (step-down transformer 220 V ~ / 12 V);
- experimental elements (balls of different diameters and materials);
- fluid (SynTech Diesel 10w-40 oil - semi-synthetic motor) [14,15].



Figure 5: Laboratory installation for determining the coefficient of dynamic viscosity of the liquid by the Stokes method

To measure the distance of the ball, we used meter-long metal rulers attached to a wooden panel. To improve the lighting near the oil pipes, a diode strip is attached, which works from the 220 V mains through an adapter.

For a better analysis of the results for each experiment, video surveying was performed.

4.2. Processing the results of the experiment

The results of the experiment to determine the dynamic viscosity of the liquid were processed using the Microsoft Exel software environment. To do this, we substantiated the linear dependence of the time of movement of the ball in the liquid on the length of the path traveled and wrote the equation in the form:

$$y = kx + b \quad (3)$$

where: $b = 0$; $k = \eta$; $x_1 = 3l$ (Task 1); $x_2 = 3l \cdot \left(1 + 2,4 \cdot \frac{d}{D}\right)$ (Task 2);

$$y = \frac{(\rho_T - \rho_P) g d^2}{6} t$$

Earlier [15] it was shown in detail how, using the analytical capabilities of Microsoft Exel, you can enter formulas, calculate the necessary parameters and build a linear relationship. In fig. 8 presents tables of Microsoft Exel with the calculated parameters for the linear dependence $y = kx + b$ in the case of computer simulation (fig. 6, a) and the real experiment (fig. 6, b).

B	C	D	E	F	G	H	I	A
Задача 1		Задача 2		Задача 1		Задача 2		
t, м	t, с	x	y	x	y	x	y	
0	0	0	0	0	0	0	0	
0,1	1,199	1,877	0,3	0,2604031	1,4771197	1,2806816		
0,15	1,796	2,813	0,45	0,3900617	2,2156796	1,9193166		
0,2	2,39	3,745	0,6	0,5190688	2,9542395	2,5552224		
0,25	2,988	4,683	0,75	0,6485446	3,6927994	3,195222		
0,3	3,586	5,619	0,9	0,7782204	4,4313592	3,833857		
0,35	4,185	6,557	1,05	0,9089133	5,1699191	4,4738566		
0,4	4,78	7,492	1,2	1,0393176	5,908479	5,1118094		
0,45	5,378	8,428	1,35	1,1698133	6,6470389	5,7504444		
0,5	5,976	9,365	1,5	1,2978091	7,3855987	6,3897617		
0,55	6,573	10,301	1,65	1,4275477	8,1241586	7,0283967		
0,6	7,169	11,236	1,8	1,5569892	8,8627185	7,6663484		
ρm = 1850кг/м³		ρp = 865кг/м³						

M	N	O	P	Q	R	S	b
Задача 1				Задача 2			ρm = 1847кг/м³
t, с	l, м	x	y	x	y		ρp = 865кг/м³
0	0	0	0	0	0		
0,98	0,1	0,3	0,2557854	1,4668382	1,0030675		
1,63	0,15	0,45	0,4254389	2,2002573	1,6683674		
2,28	0,2	0,6	0,5950925	2,9336763	2,3336672		
2,84	0,25	0,75	0,7412555	3,6670954	2,9068487		
3,4	0,3	0,9	0,8874186	4,4005145	3,4800301		
4	0,35	1,05	1,0440219	5,1339336	4,094153		
4,62	0,4	1,2	1,2058453	5,8673527	4,7287467		
5,24	0,45	1,35	1,3676687	6,6007718	5,3633405		
5,85	0,5	1,5	1,526882	7,3341908	5,9876988		
6,36	0,55	1,65	1,6599948	8,0676099	6,5097033		
6,86	0,6	1,8	1,7904975	8,801029	7,0214724		

Figure 6: Data obtained by computer simulation (a) and experimental data (b)

In fig. 7 presents linear dependences according to task 1, 2. The analysis of the diagrams shows a sufficient correlation between the results of the real experiment and the computer simulation. The reliability of the obtained data was analyzed using the analytical capabilities of Microsoft Exel by the method of least squares.

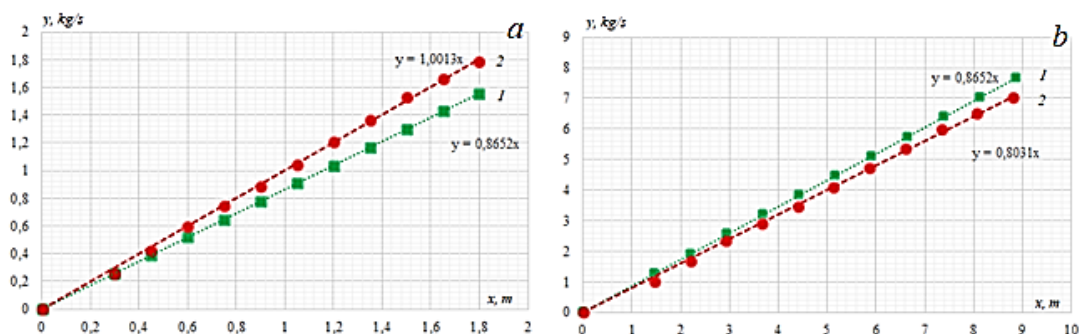
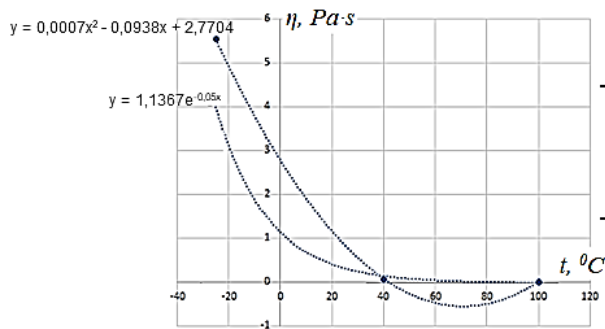


Figure 7: Task 1 (a) and task 2 (b): 1 - simulation data; 2 - experimental data

In addition, all the obtained values of dynamic viscosity belong to the range of values of the coefficient of dynamic viscosity of engine oil 10w-40 in accordance with fig. 8 ($0,4 \leq \eta \leq 11,1$ (Pa · s)) at a temperature of 21 °C [14].



	Computer simulation	Experiment
Task 1	$\eta = 0,8652 \pm 0,0098$ $\varepsilon = 1,1 \%$	$\eta = 1,0013 \pm 0,0714$ $\varepsilon = 7 \%$
Task 2	$\eta = 0,8652 \pm 0,0062$ $\varepsilon = 0,7 \%$	$\eta = 0,8031 \pm 0,0572$ $\varepsilon = 7 \%$

Figure 8: Graph of the dependence of the dynamic viscosity of oil 10w-40 on temperature and the results of the experiment

5. Introduction to the educational process

During the distance learning in the 2020-2021 academic year, students of different specialties and faculties were invited to perform laboratory work using computer simulations. After completing the physics course and receiving grades for the course, students were asked to take a survey on the feasibility of using computer simulations in full-time, distance and blended learning. The results of the survey are presented in fig. 9.

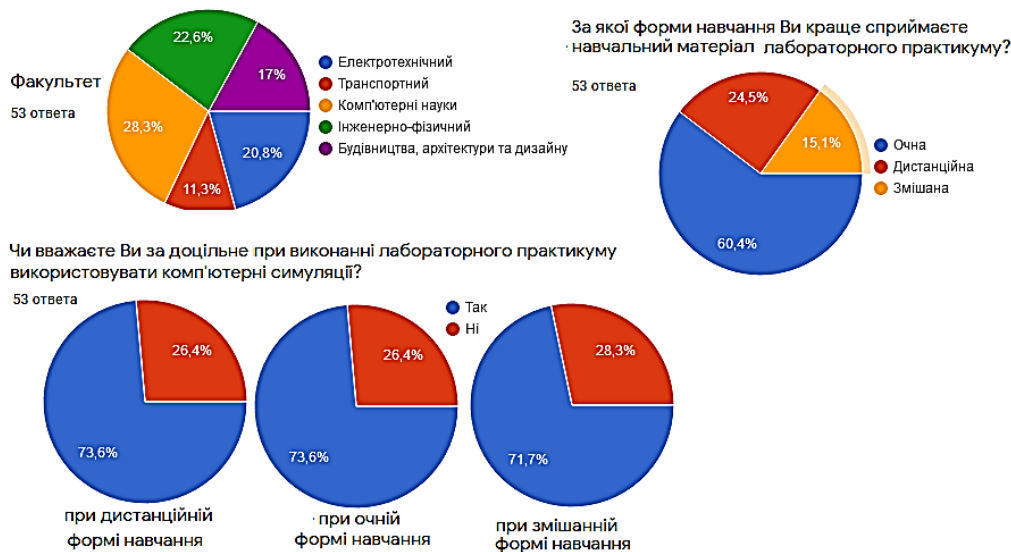


Figure 9: The results of the survey

In general, students were satisfied with the use of computer simulations during the learning process, the program interface did not cause difficulties in perception. The results of the course study are almost indistinguishable in the actual performance of laboratory work and the use of computer simulations.

6. Conclusions

In the process of working on the project we achieved our goal, namely:

- created a new intellectual product - a computer simulation for the implementation of the physical workshop "Study of Stokes' law" by students majoring in 121 "Software Engineering", 141 "Electricity. Electrical Engineering and Electromechanics", 192 "Construction", 136 "Metallurgy";
- stimulated the development of professional competencies of students majoring in 121 "Software Engineering";
- upgraded the actual installation to verify Stokes' law;

- compared the data obtained by computer simulation and a real experiment for 10w-40 engine oil and found that the obtained value of dynamic viscosity corresponds to the tabular values, the reliability of the experiment is 1...7%;

- stimulated the development of information competence by students majoring in 121 "Software Engineering", 141 "Electricity. Electrical Engineering and Electromechanics", 192 "Construction", 136 "Metallurgy" when performing a physical workshop using a ready-made information product, such as a computer simulation "Study of Stokes' law", and processing the results of the experiment using analytical capabilities of Microsoft Excel.

In the future it is planned to create an educational and methodological complex for the performance of physical workshop in distance learning.

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