Ministry of Education and Science of the Russian Federation
Federal Independent Educational Institution
«NATIONAL RESEARCH TOMSK POLYTECHNIC UNIVERSITY»

Research School of Chemical and Biomedical Technologies
Direction of training 12.04.04 «Biotechnical systems and technologies»

MASTER'S THESIS

Topic of the work
Разработка портативной оптической системы для сорбционно-фотометрического определения веществ (Development of a portable optical system for sorption-photometric determination of substances)

UDC 681.7.01:543.422.3:544.723

Student

Group	**Full name**	**Signature**	**Date**
1DM7I	Kyrov Ilya Vladimirovich		

Scientific Supervisor and Technical Advisor

Position	**Full name**	**Academic degree, rank**	**Signature**	**Date**
Assistant professor	Gubarev Fedor Aleksandrovich	Candidate of Technical Sciences		

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Head of Department	**Full name**	**Academic degree, rank**	**Signature**	**Date**

Tomsk – 2019

Planned program learning outcomes

Код резуль-тата	Результат обучения (выпускник должен быть готов)	Требования ФГОС, критериев и/или заинтересованных сторон
	Профессиональные компетенции	
P1	Применять глубокие специальные естественнонаучные, математические, социально-экономические и профессиональные знания в инновационной инженерной деятельности при разработке, производстве, исследовании, эксплуатации, обслуживании и ремонте современной биомедицинской и экологической техники	Требования ФГОС (ОК-2, ОПК-2), Критерий 5 АИОР (п. 5.2.1), согласованный с требованиями международных стандартов *EUR-ACE* и *FEANI*
P2	Ставить и решать инновационные задачи инженерного анализа и синтеза с использованием специальных знаний, современных аналитических методов и моделей	Требования ФГОС (ОПК-1, 3; ПК- 1 – 4), Критерий 5 АИОР (п. 5.2.2), согласованный с требованиями международных стандартов EUR-ACE и FEANI
P3	Выбирать и использовать необходимое оборудование, инструменты и технологии для ведения инновационной практической инженерной деятельности с учетом экономических, экологических, социальных и иных ограничений	Требования ФГОС (ОК-9, ПК-10, 14, 18). Критерий 5 АИОР (пп. 5.2.3, 5.2.5), согласованный с требованиями международных стандартов EUR-ACE и FEANI
P4	Выполнять комплексные инженерные проекты по разработке высокоэффективной биомедицинской и экологической техники конкурентоспособной на мировом рынке	Требования ФГОС (ОК-2, 3; ПК-5 – 11, 14), Критерий 5 АИОР (пп. 5.2.3, 5.2.5), согласованный с требованиями международных стандартов *EUR-ACE* и *FEANI*
P5	Проводить комплексные инженерные исследования, включая поиск необходимой информации, эксперимент, анализ и интерпретацию данных с применением глубоких специальных знаний и современных методов для достижения требуемых результатов в сложных и неопределенных условиях	Требования ФГОС (ОК-2, 3; ОПК-5, ПК-1 – 4). Критерий 5 АИОР (пп. 5.2.2, 5.2.4), согласованный с требованиями международных стандартов *EUR-ACE* и *FEANI*
P6	Внедрять, эксплуатировать и обслуживать современное высокотехнологичное оборудование в предметной сфере биотехнических систем и технологий, обеспечивать его высокую эффективность, соблюдать правила охраны здоровья и безопасности труда, выполнять требования по защите окружающей среды	Требования ФГОС (ОПК-1, 2), Критерий 5 АИОР (пп. 5.2.5, 5.2.6), согласованный с требованиями международных стандартов *EUR-ACE* и *FEANI*
	Универсальные компетенции	
P7	Использовать глубокие знания в области проектного менеджмента для ведения инновационной инженерной деятельности с учетом юридических аспектов защиты интеллектуальной собственности	Требования ФГОС (ОПК-2; ПК-14, 15). Критерий 5 АИОР (п. 5.3.1), согласованный с требованиями международных стандартов *EUR-ACE* и *FEANI*
P8	Владеть иностранным языком на уровне, позволяющем активно осуществлять коммуникации в профессиональной среде и в обществе, разрабатывать документацию, презентовать и защищать результаты инновационной инженерной деятельности	Требования ФГОС (ОК-1), Критерий 5 АИОР (п. 5.3.2), согласованный с требованиями международных стандартов *EUR-ACE* и *FEANI*
P9	Эффективно работать индивидуально и в качестве члена и руководителя команды, состоящей из специалистов различных направлений и квалификаций, с делением ответственности и полномочий при решении инновационных инженерных задач	Требования ФГОС (ОК-3, ОПК-3; ПК-3, 12, 13), Критерий 5 АИОР (п. 5.3.3), согласованный с требованиями международных стандартов *EUR-ACE* и *FEANI*
P10	Демонстрировать личную ответственность, приверженность и готовность следовать профессиональной этике и нормам ведения инновационной инженерной деятельности	Критерий 5 АИОР (п. 5.3.4), согласованный с требованиями международных стандартов *EUR-ACE* и *FEANI*
P11	Демонстрировать глубокие знание правовых социальных, экологических и культурных аспектов инновационной инженерной деятельности, компетентность в вопросах охраны здоровья и безопасности жизнедеятельности	Критерий 5 АИОР (п. 5.3.5), согласованный с требованиями международных стандартов *EUR-ACE* и *FEANI*
P12	Самостоятельно учиться и непрерывно повышать квалификацию в течение всего периода профессиональной деятельности	Требования ФГОС (ОК-2, 4; ОПК-4), Критерий 5 АИОР (п.5.3.6), согласованный с требованиями международных стандартов *EUR-ACE* и *FEANI*

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APPROVED BY
Head of the Program
_________ _________
(Signature) (Date)

ASSIGNMENT
for the Master's Thesis completion

In the form:

Master's Thesis

For a student:

Group	**Full Name**
1DM7I	Kyrov Ilya Vladimirovich

Topic of the work:

Разработка портативной оптической системы для сорбционно-фотометрического определения веществ (Development of a portable optical system for sorption-photometric determination of substances)	
Approved by the order of the Head (date, number)	

Deadline for completion of the Master's Thesis:	

TERMS OF REFERENCE:

Initial data for work: *(the name of the object of research or design; performance or load; mode of operation (continuous, periodic, cyclic, etc.); type of raw material or material of the product; requirements for the product, product or process; special requirements to the features of the operation of the object or product in terms of operational safety, environmental impact, energy costs; economic analysis, etc.).*	Development of a portable spectrophotometer for photometric determination of substances Power supply - 5 V; The device must contain a semiconductor laser; The device must contain a photodiode; The device must contain a display; The developed spectrophotometer should be compact, inexpensive, with the possibility of implementation and testing in the laboratory conditions TPU.
List of the issues to be investigated, designed and developed *(analytical review of literary sources in order to elucidate the achievements of world science and technology in the field under consideration, the formulation of the problem of research, design, construction, the content of the procedure of the research, design, construction, discussion of the performed work results, the name of additional sections to be developed; work conclusion).*	1) Literature review; 2) Selection and justification of the structural and schematic diagram of the device; 3) Selection of circuit elements and the calculation of the concept of the device; 4) Algorithm and program code; 5) Financial management, resource efficiency and resource conservation; 6) Social responsibility; 7) Conclusion.

List of graphic material *(with an exact indication of mandatory drawings)*	Electrical schematic diagram Detail drawing List of items
Advisors on the sections of the Master's Thesis	
Chapter	**Advisor**
Section «Financial Management, Resource Efficiency and Resource Saving»	Senior Lecturer, Department of Social and Human Sciences Potekhina Nina Vasilyevna
Section «Social Responsibility»	Associate Professor of General Technical Disciplines Mikhail Vladimirovich Gorbenko

Date of issuance of the assignment for Master's Thesis completion according to a line schedule	

The task was issued by the Scientific Supervisor and Technical Advisor:

Position	Full Name	Academic degree, rank	Signature	Date
Assistant professor	Gubarev Fedor Aleksandrovich	Candidate of Technical Sciences		

The assignment was accepted for execution by the student:

Group	Full Name	Подпись	Дата
1DM7I	Kyrov Ilya Vladimirovich		

TASK FOR SECTION
"FINANCIAL MANAGEMENT, RESOURCE EFFICIENCY AND RESOURCE SAVING"

To a student:

Group	Full name
1DM7I	Kyrov Ilya Vladimirovich

School	Research School of Chemical and Biomedical Technologies	**School Department**	
The level of education	Master degree	**Direction / specialty**	04.12.04 Biotechnical systems and technologies

Background data to the section "Financial management, resource efficiency and resource saving":	
1. *The cost of scientific research (NI) resources: logistical, energy, financial, informational and human*	*Salary of the head - 33664 rub.* *Engineer's salary - 21,760 rubles.* *The cost of materials and components is determined on the basis of price lists of companies*
2. *Norms and standards of resource use*	*Overhead costs 16%;* *District coefficient of 30%.* *Depreciation rate 33,3%*
3. *Used tax system, rates of taxes, deductions, discounting and lending*	*The ratio of tax for payment to extra-budgetary funds is 30%.*
The list of issues to be investigated, designed and developed:	
1. *Evaluation of the commercial and innovative potential of STI*	*Potential consumers of research results* *QuaD technology* *SWOT analysis*
2. *Development of a scientific and technical project charter*	*Building a tree of project objectives, a description of the project stakeholders, the working group*
3. *STI management process planning: structure and schedule, budget, risks and procurement organization*	*Planning work stages, determining the schedule of the study* *Determination of project risks, assessment of risk and loss probability*
4. *Determination of resource, financial, economic efficiency*	*A description of the potential effect of the project.*
The list of graphic material (with the exact indication of the mandatory drawings):	
1. *Market Segmentation Map* 2. *QuaD development analysis* 3. *SWOT- analysis matrix* 4. *Project Objective Tree* 5. *Temporary development indicators* 6. *Estimated project cost* 7. *The main measures to reduce risks*	

Date of assignment for the section on a linear schedule	

Assignment issued by a consultant:

Position	Full name	Degree, title	Signature	Date
Senior Lecturer	Potekhina Nina Vasilyevna	-		

The task was accepted for execution by the student:

Group	Full name	Signature	Date
1DM7I	Kyrov Ilya Vladimirovich		

TASK FOR SECTION

"SOCIAL RESPONSIBILITY"

To a student:

Group		**Group**	
1DM7I		Kyrov Ilya Vladimirovich	
School	Research School of Chemical and Biomedical Technologies	**Department**	
The level of education	Master degree	**Direction / specialty**	04.12.04 Biotechnical systems and technologies

Background to the section "Social Responsibility":	
1. Characteristics of the object of study (substance, material, device, algorithm, method, working area) and its areas of application	Object of study: optical system for sorption-photometric determination of substances Application area: - spectrophotometric installations - research laboratory
The list of issues to be investigated, designed and developed:	
1. Legal and organizational security issues:	Compliance with laws (labor and civil codes) and workplace requirements. The manager (responsible) assumes the obligations to fulfill and organize the evacuation rules and to observe the safety requirements in the room, as well as to monitor the health of the work in the room. Regulations.
2. Industrial safety 2.1. Analysis of the identified harmful factors in the development and operation of the designed solution in the following sequence: 2.2. Analysis of the identified hazards in the development and operation of the designed solution in the following sequence:	2.1 Analysis of identified harmful factors: -microclimate; - lack of natural light, insufficient illumination of the working area; - increased noise level at the workplace; - increased level of electromagnetic radiation; -harmful substances 2.2. Analysis of identified hazards: - electric shock - mechanical hazards - thermal hazards - increased level of static electricity. - fire hazard
3. Ecological safety:	- When soldering radio elements evaporate harmful substances into the atmosphere; - Practically no impact on the lithosphere; - Low impact on the hydrosphere - Ways of recycling in the presence of waste.

4. Safety in emergency situations:	In the laboratory room may occur emergencies such as: - Natural situations of nature. - Man-made ES

Date of assignment for the section on a linear schedule	

Assignment issued by a consultant:

Position	Full name	Degree, rank	Signature	date
Assistant professor	Gorbenko Mikhail Vladimirovich	Candidate of Technical Sciences		

The task was accepted for execution by the student:

Group	Full name	Signature	date
1DM7I	Kyrov Ilya Vladimirovich		

Abstract

Master's Thesis contains 96 pages, 11 figures, 29 tables, 15 references, 6 appendix.

Keywords: portable spectrophotometer, sorbents, photometry, metals

The object of the study is water with metal impurities.

Objective: to develop a portable compact spectrophotometer to determine the concentration of metals in water.

In the course of the study, a review of the literature on various types of photometry, spectrophotometers available on the market, various test methods and sorbents was carried out. The material base was also investigated and the optimal components were selected. Based on the review, an analysis was made and the most economically and energy-efficient scheme for developing the device was built.

As a result of the study, a working model of the device was developed and the algorithm and code of the program operation were given.

Scope: This tester is designed for use in small laboratories, performance in the field at this stage is questionable, as it does not have the means for autonomous work and requires a smooth, stable surface for accurate measurement.

Economic efficiency / importance of the work: calculations of the project efficiency showed that the project has a high level of scientific and technical effect, which fully justifies the economic costs of creating this spectrophotometer.

In the future, it is planned to refine the circuit, algorithm and program code taking into account all the shortcomings of this development, expanding the number of available wavelengths.

Definitions, designations, abbreviations, normative references

GOST 12.1.005-88 SSBT. General sanitary and hygienic requirements for working area air.

SanPiN 2.2.4.548-96. Hygienic requirements for the microclimate of industrial premises.

SNiP 23-05-95 (joint venture 52.13330.2011). Set of rules. Natural and artificial lighting. Updated edition SNiP 23-05-95.

GOST 12.1.003 - 2014. SSBT. Noise. General safety requirements.

SanPiN 2.2 / 2.2.1340. "Hygienic requirements for personal electronic computers and work organization"

GOST 12.1.007 - 76. SSBT. Harmful substances. Classification and general safety requirements.

GOST 12.1.033 - 81. SSBT. Fire safety. Terms and Definitions.

Airbag 105-03. Definition of categories of premises, buildings and outdoor installations for explosion and fire hazard.

SNiP 2.01.02-8. Fire regulations.

GOST R 12.1.019-2009. SSBT. Electrical safety. General requirements and nomenclature of types of protection.

GOST 12.1.030-81. SSBT. Electrical safety. Protective grounding.

The following abbreviations are used in this paper:

MK – microcontroller;

ADC - analog digital converter;

PC - personal computer.

Contents

INTRODUCTION

In the modern world, devices of optical spectral analysis are widely used in practice, allowing for a quick and reliable comparative analysis of substances. Interest in such devices due to their simplicity, versatility and the possibility of application in many areas of medicine, biology, chemistry, physics.

It is known that each substance has its own spectral properties, different from the spectral properties of other substances. Substances can be analyzed in both quantitative and qualitative aspects. The methods that are commonly used in various fields of science are spectrophotometry, photometry, colorimetry. However, the most important basic method, both for assessing the color of industrial products, and for basic research in the field of science is spectrophotometry. The main difference between a spectrophotometer and a photocolorimeter is the ability to measure the light flux transmitted through the sample (or reflected from the sample) of any desired wavelength, to make photometric measurements, scanning the entire optical wavelength range not only in the visible range from 380 to 750 nm, but also in the region of the near ultraviolet (UV) - from 200 to 380 nm., as well as in the infrared region (IR) up to 2500 nm.

In the final qualifying paper, theoretical and practical issues of development, research and design of a portable spectrophotometer are considered. Solutions to these issues are of particular scientific and practical interest, are relevant and timely task.

The aim of the work is to develop a portable spectrophotometer for photometric determination of substances with given technical characteristics. The projected spectrophotometer is powered by a 5 V DC source and must also contain a semiconductor laser with a wavelength of 532 nm and a power of 5 mW, a photodetector sensitive to the wavelength used, a display, for information output.

As a result of the research it is necessary to solve the following tasks:

• Review literature on this topic;

• Develop a block diagram of the device;

• Develop a schematic diagram of the device;

• Develop the instrument case;

• Assemble and debug the device;

• Test the instrument in real conditions.

1 REVIEW OF LITERATURE

1.1 The history of the development of optical spectrometry

The word "spectrum" in Latin means "appearance" or "scheme." Isaac Newton, in 1666, was the first to use a prism to spread out the sun into spectral elements (Fig. 1). In 1758, Marcgraf for the first time, using the color of the flame, discovered a method for the visual determination of a substance. In 1802, the English physicist Volduston explained Newton's experiment with a prism, perfected it, and for the first time observed numerous dark lines in the solar spectrum. A few years later, English scientists Herschel and Talbot experimented with the light of the flame, and in 1834. Talbot spectrally separated the red color of the strontium flame and the red color of lithium, which was the birth of analytical optical spectroscopy.

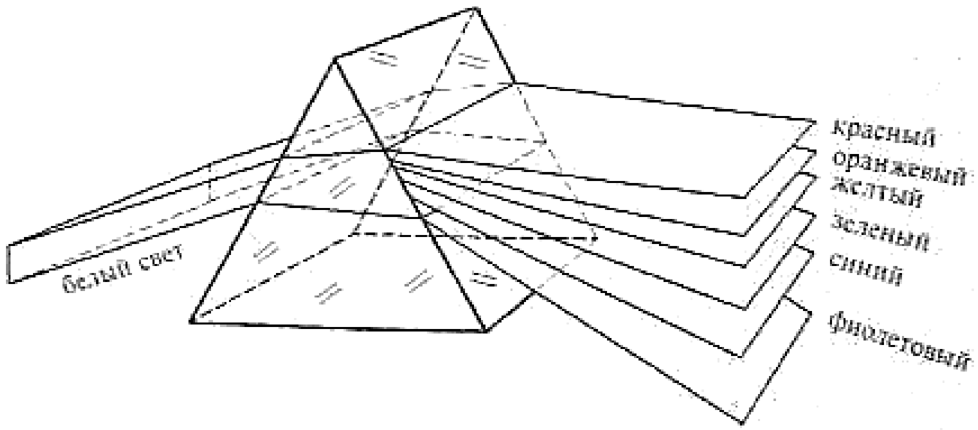

Fig. 1. The decomposition of parallel sunlight into its components in the spectrum

This new research method, called optical spectroscopy, has been developing since 1834 until now. Special attention should be paid to the work of the physicist Fraunhofer, who developed diffraction grating spectroscopy and obtained 1500 lines in the spectrum of sunlight.

Until the 20th century, there were no theories that could satisfactorily explain the complex behavior of all substances. The following scientists made the most significant contribution to modern understanding of spectral manifestations. In 1885, the Swiss scientist Ballmer discovered a series of so-called "Balmer" spectral lines in the spectrum of hydrogen. In 1897, the English scientist Thompson discovered an electron, but in 1911 his compatriot Ernest Rutherford - the atomic nucleus. In 1900, Max Planck formulated the first laws of quantum theory. Werner Heisenberg (1932) and Erwin Schrödinger (1933) received the Nobel Prize for his work on quantum mechanics. In the future, the concept of quantum mechanics was developed by Paul Dirac and Wolfgang Pauli (1945), who also won the Nobel Prize [1].

The history of science is connected with the history of the development of measurement and analysis of methods, and the history of optical spectroscopy largely reflects the history of astronomy, and therefore the history of atomic spectroscopy. Only at the end of the 19th century, molecular spectroscopy became a powerful analytical method. For example, with a spectrophotometer capable of detecting specific “bands” of hemoglobin, blood can be distinguished from a red dye, so today, criminologists can find the killer for small drops of blood.

For many decades, ordinary tungsten incandescent lamps, prisms, diffraction gratings, as well as light detectors, which limit the results in a narrow range of the visible spectrum from 500 to 700 nm, have been used in spectroscopy.

Until the 40s of the 20th century, only a few types of commercial spectrophotometer were available (General Electric spectrophotometer, Kenko spectrophotometer model DM Coleman), in addition to them was hard work and they were made in small batches. While “measuring”, to determine the concentration of absorption, a consistent visual comparison of the two fields is performed, just as it is done now to check the color vision with the Nagel Anomalescope. In 1941, he was released in the press about 800 articles to determine the concentration of clinically important components of blood and other body fluids with similar spectrophotometers [2].

After World War II, the market for spectral analytical equipment began to grow rapidly and improve. Due to higher resolution and less scattered light, diffraction gratings and a double monochromator with automatic scanning were used instead of prisms, giving corrected spectra, which promoted their use in routine analytical work. A significant decrease in the scattered light led to an improvement in the defining features of spectrophotometers by 4-5 orders of magnitude.

Soon, specialized photometer instruments appeared on the market, for example, for radiometry, colorimetry, or two-wave analysis. In the late seventies, when computer prices began to decline, spectrometers began to be manufactured on the basis of microcomputers. This made it easier to measure, and allowed for continuous analysis.

1.2 Spectrophotometry, types of absorption spectrometers

Spectrophotometry is a physicochemical method for studying solutions and solids, based on the study of absorption spectra in the ultraviolet (200–400 nm), visible (400–760 nm) and infrared (> 760 nm) spectral regions. The main dependence studied in spectrophotometry is the dependence of the absorption intensity (as a rule, optical density is measured - the logarithm of light transmission, since it depends linearly on the concentration of the substance) of the incident light on the wavelength. Spectrophotometry is widely used to study the structure and composition of various compounds (complexes, dyes, analytical reagents, etc.), for the qualitative and quantitative determination of substances (finding trace elements in metals, alloys, technical objects).

1. Colorimeters and photocolorimeters

Photocolorimeters - devices designed to determine the amount of colored matter by measuring the values of absorption and transmission in the visible part of the electromagnetic spectrum.

2. Spectrophotometers

A spectrophotometer is a device designed to measure the relationship between two streams of optical radiation, one of which is the stream incident on the sample under investigation, the other is the stream that has experienced one or another interaction with the sample. This allows you to measure for different wavelengths of optical radiation, respectively, as a result of measurements, a spectrum of flux ratios is obtained. Usually used to measure transmission spectra or reflection spectra. A spectrophotometer is the main instrument used in spectrophotometry.

The main difference between a spectrophotometer and a photocolorimeter is the ability to pass a luminous flux of any desired wavelength through the sample, to conduct photometric measurements, scanning (scanning) the entire wavelength range not only of visible (VIS) light from 380 to 750 nm, but also near ultraviolet (UV) - from 200 to 380 nm.

The latter circumstance does not exclude the expediency of producing inexpensive spectrophotometers that do not have a source of ultraviolet radiation and work only in the visible part of the optical wavelength range.

The purpose of the aforementioned and very important mode of operation of spectrophotometers - scanning mode - is to build a spectral absorption (absorption) curve and to find peaks on it, as well as to study interference processes and search for false peaks that lead to erroneous results in spectrophotometric studies.

3. Two-wave spectrophotometers

In the early 50s of the last century, Brighton Chance proposed a new method for measuring very small changes in the absorption of highly scattering and turbid samples. The basic idea is very simple. While in two-beam spectroscopy, where two cuvettes, with sample and comparison, are irradiated with one but variable wavelength, two-wavelength absorption spectrophotometry uses only one cell with the sample, which is irradiated with two different wavelengths, and the difference in absorbances between 1 and 2.

The wavelength resolution here, as opposed to luminosity, is of secondary importance. Therefore, narrowband interference filters are quite suitable as a “monochromator” for a two-wavelength spectrophotometer. They have a greater luminosity than grating monochromators. Two beams of light with wavelengths 1 and 2 are alternately irradiating the sample with a mirror oscillating with a frequency from 30 to 100 Hz. The corresponding signals I and I are fed to the input of a phase-sensitive amplifier, the output of which, after a certain conversion, is fed to the computer for processing.

The sample cuvette is located in a special thermostatic holder, which guarantees a constant measurement temperature. [3]

4. Photodiode Spectrophotometers

A special type of spectrophotometers are devices with a photodiode array or a matrix. Here, the light from the source is directed directly to the sample and already after that - onto the diffraction grating, which projects the light spread in sub-bands onto the photodiode array or matrix. The latter contain a certain number of photodiode sensors that convert light energy into electrical impulses. Therefore, any range of wavelengths with a similar design of the spectrophotometer gives its "response" almost instantly, rather than consistently, as is the case in traditional spectrophotometry. Electrical pulses from photodiodes are usually processed by a microcomputer with the results displayed on the display. Depending on the wave band used for the operation, deuterium and/or tungsten lamps are used. The number of photodiodes determines the resolution of the spectrophotometric instrument.

The use of a photodiode array is an important element of the kinetic studies, which allows you to simultaneously measure the substrate under investigation and the product formed during the reaction at different wavelengths. The use of this scheme provides high speed when the spectrophotometer is operating in scan mode: less than one second per scan range.

1.3 Principle of operation of spectral instruments

Spectrophotometers allow you to decompose white light into a continuous spectrum, select a narrow wavelength range from this spectrum, within which a light beam can be considered monochromatic (the width of the allocated spectrum band is 1-20 nm), pass an isolated light beam through the analyzed solution and measure it with a high degree of accuracy the intensity of this beam. The absorption of light by the colored substance in the solution is measured by comparing it with the absorption of the zero solution. A photometric spectrophotometer combines two main devices: a monochromator, which is used to obtain a monochromatic light flux, and a photoelectric photometer, designed to measure the intensity of light. A monochromator consists of three main parts: a light source, a dispersing device (a device that decomposes white light into a spectrum) and a device that controls the size of the wavelength interval of a light beam incident on a solution. For the decomposition of light in the spectrum used glass and quartz prisms, as well as diffraction gratings. Prisms have a fairly large dispersion and a large luminosity. Quartz prisms make it possible to work in the ultraviolet region of the spectrum. A very important part of the spectrophotometer is the slit, with which you can adjust the intensity of the light flux: the smaller its opening, the less light passes through it and the narrower the wavelength interval of the light beam transmitted by the slit. A photoelectric photometer consists of vacuum photovoltaic cells, a direct current amplifier and a compensating device (potentiometer), the scale of which is calibrated in units of optical density and the percentage of light transmission. The basis of the spectrophotometer is the principle of measuring the ratio of two light fluxes: the flux passing through the sample under study, and the stream incident on the sample under study (or passing through a control sample). The light beam from the illuminator enters the monochromator through the entrance slit and is decomposed into a spectrum by a diffraction grating. In the monochromatic radiation flux coming from the exit slit into the cuvette compartment, the control and test samples are alternately introduced. The radiation transmitted through the sample enters the cathode of the photocell in the receiving amplifier unit. The electric current passing through the resistor RH, which is included in the anode circuit of the photocell, creates a voltage drop across the resistor proportional to the radiation flux incident on the photocathode. A DC amplifier with a gain close to unity provides the signal transmission to the input of the microprocessor system. The MPS measures and remembers UT and U voltages proportional to the dark photocell flux, the flux passed through the test sample, and the flux passed through the test sample . After measuring, the MPS calculates the transmittance T of the test sample. The value of the measured value is displayed on the digital photometric display.[4]

Structurally, the spectrophotometer consists of: a light source, a monochromator, a compartment for placing the sample under study, a photodetector, a low-noise, highly stable amplifier, and optical elements. The two main instruments of the spectrophotometer are: a monochromator, used to obtain a monochromatic light flux, and a photoelectric photometer, designed to measure the intensity of light.[5]

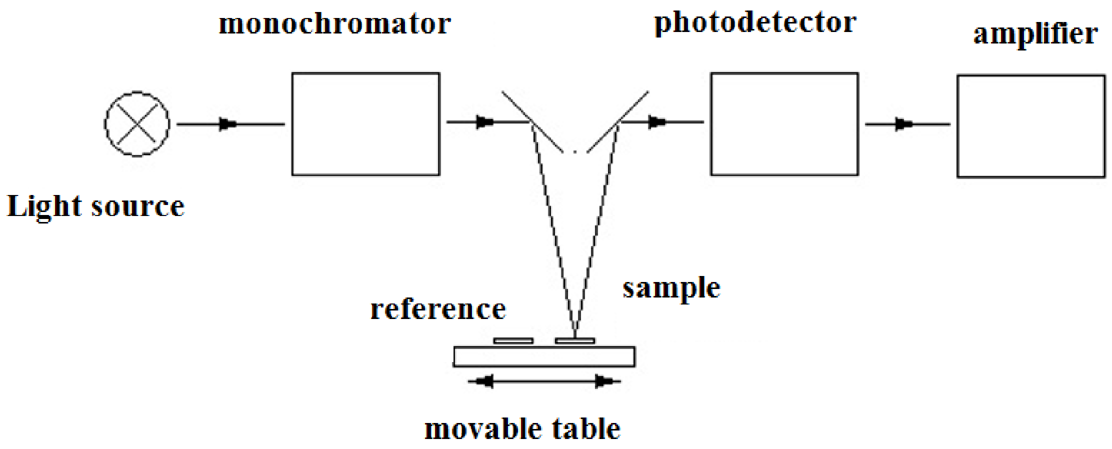

Fig.2 Spectrophotometer design

1.4 Review of existing technical solutions

Photocolorimeter KFK-3-01 - photoelectric is designed to perform chemical and clinical analyzes of solutions.

Photocolorimeter KFK-3-01 provides:

• determination of the content of substances (eg copper, iron, chlorine, silver) in various solutions;

• determination of blood and urine sugar, bilirubin, glucose, cholesterol, creatine;

• determination of the content in chemical solutions of urea, total protein, alkali, phosphates.

The photocolorimeter KFK-3-01 is presented in Figure 3, gives the measurement results on a digital display in units of transmittance t, optical density D, concentration C and allows kinetic measurements to be performed in 1, 2, 3, 4, 5 minutes.

Figure 3 - Appearance of Photocolorimeter KFK-3-01

Advantages of photocolorimeter KFK-3-01:

• a wide and continuous spectral range, which is provided by the integrated monochromator on the diffraction grating;

• a set of cuvettes with various lengths from 0.1 to 10 cm and a micro cuvette with a volume of test solution of 0.6 cm3;

• the ability to perform microanalysis in a continuous flow of liquid, and with partial filling;

• processing the results and issuing them on the scoreboard with high precision thanks to the microprocessor system.[6]

Technical characteristics of KFK-3-01 are given in table 1.

Table 1 - Characteristics of KFK-3-01

Specifications	Options
Transmittance t,%	0 – 100
Optical density	2 – 0
Concentration, concentration units	0,001 – 9999
Spectral range of work, nm	315 – 990
Allocated spectral range, nm, not more	7
The limit of permissible value of the basic absolute error in measuring the transmittance,%	0,5
Power supply, V	220
Overall dimensions, mm	500x330x165
Weight, kg, not more	15

Photometer KFK 3 KM photoelectric

The photometer photoelectric KFK-3 KM is a device produced in Russia using imported components and is designed to measure transmittance, optical density and concentration of solutions. [7] Favorably different bright and unusual design, figure 4.

The photometer photoelectric KFK-3 KM is designed for domestic operating conditions and is manufactured to meet Russian laboratory requirements. The technical characteristics and capabilities completely replace photocolorimeters and photoelectric photometers widely used in laboratory practice, such as FEC, KFK-2, KFK-3, KFK-5, combining high reliability, measurement accuracy, compactness, convenience and ease of management.

The method of analysis is photometric. The working length of the cuvette is 5–10–20–30– 40–50 mm. The wavelength setting is manual. It is possible to connect to a personal computer through the RS-232 port for saving and processing measurement results. The photometer is ready for use immediately after delivery to the laboratory. Warranty 2 years from the date of delivery.

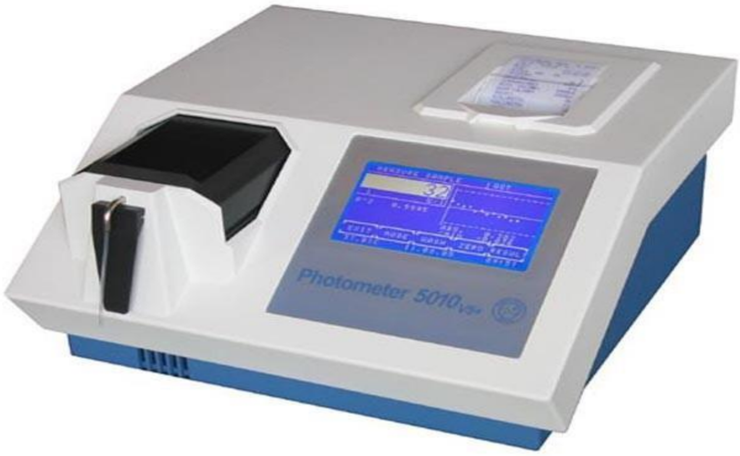

Figure 4 - Appearance of photometer photoelectric KFK-3 KM

The photometer photoelectric KFK-3 KM is a desktop single-beam optical device operating in the visible region of the spectrum (325-1000 nm). The photometer consists of five parts:

• halogen lamp as a light source;

• monochromator (diffraction grating to highlight the spectral range of the required wavelengths);

• cuvette compartment, which is used for placement of samples and calibration solutions;

• a detector for recording light and converting it into an electrical signal;

• digital display to indicate optical density and transmittance.

Technical characteristics of the photometer photoelectric KFK-3 KM are given in table 2.

Table 2 - The main technical characteristics of KFK-3 KM

Specifications	Options
Spectral wavelength range	325 - 1000 nm
Photometric range: -transmittance (T) -optical density (A)	From 0 to 125% 0 to 3.0
The error in determining the coefficient bandwidth, not more	1,0 % T
Wavelength setting error, not more	2 nm
Wavelength repeatability	1 nm
Zero line drift	0,004 A/h
Spectral slit width	5 nm
Diffuse Light (Interference Radiant Energy)	<0.5% T at 340 nm and 400 nm
Optical layout	single beam; 1200 lines/mm
Radiation source	Halogen lamp
Ditch holder	under three cuvettes 24 mm wide, with optical path length 10–50 mm, standard KFK-3
Working Ditch	5–10–20–30–40–50 mm
Digital output	RS – 232
Photometer power	200 watts
Power Requirements	220 V ± 10%, 50 Hz
Dimensions (length × width × height × weight)	408 × 308 × 185 (mm); 7 kg

Biochemical analyzer (photometer) "BIALAB-100"

Distinctive features of a semi-automatic photometric biofluid analyzer with extensive hardware and methodological capabilities:

- determination of glucose, hemoglobin, total protein, albumin, creatinine, bilirubin, urea, uric acid, cholesterol, triglycerides, activity of AlT, AST, LDH, amylase, acidic and alkaline phosphatase, as well as macroelements and electrolytes;
- memory for 100 programs of user defined techniques;
- password protection programs;

• automatic installation of filters in the measuring channel;

• change of the sample number;

• conducting repeated measurements of the sample;

• automatic control of the results of falling into the range of "norm";

• up to 31 optical density measurements per minute when measuring the type of "kinetics";

• display in real time of the optical density values during kinetic measurements;

• display on the display screen and printer of a graph of the dependence of optical density on time and average values per minute during kinetic measurements;

• display on the display screen and printer calibration schedules;

• automatic control of the presence of air (liquid) in the flow system;

• built-in program for quality control (norm and pathology);[8]

Technical characteristics of the biochemical analyzer (photometer) "BIALAB-100" are given in table 3.

Table 3 - Characteristics of "BIALAB-100"

Specifications	Options
Analysis Methods	optical density, end point, kinetics, fixed time, nonlinear, two-wave, turbidimetry
Light source	halogen lamp (12 V, 20 W) with a slow start system for longer life

Optical density measurement range	0 - 2.5 E.O.p.
Measurement error	no more than 1% of optical transmission
Memory	100 measurement programs
Thermostating of the measuring cuvette	built-in thermostat with Peltier element: 25, 30, 37 ° C; accuracy ± 0,2 ° C
Sample Incubation Thermostat	external, for 16 tubes
Flow cell volume	32 μl
Reagent consumption	from 250 μl
Printer	built-in matrix printing on plain paper with a tape width of 56 mm
Display	liquid crystal: 4 lines of 20 characters
Performance	up to 100 analyzes / hour by the end point method
Dimensions and weight	no more than 355x355x185 mm; 8.5 kg

1.5 Sorbents for concentrating metals

To date, thousands of sorbents are produced with various matrix materials, functional groups, methods of their fixation, containers, mechanical properties, granulation and other characteristics. The choice of the optimal sorbent depends on the task assigned to the researcher. To a large extent, the choice of sorbent is determined by the nature of the microcomponent — the form of existence of this component in solution, the size and charge of the ion or molecule, the ability of this form to react with functional groups or directly with the surface of the sorbent. When choosing a sorbent it is necessary to consider the mode of concentration. So, after sorption extraction in static conditions, the sorbent concentrate should be easily separated from the mother liquor; when used in dynamic mode - it is undesirable to use highly swelling sorbents, as well as too small fractions of sorbents.

In combined methods, where the first step is concentration, and the second may be spectroscopic methods, such as spectrophotometry, atomic absorption spectroscopy (AAS), atomic emission spectroscopy with inductively coupled plasma (AES-ICP), mass-spectrometry with inductively coupled plasma (MS-ICP), the possibility of rapid and quantitative elution of elements is taken into account. In the case of diffuse reflectance spectroscopy or solid-phase spectrophotometry, sorbents should not be intensely colored. When using the X-ray fluorescence method, it is advisable to use thin-layer sorbents that do not contain heavy metals. Also important when choosing a sorbent is the possibility of selective extraction of elements or groups of elements.

Sorbents for the concentration of inorganic microcomponents can be divided into organic and inorganic. Organic - usually polymeric (natural and synthetic origin), inorganic matrices - are oxides of elements insoluble in aqueous solutions (silica, oxides of aluminum, titanium, aluminosilicates, etc., as well as activated carbon, carbon black, graphite powder.

1.6 Organic based sorbents

A characteristic difference in chelating polymer sorbents from other types of sorbents is the presence in the matrix of chemically active groups that can interact with metal ions in solution to form chelate complexes. Such groups can be introduced into the polymer matrix by chemical transformations or they are formed during the synthesis of a polymer sorbent. The complexing properties of polymeric sorbents depend on many factors: the nature of the matrix and functional groups, the degree of homogeneity and spatial arrangement of groups, the presence of other functional groups. In this connection, the mechanism of interaction of complexing sorbents is in many cases rather complicated and remains unclear. It is possible to conditionally define chelating sorbents as organic polymeric compounds containing groups that, in accordance with the chemical nature of the active groups and their geometric and coordination capabilities, can form chelate complexes when interacting with metal ions in solution.

A feature of chelating sorbents is their selectivity in the interaction with metal ions in solution. This is mainly determined by the nature of the chemically active groups contained in the polymer. If these groups are capable of coordinating interaction with metal ions, then during sorption, the formation of complexes in the polymer phase is possible due to the coordination bond [9]. At present, various compounds are used as polymer matrices for the synthesis of chelating sorbents: linear and spatial polymers obtained by polycondensation and polymerization, natural organic polymers, synthetic fibers and other compounds. Recently, cellulose, copolymers of styrene and divinylbenzene of methyl methacrylate, acrylonitrile, and other polymers have been increasingly used as polymer matrices.

1.7 Sorbents based on inorganic matrices

Currently, there is a wide variety of sorbents, the matrix of which is inorganic in nature: these are activated carbons, carbon black, graphite powders, metal oxides and hydroxides, zeolites, chained and layered silicates, aluminosilicates, clays. Most of these sorbents are primarily used for group extraction. For selective extraction of metal ions, it is preferable to use sorbents with a modified surface. Most widely, inorganic metal oxides, such as silicon (silica), aluminum, zirconium or titanium oxides, are used as a matrix for modification.

Among other inorganic and organic matrices, they are favorably distinguished, first of all, by the possibility of varying their structural characteristics over a wide range (specific surface area, diameter and pore volume, particle size and shape), insignificant catalytic activity, non-swelling, thermal and hydrolytic stability, availability and cheapness. Due to the surface arrangement of the functional groups, the sorbents have high rates of establishment of sorption equilibrium, which allows for concentration in both static and dynamic modes, and provides ease of desorption of sorbed elements. Another important argument when choosing inorganic oxides as sorbents is the absence of intrinsic color and luminescence, which allows the use of sorbents on an inorganic basis when developing methods for sorption photometric and sorption-luminescent determination of elements directly in the sorbent phase.

Among the mineral carriers for the modification with organic reagents, oxides of aluminum, zirconium, and titanium are less studied. Their rarer application is associated with less variability of pore size and specific surface area than silica, and the Lewis and Brønsted acid sites active on the surface of these oxides cause various uncontrolled transformations. Consider the structure of the silica surface, since the choice of modifier depends on the hydrophilicity or hydrophobicity of the matrix. Silanol and siloxane groups are present on the silica surface; depending on the degree of dehydroxylation of the surface, their ratio can vary greatly. In extremely hydroxylated silica, there are 4.6–4.8 OH groups/nm2 or about 8 μmol/m2 on the surface. Silanol groups are much more active and easier to enter into chemical reactions than siloxane groups, since the proton of the silanol group has a weakly acidic character and is capable of entering into exchange reactions [10]. 5 types of groups are distinguished on the surface of silica in various ratios [11]: a) silanol (bound) water — free, free-standing OH groups; b) physically bound water — water molecules that have hydrogen bonds with silanol groups; c) dehydrated - oxides - siloxane groups; d) twin (geminal) OH groups bound to a single silicon atom; e) reactive vicinal OH groups prevailing in fine-porous silica - adjacent, closely located OH groups linked by hydrogen bonds: Hydrophobic silica surface can be achieved by heating it to 1200 °C, while the silanol groups are converted to siloxane, water is removed in the form of a pair. Initially, the physically bound water is removed, and then the condensation of silanol groups occurs. The temperature at which sorbed water is removed depends on the structure of the silica. The process is reversible by prolonged boiling in water (about 60 hours) of hydrophobic silica samples (aerosil). Based on silica, a large number of various modified materials have been obtained that possess the chemical identity of the analytical reagent and the properties of silica as a solid. To fix the analytical reagent on the matrix using a number of techniques. One of them, synthetic, is a so-called covalent graft of a modifying reagent. Another technique is the sol-gel method, which allows to obtain silica matrices in the form of a sol with a further production of a gel with an adjustable porous structure.

1.8 Sorption-photometric and sorption-luminescent determination of metal ions

There is a linear relationship between the light absorption of the sorbent solid phase and the concentration of a substance sorbed on its surface. The use of a method based on this observation, called solid-phase spectrophotometry, can significantly increase the sensitivity of the analysis compared to measuring the light absorption of the analyte after it is eluted into a solution. Depending on the method of measuring the analytical signal, solid-phase spectrophotometry, diffuse reflection spectroscopy, solid-phase luminescence, and colorimetry are distinguished. One of the main requirements for sorbents in these methods is their own small color or luminescence, which ensures the minimum value of the control experiment. Silica non-covalently modified with quaternary ammonium and xylene orange was used as a sorption material for selective concentration and determination of Pb (II) in natural water and food products using diffuse reflectance spectroscopy [12]. The concentration of the metal was determined by the calibration curve, built at 580 nm, the detection limit was 2 μg/l during sorption from 100 ml of solution. Investigated the interfering effect of related metal ions. Silica gel immobilized with 1- (2-thiazolylazo) -2-naphtol was proposed as a sorbent for concentrating Cu (II) and Zn (II) from natural and tap waters with subsequent determination of diffuse reflectance spectroscopy, since the sorbent becomes colored upon contact with metals in purple color [13]. The pH of quantitative extraction of metals is different, therefore it is possible to separate the determination of metals with the joint presence, the maximum of the LMS is located at 570 nm. The metal concentration was determined in the range of 0.65-13 μg/l, the detection limits were 10 and 15 μg/l, respectively. The interaction of Zn (II) with non-covalently immobilized on silica 1,10-phenanthroline in the presence of bromophenol blue was studied [14]. The optimal reaction conditions and the composition of mixed-ligand complexes formed on the surface are established. A sorption-37 spectrophotometric method was developed for the determination of zinc with a detection limit of 0.011 mg/l, the linearity of the calibration curve is maintained in the concentration range of 0.01-0.3 mg/l. The technique is applied to the determination of mobile forms of zinc in the soil. For sorption-photometric determination of iron, sorbents based on inorganic oxides (SiO2, Al2O3, ZrO2) sequentially modified with polyhexamethyleneguanidine and 4,7-diphenyl-1,10-phenanthrolindisulfonic acid have been proposed [15]. Sorbents quantitatively extract iron (II) from solutions with a pH of 4.0–8.0 and a time to establish sorption equilibrium of 5 min. The formation of colored iron (II) complexes on the surface of sorbents was used in the development of methods for its sorption-photometric determination. The linearity of the calibration graphs is maintained up to 6-8 μg/0.1 g, the detection limit is 0.02-0.05 μg/0.1 g. The techniques are used in the determination of iron in natural waters.

2 SELECTION AND JUSTIFICATION OF DEVICE STRUCTURE DIAGRAM

In order to start designing a portable spectrophotometer, it is necessary to understand what functional units the instrument will consist of. The measurement method, based on the reflection coefficient of the substance, involves the use of a radiator and a photodetector. To process the data from the photodetector must be converted to digital format. After processing the result is displayed on the display. You also need an input device and power supply. Based on these requirements, you can present a block diagram of the device, where 1 is the radiator, 2 is the power supply, 3 is the control system, 4 is the input device, 5 is the object of study, 6 is the output device, 7 is the radiation receiver, 8 is the signal converter.

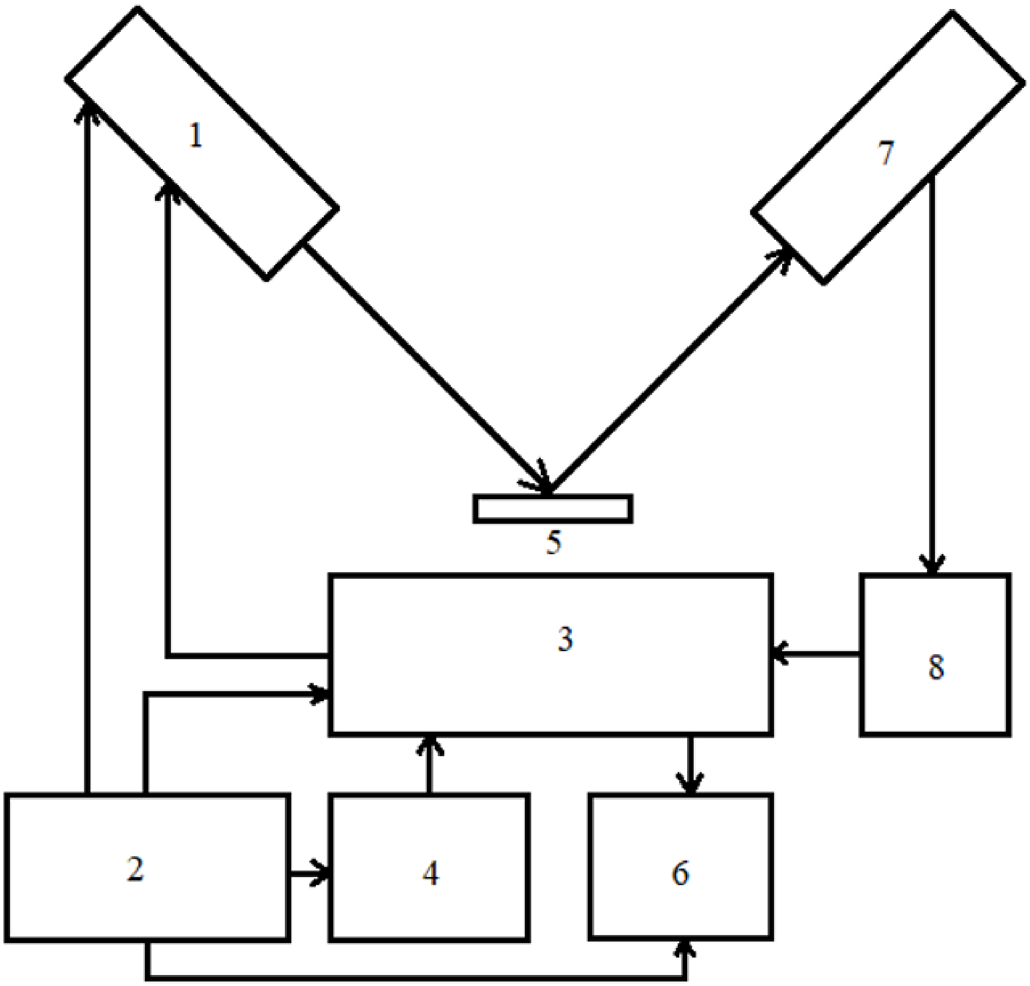

Fig. 5. Block diagram of the device.

As the emitter (1) it is necessary to use a semiconductor laser. The power source (2) is designed to power the entire device as a whole and its individual elements in particular. A power source with a supply voltage of 5 V will be used as the power source. The control system (3) of the portable spectrophotometer is a microcontroller. The input device (4) is a peripheral equipment designed to input (input) data or signals to a computer or other electronic device during its operation. In this design, the input device is a button. The object of study (5) is the substance from which the signal is reflected. The output device (6) is a device designed to display or signal monitored parameters, in this case, this display. The photodiode acts as a radiation receiver (7). The signal converter (8) is an operational amplifier.

3 SELECTION OF ELEMENT SCHEME

A microcontroller is needed to control the laser and process the signal received from the photodiode. The main requirement for the microcontroller is the presence of the ADC. Since no complicated calculations are planned, the performance of the microcontroller does not play a big role, but it is important that there are enough ports to connect all the necessary devices. An Arduino nano debug board based on the ATMega328p 8-bit microcontroller was selected for this task. The ATmega328P has 32 kB of flash memory, 2 kB of RAM, 1 kB of EEPROM (permanent data memory). This microcontroller contains the following peripherals:

- Two 8-bit timer / counter with comparison modules and frequency dividers;
- 16-bit timer / counter with a comparison module and a frequency divider, as well as with a recording mode;
- 10-channel DAC with built-in temperature sensor;
- Programmable watchdog timer with a separate internal generator;
- Interrupt and wake-up processing unit when the voltages on the microcontroller terminals change
- Real-time counter with separate generator.

This MK is suitable for us on the supply voltage (given 5 V). Its main advantages are compactness and the presence of a built-in USB-UART converter for ease of programming. The 10-bit ADC built into this controller is quite enough for the tasks.

The emitter should be a source of visible point monochromatic radiation of sufficient power with a wavelength as close as possible to the corresponding peak reflectance of the substance. A laser is ideal for this task. Figure 2 shows the diffuse reflectance spectra of the iron (II) complex on the surface and in solution. The maximum reflection, according to the graphs, corresponds to 570 nm. Due to the lack of affordable compact lasers with a wavelength of 570 nm on the market, a semiconductor laser with a wavelength of 532 nm and a power of 5 mW was chosen.

As can be seen in Figure 6, this wavelength is suitable for measurements with small assumptions. A power of 5 mW is sufficient to register with standard optical radiation receivers, and at the same time, small enough to affect the object of study.

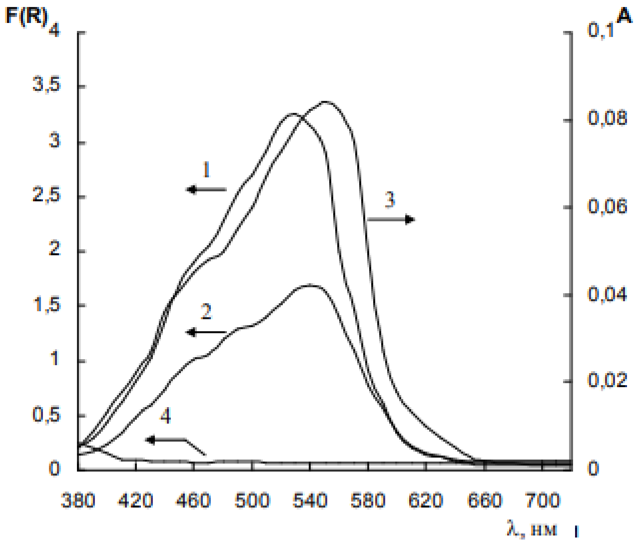

Fig. 6. Diffuse reflectance spectra of the iron (II) complex on the surface of SiO2 -PGMG-Batophen (1), ZrO2 -PGMG Batophen (2) and the complex of iron (II) with Batophen in solution (3).

To receive reflected radiation, a photodetector is needed that is sensitive to the wavelength used. The photodiode FD256 widely used in the measurement technique in terms of spectral range meets the requirements of work. The characteristics of the photodiode are presented in table 4.

Table 4. Technical characteristics of the photodiode FD256

Available in an airtight metal-glass case.	
Entry window: Uncoated glass	
Spectral photosensitivity range	0.4 ... 1.1 μm
The wavelength of the maximum spectral distribution of photosensitivity	0.8 ... 0.9 μm
Rated operating voltage	10B
Dark current	not more than 0.5 nA
Current photosensitivity	not less than 0.6 μA/lx
Size of sensitive area	1.45 x 1.45 mm

Working temperature	-60° C - +85°C
Number of items	1

Since the photodiode generates a voltage of 0.1-1 mV in the generation mode, the signal must be amplified before performing the analog-digital conversion. For this task, an op amp with a unipolar power supply, for example, 5V, and a low bias voltage, made in a DIP package for ease of installation, is best suited. From commercially available microcircuits, the LM358N meets the requirements.

The choice of output device is reduced to the analysis of the volume and type of information provided by the device. It is supposed to display integers and short system messages. For this, a text LCD display with a resolution of 16 * 2 characters is well suited. Also on the selected display there is a backlight for comfortable reading of data and an I2C expansion chip to reduce the number of wires necessary to connect the display to the controller.

The supply voltage of the device is selected on the basis of the maximum supply voltage of one of its components. Therefore, in this case, we choose a microcontroller supply voltage of 5 V to power the device. Since the current consumption of the system is less than 0.5 A, power can be supplied from a standard mini-USB charger.

4 SELECTION, JUSTIFICATION AND CALCULATION OF THE DEVICE PRINCIPLE SCHEME

The main task in drawing up the concept of the device is the selection of the switching circuit of the operational amplifier and its calculation. There are many various amplifier circuits for this purpose. You can select the desired scheme in accordance with the required parameters: linearity, constant offset, noise and bandwidth.

Constant sensitivity at a constant applied voltage allows us to conclude that in order to obtain a linear dependence of the output signal on the light energy, it is necessary to use current measurement. A meter for this current must have zero input impedance so that the voltage drop across the diode is also zero. The zero impedance is provided by the operational amplifier, since due to the large amplification its feedback establishes a zero voltage difference between the inputs. This is the key point of the basic circuit of the current-to-voltage converter shown in fig. 1. It provides an input impedance equal to R1/A, where A is the gain of the operational amplifier with an open feedback loop. Despite the fact that the resistance R1 is usually very large, the resulting input resistance remains negligible compared to the output resistance of the photodiodes. The current of the diode practically does not flow through the input of the operational amplifier, wholly heading to the feedback resistor R1. To obtain this effect, the operational amplifier sets at its output a voltage equal to the product of the current of the photodiode and the resistance R1. To obtain a current-to-voltage ratio as large as possible, the resistance R1 is made as large as current limitations allow.

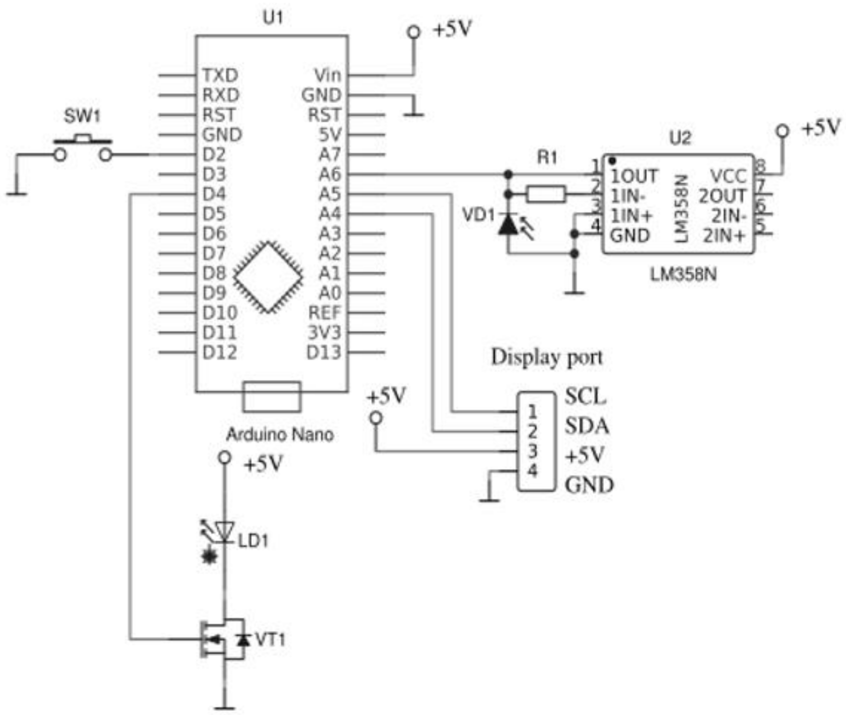

Fig.7 Schematic diagram of the device

Since the supply voltage is 5V, the output voltage of the op amp should be between 1 - 3 V to avoid saturation. Then with medium illumination:

$$U_{out} = I_{VD1} \times R_1 = E_U \times S \times R_1$$

$$\mathrm{R_1} = \frac{\mathrm{U_{out}}}{\mathrm{E_U \times S}} = 9090909\ \ \mathrm{Om}$$

Choose a resistor of 10 MOm from the E24 series, since the high accuracy of the resistance is not important.

The main task in the design of the device is to choose a compact and reliable layout. The laser, photodiode and compartment for the object should be positioned so that the reflected radiation falls exactly into the diode. In order to be able to explore liquid objects inside the compartment there will be a notch for the cuvette. Since one wall will be missing for convenient placement of the object of study, the display should be positioned on the other side, and the measurement start button should be positioned from the end. The compartment with the device board is located in the lower part of the device under the partition separating it from the working area, and is closed with a cover with provided ventilation holes. Since a tight girth of a laser and a photodiode is necessary, the body is assembled from two parts with glue and special connecting protrusions, and grooves located on its parts. The body is made of PLA plastic on a 3D printer.

5 ALGORITHM AND PROGRAM WORK CODE

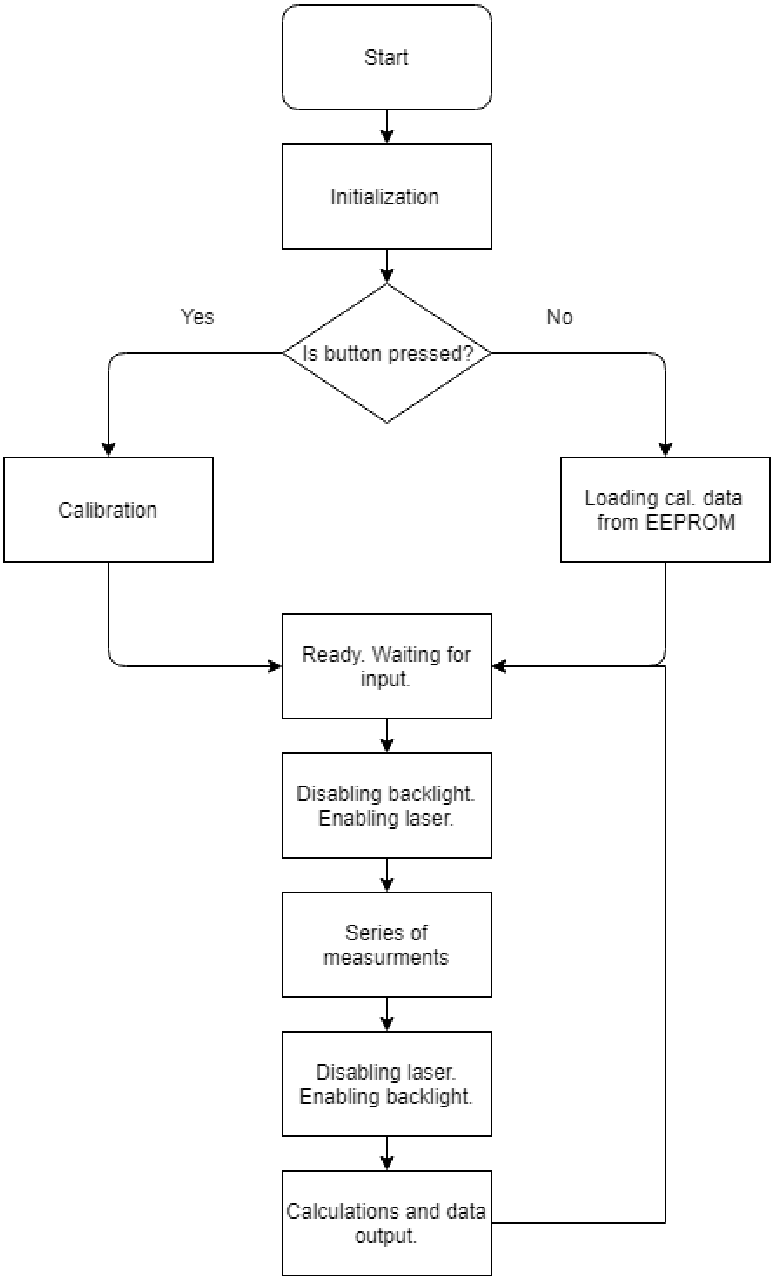

Fig.8 Program Algorithm

Program code executed in the Arduino IDE

#include <Wire.h> // Connecting the library necessary for the library to work LiquidCrystal_I2C.h

#include <LiquidCrystal_I2C.h> // Connecting the library to work with the text display protocol I2C

#include <EEPROM.h> // Connecting the library to work with EEPROM

```
#define BUT 2 // Button input
#define LAS 6 // Transistor output
#define AN 6 // ADC input
int andata[9]; // Data array
uint8_t zero; // Variable to store the calibration value
LiquidCrystal_I2C lcd(0x27,16,2); // Setting the display format and its address on the I2C bus
void setup()
{
  pinMode(LAS,OUTPUT); // Putting output into push-pull mode
  pinMode(BUT,INPUT_PULLUP);// Transfer of the output to the input mode with a pull-up to 5V
  digitalWrite(LAS,LOW);// Setting the logical 0 output
  lcd.init(); // Display initialization
  zero = EEPROM.read(0); // Read calibration value from EEPROM memory
    if((zero ==255)|(digitalRead(BUT)==0)) // If no value or forced calibration {
     for(uint8_t i = 0; i<9;i++)  // ADC voltage measurement in the dark
    {
      andata[i] = analogRead(AN);
      delay(100);
    }
    zero = (andata[6] + andata[7] + andata[8])/3; // Averaging the dark voltage value
    EEPROM.write(0,zero); // Writing the resulting value to the EEPROM memory
    }
  lcd.backlight(); // Turn on the display backlight
   lcd.print("z="); // Display calibration value on display
   lcd.print(zero);
```

```
lcd.print("Ready"); // Readiness message
while(!digitalRead(BUT)) {} // Waiting for button release
  }
void loop()
{
 int result =0; // Variable to store the average result
 while(digitalRead(BUT)) // Waiting for button click
 {
 }
 lcd.clear(); // Cleaning display
lcd.noBacklight(); // Turn off the backlight display
 digitalWrite(LAS,HIGH); // Turn on the laser
 delay(1000); // Delay to start the laser
  for(uint8_t i = 0; i<10;i++) // cycle of 10 signal measurements from an op
amp with a period of 100 ms
    {
    andata[i] = analogRead(AN);
    delay(100);
  }
   digitalWrite(LAS,LOW); // Turn off the laser
 lcd.backlight(); // Turn on the display backlight
  for (uint8_t i =0;i<10;i++) // Calculate averaged value
 {
  result+= andata[i];
 }
 result = result/10;
 lcd.print(result); // Output of the result
 }
```

6 EXPERIMENTAL PART

The purpose of the experimental part is to confirm the performance of the instrument for carrying out spectrophotometric studies.

For the experiments were used:

1) Mirror
2) Steel knife
3) Black cardboard with a glossy surface
4) White cardboard with matte finish
5) Black sponge
6) Glue BF
7) Liquid soap "Iris" purple.

In order to carry out direct studies on objects, it is necessary to calibrate the device, that is, to set the ratio between the displayed result and the reflection coefficient of the substance. For calibration, an experiment was conducted using a mirror and empirically determined by a reflection coefficient of 76% and direct radiation into the photodetector. Before conducting the experiments, it is recommended to auto-adjust the instrument to determine the dark voltage on the ADC. To do this, before starting the device, you need to hold the measurement button and close the compartment lid to place the objects of study. The default is the previous voltage read from the controller EEPROM. The results of the experiment are presented in table 5.

Table 5. Reference Reflection Ratios

An object	**The result**	**Reflection coefficient**
Mirror	47	76%
Straight beam	62	100%

Having a value of the reflection coefficient of the mirror and implying that the dependence of the diode current on the illumination is linear, we calculate the ratio between the results obtained from the device and the coefficient.

$$\mathrm{C} = \frac{\Delta \text{Рез}}{\Delta K} = \frac{15}{24} \approx 0.625$$

Having obtained the calibration coefficient between the measurement results and the reflection coefficient, it is possible to conduct an experiment on measuring the reflection coefficient of various objects.

For the experiment were taken various materials and substances. The solids were placed in the cavity for the cuvette so that their surface was flush with the upper border of the cavity. This is necessary to maintain the accuracy of the reflection. Liquid substances were placed in a special cuvette, made of transparent plastic using a 3D printer. The results of the study are presented in table 6.

Table 6. The reflection coefficients of various objects.

An object	**The result**	**Reflection coefficient**
Steel	27	43%
Cardboard (black)	13	21%
Cardboard (white)	20	32%
Plastic (white)	15	24%
Sponge (black)	11	18%
Glue	15	24%
Liquid soap “Iris”	13	21%

7 FINANCIAL MANAGEMENT, RESOURSE EFFICIENCY AND RESOURCE SAVING

7.1.1 Potential consumers of research results

The purpose of this section is to determine the prospects and success of a research project from an economic point of view. The objectives of this section: a description of the potential customer development, QuaD and SWOT analysis, building a tree of goals, identifying development stakeholders, planning work phases and scheduling work, determining development risks, and budgeting costs.

In the course of this work, a portable optical system for sorption-photometric determination of substances was developed. A separate complex of a portable optical system is a spectrophotometer - a device designed to study the properties of substances, objects by analyzing the spectrum of the optical range of electromagnetic radiation transmitted through a sample, or reflected from it. The results of the work will be used to create the hardware of the complex for the evaluation of the studied organic or inorganic substance.

The target market is called the market segments, which will be the main consumer of the development in the future, and the market segment is called the part of the market or a group of consumers, identified by special common features. Market segmentation was carried out for a separate complex of the developed optical system - a portable spectrophotometer.

Firstly, we choose the medical field as a general application area for selection, since analyzing the results of organic matter research with a portable spectrophotometer requires qualified medical personnel, medical equipment and patient data.

Secondly, the results of this study are directed to research centers that are associated with the study of color composition, the determination of the chemical composition and the presence of impurities in substances.

And finally, thirdly, the study is intended for the food industry, as with the help of spectrophotometric analysis is determined by the degree of readiness and compliance with product standards.

The map of market segmentation is presented in table 7.

Table 7 - Market Segmentation Map

	Scope of application	
	Study	Evaluation of the result of the study
Individuals		
Medical research centers, chemical laboratories		
Medical institutions		

	Segment not mastered
	The segment is poorly developed
	Segment mastered

The main segment is medical research centers, on which this development is oriented, as well as institutions that provide medical services related to the chemical analysis of organic substances and tissues, such as polyclinics and hospitals.

7.1.2 QuaD technology

To describe the quality of the new development and its prospects in the market, which allows you to decide whether to invest money in a research project, we use QuaD technology (Table 8).

Table 8 - QuaD development analysis

Criteria for evaluation	**Weight criteria**	**Points**	**Max score**	**Relative value**(3/4)	**Weighted average value**(5/2)
1	2	3	4	5	
Indicators for assessing the quality of development					
1. Energy efficiency development	0,1	80	100	0,8	8
2. Development safety	0,1	90	100	0,9	9
3.Functional power	0,1	80	100	0,8	8
4. Easy operation	0,1	90	100	0,9	9
5. Quality of the intelligent interface	0,05	80	100	0,8	16
6.Visualization of results	0,1	70	100	0,7	7
7. The need for memory resources	0,1	80	100	0,8	8
Indicators for assessing commercial development potential					
8. Product Competitiveness	0,1	80	100	0,8	8
9. Price	0,15	90	100	0,9	6
10. Financial effectiveness of scientific development	0,1	80	100	0,8	16
Total	**1**			**8,2**	**95**

Quality assessment and prospects for technology QuaD is determined by the formula:

$$П_{ср} = \sum В_i \cdot Б_i ,$$

where $П_{ср}$ - the weighted average value of the indicator of quality and prospects of scientific development;

$В_i$ - weight of the indicator (in units of units);

$Б_i$ - weighted average of the i -th indicator.

Since the weighted average value belongs to the range from 100 to 80, such development is considered promising. Specifically, this development of a portable spectrophotometer is promising, because current trends, such as energy efficiency, small dimensions, the cost of minimal resources (human, memory, etc.) for maximum results, are preserved. Since this project is promising, we can conclude that there will be funding for its production, and possible further improvement.

7.1.3 SWOT analysis

SWOT analysis is one of the most effective tools in strategic management, which consists in analyzing the external and internal factors of a company, assessing the competitiveness and risks of goods in the industry.

Table 9 – SWOT- analysis matrix

	Strengths of a research project: Ct1. Demand for development; Ct2. Relevance of the development; Ct3. The presence of a prototype of scientific development; Ct4. Availability of budget funding from the Department of IHBBT; Ct5. Ability to develop with a minimum set of technical tools.	**Weaknesses of a research project:** We1. To create a prototype of scientific research, basic knowledge of the basics of such disciplines as electrical engineering and electrical circuit theory is necessary; We2. The relative accuracy of the results; We3. Difficulty in obtaining the necessary data; We4. Time consuming; We5. Limitations in conducting this study for certain groups of individuals.
Opportunities: Op1. Widespread method; Op2. The use of innovative infrastructure TPU; Op3. The appearance of additional demand; Op 4. Increasing the cost of competitive development.	This development is considered relevant and popular, and in the future, with proper funding from TPU and consumer interest, it is possible to further improve the development in order to enter the market.	The method of spectrophotometric analysis of substances is widely used in medical institutions. For the initial testing of the development, it is possible to use the clinics of SibSMU due to the developed cooperation with TPU.
Threats: Th1. The emergence of a better design; Th2.The introduction of additional state requirements for product certification; Th3. The late financial support of scientific research from the state.	The availability of a working prototype of a portable spectrophotometer, made from a minimum set of components, will allow a competitive presentation to find investors for the project.	Due to the lack of visual results of this work may lead to a reduction in funding, which means that this device will be upgraded at a low speed. There is also a possibility that certification of products for which you need to allocate money and time will be required.

According to the results of the SWOT analysis, it is possible to draw conclusions that it is necessary to develop and improve the methods of the performed scientific and technical research. Strengths, such as the relevance of the research and the availability of a prototype of the development, will help to develop the possibilities of promoting research in a dedicated market segment, as well as reduce the influence of weaknesses and threats that affect the ability of this work to compete.

7.2 Initiation of development

The goals of the project, the structure of the project and the organization of the project participants can be described by interrelated hierarchical (tree-like) structures in which the relations between the components can be established: goals - parts of the project - participants, etc.

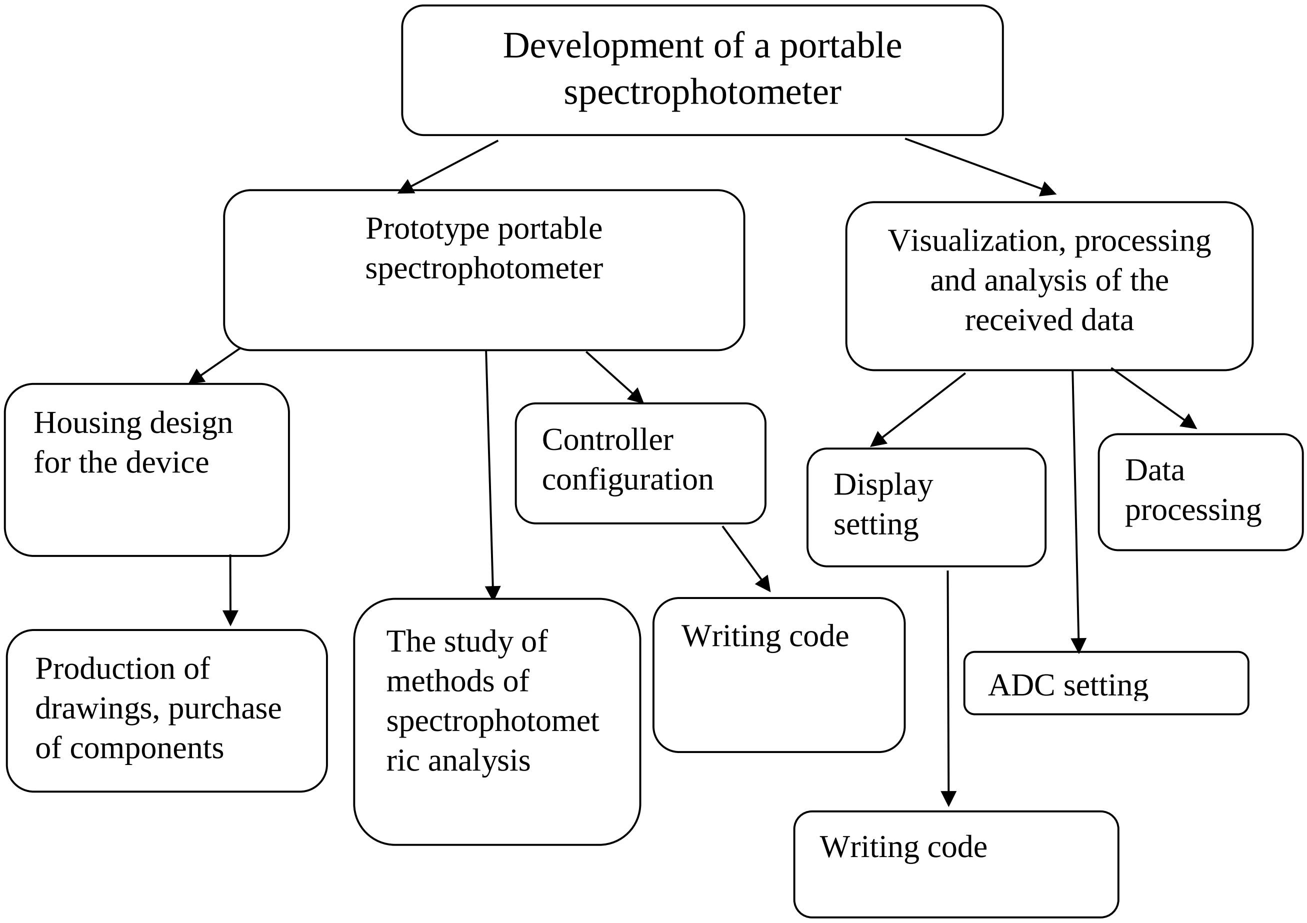

Figure 9 - Project Objective Tree

Table 10 presents the development stakeholders and highlights the key expectations of the stakeholders.

Table 10 - Stakeholders of the development

Project stakeholders	**Stakeholder expectations**
Medical institutions	Obtaining reliable results of spectrophotometric analysis
Research laboratories	
TPU	Creating a patentable instrument

Table 11 presents the working group for development, defines the role and main functions of each participant in the development.

Table 11 - Working Group Development

№	**FULL NAME, main place of work position**	**Role in the design**	**Functions**	**The complexity of the work, $T_{РД}$**
1	Gubarev F.A., TPU	Supervisor	The approval of the main sections, the issuance of tasks for execution, coordination of the activities of the contractor	11
2	Kyrov I.V., student of TPU	Executor	Execution of tasks	94
TOTAL:				105

The requirements for the final version of the development are quite high - portability, compactness, reliability of the results in the analysis of substances, the presence of a working layout. All of the above requirements will be checked at the time of the development of the research supervisor and in the further commissioning.

This section reflects the fact that the work performed is quite large. Stakeholders of the project expect sufficiently high-quality results to be achieved by the performer.

7.3 Planning development management

8.3.1 Development Plan

A group of planning processes consists of processes that are carried out to determine the overall content of the work, clarify the objectives and develop a sequence of actions required to achieve these goals.

As part of the planning of a research project, it is necessary to build a project calendar and network schedules. The list of stages, works and distribution is presented below in Table 12.

Table 12 - List of stages, work and distribution of performers

Main steps	№ раб	Content of work	Position performer
Development of technical specifications	1	Drafting and approval of technical specifications	Gubarev F.A.
Choosing the direction of research	2	Selection and study of materials on the topic	Kyrov I.V.
	3	Choosing the direction of research	Gubarev F.A. Kyrov I.V.
	4	Scheduling work on the topic	Kyrov I.V.
Choosing the direction of research	5	Evaluation of the effectiveness of the results and determination of the feasibility of OCD	Kyrov I.V.
	6	Purchase of components	Kyrov I.V.
Summary and evaluation of results	7	Analysis of the data, assessment of the accuracy of the data	Gubarev F.A.

Development of technical documentation and design	8	Development of the program algorithm	Kyrov I.V.
	9	Development and calculation of parameters of the concept	Gubarev F.A. Kyrov I.V.
Manufacturing and testing the layout (prototype)	10	Design and manufacture of the layout	Gubarev F.A. Kyrov I.V.
	11	Laboratory test layout	Gubarev F.A. Kyrov I.V.
Preparation of a report on research (set of documentation for OCD)	12	Drawing up an explanatory note (operational and technical documentation)	Kyrov I.V.

7.3.2 Determination of the complexity of the work

We use the following formula to determine the expected value of labor intensity:

$$t_{\text{ожі}} = \frac{3t_{\min i} + 2t_{\max i}}{5}$$ where

$t_{\text{ожі}}$ - the expected complexity of the i-th work person-days;

$t_{\min i}$ - the minimum possible laboriousness of performing the specified i-th work (optimistic estimate: assuming the most favorable set of circumstances), man-days;

$t_{\max i}$ – the maximum possible labor-intensiveness of performing a given i-th job (pessimistic assessment: assuming the most unfavorable set of circumstances), man-day.

Once calculated $t_{\text{ожі}}$, the duration of each work in working days is calculated: $T_{\text{р}_i} = \frac{t_{\text{ожі}}}{\text{Ч}_i}$, Where

$T_{\text{р}i}$ – the duration of one job, slave. Mon .;

$t_{ожi}$ – the expected complexity of doing one job, man-d

$Ч_i$ – the number of performers performing simultaneously the same work at this stage, pers.

7.3.3 Development development schedule

To develop a schedule for conducting a scientific study, a Gantt chart will be used - a horizontal tape chart on which work on a topic is represented by lengthy segments, characterized by dates of the beginning and end of the work.

For the convenience of plotting, the duration of each of the stages of work from working days should be translated into calendar days. To do this, use the following formula:

$T_{кi} = T_{рi} \cdot k_{кал}$, Where

$T_{кi}$– the duration of the i-th work in calendar days;

$T_{рi}$ – the duration of the i-th work in working days;

$k_{кал}$– calendar factor.

The coefficient of calendar is determined by the following formula: $k_{кал} = \dfrac{T_{кал}}{T_{кал} - T_{вых} - T_{пр}}$, Where

$T_{кал}$ – the number of calendar days per year;

$T_{вых}$ – the number of days off per year;

$T_{пр}$ – the number of holidays per year.

According to the production calendar (for a 6-day working week) in 2019, 365 calendar days, 299 working days, 66 days off / holidays.

$$k\text{кал} = \frac{\text{Ткал}}{\text{Ткал} - \text{Твых} - \text{Тпр}} = \frac{365}{365 - 66} = 1{,}22$$

All calculation results are listed in the table below.

Table 13 - Temporary development indicators

Stage	Executor		Duration of work			The complexity of the work on the performers person- days.			
						$T_{РД}$		$T_{КД}$	
			t_{min}	t_{max}	$t_{ож}$	Gubarev	Kyrov	Gubarev	Kyrov
Drafting and approval of technical specifications	Gubarev	100%	2	4	2,8	3	–	4	–
Selection and study of materials on the topic	Kyrov	100%	5	9	6,6	–	7	–	9
Choosing the direction of research	Gubarev Kyrov	20% 80%	3	6	4,2	1	4	1	5
Scheduling work on the topic	Kyrov	100%	1	3	1,8	–	2	–	2
Conduct theoretical calculations and justifications	Kyrov	100%	8	12	9,6	–	10	–	12
Purchase of components	Kyrov	100%	22	36	27,6	–	28	–	34
Evaluation of the effectiveness of the results and determination of the feasibility of OCD	Kyrov	100%	2	4	2,8	3	–	4	–
Development of the program algorithm	Kyrov	100%	18	22	19,6	–	20	–	24
Development and calculation of parameters of the concept	Gubarev Kyrov	30% 70%	4	8	5,6	2	5	2	6
Design and manufacture of the layout	Gubarev Kyrov	30% 70%	5	10	7	2	5	2	6
Laboratory test layout	Kyrov	100%	2	4	2,8	–	3	–	4
The final design of the work	Kyrov	100%	9	12	10,2	–	10	–	12
Total:			**81**	**130**	**100,6**	**11**	**94**	**13**	**114**

7.3.4 Budget of the project

When planning a development budget, a reliable and complete reflection of all types of expenses that are associated with its implementation should be ensured. In the process of budgeting a scientific and technical study, the following grouping of expenditures by items is used:

- material costs;
- depreciation;
- basic salary of the performers of the topic;
- additional salary for the performers of the topic;
- payments to extra-budgetary funds (labor tax);
- overhead.

7.3.4.1 Calculation of material costs and components

This article includes the cost of all materials that are used in the development of the project. The calculation will be made on all performers.

Table 14 - Material costs

Name	Unit of measurement	Amount	Price per unit, rub.	The cost of materials, rub.
Ballpoint pen	rub	2	15	30
Paper Packing (A4)	rub	1	350	250
Solder	rub	1	200	200
Rosin	rub	1	100	100
Connecting wire assembly	rub	1	180	180
Total:				860

Total for the item "Material costs" - 860 rubles.

This item includes the cost of special equipment that was needed for development.

Table 15 - The cost of component parts

№	Equipment identification	Number of equipment	Unit price, rub.	The total cost of equipment, rub.
1.	AVR328P microcontroller	2	300	300
2.	Button and LED in one case	8	180	1440
3	Plastic for the housing of the spectrophotometer	1	300	300
4	Display	1	100	100
Total:				2140

Total for the article "Components" - 2140 rubles.

7.3.4.2 Depreciation

Depreciation is the process of periodically transferring the initial value of an asset or intangible asset to production, commercial or general business expenses, depending on how this asset is used.

There are several depreciation methods, but the simplest is linear depreciation. We use the classifier of fixed assets for depreciation groups, approved by Government Decree No. 1 of 01/01/2002. Taking into account the fact that the PC that was used to write the work, has an initial cost of 45,000 with a useful life of 3 years and the writing of the work occurred within 3 months. Then:

- depreciation rate:

$$\text{Ан} = \frac{1}{n} * 100\% = \frac{1}{3} \times 100\% = 33{,}33\%$$

- annual depreciation charges:

$$\text{Аг} = 45000 \times 0{,}33 = 14850 \text{ rubles}$$

- monthly depreciation charges:

$$\text{Ам} = \frac{14850}{12} = 1237.5 \text{ rubles}$$

- the total amount of depreciation of fixed assets:

$$\text{A} = 1237.5 \times 3 = 3713 \text{ rubles}$$

Total for "depreciation" - 3713 rubles.

7.3.4.3 Basic salary

This article includes the labor remuneration of the supervisor and the student, and a bonus of 12–20% of the salary is also paid monthly. The salary of the head is 33664 rubles without a district coefficient. For an engineer, the salary is 21,760 rubles without a district coefficient. (DC = 1.3)

Thus, salary are calculated using the following formula:

$З_{зп} = З_{осн} + З_{доп}$, Where

$З_{осн}$ – basic salary;

$З_{доп}$ – additional salary.

$З_{осн} = З_{дн} \cdot T_p$, Where

$З_{осн}$ – basic salary per employee;

T_p – the duration of the work performed by the scientific and technical worker, working days

$З_{дн}$ – average daily salary of an employee, rub.

The average daily salary is calculated by the formula:

$З_{дн} = \frac{З_м \cdot М}{F_д}$, Where

$З_м$ – monthly salary of an employee, rub .;

M – the number of months of work without vacation during the year (with a vacation of 24 working days M = 11.2 months, 5 days a week; with a vacation of 48 working days M = 10.4 months, a 6-day week);

$F_д$ – valid annual working time fund of scientific and technical personnel, working days.

Table 16 - The balance of the working day

Working time	Engineer	Scientific director
Calendar number of days	365	365
The number of non-working days - weekend - holidays	66	66
Loss of working time - vacation - absences due to illness	56	56
Valid annual working time fund	243	243

Monthly salary of an employee:

$З_м = З_{тс} \cdot k_р$, Where

$З_{тс}$ – salary at the tariff rate, rub.;

$k_р$ – district coefficient equal to 1.3 (for Tomsk).

Table 17 - Calculation of basic salary

Performers	$З_{тс}$, rub.	$k_р$	$З_м$, rub.	$З_{дн}$, rub.	$Т_р$, working days	$З_{осн}$, rub.
Scientific director	33664	1,3	43763	1873	11	20603
Engineer	21760	1,3	28288	1211	94	113834

Total for the article "Basic salary" - 134437 rubles.

7.3.4.4 Additional salary

The costs of additional salary for the executors of the topic take into account the amount of additional payments for deviation from normal working conditions, as well as payments related to the provision of guarantees and compensations, provided by the Labor Code of the Russian Federation.

The calculation is made according to the following formula:

$З_{доп} = k_{доп} \cdot З_{осн}$, Where

$k_{доп}$ – the coefficient of additional salary is assumed to be 0.13.

$Здоп(\text{supervisor}) = 2678(\text{rub.})$

$Здоп(\text{Engineer}) = 14798(\text{rub.})$

Total for the article "additional salary" - 17,476 rubles.

7.3.4.5 Labor tax

This item of expenditure reflects obligatory deductions, according to the standards established by the legislation of the Russian Federation, to the state social insurance (FSS), pension fund (PF) and medical insurance (FFOMS) from the costs of workers.

The amount of contributions to extra-budgetary funds is determined on the basis of the following formula:

$З_{внеб} = k_{внеб} \cdot (З_{осн} + З_{доп})$, Where

$k_{внеб}$ – coefficient of deductions for payment to extra-budgetary funds, equal to 30% (0.3).

Table 18 - Labor tax

Executor	Basic salary, rub.	Additional salary, rub.	Deductions to extrabudgetary funds, rub.
Supervisor	20603	2678	6984
Engineer	113834	14798	38589

Total for the item "Deductions to extrabudgetary funds" - 45573 rubles.

7.3.4.6 Overhead

Overhead costs take into account other expenses of the organization that are not included in the previous cost items: printing and photocopying of research materials, payment of communication services, electricity, postal and telegraph expenses, reproduction of materials, etc. Their value is determined by the following formula:

$З_{накл} = (\text{сумма статей } 1 \div 5) \cdot k_{нр}$, Where

$k_{нр}$ – overhead factor.

The value of the overhead ratio can be taken in the amount of 16%.

Under the item "overhead" - 32677 rubles.

7.3.4.7 Budgeting development costs

This article discusses the total budget of the costs of this development, which is calculated as the sum of all previous articles.

Table 19 - Estimated project cost

Article title	Amount, rub.	Cost share,%
1. Material costs and components	3000	1,27
2. Depreciation	3713	1,58
3. Expenses for the basic salary of performers	134437	56,74
4. Costs for additional artists' salary	17476	7,376
5. Extrabudgetary contributions	45573	19,23
6. Overhead	32677	13,84
Total:	236876	100

The total budget of expenditures was 236876 rubles.

7.3.5 Risk Register

Risk is the possibility of the occurrence of some adverse event that entails the occurrence of various kinds of losses. There is no uniform classification of development risks. We can single out the following main groups of risks inherent in almost all projects: political, economic, social, technological, environmental, financial, organizational, marketing, personnel, technical.

First, it is necessary to determine the main risk groups of development, to describe what each risk group consists of.

Table 20 - The definition of risk

№	Risk name	Risk description
1	Political	No risk
2	Economic	Economic problems among the population and as a consequence the inability to pay for the tests
3	Social	Difficulties in some patients when interacting with the rehabilitation system
4	Ecological	Harmful effects of equipment on the environment
5	Technological	Violation of the technology of analysis of substances
6	Financial	Lack of finance for high-quality research
7	Organizational	Difficulties with the organization of workplaces in the laboratory
8	Marketing	Distrust of customers to the developed equipment
9	Personnel risks	Shortage of highly qualified staff for maintenance
10	Technical	Equipment failure

Then it is necessary to perform an assessment of the probability of risk on the scale of the probability of risk and the scale of assessment of the level of losses.

Table 21 - Risk probability estimation

№	Risk name	Risk probability estimate (low, medium, high)
1	Political	low
2	Economic	medium
3	Social	medium
4	Ecological	low
5	Technological	medium
6	Financial	low
7	Organizational	low
8	Marketing	high
9	Personnel risks	low
10	Technical	low

Table 22 - Estimation of the level of losses

№	Risk name	Loss assessment (low, medium, high)
1	Political	low
2	Economic	high
3	Social	medium
4	Ecological	low
5	Technological	high
6	Financial	high
7	Organizational	high
8	Marketing	medium
9	Personnel risks	medium
10	Technical	high

After that, it is necessary to fill in a matrix of probability of risks and losses, as well as to develop basic measures for risk reduction, where:

- Red area - high risk;
- Yellow area - significant risk;
- Blue area - moderate risk;
- Green area - a minor risk.

Table 23 - The main measures to reduce risks

№	Risk name	Risk reduction measures
1	Political	Not needed
2	Economic	Reducing the cost of services, the provision of benefits and a system of discounts.
3	Social	Verify the instrument to prove the fact of the reliability of the results.
4	Ecological	To study equipment recycling methods in case of equipment failure.
5	Technological	Develop instructions for the doctor on the correct use of the spectrophotometer.
6	Financial	Conduct a presentation on the relevance and need for development to obtain funding from TPU.
7	Organizational	Conduct presentations on the relevance and need for development to obtain a laboratory room for the further development of the project.
8	Marketing	Develop advertising posters to attract investors.
9	Personnel risks	Development of detailed methodological manuals on the use and adjustment of the spectrophotometer.
10	Technical	To carry out maintenance of equipment, to clean from dust and dirt.

Thus, the existing risks for this research project were considered, and the measures listed above were developed to reduce the existing risks.

7.4 Description of potential effect

A spectrophotometer is a necessary tool in any scientific and clinical laboratory: biochemical, molecular genetic, pharmacological, immunological, microbiological. Spectrophotometers are more complex and more expensive than conventional photocolorimeters, but they are more accurate and allow you to solve more complex problems. The big advantage of spectrophotometers is the ability to make a conclusion about the composition of the substance, the presence and amount of impurities, while photocolorimeters work only with already known solutions. Modern spectrophotometers are quite large, which makes them stationary. A prototype of a portable spectrophotometer was created at the research laboratory of the Institute of Industrial Chemistry and Mass Storage, which, with appropriate modifications and much-needed funding, can compete with stationary spectrophotometers already on the market.

In this section of the work, potential consumers of the research results are identified, a SWOT analysis is performed, which showed that it is necessary to develop and improve the methods of scientific and technical research, as well as to look for sources of funding for the development and improvement of this research. Consideration of weaknesses showed that the problem also lies in the issue of financing, which will help develop a competitive device based on the research conducted in this research work. Strengths, such as the relevance of the study, its novelty and relevance can ensure that the development will be in demand, which will also lead to an influx of funding. These factors will help to develop opportunities to promote development in a dedicated market segment, as well as reduce the influence of weaknesses and threats that affect the ability of this work to compete.

In addition, a QuaD analysis was performed, which showed that this development is a prospect and, with proper funding, it can become competitive in the market of spectrophotometers.

The authors of the research topic were determined; the total duration of the development was 4 months. The budget amounted to 236913 rubles.

At the end of this section, the risks for this development were considered: they showed that this development does not bear risks from the environmental, political and economic parts, while marketing, financial and organizational risks can bring problems when doing research. Measures to reduce these risks were also reviewed and described.

8 SOCIAL RESPONSIBILITY

Introduction

Production and design of the optical system for the sorption-photometric determination of substances was carried out in the laboratory of the department of electronic engineering. The laboratory has devices with which you can carry out radio installation of mounted electronic components, programming microcontrollers and testing the layout of the device. In order to ensure safety for workers, society and the environment, we will develop a set of measures of a technical, organizational nature that minimize the negative consequences of the projected activity.

8.1.1 Legal and organizational security issues

Most of the work that is performed in production is directly related to the presence of dangerous and (or) harmful production factors. Working conditions according to the degree of harmfulness and (or) danger are divided into four classes - optimal, permissible, harmful and dangerous working conditions.

In accordance with Art. 221 - 225 of the Labor Code of the Russian Federation, at work with harmful and (or) hazardous working conditions, as well as at work performed in special temperature conditions or related to pollution, employees are given free compulsory certification or declaration of compliance with special clothing, special shoes and other means personal protection, as well as washing and (or) neutralizing agents in accordance with the model rules, which are established in the manner determined by the Government of the Russian Federation.

It is also envisaged to undergo a medical examination for workers who perform work in conditions with hazardous and (or) harmful production factors, which is specified in article 213 of the Labor Code of the Russian Federation.

Moreover, and in employment, and in the process. In the order of the Ministry of Health and Social Development of the Russian Federation of 12.04.2011 No. 302n. specified procedure for conducting a medical examination. The requirements of this document provide that a medical examination should be carried out once a year, or twice a year. It depends on the type of activity of the worker in production, as well as on the presence of specific harmful factors.

According to Part 6 of Article 213 of the Labor Code of the Russian Federation, workers engaged in certain types of activities, including those associated with sources of increased danger (with the influence of harmful substances and adverse production factors), as well as working in conditions of increased danger, undergo an obligatory psychiatric examination at least once every five years in the manner established by the federal executive body authorized by the Government of the Russian Federation.

8.1.2 Organizational measures in the layout of the working area

The working zone is a space up to 2 m high above the site of permanent or temporary stay of workers. The place of stay is considered permanent if the employee is on it for more than 50% of the total, or 2 hours of continuous working time. A workplace is a place of temporary or permanent stay of production workers in the course of their employment.

The organization of the workplace is a complex of measures for equipping the workplace with objects and means of labor, as well as their placement in a specific order.

The organization of the workplace is a set of activities that include:

1) Rational workplace specialization;

2) Equipping it with the required sets of main and auxiliary equipment;

3) Technological equipment and inventory;

4) Creating comfortable working conditions; optimal arrangement of equipment, convenient placement of equipment and objects of labor in the workplace;

5) Uninterrupted service of the worker in accordance with his functional needs.

The specific composition and content of work on the rational organization of the workplace depends on a number of factors: industry, type of production, type of labor, degree of cooperation and division of labor, levels of technical equipment and mechanization of labor, working conditions, etc.

When designing a workplace, one should not forget about microclimatic factors: temperature, noise, light, dust emission and other sanitary and hygienic requirements for the organization of workplaces.

It is necessary that the working room be provided with the correct location and layout of the workplace. GOST 12.2.032-78 “SSBT. Workplace when working sitting. General Ergonomic Requirements” establishes general ergonomic requirements for workplaces when working in the sitting position when designing a new and modernizing existing equipment and production processes. It is stipulated that the mutual arrangement of all its elements must comply with the physiological, psychological and anthropometric requirements. And besides this match the nature of the work.

Quite an important aspect in the organization of the workplace is the periodic ventilation of the working room, established by the schedule of technological breaks. For women and men, the height of the working surface when doing computer work should be 655 mm. Work is done only at a personal computer, therefore, the working surface will be rectangular in shape. The permissible location of the monitor is a vertical plane at an angle of ± 30° from the normal line of sight and in a horizontal plane at an angle of ± 30° from the sagittal plane.

8.1.3 Industrial safety

Hazardous and harmful factors in the performance of work on the development of a device for diagnosing digital microcircuits are given in Table 24.

Table 24 - Dangerous and harmful factors in the development of a device for diagnosing digital circuits

Source of factor, name of types of work	Factors		Regulations
	Harmful	Dangerous	
Device Development: 1. Calculation of the concept; 2. Creation of the printed circuit board; 3. Assembly of the printed circuit 4. Programming device; 5. Creating a prototype; 6. An experimental study of the characteristics and parameters; 7. Test sample.	1. Deviation of microclimate indicators; 2. Insufficient illumination of the working area; 3. The increased level of electromagnetic radiation; 4. Harmful substances; 5. Increased noise level.	1. Moving parts of processing equipment; 2. Electric current; 3. thermal burn; 4. The increased level of static electricity; 5. Fire safety.	GOST 12.1.003 - 2014 SSBT; GOST R 12.1.019-2009; GOST 12.2.003–91 SSBT; GOST 12.1.038–82 SSBT; SanPiN 2.2.4-548-96; SanPiN 2.2.4.1191–03; SN 2.2.4 / 2.1.8.562–96; SP 52.13330.2011.

8.2.1 Analysis of identified harmful factors

8.2.1.1 Deviation of microclimate indicators

The microclimate of the production premises has a great influence on the human body, on its health and well-being, efficiency and productivity.

The workers, unable to effectively influence the climate-forming processes in the atmosphere, have quality control systems for air factors inside the production premises.

Under the microclimate understand the climate of the internal environment of the premises, which is determined jointly by the relative humidity, temperature and intensity of thermal radiation, as well as the temperature of surrounding surfaces according to GOST 12.1.005-88.

To the indicators characterizing the microclimate in accordance with GOST 12.1.005-88. relate:

- air temperature [˚C];
- relative humidity [%];
- air velocity [m/s].

We present the optimal and acceptable indicators of the microclimate of industrial premises in accordance with SanPiN 2.2.4.548-96 in Table 25 and 26.

Table 25 - Optimum microclimate indicators

Period of the year	Category of works on energy consumption levels, kcal/h	Air temperature,°C	Relative humidity, %	Air velocity, m/s
Cold	Iб (140-174)	21-23	40-60	0,1
Warm	Iб (140-174)	22-24		0,2

Table 26 - Permissible microclimate indicators at workplaces of industrial premises (SanPiN 2.2.4.548-96)

Period of the year	Category of works on energy consumption levels, kcal/h	Air temperature,°C		Relative humidity, %	Air velocity, m/s permissible in permanent jobs
		Lower limit	Upper limit allowed		
Cold	Iб (140-174)	20	24	20-80	≤ 0,2
Warm	Iб (140-174)	21	28	20-80	0,1-0,3

In the winter period 12/20/2018, the temperature in the room was measured with a technical thermometer with a range from -40 °C to 40 °C, with a scale scale of 1 °C and a maximum deviation of ±1 °C. The outside temperature was measured using the same technical thermometer. Indoor temperature: T = 22 °C. Outdoor temperature: Tnar = -25 °C.

In the spring/summer period 04/20/2019, the temperature in the room was measured with a technical thermometer with a range from -40 °C to 40 °C, with a scale scale of 1 °C and a maximum deviation of ± 1 °C. The outside temperature was measured using the same technical thermometer. Indoor temperature: T = 24 °C. Outdoor temperature: Tnar = 18 °C.

The laboratory and the building has central heating. To work with the release of combustible and burning vapors and gases, the laboratory is equipped with a ventilation system. The measured indices of the laboratory microclimate correspond to the optimal indices. Recommendations for creating optimal conditions:

- Heating during the cold season

- Ventilation system in the warm season
- Use of PPE

In the process of designing the device, you must use the following PPE:

- Antistatic bathrobe
-Protective glasses
- Antistatic bracelet
- Medical mask when working with tin-lead solder

8.2.1.2 Insufficient illumination

Light is one of the most important environmental factors, which has a diverse biological effect on the body and plays an important role in maintaining health and high performance. Increased labor productivity, a high level of efficiency and a positive psychological effect on a person are highly dependent on properly designed lighting.

The laboratory uses two types of lighting:

- natural
- artificial

Natural side and artificial working, as well as combined, which consists of local lighting of workplaces and general room lighting.

With poor lighting quickly tired eyes as a result of the organism as a whole. Insufficient lighting can lead to injury: poorly lit hazardous areas, blinding lamps, sharp shadows worsen or cause complete loss of sight and orientation.

According to SNiP 23-05-95 * (joint venture 52.13330.2011), in the process of executing the experimental part of the master’s thesis, visual work related to category 3 was performed - high accuracy, the smallest object of discrimination 0.3 - 0.5 mm, the work subdivision - c, the contrast of the object of discrimination with the background is large, the characteristic of the background is dark, the value of the combined illumination is 600 Lx. The value of the blinding index (P) is not more than 20, and the pulsation coefficient (KP) is not more than 15%.

The coefficient of natural illumination with upper or combined illumination is 3%, with lateral - 1.2%.

The laboratory in which the work was carried out has the following dimensions: length of the room A = 8 m, width B = 6 m, height H = 3.5 m. Height of the working surface above the floor $h_p = 0{,}8\ m$.

Calculate the area of the room S:

$S = A * B$, Where

A – length, m;

B – width, m.

$$S = 6*8 = 48\ \ m^2$$

The reflection coefficient of freshly whitewashed walls with windows, no curtains, freshly whitewashed ceiling $\rho_п = 70\,\%$. The safety factor, taking into account the pollution of the lamp, for rooms with low dust emissions is equal to $K_з = 1{,}5$. Uneven Coefficient for Fluorescent Lamps $Z = 1{,}1$.

Choose a fluorescent lamp LHB-40 luminous flux is equal to $Ф_{ЛД}$=2700Лм.

Choosing lamps with fluorescent lamps such as Shod-2-80. This lamp has two lamps with a power of 80W each, the length of the lamp is 1227 mm, and its width is 265 mm.

The integral criterion for the optimal arrangement of luminaires is the value of λ, which for fluorescent luminaires with a protective grid lies in the range of 1.1-1.3. Accept λ = 1.1, the distance of the lamps from the ceiling (overhang) h_c = 0,3 m.

The height of the lamp above the working surface is determined by the formula:

$$h = h_n - h_p,$$

where h_n – the height of the lamp above the floor, the height of the suspension,

h_p – the height of the working surface above the floor.

The smallest permissible height of the suspension above the floor for two-lamp SOD lamps: $h_n = 2{,}5$ m.

The height of the lamp above the working surface is determined by the formula: $h = H - h_p - h_c = 3{,}5 - 0{,}8 - 0{,}3 = 2{,}4$ м

The distance between adjacent lamps or rows is determined by the formula:

$$L1 = \lambda * h = 1{,}1 * 2{,}4 = 2{,}7 \ \text{m}$$

$$L2 = \ 2{,}128 \ \text{m}$$

The number of rows of lamps in the room:

$$N_b = \mathbf{B} / \mathbf{L} = 6 / 2{,}7 = 2{,}22 \approx \mathbf{2}$$

Number of lamps in the row:

$$N_a = A / L = 8 / 2{,}64 = 3{,}03 \approx 3$$

Total number of fixtures:

$$N = N_a * N_b = 2 * 3 = 6$$

The distance from the extreme lamps or rows to the wall is determined by the formula:

$$l1 = L1 / 3 = 2{,}7 / 3 = 0{,}9 \ \text{m}$$

$$l2 = L2 / 3 = 2{,}128 / 3 = 0{,}709 \text{m}$$

Substitute all values for verification:

A=2*L1+2/3*L1+3*265=2*2700+2/3*2700+3*265=8000

B=L2+2/3L2+2*1227=2128+2/3*2128+2*1227=6000

We depict the layout of lamps in the room in Figure 10.

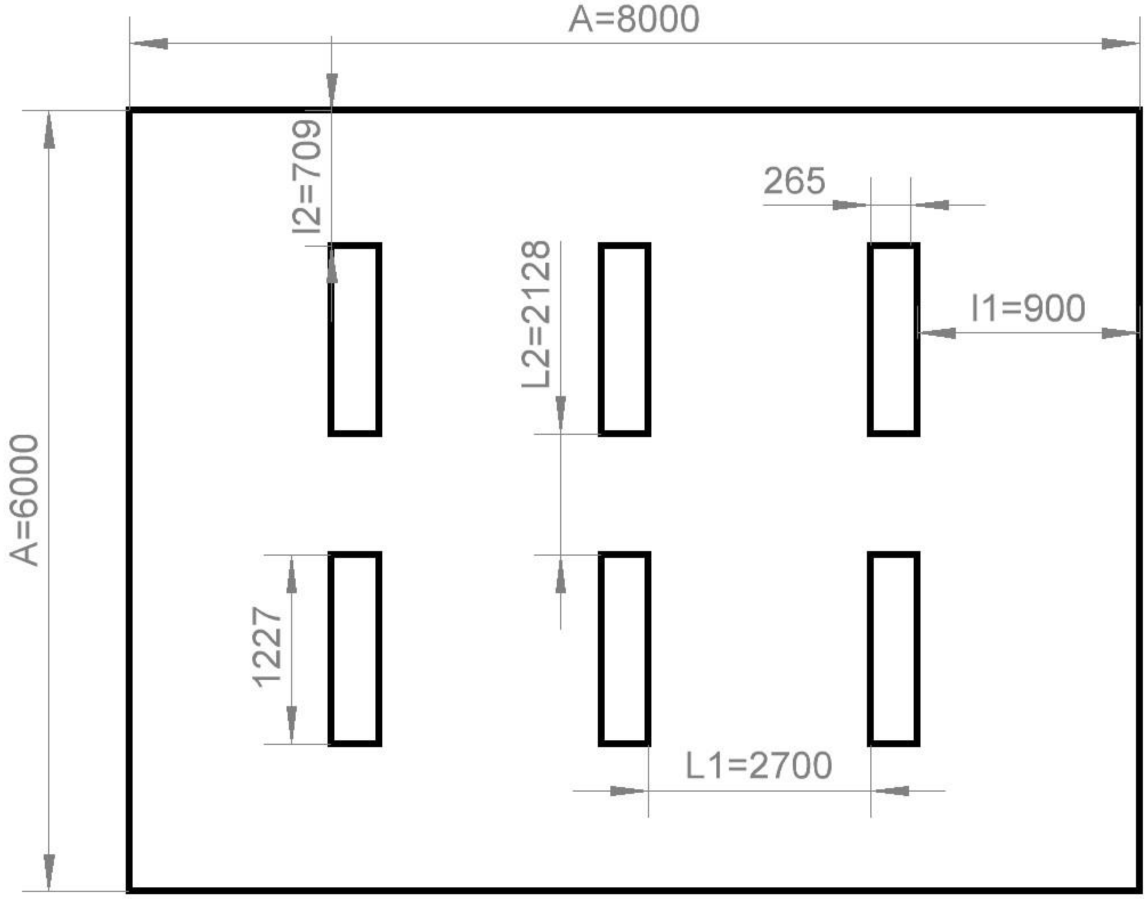

Figure 10– Luminaire layout

The index of the premises is determined by the formula: $i = \frac{A \cdot B}{\mathrm{L1} \cdot (A + B)} = \frac{\mathbf{8 \cdot 6}}{2{,}7 \cdot (8 + 6)} = 1{,}29 \approx 1{,}3$

The coefficient of use of the luminous flux, which shows how much of the luminous flux of the lamps falls on the working surface, for SHOD luminaires with fluorescent lamps with $\rho_{п}$=70 %, $\rho_{с}$=50 % and room index i = 1,3 equals η = 0, 5.

The required luminous flux 1 of the fluorescent lamp of the lamp is determined by the formula:$\varPhi_n = \frac{E \cdot A \cdot B \cdot K_з \cdot Z}{N \cdot \eta} = \frac{200 \cdot 8 \cdot 6 \cdot 1{,}5 \cdot 1{,}1}{2 * 6 \cdot 0{,}5} = 2640$

Make a check on the condition: $-10\% \le \frac{\Phi_{лд} - \Phi_{п}}{\Phi_{лд}} \cdot 100\% \le 20\%$

Thus, we have obtained that the required luminous flux does not exceed the required range. Now we calculate the power of the lighting installation:

$$P_{oy} = N * P_{SHOD}$$

$$P_{oy} = 6 \cdot 2 \cdot 80 = 960\,W$$

8.2.1.3 Increased noise level

At the workplace, noise occurs when the lamps of the pulsed heating, the ventilation of a personal computer and when exposed to external factors.

Noise adversely affects the human body, causes mental and physiological disorders, hearing loss, performance, creates the prerequisites for common and occupational diseases and industrial injuries, as well as weakening of memory, attention, violation of blood pressure and heart rate.

Noise levels should not exceed the values specified in GOST 12.1.003 - 2014, and they should be checked at least twice a year. The main characteristic of noise is the maximum permissible noise level (RC). The maximum permissible level (noise level) of a noise is the level of a factor that, when working daily (except weekends), but not more than 40 hours a week during the entire working period, should not cause diseases or deviations in health, which are detected by modern research methods process of work or in the remote periods of life of the present and subsequent generations. Compliance with the noise level of the remote control does not preclude health problems in hypersensitive individuals.

According to GOST 12.1.003 - 2014, the noise parameters are normalized and during the work the noise level should not exceed 82 dB;

At values above the permissible level, it is necessary to provide for personal protective equipment and collective protection devices against noise.

Collective protection:

– elimination of the causes of noise or its significant weakening in the source of education;

– isolation of noise sources from the environment (use of silencers, screens, sound-absorbing building materials);

– the use of tools that reduce noise and vibration in the way of their distribution;

Personal protective equipment:

– the use of protective clothing and hearing aids: headphones, earplugs, antiphones.

8.2.1.4 Increased Electromagnetic Radiation

The source of electromagnetic radiation are conductors, discrete radio elements, contact points, PC. Electromagnetic emissions are electric and magnetic fields propagating in space.

The oscilloscope and the laboratory power source are the least influential among all sources, as it uses shielding with a material with high magnetic permeability, so it will not do much harm.

In the process of working with a computer it is necessary to observe the correct mode of work and rest. Otherwise, personnel experienced significant stress in the visual apparatus with complaints of dissatisfaction with work, headaches, irritability, sleep disturbance, fatigue and painful sensations in the eyes, lower back, neck and hands.

Sanitary regulations establish sanitary and epidemiological requirements (SanPiN 2.2.4.1191–03.) For the conditions of industrial impacts of EMF, which must be observed in the design, reconstruction, construction of industrial facilities, in the design, manufacture and operation of domestic and imported technical means that are sources of EMF.

Thus, at a distance of half a meter, the laptop monitor emits an electromagnetic field of 2 mGs, and this dose begins to have a bad effect on the body. At a distance of 10 cm from the laptop screen, induction is equal to 8 to 10 mT, which does not exceed the norm. The distance safe for a person working at a computer is 80 cm or more from the monitor screen.

According to SanPiN 2.2/2.2.1340, the temporary permissible levels of EMF generated by a PC are:

– electric field strength in the frequency range 5 Hz - 2 kHz - 25 V/m;
– electric field strength in the frequency range 2 kHz - 400 kHz - 2.5 V/m;
– magnetic flux density in the frequency range 5 Hz - 2 kHz - 250 nT;
– magnetic flux density in the frequency range 2 kHz - 400 kHz - 25 nT;
– Electrostatic potential of the video monitor screen - 500 V.
– protection of a person from exposure to electromagnetic radiation by using PPE and RMS.

Collective protection:

– shielding the radiation source and the workplace (active and passive; source of electromagnetic radiation or the object of protection; complex shielding);
– the establishment of a sanitary protection zone;
– reduction of radiation from the source;
– constructive improvement of equipment in order to reduce the used levels of EMF, the total consumed and radiated power of the equipment;
– absorption or reduction of the formation of charges of static electricity;

Personal protective equipment:

– Points and special clothes made of metallized fabric (chain mail). It should be noted that the use of PPE is possible during short-term work and is a measure of an emergency nature. Daily maintenance staff must be provided by other means.
– Instead of ordinary glasses, glasses coated with a thin layer of gold or tin dioxide (SnO2) are used.

8.2.1.5 Harmful substances in the air of the working area

The device under study includes:

– Microcontroller;

– discrete electronic components;

The connection of electronic components on the printed circuit board is done by soldering. Soldering is carried out using tin-lead solder and the use of rosin, to remove the oxide film. Soldering results in the evaporation of harmful substances, which in turn affect human health and the environment. Let us give in the table the substances that are released during the soldering process, as well as the hazard class and maximum permissible concentrations (MPC) for solders.

Table 27 - Hazard Class and MPC Solders

Substance (composition)	Hazard Class	Maximum concentration limit in air of working zone mg/m3
Solders Pic 40; Pic 61 POC 10; POC 55	1 3	0.01 (by lead) 10 (Tin)

where is the hazard class according to the degree of impact on the body:

1 - extremely dangerous;

3 - moderately dangerous.

To reduce harmful factors, the laboratory should be equipped with a VHC, and it is also necessary to use personal protective equipment:

– rubber gloves according to GOST 20010;

– safety glasses according to GOST 12.4.013;

– cotton bathrobes according to GOST 12.4.132 and GOST 12.4.131;

– aprons in accordance with GOST 12.4.029 in accordance with the "Typical industry norms for the issuance of workwear, special footwear and other personal protective equipment", enacted by the Ministry of 09.02.83, N 74.

Collective protection:

– General exhaust ventilation at production sites;

– local exhaust ventilation at workplaces for degreasing, tinning, soldering, cleaning of flux residues in accordance with GOST 12.4.021, OST 4G 0.029.233, OST 4G 0.033.200, SNiP 2.04.05, ensuring the presence in the air of the working zone of harmful vapors and aerosols not exceeding the maximum permissible concentration (MPC) according to GOST 12.1.005.

8.2.2 Analysis of identified hazards

8.2.2.1 Electric Shock

Electrical safety is a system of organizational and technical measures and means to protect people from the harmful and dangerous effects of electric current, electric arc, electromagnetic field and statistical electricity.

The main source of electrical current is the power source of the electronic node.

The causes of the impact of current on a person are: accidental penetration or approaching a dangerous distance to live parts; the appearance of voltage on the metal parts of the equipment as a result of damage to the insulation; short circuit, etc.

Depending on the possibility of electric shock, the premises are divided into three groups:

– without increased danger;
– with increased danger;
– especially dangerous.

The rooms without increased danger include dry, dust-free rooms with normal air temperature and insulating floors.

Premises with increased danger are characterized by the presence in them of one of the following conditions that create an increased danger:

– Dampness (relative humidity of air for a long time exceeds 75%) or conductive dust;

– Conducting floors (metal, reinforced concrete, brick, etc.);

– Heat;

– The possibility of simultaneous contact of a person with metal structures of buildings connected to the ground, technological devices, etc., on the one hand, and metal enclosures of electrical equipment, on the other.

Particularly dangerous premises are characterized by the presence of one of the following conditions:

– Special dampness (relative humidity of air is close to 100%);

– Chemically active or organic medium;

– Simultaneous fulfillment of two or more conditions of increased danger.

The laboratory refers to a room with an increased risk of electric shock. The following measures of protection against electric shock are applied in the room: inaccessibility of live parts for accidental contact, all live parts are isolated and fenced. Unavailability of current-carrying parts is achieved by their reliable isolation, the use of protective barriers (covers, covers, grids, etc.), the location of current-carrying parts at an inaccessible height.

Electric shock most often occurs with careless handling of devices, with electrical equipment malfunctioning or if they are damaged.

Correctly assess the danger of electric shock allow the maximum permissible values of the touch voltage and the current flowing through the human body in the normal and emergency modes of industrial and domestic electrical installations with a voltage up to and above 1 kV, depending on the duration of the current.

The maximum allowable values of touch voltages and currents are set for the paths of current from one hand to the other and from hands to legs.

The touch voltages and currents flowing through the human body during the normal (non-emergency) mode of the electrical installation should not exceed the values shown in Table 28.

Table - 28 Permissible contact voltage Uh and current Ih flowing through the human body during normal operation of the electrical installation

Type and current frequency	Uh, В no more	Ih, мА no more
Variable 50 Hz	2,0	0,3
Variable 400 Hz	3,0	0,4
Constant	8,0	1,0

Note:

1. Contact voltages and currents are given with a duration of exposure of not more than 10 minutes. per day and installed on the basis of the reaction of sensation.

2. Contact voltages and currents for persons performing work in conditions of high temperature (above 25 ° C) and humidity (relative humidity of more than 75%) should be reduced by 3 times.

The maximum permissible levels of contact voltages and currents in case of emergency operation of industrial and domestic electrical installations with voltage up to 1 kV should not exceed the values indicated in Tables.

Table 29 - Maximum permissible contact voltage Uh and current Ih flowing through the human body during emergency operation of industrial electrical installations with voltage up to 1 kV

Type and current frequency	Normalized value	Maximum permissible values Uh, Ih with a duration of exposure not more than t,s											
		0,01-0,08	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1,0	>1,0
Variable 50 Hz	Uh, V	550	340	160	135	120	105	95	85	75	70	60	20
	Ih, mA	550	400	190	160	140	125	105	90	75	55	50	6

Variable 400 Hz	Uh, V	650	500	500	330	250	200	170	140	130	110	100	36
	Ih, mA	650	500	500	330	250	200	170	140	130	110	100	8
Constant	Uh, V	650	500	400	350	300	250	240	230	220	210	200	40
	Ih, mA	650	500	400	350	300	250	240	230	220	210	200	15
Rectified full-wave	Uhampl, V	650	500	400	300	270	230	220	210	200	190	180	-
	Ihampl, mA	650	500	400	300	270	230	220	210	200	190	180	-
Rectified half-wave	Uhampl, V	650	500	400	300	250	200	190	180	170	160	150	-
	Ihampl, mA	650	500	400	300	250	200	190	180	170	160	150	-

Ensuring electrical safety by technical methods and means in accordance with GOST 12.1.019-79.

To ensure protection against accidental contact with live parts, it is necessary to apply the following methods and means:

– protective shells;
– protective fences (temporary or stationary);
– safe location of current carrying parts;
– insulation of current-carrying parts (working, additional, reinforced, double);
– isolation of the workplace;
– low voltage;
– safety shutdown;
– warning signaling, blocking, safety signs;
– organizational and technical measures to ensure electrical safety.

To ensure the safety of work in existing electrical installations, the following organizational measures should be performed:

– the appointment of persons responsible for the organization and safety of work;

– registration of the order or order for work;

– the implementation of admission to the work;

– organization of supervision of work;

– registration of the termination of work, breaks in work, transfers to other workplaces;

– the establishment of rational regimes of work and rest.

8.2.2.2 Mechanical safety

The process of preparing a printed circuit board for installation includes straightening, molding, trimming, tinning, drilling holes, as well as the preparation of the printed circuit board itself. Injuries can be caused by moving, rotating parts, cutting sharp edges, stabbing sharp protrusions, burrs, and insufficient stability of the product. Therefore, in order to avoid an accident it is necessary to be extremely careful, as well as to use personal protective equipment. Before working with the machine, the researcher must pass a knowledge test and safety briefing.

Therefore, when installing electronic equipment, it is necessary to strictly and strictly observe the following rules for safe installation work:

– Perform work on serviceable equipment, using serviceable tools and devices, and use them only for their intended purpose;

– Using the side cutters (side cutters), bite off the wire from yourself and make sure that the particles flying off the wire do not fall into the surrounding;

– Work on fiberglass-insulated wires in cotton gloves;

– Dismantling of electronic equipment and wire stripping from contact lobes and electrical connections should be made in protective glasses;

– The quality of the ration and installation of installation should exclude the occurrence of breakdowns or sparks.

8.2.2.3 Fire hazard

When creating the device, an emergency situation of a fire nature may occur.

The fire is called uncontrolled burning outside a special hearth that causes material damage. According to GOST 12.1.033 - 81, the concept of fire safety means the condition of an object in which the probability of occurrence and development of a fire and the exposure of people to dangerous factors of a fire is excluded with an established probability, and material values are also protected.

Fire safety involves ensuring the safety of people and preserving the material values of an enterprise at all stages of its life cycle. The main fire safety systems are fire prevention and fire protection systems, including organizational and technical measures.

According to the explosion and fire hazard of the premises are divided into categories A, B, B1-B4, G and D, and the building into categories A, B, C, G and D.

According to NPB 105-03, a laboratory is classified as category B - combustible and difficult combustible liquids, solid combustible and difficult combustible substances and materials, substances and materials that can only burn when interacting with water, oxygen or any other oxygen, provided that the rooms, in which it is located, are not classified as the most dangerous A or B.

According to the degree of fire resistance this room belongs to the 1st degree of fire resistance according to SNiP 2.01.02-85 (made of brick, which refers to difficult-to-combustible materials).

The occurrence of a fire when working with electronic equipment may be due to both electrical and non-electrical reasons.

Causes of fire non-electric nature:

a) negligent careless handling of fire (smoking, heaters left unattended, use of open fire);

Causes of electric fire: short circuit, overcurrent, sparks and electric arcs, static electricity, etc.

To localize or eliminate ignition at the initial stage, primary fire extinguishing agents are used. Primary fire extinguishing agents are usually used until the fire brigade arrives.

Fire extinguishers (OHVP-10) are used to extinguish the fires without the presence of electricity. Carbon dioxide (OU-2) and powder fire extinguishers are designed to extinguish electrical installations that are under voltage up to 1000V. To extinguish current-carrying parts and electrical installations, a portable powder fire extinguisher is used, for example OP-5.

At least two portable fire extinguishers should be placed in public buildings and structures on each floor. Fire extinguishers should be located in prominent places in the vicinity of exits from the premises at a height not exceeding 1.35 m. Placing primary fire extinguishing equipment in corridors and passages should not impede the safe evacuation of people.

To prevent fire and explosion, it is necessary to provide for:

– special insulated rooms for the storage and spill of flammable liquids (flammable liquids), equipped with supply and exhaust ventilation in explosion-proof design - in accordance with GOST 12.4.021-75 and snip 2.04.05-86;

– special rooms (for storage in containers of dusty rosin), isolated from heating devices and heated equipment parts;

– primary fire extinguishing equipment at production sites (mobile carbon dioxide fire extinguishers GOST 9230-77, foam fire extinguishers TU 22-4720-80, sandbags, felt felt or asbestos cloth);

– automatic signaling devices (type SVK-ZM 1) for signaling the presence of pre-explosive concentrations of combustible vapors of solvents and their mixtures in the air of premises;

– The laboratory fully complies with fire safety requirements, namely, the presence of fire alarm, evacuation plan, shown in Figure 2, powder fire extinguishers with an attorney stamp, signs indicating the direction to the emergency exit.

Figure 11 - Evacuation Plan

8.3. Ecological safety

8.3.1 Analysis of the impact of the object of research on the environment

Environmental protection - a set of measures designed to limit the negative impact of human activity on nature. Such measures may be, limiting emissions to the atmosphere and hydrosphere in order to improve the overall environmental situation, as well as the transition to waste-free or low-waste production technologies. In the course of the thesis, a device is developed which consists of a set of microcircuits and electronic components. Electrical connections are made primarily of tin-lead solder. Lead is one of the toxic metals and is included in the lists of priority environmental pollutants. Therefore, in recent years, mankind has abandoned lead solders and coatings, which leads to changes in the soldering technology and the infrastructure of assembly tools. There is an adjustment of the soldering modes and, as a result, the refinement of the process equipment.

8.3.2 Analysis of the "life cycle" of the object of study

The life cycle of an instrument for diagnosing digital microcircuits includes the following main stages:

The pre-project (initial) stage includes pre-planned patent search, development and coordination of technical specifications, the choice of the direction of research; investment analysis, registration of initial permissive documentation, attraction of credit investment funds.

The design stage includes the development of structural and conceptual schemes, the organization of financing, and the management of design.

Stage assembly. At this stage, the device is assembled, namely the assembly of the printed circuit assembly.

The stage of operation of the device involves the use of the device for general use.

Recycling stage.

Disposal of an electronic device is the only way to get rid of unnecessary equipment without causing irreparable harm to the environment. Devices can not just be thrown into a landfill, because there they are exposed to the negative influence of external factors - sunlight, wind, rain. All this leads to the occurrence of chemical reactions and the release into the air of harmful chemical compounds. Such substances are very dangerous for the environment and human health.

Utilization of old equipment takes place in several stages:

– the device is disassembled and sorted parts by type of materials;

– electronic boards that contain precious materials are sent to a refining plant, after which pure metals are handed over to the State Fund;

– parts that cannot be disassembled are loaded into the crushing machine;

– the obtained small plastic crumb is separated from the metals by air exhausts;

– the metal mixture is sent to the smelter.

With proper disposal, about 70–80% of waste from old equipment is suitable for recycling.

8.4. Safety in emergency situations

Production is located in Tomsk with a sharply continental cyclonic climate. Natural phenomena (earthquakes, floods, droughts, hurricanes, etc.) are absent in this city with the exception of severe frosts and emergencies resulting from sabotage. Often, such threats are false. But there are explosions in reality.

Frosts are characteristic of Siberia in the winter season. Achieving critically low temperatures will lead to accidents of heating and life support systems, suspension of work, frostbite and even casualties among the population.

To prevent the likelihood of sabotage, the company must be equipped with a video surveillance system, round-the-clock security, a pass-through system, a reliable communication system, as well as no information dissemination about the facility’s security system, location of premises and equipment in the premises, security systems, alarms, their installation sites and quantities. Officials every six months conduct training to develop actions in case of emergency evacuation.

Achieving critically low temperatures and a huge amount of snow precipitation will lead to accidents of heating systems, water supply, electrical networks. In case of pipe re-frosting, spare heaters, supply of drinking water, as well as electric generators should be provided in the event of an electrical network failure. Their quantity and power should be enough so that work in production does not stop. During heavy snowfall, which leads to difficulties or full stop of public transport, you must have personal transport or transport from the organization.

8.5. Regulatory and technical documentation

GOST 12.1.005-88 SSBT. General sanitary and hygienic requirements for working area air.

SanPiN 2.2.4.548-96. Hygienic requirements for the microclimate of industrial premises.

SNiP 23-05-95 (joint venture 52.13330.2011). Set of rules. Natural and artificial lighting. Updated edition SNiP 23-05-95.

GOST 12.1.003 - 2014. SSBT. Noise. General safety requirements.

SanPiN 2.2 / 2.2.1340. "Hygienic requirements for personal electronic computers and work organization"

GOST 12.1.007 - 76. SSBT. Harmful substances. Classification and general safety requirements.

GOST 12.1.033 - 81. SSBT. Fire safety. Terms and Definitions.

Airbag 105-03. Definition of categories of premises, buildings and outdoor installations for explosion and fire hazard.

SNiP 2.01.02-8. Fire regulations.

GOST R 12.1.019-2009. SSBT. Electrical safety. General requirements and nomenclature of types of protection.

GOST 12.1.030-81. SSBT. Electrical safety. Protective grounding.

Conclusion

This section provided a description of social responsibility that accompanies the implementation of final qualifying work.

Industrial and environmental safety were described, various harmful and dangerous factors and methods of combating them were identified. In addition, a list of measures to reduce the threat in the event of an emergency was given, and legal and organizational security issues were examined. On top of this, the most important points of the organizational arrangements for the design of the working area are presented.

CONCLUSION

In the course of completing the assignment for final qualifying work, we managed to complete most of the important tasks for successfully completing the development of a portable spectrophotometer. A review of the literature on this subject was conducted and the options for performing the task were analyzed. I have chosen a microcontroller, a semiconductor laser and a photodiode with the help of which the task will be realized. All components have been purchased and studied. In practice, according to the developed structural and conceptual scheme, all the elements of the scheme were connected in a package printed on a 3D printer. The algorithm of the program is written, the code is written. A working model for photometric analysis of substances was also assembled.

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4. Фотоколориметры [Electronic resource]. - Access mode: https://dentanshop.com.ua/g61982790-fotokolorimetry [Date of application: 3.05.19].
5. Справочник химика [Electronic resource]. - Access mode: https://chem21.info/info/5641/ [Date of application: 4.05.19].
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Appendix A

Chapter 1. Literature review

Student:

Group	Full name	Signature	Date
1DM7I	Kyrov Ilya Vladimirovich		

Scientific Supervisor and Technical Advisor:

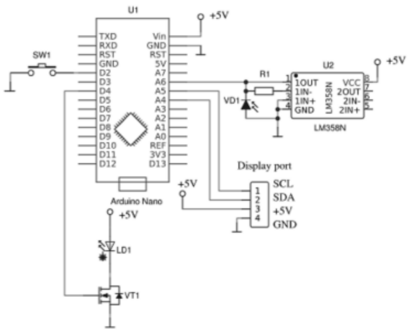
Position	Full name	Academic degree, rank	Signature	Date
Assistant professor	Gubarev Fedor Aleksandrovich	Candidate of Technical Sciences		

Advisor-linguist of the Department of Foreign Languages:

Position	Full name	Academic degree, rank	Signature	Date
Assistant professor	Glushkov Sergey Viktorovich	Candidate of Philology		

Appendix B

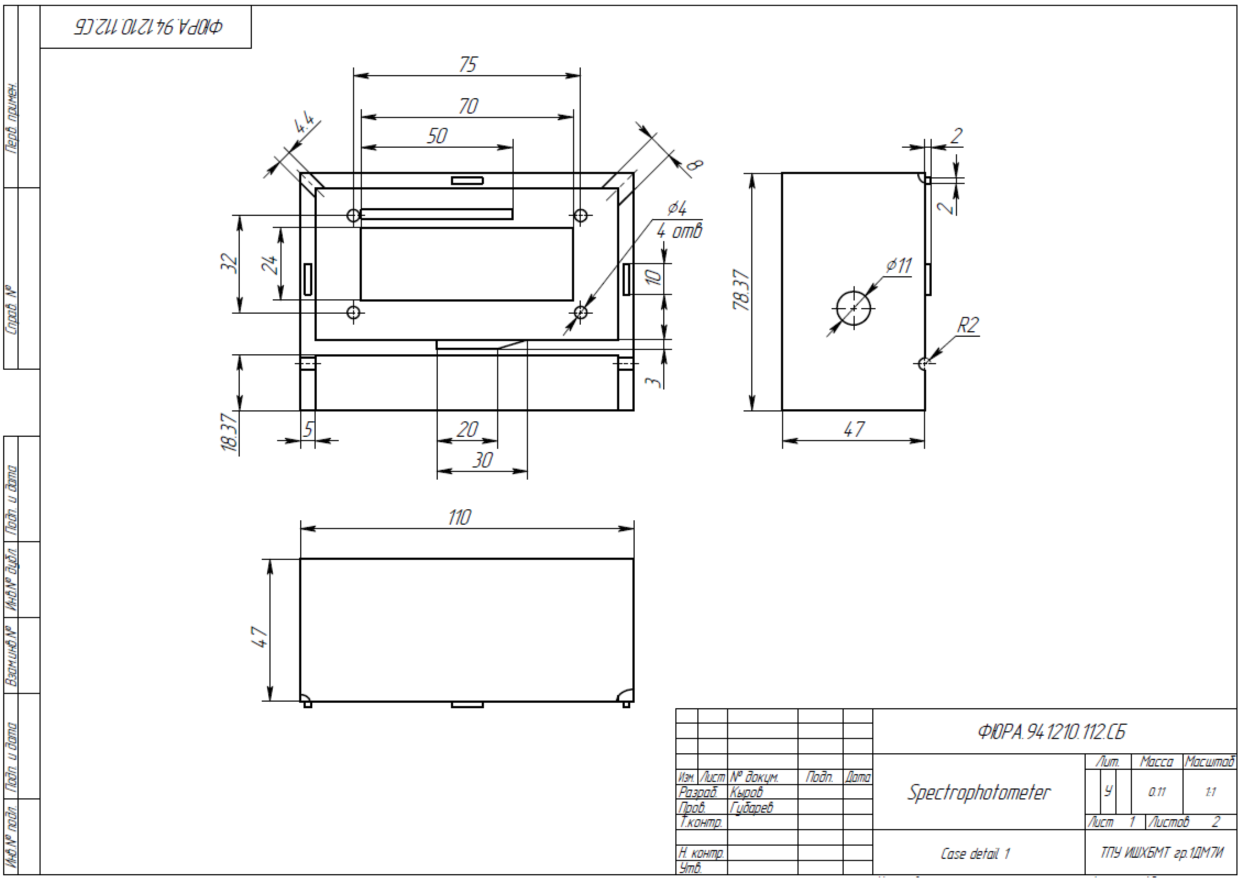
ФЮРА.941210.112.33



Изм.	Лист	№ докум.	Подп.	Дата	ФЮРА.941210.112.33
Разраб.	Кыров				Spectrophotometer
Пров.	Губарев				Лит.: У; Масса; Масштаб: 1:1
Т.контр.					Лист; Листов: 1
Н. контр.					Schematic
Утв.					ТПУ ИШХБМТ гр. 1ДМ7И

Подп. и дата | Инв.№ дубл. | Взам.инв.№ | Подп. и дата | Инв.№ подл.

Appendix C



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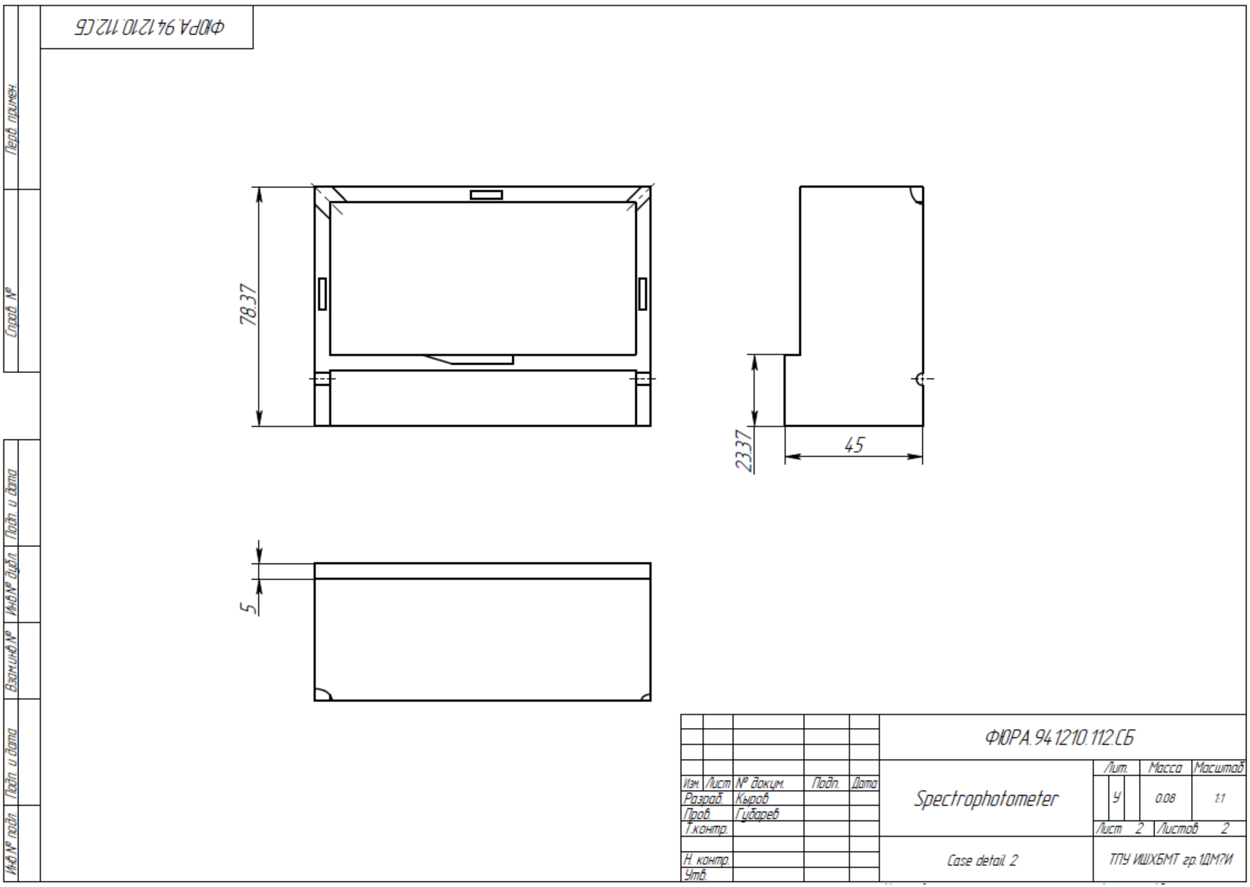
Spectrophotometer
Case detail 1
ТПУ ИШХБМТ гр.1ДМ7И
Разраб. Кыров
Пров. Губарев
Масштаб 1:1
Масса 0.11
Лист 1
Листов 2

Appendix D


ФЮРА.941210.112.СБ
78.37
23.37
45
5
Spectrophotometer
Case detail 2
Разраб. Кыров
Пров. Губарев
Т.контр.
Н. контр.
Утв.
Лит. Масса Масштаб
У 0.08 1:1
Лист 2 Листов 2
ТПУ ИШХБМТ гр.1ДМ?И

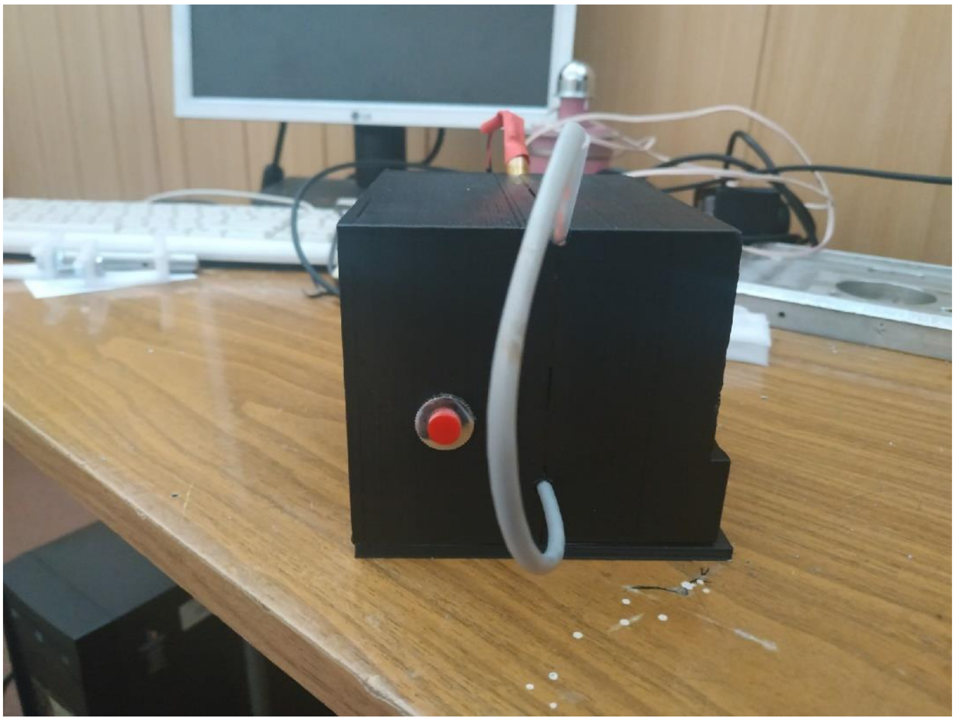
Appendix E

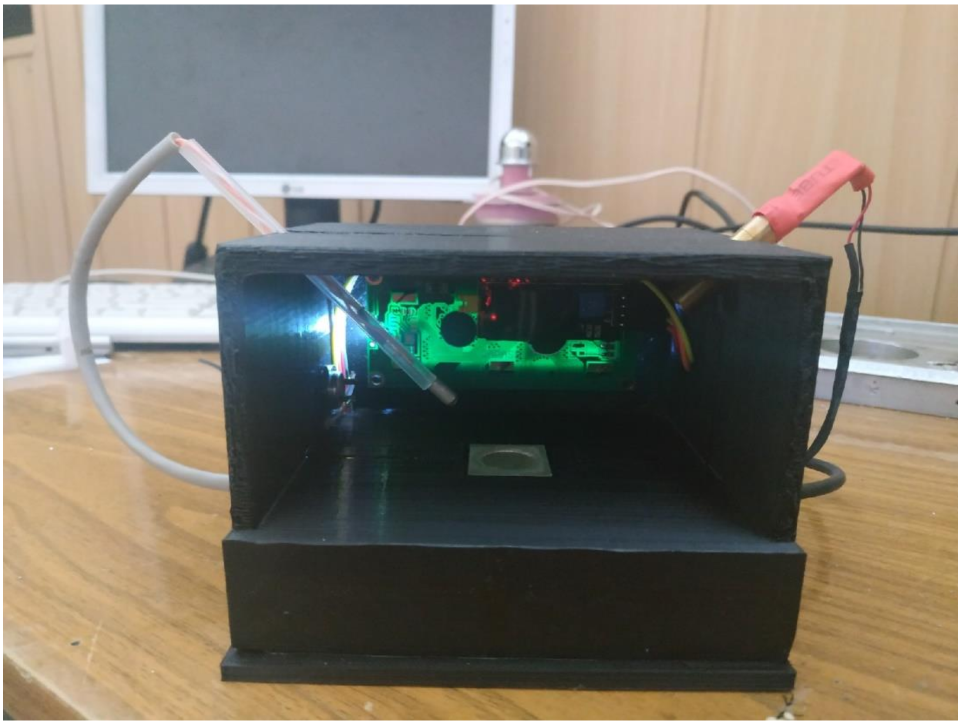
Формат	Зона	Поз.	Обозначение	Наименование	Кол.	Приме-чание
				Resistors		
			R1	Resistor gen. 10M ± 5%	1	
				Microschemes		
			U1	AtMega328P	1	
			U2	LM358N	1	
				Diodes		
			VD1	ФД256	1	
				Misc		
			LD1	Kolomoff 5mW 532nm laser	1	
			SW1	Button DS-316	1	
			VT1	IRL2703 PBF MOSFET	1	
				16*2 I2C LCD Display	1	

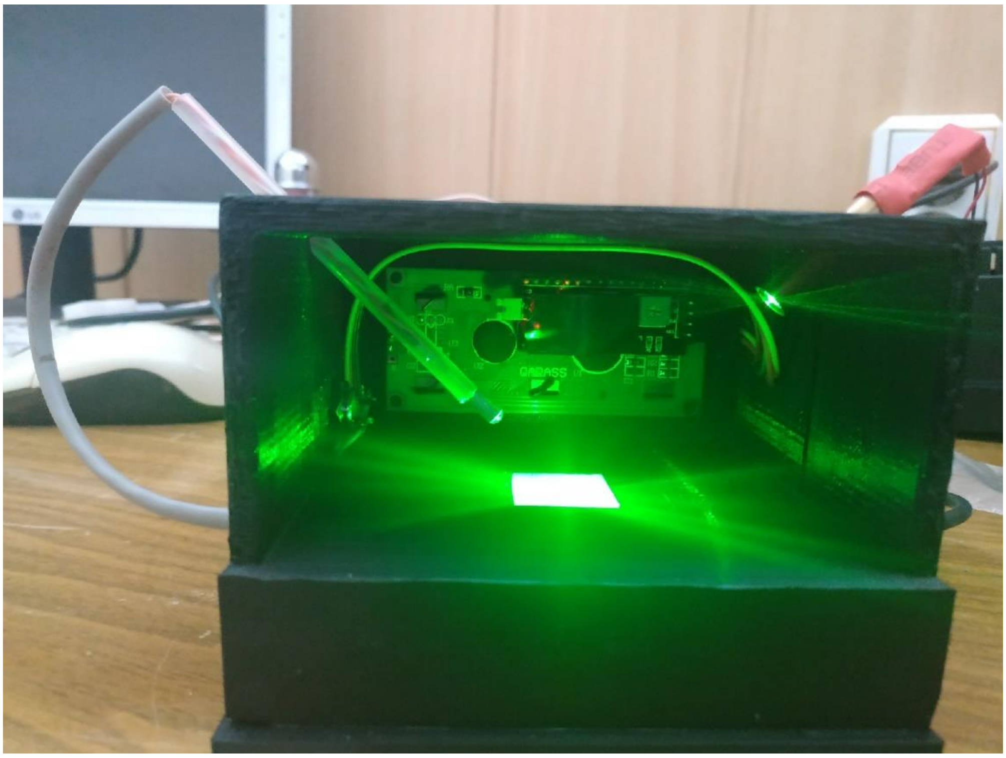
Подп. и дата | Инв. № дубл. | Взам. инв. № | Подп. и дата | Инв. № подл.

Изм.	Лист	№ докум	Подпись	Дата	ФЮРА.9412110.112.ПЭ		
Разраб.		Кыров			Spectrophotometer component list	Литера: У	Лист / Листов: 1
Пров.		Губарев				ТПУ ИШХБМТ гр. 1ДМ7И	
Н.контр							
Утв.							

Appendix F





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