Tomsk Polytechnic University

PHYSICS II
Reports on Laboratory Experiments

Tomsk 2002

UDC 53 (076)

PHYSICS II. Electricity and Magnetism. Electromagnetic Oscillations and Waves. Reports on Laboratory Experiments. Tomsk: TPU Press, 2002, 31pp.

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

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Reviewed by: V.Ya. Epp, Professor of Department Physics and Mathematics, TSPU, D.Sc.

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. Studying of an Electric Field
2. Determination of the Ionic Charge of Hydrogen
3. Measurement of Capacitance and Permittivity by Bridge Method
4. Determination of High Value Resistance and Capacitance with the Help of Relaxed Oscillations
5. Study of Semiconductor Resistance-Temperature Dependence. Determination of Activation Energy.
6. Measurement of a Solenoid Magnetic Field Strength.

Report on Laboratory Experiment No 1

Electric Field Research

The student:

Group ___________________________________

First name_______________________________

Last name________________________________

is **allowed** to do the laboratory work.

____

Date ____________________________ Signature of the teacher

Purpose of Work

Determine disposition and potentials of electric field equipotential surfaces produced by plane and cylindrical electrodes. Graphically plot electric field strengths on the basis of the measurements.

Devices and Instruments

Galvanometer, measuring circuit, electric bath, electrodes of the plane and cylindrical forms, plotting paper.

Theoretical Contents. Summary

Electric field is ____

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Field strength is ____

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Electric field potential is____

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Equipotential surface is ____

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Electric field strength and potential relation - ______________________________

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Method of electric field research -______________________________________

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Principle of determination of the equipotential surfaces - ____________________

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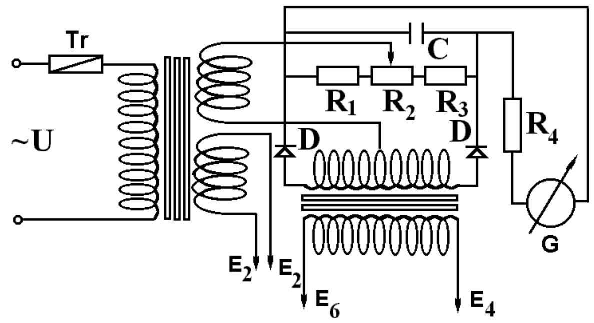
Electric Scheme



R_4 - ______________________________

D -______________________________

Table of symbols

E_2 -______________________________

E_6 -______________________________

E_4 - ______________________________

R_1 - ______________________________

R_2 - ______________________________

R_3 - ______________________________

G -______________________________

U -______________________________

C -______________________________

Tr. - ______________________________

Scheme of the Electrode's Allocation in the Electrolytic Bath.

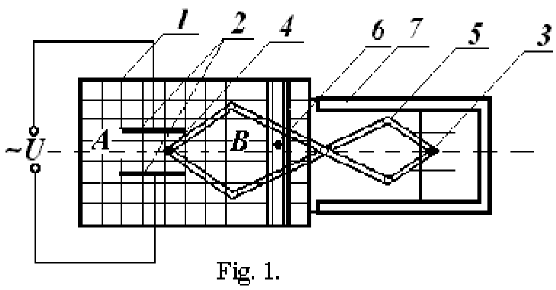


Fig. 1.

A - ______________________________

Table of symbols

1 - ______________________________

2 - ______________________________

3 - ______________________________

4 - ______________________________

5 - ______________________________

6 - ______________________________

7 - ______________________________

U - ______________________________

B - ______________________________

Calculation Formulas

1. Potential of the equipotential surfaces produced by plate electrodes

$$\varphi =$$

where U –
l –

x –

2. Potential of the equipotential surfaces produced by cylindrical electrodes

$$\varphi =$$

where U –

d –

x –

a –

Measurement Results

Necessary data for calculation of potential are determined from graphics of equipotential surfaces. Results of measurements and calculations are recorded in tables.

1. Plate electrodes.

Table 1

Order of equipotential surfaces	Distances		U (Volt)	φ (Volt)
	x	ℓ		

2. Cylindrical electrodes

Table 2

Order of equipotential surfaces	Distances		U (Volt)	φ (Volt)
	x	d		

Measured by the student: ______________________
Name

Verified by the teacher: ______________________
Signature of the teacher

Note: Graphics of field lines are enclosed with this report.

Resume

Test Questions

1. Give a definition of the term: an electric field.
2. Give a definition of the term: field strength.
3. Give a definition of the term: potential of electric field.
4. How are the field strength and potential at a given point of field mathematically connected?
5. Prove that field lines and equipotential surfaces are mutually perpendicular.
6. What surface is called equipotential?
7. What electric field is called potential?
8. How do electrode forms influence the electric field?
9. What electric field is called uniform?

Answers

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Executed 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 the Charge of Hydrogen Ion

The student:

Group ______________________________

First name___________________________

Last name____________________________

is allowed to do the laboratory work.

____

Date ______________________ Signature of the teacher

Purpose of Work

Determine the charge of hydrogen ion and compare it with the elementary charge.

Devices and Instruments

Hoffman's voltmeter, rheostat, source of direct current, milliammeter, switch, connecting wires.

Theoretical Contents. Summary

Electrolysis is the phenomenon____

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The ions of hydrogen are produced as a result of electrolysis of aqueous solution of sulphuric acid H_2SO_4. According to the reaction ____________________

____

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Molecules of oxygen appear near the anode as a result of the following process ______

____

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Charge of ion can be determined_______________________________________

____

where Q^+ - ______________________ n^+ - ______________________

Calculation Formulas

(with explanation of values which are used)

$$q^+ = \frac{RTIt}{2N_0 P_{H_2} V},$$

V – ______________________

I – ______________________

t – ______________________

N_0 – ______________________

T – ______________________

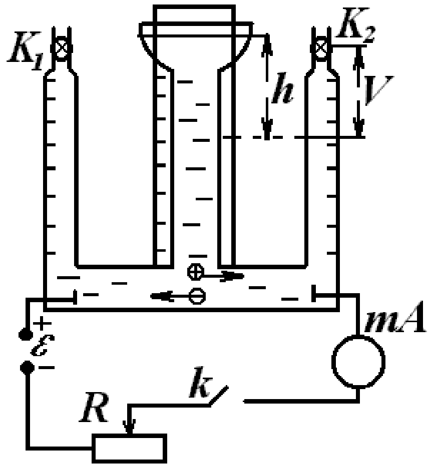
$$P_{H_2} = P_{am} + \rho gh - aP_t,$$

ρgh – ______________________

P_t – ______________________

a – ______________________

Experimental Assembly



where

K_1, K_2 – ______________________

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R – ______________________

____

k – ______________________

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mA – ______________________

____

V – ______________________

____

ε – ______________________

____

Measurement Results

№ exp	I [A]	T [sec]	T [^0K]	V [m^3]	P_{at} [kPa]	h [m]	P_h [kPa]	P_t [kPa]	P_{H2} [kPa]	q^+ [C]
1.										
2.										
3.										
4.										
Average value										

Measured by the student: ______________________
Name

Verified by the teacher: ______________________
Signature of the teacher

Analysis

Let's introduce experimental results into the formulas and calculate the charge of hydrogen on:

$q_1^+ =$

$q_2^+ =$

$\overline{q}^+ =$

Let's compare the calculated results with the value of elementary charge:

$\ell =$ ____

Resume

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Absolute and ratio errors of the value of q^{+} for the experiment are:

$$\frac{\Delta \bar{q}}{\bar{q}} = \sqrt{\left(\frac{\Delta \bar{T}}{\bar{T}}\right)^2 + \left(\frac{\Delta \bar{I}}{\bar{I}}\right)^2 + \left(\frac{\Delta \bar{t}}{\bar{t}}\right)^2 + \left(\frac{\Delta \bar{P}_{H_2}}{\bar{P}_{H_2}}\right)^2 + \left(\frac{\Delta \bar{V}}{\bar{V}}\right)^2};$$

Basis of errors:

$\Delta \bar{T}_{SM} = 0{,}95 \cdot \ell_T =$______________; where $\ell_T =$ ______________, since value of T is measured_________________________ with accuracy __________________________

$\Delta \bar{I} = 0{,}95 \cdot \Delta I =$__________________________, where $\Delta I = \frac{k}{100\%} \cdot I_{\max} =$__________

($k -$ grade of accuracy of device, $I_{\max} -$ limiting value of the device scale)

$k =$________________________________, $I_{\max} =$________________________________

$\Delta \bar{t}_{SM} = 0{,}95 \cdot \ell_t =$__________________________, where $\ell_t =$__________________, since value of t is measured_________________ with accuracy ____________________

$$\Delta \bar{P}_{H_2} = \sqrt{(\Delta \bar{P}_{at})^2 + (\rho g \Delta \bar{h})^2 + (0{,}9 \Delta \bar{P}_T)^2}$$

$\Delta \bar{P}_{at} = 0{,}95 \ell_{P_{at}} =$__________________________, where $\ell_{P_{at}} =$___________________, since value of P_{at} is measured________________ with accuracy____________________

$\Delta \bar{h} = 0{,}95 \ell_h =$____________________________, where $\ell_h =$ ____________________, since value of h is measured__________________ with accuracy ___________________

$\Delta \bar{P}_T = 0{,}95 \ell_{P_t} =$__________________________, where $\ell_{P_t} =$______________________, is defined in the following way:

at temperature $(t+1)^0 C$ value of $P_{t_1} =$ (from Table)

at temperature $(t-1)^0 C$ value of $P_{t_2} =$

$$\ell_{P_t} = \frac{P_{t_2} - P_{t1}}{2} =$$

$\Delta \bar{V} = 0{,}95 \ell_V =$____________________________, where $\ell_V =$ ____________________, since value of V is measured__________________ with accuracy ___________________

$$\frac{\Delta \bar{q}}{\bar{q}} =$$

$$\Delta \bar{q} =$$

Final Result

$\bar{q} + \Delta \bar{q} =$ with probability $\alpha = 0{,}95$.

Test Questions

1. What is the value of elementary charge?
2. What is the effect of electrolytic dissociation?
3. Formulate the first Faraday law.
4. What charge type has the ion of hydrogen?
5. Where would be larger the volume of evolved gases, near cathode or anode? Why?
6. You mix the acid and water. The order of mixture: the first component is acid and water is the second. Why is such order used?
7. What influences the value of the electrolyte conductivity?

Answers

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Executed by the student:
Group ______________________________
First name____________________________
Last name____________________________

Approved by the teacher:

____

Date ________________________________ Signature of the teacher

Report on Laboratory Experiment No 3

Measurement of Capacitance and Permittivity by the Bridge Method

The student:
Group ___________________________________
First name_______________________________
Last name________________________________
is allowed to do the laboratory work.

____

Date ______________________________ Signature of the teacher

Purpose of work: capacitance measurement of two capacitors, capacitance of capacitors in series and parallel connection and permittivity of a substance.

Devices and instruments: sound-frequency generator, oscillograph, two standard capacitors, two capacitors to be investigated, plane air capacitor, dielectric plates, variable resistor, trammel, ruler.

Theoretical Contents. Summary

Capacitance is____
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Permittivity of a substance is ____
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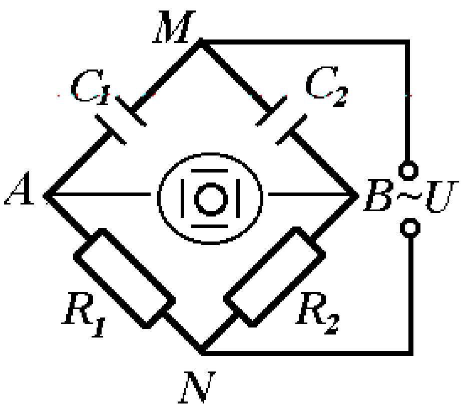

A bridge method of capacitance measurement means ______________________________

In the capacity of the null-voltage indicator ______________________ is being used. For the reason ______________________________

will get $C_1 = C_2 \frac{R_2}{R_1}$,

where C_2 – ______________________________

R_2 – ______________________________

R_1 – ______________________________

The electric scheme of a capacity bridge is shown:

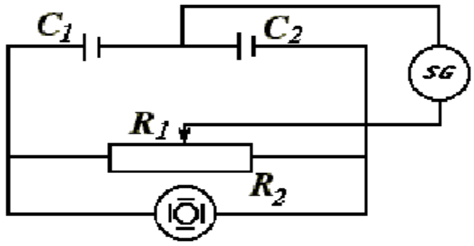

Table of symbols:

C₁ – ______________________

C₂ – ______________________

R₂ – ______________________

R₁ – ______________________

SG – ______________________

O – ______________________

To measure the permittivity of a substance ε______________________________

______________________________is used.

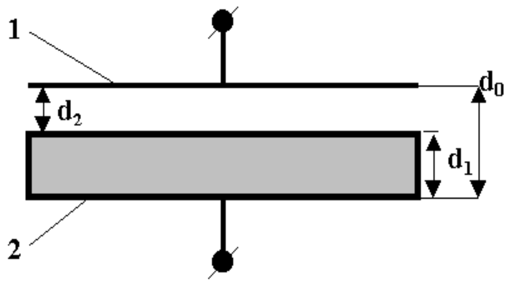

Table of symbols:

1 – ____________________

2 – ____________________

d_0 – ____________________

d_1 – ____________________

d_2 – ____________________

The permittivity ε is calculated by using the capacitance bridge method

$\varepsilon =$

where C - ______________________________

d_2 ______________________________

ε_0 - ______________________________

S - ______________________________

d_1 - ______________________________

Results of the Measurements and Calculations of Capacitances

Table 1.

Investigated capacitance	R_1 (Ohm)	$\overline{R_1}$ (Ohm)	$\overline{R_2}$ (Ohm)	Value of capacitance (microfarad)
C_{x1}				
C_{x2}				
C_{xP} (in parallel)				
C_{xS} (in series)				

Measurement Results of the Permittivity of a Substance ε

Table 2.

Dielectric	d_0 (mm)	d_1 (mm)	d_2 (mm)	S (m^2)	C (picofarad)	ε

Calculations of the Capacitances

$C_{x1} =$	$R_1 =$	$R_2 =$
$C_{x2} =$	$R_1 =$	$R_2 =$
$C_{xP} =$	$R_1 =$	$R_2 =$
$C_{xS} =$	$R_1 =$	$R_2 =$

Let's compare the results of measurements C_{xP} and C_{xS} with the calculations on the basis of the measured C_{x1} and C_{x2}.

Measurements	**Calculations**

Calculations of the Permittivities of Substances

$\varepsilon_1 =$ $\varepsilon_2 =$

Comparison with the Table Results

Table data	**Data you've got**
Glass $\varepsilon = 5 - 7$	$\varepsilon =$
Viniplast $\varepsilon = 2 - 2{,}5$	$\varepsilon =$

Analysis of Measurements

Let's calculate precision of measurements by using the estimation method of indirect measurements.

Formula construction for the uncertainty of measurement

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Evaluation of inaccuracy of measurements

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Measurement's results:

$C_{x1} = \overline{C}_x \pm \Delta C_{x1} =$ with the probability $\alpha = 0{,}95$

Ratio error of measurements:

Resume

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Test Questions

1. Why is the capacitance of a capacitor larger than the capacitance of an electric conductor?
2. Which parameters influence the permittivity of a substance?
3. What preferences do you get using the bridge method for the measurements of capacitance and permittivity?
4. How can you get minor geometric dimensions of the capacitors and a large capacitance simultaneously?
5. Why do we need to use capacitors in electric circuits?
6. What purposes are series and parallel connection of the capacitors applied?

Answers

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Executed by the student:
Group ___________________________
First name________________________

Last name______________________

Approved by the teacher:

____

Date ____________________________ Signature of the teacher

Report on Laboratory Experiment No 4

Determination of High Value Resistance and Capacitance with the Help of Relaxed Oscillations

The student:

Group ____________________________________

First name________________________________

Last name_________________________________

is allowed to do the laboratory work.

____

Date ______________________________ Signature of the teacher

Purpose of Work

capacitance measurement of two capacitors, capacitance of capacitors in series and parallel connection. Do measurement for the resistance of two resistors analogous way.

Theoretical Contents. Summary

Relaxed oscillations are____

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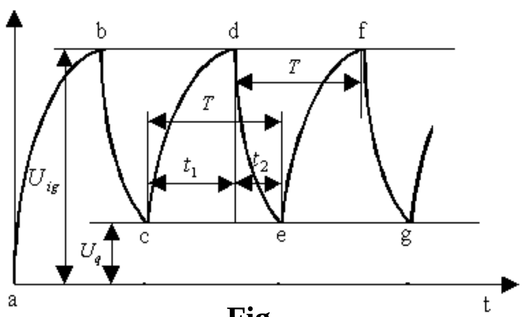

Fig.

The capacitor voltage-time dependence is shown in Fig. 1. The table of symbols:

t_1 ________________________________

t_2 ________________________________

U_{ig} ________________________________

U_q ________________________________

The principle of operation of the relaxed oscillation generator is consist in ________________________________

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According to the second Kirchhoft law $U_0 = IR + U_c$, where U_0 - ____________________

I -__________________, R -___________________, U_c -______________________

Calculation Formulas

$$\frac{T_1}{T_2} = \frac{R_1}{R_2} \quad (C = const), \text{ where}$$

$$\frac{T_1}{T_2} = \frac{C_1}{C_2} \quad (R = const), \text{ where}$$

T_1 ______________________________________

T_2 ______________________________________

R_1 ______________________________________

R_2 ______________________________________

T_1 ______________________________________

T_1 ______________________________________

C_1 ______________________________________

C_2 ______________________________________

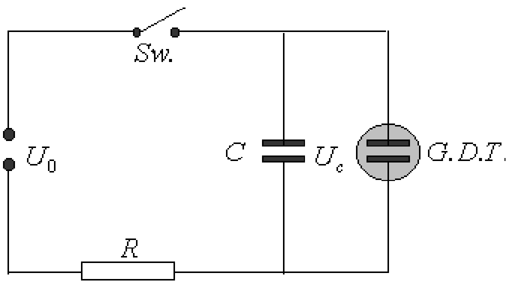

Fig. 2.

ectric Scheme

D.T. - ____________________________

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-___________________________________

-___________________________________

-___________________________________

easurements results

Table 1.

Electric circuit parameters	The order of experiment	The numbers of flashes, n	t [sec]	T [sec]	$\overline{T}$ [sec]	Unknown quantity
$C_1 =$ $R_1 =$						
$R_1 =$ C_{X1};						$C_{X1} =$
$R_1 =$ C_{X2};						$C_{X2} =$
$R_1 =$ C_{XP};						$C_{XP} =$
$R_1 =$						$C_{XS} =$

C_{XS};						

Table 2.

Electric circuit parameters	The order of experiment	The numbers of flashes, n	t [sec]	T [sec]	$\overline{T}$ [sec]	Unknown quantity
$C_1 =$ $R_1 =$						
$C_1 =$ R_{X1};						$R_{X1} =$
$C_1 =$ R_{X2};						$R_{X2} =$
$C_1 =$ R_{XP};						$R_{XP} =$
$C_1 =$ R_{XS};						$R_{XS} =$

Measured by the student: ________________________________
Name

Verified by the teacher: ________________________________
Signature of the teacher

Analysis of Measurements

Calculate ratio and absolute errors of only one series of measurement on teacher's option.

Formula for the error calculation:

$$\frac{\overline{\Delta C_X}}{\overline{C_X}} =$$

$$\frac{\overline{\Delta R_X}}{\overline{R_X}} =$$

Note: Values of C_1 and R_1 are defined with the ratio equaling error 10%.

Measurement's result:

$$C_X = \overline{C}_X \pm \overline{\Delta C_X} =$$

Resume

____

Test Questions

7. Can you explain the principle of operation of the relaxed oscillation's generator?

8. Get formula $T = \ln\left(\frac{U_0 - U_{ig}}{U_0 - U_q}\right)$.

9. What oscillations are called relaxed?

10. Formulate the second Kirchhoff's law.

11. Write down the differential equation of changing capacitor's charge.

Answers

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Executed by the student**:**

Group ____________________________

First name__________________________

Last name__________________________

Approved by the teacher**:**

____________________ ____________________________
Date Signature of the teacher

Report on Laboratory Experiment No 5

Study of Semiconductor Resistance-Temperature Dependence. Determination of Activation Energy

The student:
Group __________________________________
First name_______________________________
Last name________________________________
is allowed to do the laboratory work.

____

Date ____________________________ Signature of the teacher

Purpose of work

Get the voltage-current characteristic and temperature-resistance dependence of a semiconductor. Define the activation energy for the given semiconductor.

Devices and Instruments

Semiconductor resistor (theristor), vessel with water, potentiometer, direct current sources, voltmeter, microammeter, switch and wires.

Theoretical contents. Summary

An activation energy of a semiconductor is ___________________________________
____
____
____
____

Two type of semiconductors exist in nature: *n-type* and *p-type*. These are schematically shown in Fig.1.

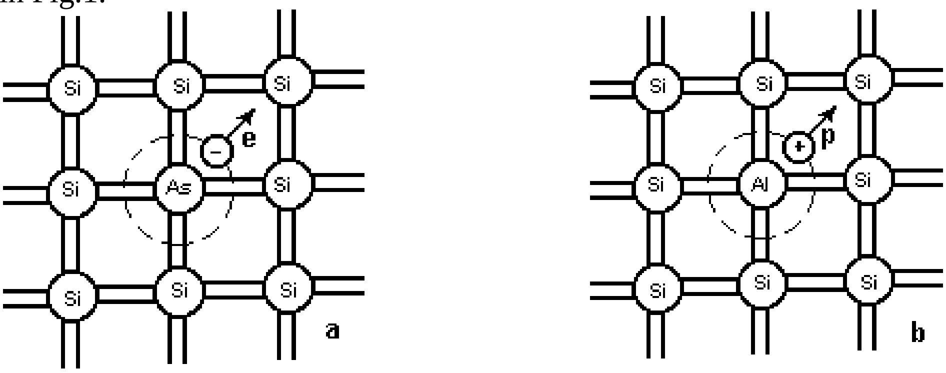

Fig.1.

The role of impurity in semiconductor of *n-type* is________________________________
____
____
____
____

The role of impurity in semiconductor of *p-type* is________________________________
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____
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____

On the empirical diagram:

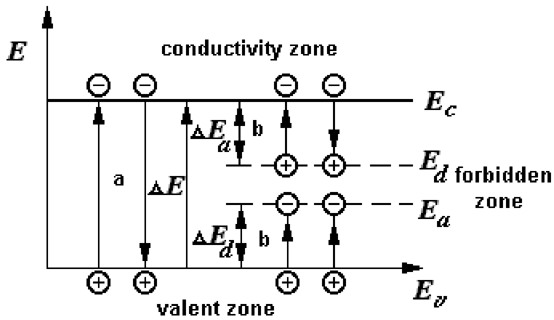


Table of symbols

E_c – ________________________________
E_V – ________________________________
E_a – ________________________________
E_d – ________________________________
ΔE – ________________________________
ΔE_a – ________________________________
ΔE_d – ________________________________

The resistance of semiconductor decreases with the increasing of its temperature:

$R =$

where, R_0 – ____________________________ ΔE – ____________________________
k – ______________________________ T – ______________________________

The $\ell n R$ - $1/T$ dependence looks like____

From this dependence it is possible to determine the value of _______________________

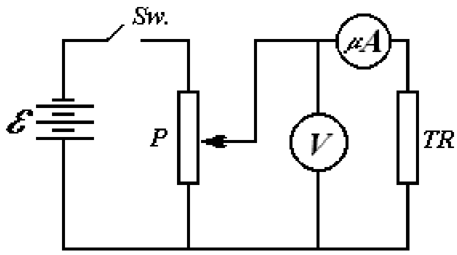
Calculation Formulas

$$R = \frac{U}{I}$$

$$\Delta E = k\, tg\varphi$$

Where, U – ______________________________________
I – ______________________________________
k – ______________________________________
$tg\varphi$ – ______________________________________
ΔE – ______________________________________

Electric Scheme



where,

ε – ______________________________

P – ______________________________

V – ______________________________

TR – ______________________________

μA – ______________________________

Sw – ______________________________

Results

Table 1.

U $(Volt)$												
I $(Ampere)$												

Table 2.

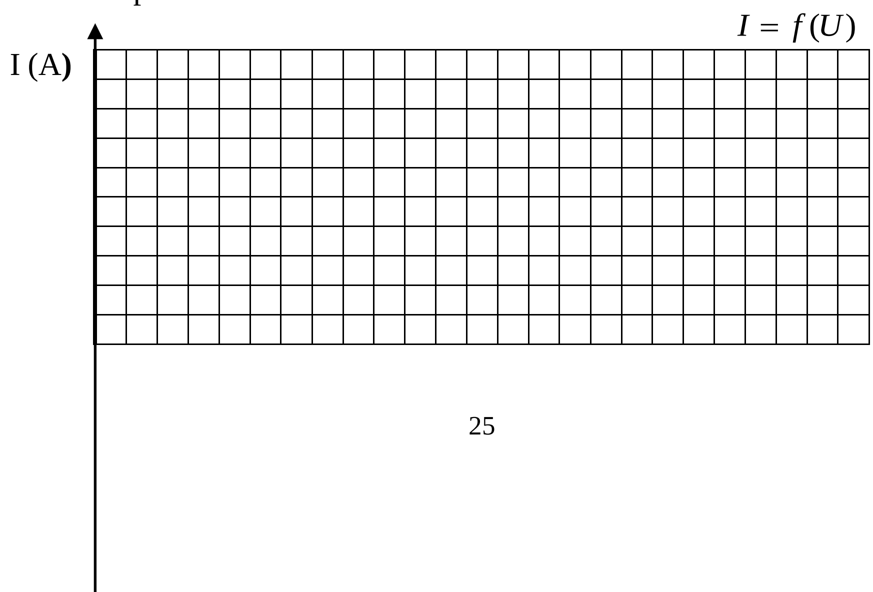
$t^O C$	$T^O K$	$1/T, K^{-1}$	I $(Ampere)$	U $(Volt)$	R (Ohm)	$\ell n R$

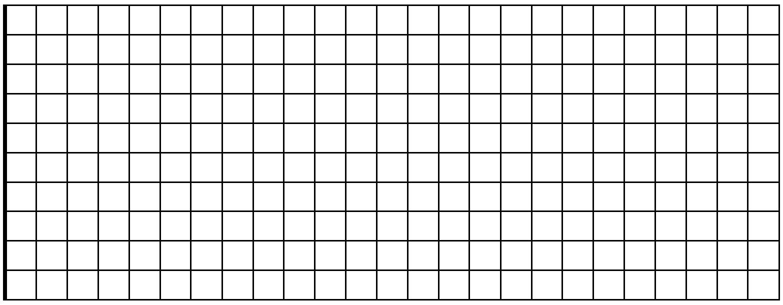
Measured by the student: ______________________________
Name

Verified by the teacher: ______________________________
Signature of the teacher

Analysis

1. Let's plot the graph of voltage-current characteristic using the data from Table 1 at the room temperature.

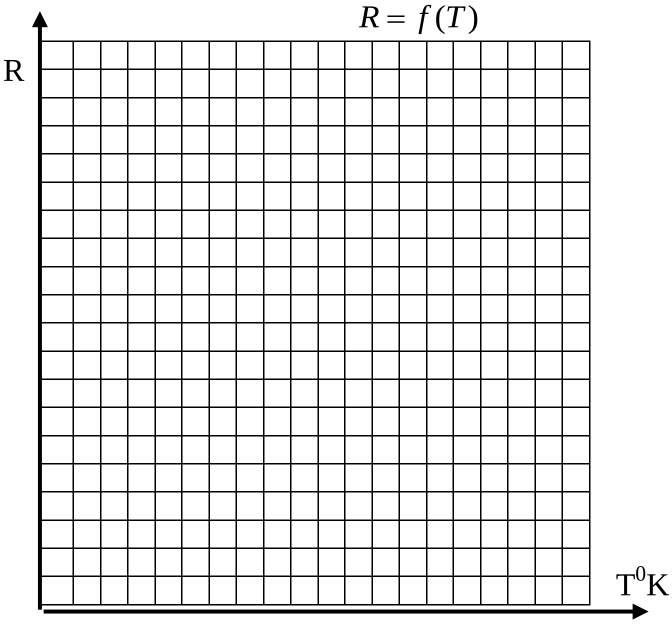




Conclusions

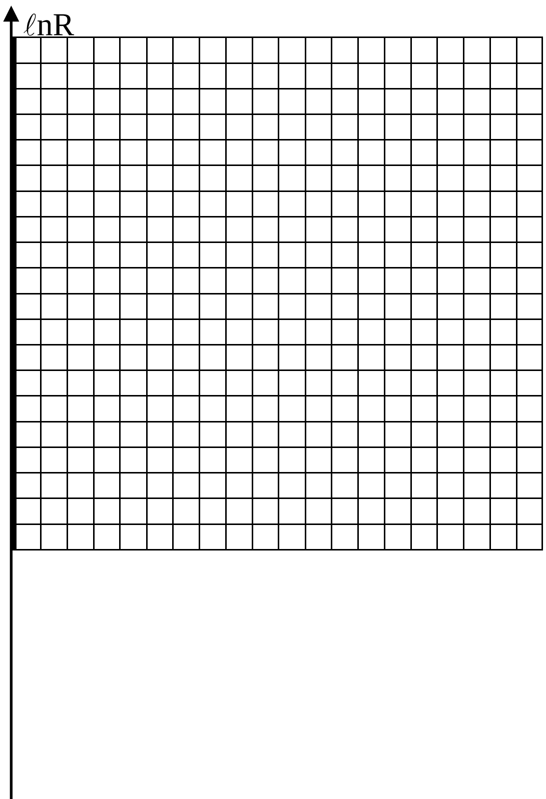
2. Let's plot the graph of temperature-resistance dependence using the data from Table 2.

$$R = f(T)$$



Conclusion:

3. Let's plot the graph $\ell nR = f(\frac{1}{T})$ using the data from Table 2.



Conclusion:

$tg\ \varphi$ is found from the graph:

$tg\ \varphi =$

Reference data:

$k = 1{,}38 \cdot 10^{-23}\ \left[Joule / Coulomb \right]$;

$1eV = 1{,}6 \cdot 10^{-19}\ \left[Joule \right]$;

$\Delta E = k\, tg\, \varphi$;

$\Delta E =$

Resume

Test Questions

1. What properties subdivide solids into dielectrics, conductors and semiconductors?
2. What value is called the activation energy of conductivity?
3. How does the resistance of semiconductor change with temperature? Why?
4. What semiconductor is called a semiconductor of *p-type*?
5. What semiconductor is called a semiconductor of *n-type*?

Answers

Executed by the student:

Group ______________________________
First name___________________________
Last name___________________________

Approved by the teacher:

__________________ ______________________________
Date Signature of the teacher

Report on Laboratory Experiment No 6

Measurement of Magnetic Field of a Solenoid

The student:
Group _____________________________________
First name_________________________________
Last name__________________________________
is **allowed** to do the laboratory work.

________________ __________________________
Date Signature of the teacher

Purpose of Work

Determination of the magnetic induction and magnetic field strength inside a solenoid at the given points along it's axis. Determination of the magnetic induction dependence on the current, passing through the turns of the solenoid.

Devices and Instruments

Solenoid, millivoltmeter, measuring coil, rheostat and connecting wires.

Theoretical Contents. Summary

A solenoid is ______ ____
____
____
____
____

The magnetic induction is____
____
____
____
____

The magnetic field strength is____
____
____
____

Method of magnetic induction measurement consists in ______________________________

Electric Circuit of the Experimental Plant

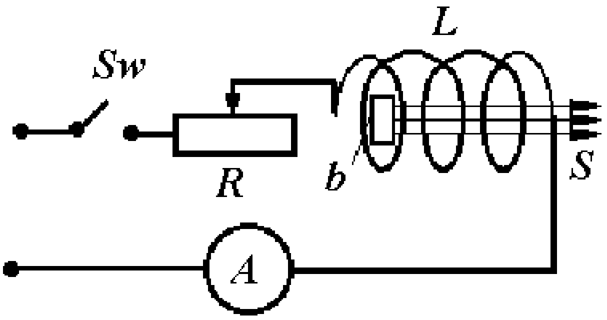


Table of symbols:

A - ______________________________
L - ______________________________
S - ______________________________
Sw - ______________________________
R - ______________________________
b - ______________________________

Calculation Formulas

3. The magnetic induction:

$B =$

where,

$\mathcal{E}$ – ______________________________ S – ______________________________

N – ______________________________

4. Magnetic field strength:

$H =$

where,

μ_0 –

Results of Measurements and Calculations

Table 1.

I ($Ampere$)	**1**	**1,5**	**2**	**2,5**	**3**	**3,5**	**4**
$\mathcal{E}$ ($Volt$)							
B ($tesla$)							
H ($Ampere/m$)							

Table 2.

I (Ampere)	x (cm)	1	2	3	4	5	6	7	8	9	10	11	12	13
	$\mathcal{E}$ (Volt)													
	B (tesla)													
	H (Ampere / m)													
I (ampere)	x (cm)	14	15	16	17	18	19	20	21	22	23	24	25	26
	$\mathcal{E}$ (volt)													
	B (tesla)													
	H (ampere / m)													

Measured by the student: ______________________

Name

Verified by the teacher: ______________________

Signature of the teacher

Analysis of Measurements

1. Plot the graphical dependence using the data from Table 1.

   a) $B = f(I)$;

2. Plot the graphical dependence using the data from Table 2.

b) $B = f(x)$

3. Calculate B using the data of measurements and Biot-Savart-Laplace law at three points on the solenoid's axis (the current strength is given by the teacher).

At the center point	$B =$
On the end side of solenoid	$B =$

Outside of solenoid	$B =$

4. Compare experimental data of B и H with the results of calculation at equal strengths of current.

5. Estimate the accuracy of measurements using an accuracy grade of devices.

$$\Delta I = (accuracy.grade) \cdot 10^{-2} \cdot I_N =$$

$$\Delta \mathcal{E} = (accuracy.grade) \cdot 10^{-2} \cdot U_N =$$

Resume

Test Questions

1. What is the difference between the magnetic induction and magnetic field strength?
2. How does an induction depend on the magnetic strength?
3. What magnetic field is called uniform?
4. How does an induction in the central point change if the length of a solenoid is decreased?
5. What phenomenon is called an electromagnetic induction? How is it used in this laboratory work?

Answers

Executed by the student**:**
Group ______________________________
First name___________________________
Last name___________________________
Approved by the teacher**:**

______________________ ________________________________
Date Signature of the teacher