Tomsk Polytechnic University

PHYSICS III
Reports on Laboratory Experiments

Tomsk 2001

PHYSICS III

Reports on Laboratory Experiments
Optics; Solid; Atomic Nucleus; Elementary Particles
TPU Press, Tomsk, 2001

These instructions have been approved by the Department of Theoretical and Experimental Physics and the Department of General Physics of TPU

Author: V. F. Pichugin

All the laboratory experiments must be performed in the TPU Physics Laboratory. The estimation of students' laboratory activity is based on their ability to perform the laboratory experiment and to present the results in conventional format. The report must be carefully prepared. It must include all the measurements and calculations.

List of laboratory experiments

1. Determination of Refractive Index of Liquids by Means of Refractometer
2. Determination of Dependence of Refraction Index of Prism from Wavelength of Light Hydrogen
3. Spectrum Research and Determination of Rydberg Constant
4. Calibration of Penumbra Polarimeter and Determination of a Sugar Solution Concentration
5. Determination of the Planck Constant and Stefan-Boltzmann Constant by Means of an Optical Pyrometer with a Disappearing Filament
6. Research of Light Diffraction from Single and Many Slits

Report on Laboratory Experiment No 1

Measurement of Refraction Index of Liquids by Means of Refractometer

The student:
Group _____
First name_____
Last name_____
is **allowed** to do the laboratory work.

_____ _____
Date Signature of the teacher

Purpose of work

Study principle of function of refractometer. Find the refractive index of different liquids relative to air and refractive index of sugar solution as function of sugar concentration.

Theoretical principals of work

1. The law of light refraction is _____
_____
_____

2. Refractive index of substances indicate that _____
_____
_____
n = _____, where c - _____; υ - _____;

3. Refractive index of solution n depends on solution concentration x (at not great values of x < 30%) by follow way:

n_0 - _____; k - _____

4. The phenomenon of _____
_____
_____
_____is the base of method of limit angle.

5. The limit angle is _____
_____
_____
_____
_____

6. March of the rays in refractometer:

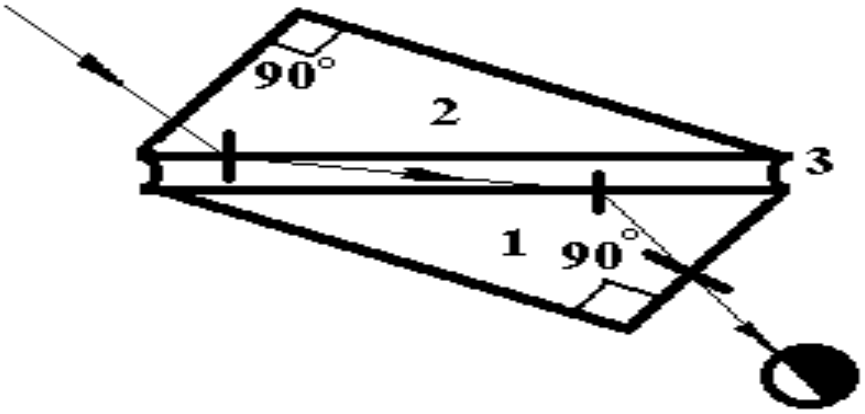


Fig. 1 March of the rays in refractometer

7. Limit of refractive index measured by refractometer magnitude is defined by the condition: _____
_____

Results of the measurements

1. Measurements of refractive index of different liquids:

Table 1

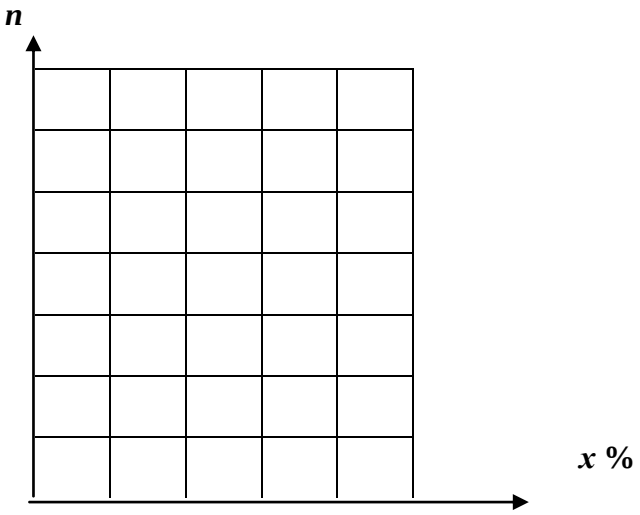
Investigated liquid	n_1	n_2	n_3	Average n
1. Water				
2. Spirit				
3. Toluol				
4.				

2. Measurements of refractive index of sugar solution as function of its concentrationa.

Table 2

Concentration of the solution	n_1	n_2	n_3	Average n
10%				
15 %				
20 %				

3. Dependence of refractive index *n* as function of concentration of sugar in solution ***x***



Calculations of the increment (*k*) of refractive index

From diagram find the increment (*k*) of refractive index as tangent of slope angle of the curve *n*(*x*).

$$k = tg\ \gamma = \text{————————}$$

Functional dependence *n*(*x*) has the form: _____
_____
_____
_____

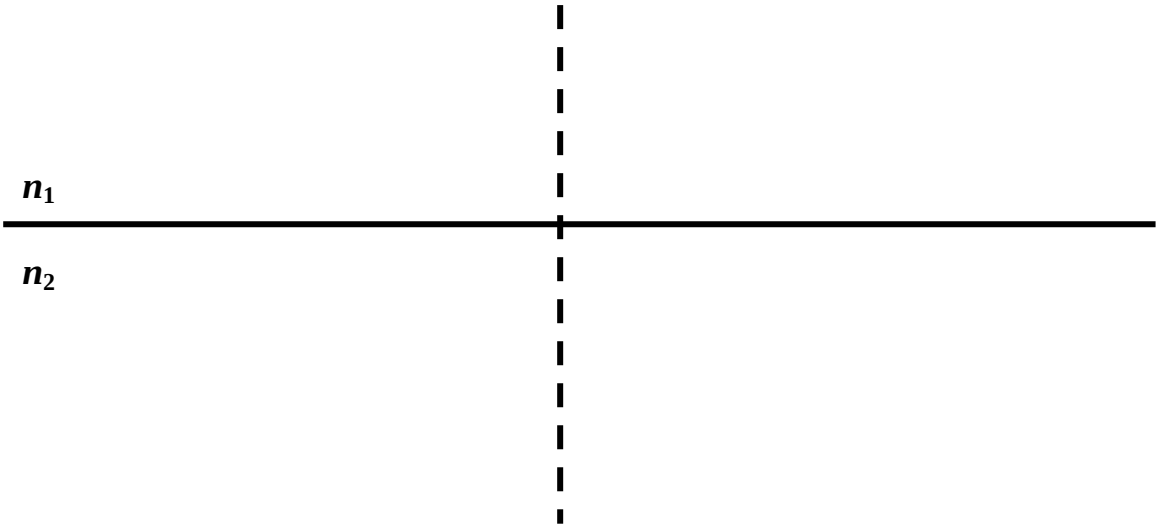
Resume.

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Test questions.

1. What devices are called the refractometers?
2. What is the design of refractometer used for measuring refractive index of liquids?
3. What is the accuracy of the experiment?

4. What is called the relative refraction index? What's called the absolute refraction index?
5. Explain the method of limit angle. Why the surface of the upper prism is matted?
6. What is the phenomenon of the "total internal reflection"? Draw the march of rays for the case of the limit angle if $n_2 > n_1$.



Answers.

_____
_____
_____
_____
_____
_____
_____
_____
_____

Realized by the student:
Group _____
First name_____
Last name_____
Approved by the teacher:

_____ _____
Date Signature of the teacher

Report on Laboratory Experiment No 2
Determination of Dependence of Refractive Index of Prism from Wavelength of Light

The student:

Group _____
First name_____
Last name_____
is **allowed** to do the laboratory work.

_____ _____
Date Signature of the teacher

Purpose of work

Determine the dependence of the refractive index of the glass prism from the wavelength of light. Draw the curve of dispersion

Theoretical principals of work.

1. The absolute refraction index of a glass is _____
_____
_____
2. Dispersion of the light is called _____
_____
_____
3. Theory of the dispersion is based on electromagnetic theory of light and electronic theory of a substance:
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

CALCULATION FORMULA

Refractive index ***n*** for given wavelength can be found from the next formula:
_____
_____
_____

Angles A and δ_{min} are shown at the Figure 1.

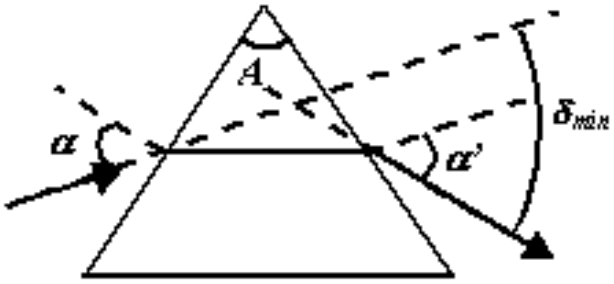


Fig.1.

Measurements of the angles A and $\delta_{\min}$ carried out by mean of goniometer with accuracy _____

Determination of the refraction angle of the prism

Figure 2 shows the disposition of the prism on the goniometer table when determine the refraction angle ***A*** of the prism.

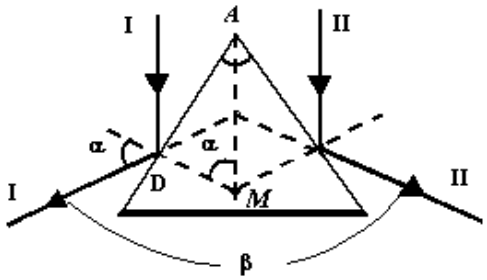


Fig. 2

Determination of the Least Deflection Angle

Figure 3 shows the disposition of the prism on the goniometer table when determine the least deflection angle δ_{min}

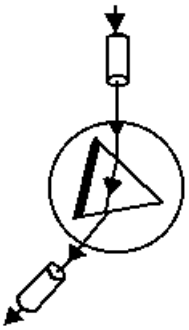


Fig.3

Measurement results

Record the data of measurement of angles A and δ_{min} and refractive index calculated for all observed wavelengths in the Tables 1 and 2.

Table 1

No.	Readings of the limb and nonius		Angle β	Average β	$A = \beta/2$
	Right side	Left side			
1					
2					
3					

Table 2

No.	Color of line	Brightness of line	λ, nm	Readings of limb and nonius		φ'-φ"	$\delta_{m,n}$	n
				Right side	Left side			
1	Red	Bright	670					
2	Orange	Faint	612					
3	Yellow	Bright	579					
4	Yellowy-green	Bright	538					
5	Bluish-green	Faint	489					
6	Blue	Bright	436					
7	Violet	Bright	405					

Diagram of refractive index of prism as function of wave length of light (curve of dispersion)

Resume

_____

_____

_____

_____

_____
_____
_____
_____
_____
_____
_____
_____

Test questions.

1. What is a dispersion of light? What properties of light the phenomenon of dispersion testifies?
2. What is a curve of dispersion?
3. What is the design of goniometer?
4. What sours of light is used in this work?

Answers.

_____
_____
_____
_____
_____
_____
_____
_____
_____

Realized by the student:
Group _____
First name_____
Last name_____
Approved by the teacher:

_____ _____
Date Signature of the teacher

Report on Laboratory Experiment No 3
Hydrogen Spectrum Research and Determination of Rydberg Constant

The student:
Group _____
First name_____
Last name_____
is **allowed** to do the laboratory work.

_____ _____
Date Signature of the teacher

Purpose of work

Study a visible region of the hydrogen emission spectrum and determination of Rydberg constant

Theoretical principals of work

Arrangement of the lines of the hydrogen emission spectrum is described by the formula:

_____(1), where
λ is _____, R is _____,
n is _____, m - _____

From expression (1) follows that the hydrogen emission spectrum consist of several series which are represented in the scheme of energetic levels (Figure 1) by the vertical arrows.

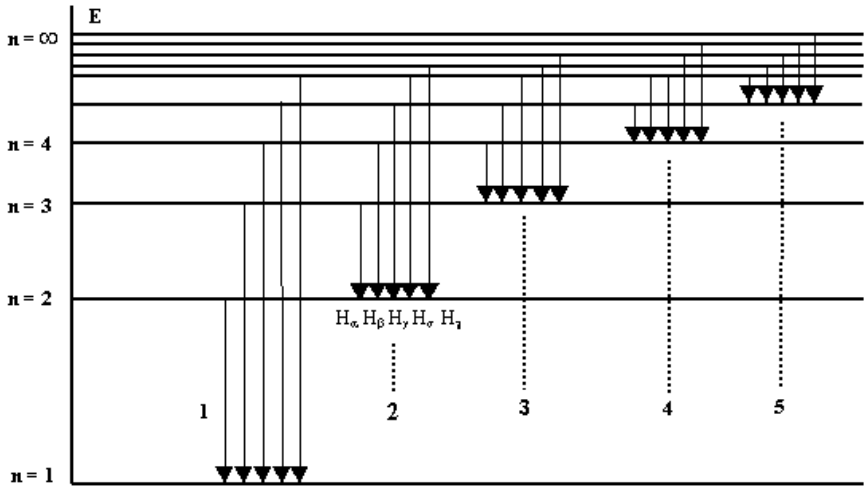


Fig.1.

It is clear from Figure 1 that Lyman series appears as a result of transition of atom from one of the higher levels with *m* = _____ to the basic one *n* = _____

The Balmer series – from the levels with m = _____ to the level with n =_____
The Pashen series – from the levels with m = _____ to the level with n =_____
The Brakket series – from the levels with m = _____ to the level with n =_____
In this laboratory experiment the wavelength of the lines of the _____series are measured. These lines are designated by the symbols:
H_α - red line (m = __), H_β - bluish-green (m = __), H_γ - blue (m = ___), H_δ - violet (m = __).

Experimental Setup

Figure 2 shows scheme of monochromator

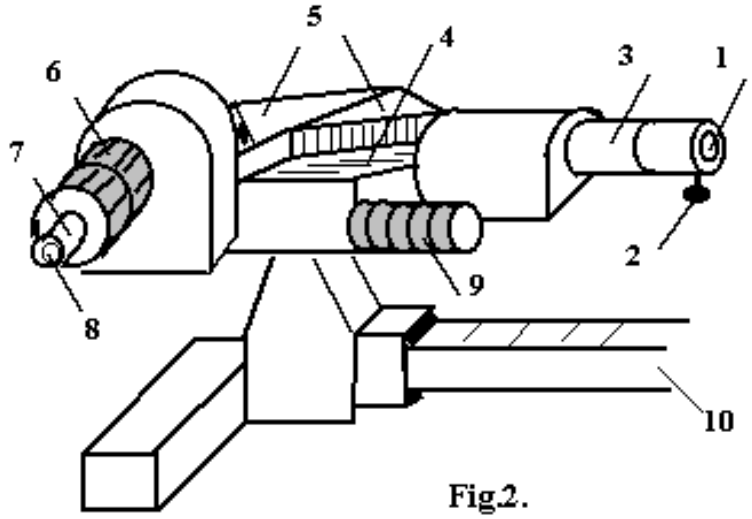


Fig.2.

Collimator is intended for _____
_____
Prism is intended for _____
Output tube is intended for _____
_____

Measurement results

a) Calibration of monochromator.

Calibrate monochromator

means_____
_____
_____
_____

Record the results of calibration according the known mercury spectrum in the Table 1

Table 1

λ , nm							
n^0							

b) The Rydberg constant determination.

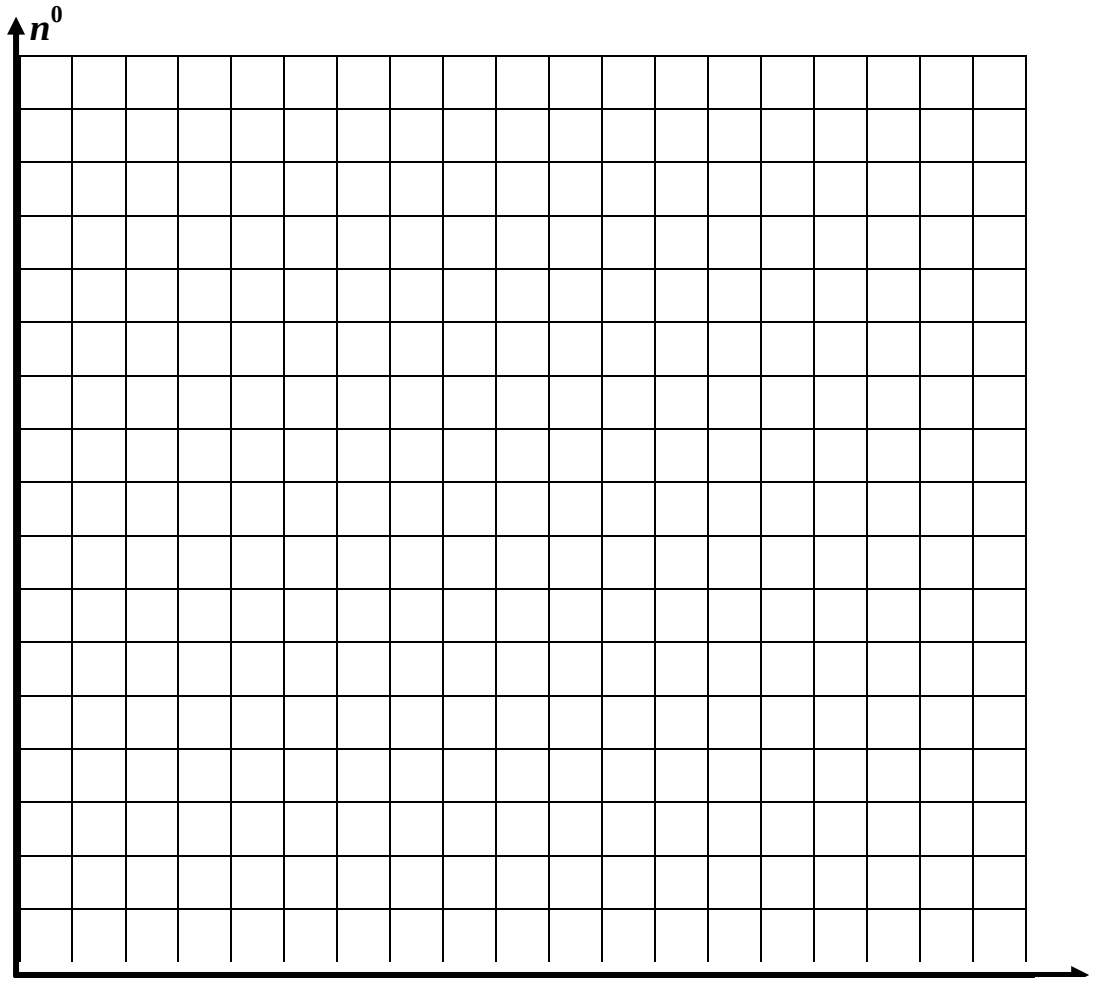
Replace mercury luminescent lamp by hydrogen discharge lamp and data of determination of spectral lines position of the Balmer series record to the table 2.

Table 2

m	3	4	5	6
n_0				
λ, nm				
$\bar{\nu}$, cm^{-1}				
R, cm^{-1}				

Results of Calculation

Calibration curve



By formula (1) calculate the Rydberg constant for m = _____

$$R = \frac{\tilde{\nu}}{\frac{1}{n^2} - \frac{1}{m^2}} = \_\_\_\_\_, \quad R_{av.} = \frac{\sum_{1}^{4} R_i}{4} = \_\_\_\_\_$$

Error Analysis

$\Delta\tilde{R} = \tilde{R}\frac{\Delta\tilde{\lambda}}{\tilde{\lambda}} -$ is estimation of absolute error for R; $\Delta\tilde{\lambda} =$ _____

_____ and finally $\Delta\tilde{R} =$ _____

Relative error $\frac{\Delta\tilde{R}}{R}\cdot 100\% =$ _____

Round off the value of $\Delta\tilde{R}$ and give the result in the form:

$$\overline{R} = \tilde{R} \pm \Delta\tilde{R} =$$

Resume

_____
_____
_____
_____
_____
_____
_____

Test questions

1. Cite Bohr's postulates.
2. What shape of the spectrum is characteristic for gaseous substances? What is the nature of spectral lines?
3. What peculiarities are in the hydrogen spectrum? Record a formula for the hydrogen spectral series. What senses have the values in this formula?
4. How many spectral series has the hydrogen spectrum? How does the Bohr theory explain an origin of these series?
5. Energy of hydrogen atom in the first exited state (n = 2) equals 3.4 eV. Calculate the energies of stationary states correspond to the H_α, H_β, H_γ, and H_δ lines.

Answers.

_____
_____
_____
_____
_____
_____

Realized by the student:
Group _____
First name_____
Last name_____
Approved by the teacher:

_____ _____
Date Signature of the teacher

Report on Laboratory Experiment No 4
Calibration of the Penumbra Polarimeter and Determination of a Sugar Solution Concentration

The student:
Group _____
First name_____
Last name_____
is **allowed** to do the laboratory work.

_____ _____
Date Signature of the teacher

Purpose of work

Study the design of penumbra polarimeter. Calibrate the scale of the device: find the relation between scale divisions and rotating angle of a polarization plane and concentration of sugar in solution. Determine unknown concentration of sugar solution.

Theoretical principals of work

1. Natural light is_____
_____
_____
_____
_____
2. Polarized light is _____
_____
_____
_____
3. Polarizer plane is _____
_____
_____
_____

Vector diagram which demonstrates the path of a natural light through polarizer and analyzer is represented in the Figure 1.

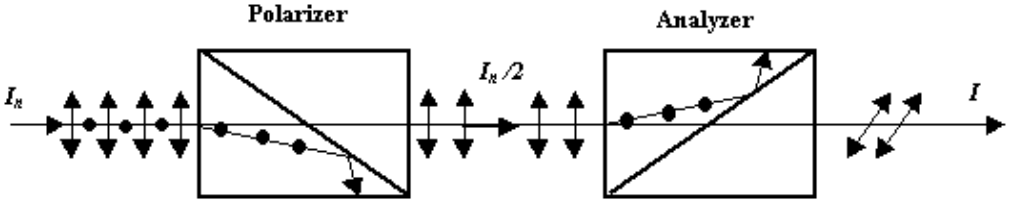


Fig.1

Calculation Formula

1. Malus's law has the form

$I = I_0 \cos^2\varphi$ where

φ is
I is
I_0 is

2. Optically active substances are

3. $\varphi = \alpha l C$, where

α is
C is
l is

Brief description of method of measurement

Optical scheme of device

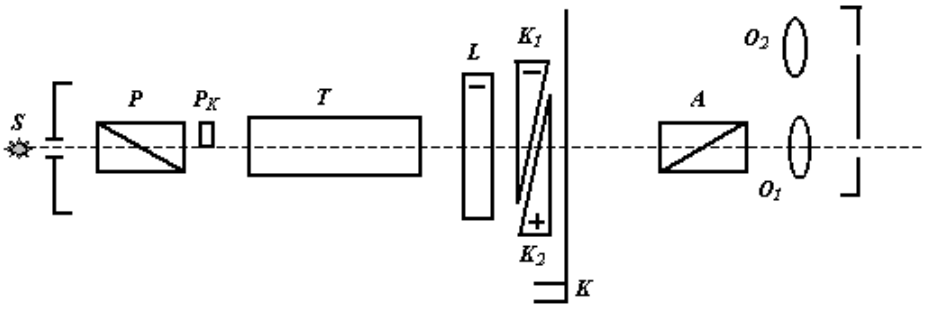


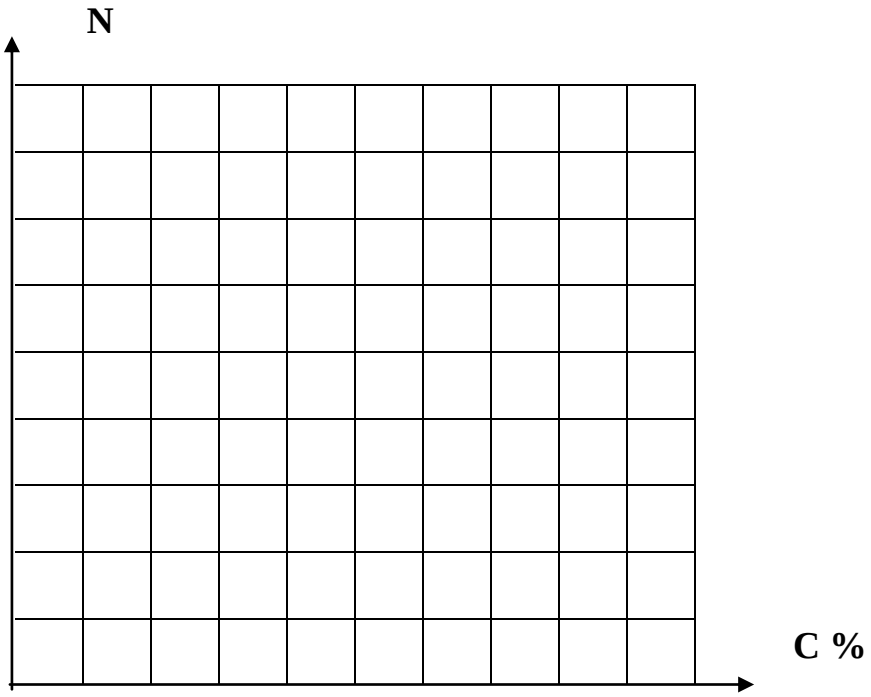
Fig.2

S is
P is
A is
T is
P_K is
L is
K_1 and K_2 are
O_1 and O_2 are

MEASUREMENT RESULTS

Concentration C [g/cm^3]	No. of exp.	Scale readings of nonius N [points]	Angle of rotation of a polarization plane φ [degrees]	An average scale reading $N_{average}$ [points]	Length of a cuvette tube l [dm]	A specific rotation of sugar [α] $\left[\frac{\deg ree}{dm \cdot g/cm^3}\right]$
C_1=	1					
	2					
	3					
	4					
	5					
C_2=	1					
	2					
	3					
	4					
	5					
C_3=	1					
	2					
	3					
	4					
	5					
C_X=	1					
	2					
	3					
	4					
	5					

Results of Calculation



Unknown concentration C_x =

From diagram find the angle of rotation of the polarization plane φ by the solution of desired concentration

$\varphi_{x=}$

Compare it with angle φ_x, recorded in the Table.

Resume

Test questions

1. What observes when the ray of polarized light falls on analyzer which is turning around the direction of the ray.
2. What optically active substance is called right-handed and what is left-handed one?
3. What is the role of the wedges K_1 and K_2? Why after polarizator there is plate from quartz P_K?
4. What quantities define the angle of rotation of polarization plane?

Answers

_____
_____
_____
_____
_____
_____
_____
_____

Realized by the student:
Group _____
First name_____
Last name_____
Approved by the teacher:

_____ _____
Date Signature of the teacher

Report on Laboratory Experiment No 5
Determination of the Planck Constant and Stefan-Boltzmann Constant by Means of an Optical Pyrometer with a Disappearing Filament

The student:
Group _____
First name_____
Last name_____
is **allowed** to do the laboratory work.

_____ _____
Date Signature of the teacher

Purpose of work

Determine the Stefan-Boltzmann and Planck constants by means of the pyrometer with the disappearing filament.

Theoretical principals of work

1. Integral emittance R_T (the radiosity) of a body is_____
_____
_____
_____

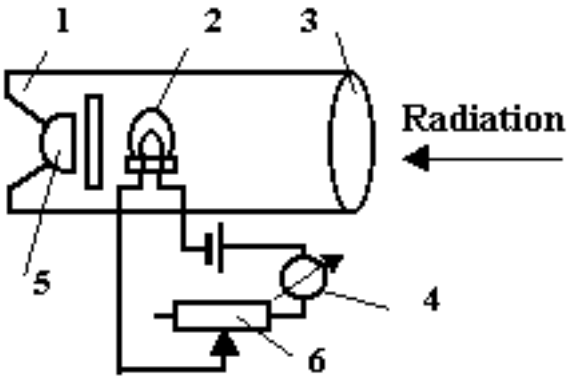
2. The spectral emittance $r_{\lambda T}$ is called_____
_____
_____
_____

3.The Stefan-Boltzmann's law is _____
_____
_____
_____

4. The integral emittance of the bodies is determined by the expression:_____
_____
_____
_____
_____

5. The principle of Optical Pyrometer with a Disappearing Filament function is follow:_____
_____
_____
_____
_____
_____
_____

Optical scheme is represented in Figure 1.



1 - _____

2 - _____

3 - _____

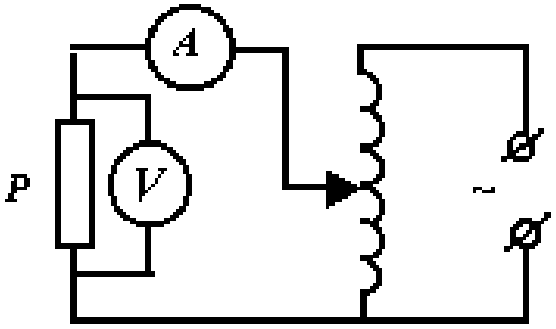
4 - _____

5 - _____

Fig. 1

Heating body is _____

Electric scheme of power supply of heating is represented in Figure 2.



P is _____

A is _____

V is _____

Fig. 2

CALCULATION FORMULA

Data of Measurement

Record the data of measurement in Table 2.

No. of test	U [Volt]	I [Ampere]	W [Watt]	T_{BR} [^0C]	T_{BR} [^0K]	T [^0K]	d [m]	l [m]	S [m^2]
1									
2									
3									

For the plate of oxide of nichrome $\alpha(T) = 0,95$ in the range of (800-1400) ^{0}C

True temperature T as a function of brightness temperature T_{BR}

Results of Calculation

$\delta_1 =$ $\quad\quad$ $< \delta > =$

$\delta_2 =$ $\quad\quad$ $h =$

$\delta_3 =$

Error Analysis

Derivation of expression for relative error δ _____

_____

_____

_____

Reasoning of calculation of errors_____

_____

_____

_____

Final result:

$\delta \pm \Delta\delta =$
with confidence probability $\alpha = 0{,}95$

$$\frac{\Delta\delta}{\delta} \cdot 100\,\% =$$

Conclusions

_____

_____

_____

_____

_____

Questions

1. Demonstrate the relation of integral and spectral radiant emittances?
2. Give definition of spectral absorption ability $\alpha_{\lambda T}$ of the body?
3. What are the dimensions of the Stefan-Boltzmann's and Planc's constants?
4. Show in the drawing how the energy emitted by absolutely black body and the selective emitter (at some temperature) is distributed in spectrum?
5. What determine the emissivity factor α_T of the body?
6. What temperature is called "brightness temperature"?

Answers

_____

_____

_____

_____

_____

_____

Realized by the student:
Group _____
First name_____
Last name_____
Approved by the teacher:

_____ _____

Date Signature of the teacher

Report on Laboratory Experiment No 5

Research of Light Diffraction from Single and Many Slits

The student:
Group _____
First name_____
Last name_____
is **allowed** to do the laboratory work.

_____ _____
Date Signature of the teacher

Purpose of work

Study the operating principle of the gas laser. Evaluate the wavelength of radiation of the gas laser. Study a diffraction pattern from a single slit and its modification depending on number of slits. Determine a slit width. Get a diffraction pattern from two slits and determine a width of an opaque area between the slits.

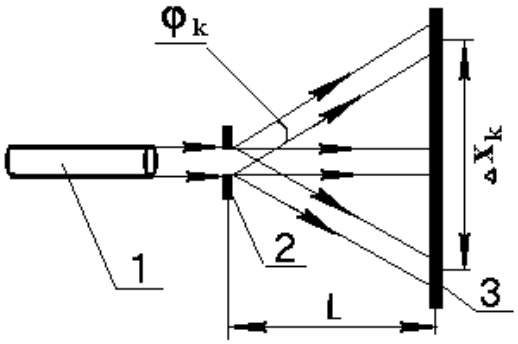
Theoretical principals of work

1. The diffraction is
_____
_____
_____
2. Condition of availability of diffraction maximum from one slit has the form:
_____ (1)
where x is _____, b is_____,
φ_k is _____, k is _____.
3. Condition of availability of diffraction maximum from several slits has the form:
_____ (2)
where x is _____, c is _____,
φ_k is _____, k is _____.
4. Constant of the diffraction grating c is _____
_____
5. When number of slits increases the diffraction pattern changes in the following way:
_____
_____
_____
6. Difference between stimulated and spontaneous emission consist in _____
_____
_____
7. Inverted population of energetic levels is called the state, when _____
_____
8. Difference of laser radiation and radiation from other sources of light consist in
_____

_____

_____

SCHEME OF SETUP



In the scheme:

Δx_k is _____

L is _____

φ_k is _____

1 - _____

2 - _____

3 - _____

Measurement results

1. Diffraction grating

Table 1

k	Δx_k, mm			$\Delta x_{k\ av.}$	φ_k	λ, μm	L, m
± 1							
± 2							
± 3							

2. Diffraction from one slit

Measure the distance between diffraction maximum and fill up Table 2

Table 2

k	Δx_k, mm			$\Delta x_{k\ av.}$	φ_k	λ, μm	L, m	b,mm
± 1								
± 2								
± 3								
± 4								
± 5								
± 6								
± 7								
± 8								
± 9								
± 10								

Evaluate diffraction angle φ_k and wavelength λ.

3. Diffraction from two slits

Table 3

k	Δx_k, mm			$\Delta x_{k\ av.}$	φ_k	λ, μm	a,mm	$a_{av.}$,mm
± 1								
± 2								
± 3								
± 4								
± 5								
± 6								
± 7								
± 8								
± 9								
± 10								

Calculation results

1. Diffraction angle φ_k:

$$tg\ \varphi_k = \frac{\Delta x_k}{2L}$$

$tg\ \varphi_1$ =_____; $tg\ \varphi_2$ =_____; $tg\ \varphi_3$ =_____;

Wavelength λ:

$$\lambda_k = \frac{c \sin \varphi_k}{k}$$

λ_1 = _____; λ_2 = _____; λ_3 = _____;

$$\lambda_{ev} =$$

1. Diffraction from one slit

Diffraction angle φ_k : $tg\ \varphi_k = \frac{\Delta x_k}{2L}$

_____
_____
_____

Width of slit b : $b = \frac{(2k+1) \cdot \lambda}{\sin \varphi_k \cdot 2}$,

b_1 - _____, b_2 - _____,
b_3 - _____, b_4 - _____

Wavelength λ is taken from Table 1:

$$\lambda =$$

2. Diffraction from two slits

Diffraction angle φ_k **:** $tg\,\varphi_k = \frac{\Delta x_k}{2L}$

$tg\,\varphi_1$ =_____; $tg\,\varphi_2$ =_____; $tg\,\varphi_3$ =_____;

Constant grating $c = a + b$. $c = \frac{k\lambda}{\sin\varphi_k}$

c_1 = _____; c_2 = _____; c_3 = _____;

Taking into account, that width of the slit equals 0,16 mm, calculate $a = c - b$, for every k.

a_1 = _____; a_2 = _____; a_3 = _____

Conclusions

_____
_____
_____
_____
_____

Questions

1. Explain the principle operation of gas laser.
2. Why the mixture of two gases **He** and **Ne** is used in the laser?
3. What is the difference between stimulated and spontaneous emission?
4. How the state of inverted population in gas laser created?
5. How the diffraction pattern depends on the width of one slit?
6. What the diffraction pattern from diffraction grating is differ from the diffraction pattern from one slit?
7. Why it is impossible to distinguish one atom by optical microscope?

Answers.

_____
_____
_____
_____
_____
_____

Realized by the student:
Group _____
First name_____
Last name_____
Approved by the teacher:

_____ _____
Date Signature of the teacher