Tomsk Polytechnic University

PHYSICS I
Reports on Laboratory Experiments

Tomsk 2000

PHYSICS I
Reports on Laboratory Experiments
Mechanics and Molecular Physics
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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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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. Measuring the linear dimensions of a body
2. Measuring the free fall acceleration
3. Determining the coefficient of sliding friction
4. Studying the distribution function of random variables
5. Elastic and inelastic collisions of balls
6. Studying dynamics laws with Athwood's machine
7. Determining the mean free path and the effective diameter of a molecule

Report on laboratory experiment No. 1
Measuring the linear dimensions of a body

The objective is to measure the linear dimensions of a body, to calculate its volume, and to estimate absolute and relative measurement errors

THEORY

There are two kinds of measurements:
direct ____
indirect____
and two types of errors:
systematic____
random____
To measure the linear dimensions of a body, you can use______________________

____
Principal scales of these devices are base rules and vernier calipers.
Vernier caliper is_______________________________________

____

One subdivision of the vernier caliper corresponds to $\frac{m-1}{m} = \left(1 - \frac{1}{m}\right)$

subdivisions of the basic ruler, where
m is ____
With the help of the vernier caliper, measurements are carried out with the accuracy
$\Delta x = y - x = \frac{y}{m}$, where____________________________________
*y*____
*x*____

The accuracy of the vernier caliper is $\frac{y}{m} =$ mm.

The length L measured by this device is $L = ky + n\frac{y}{m}$, where
k is ____
n is ____

The accuracy of the measuring scale of a micrometer caliper is $\frac{y}{m} =$ mm.

Calculation formulas

The volume of a parallelepiped is $V_P =$
where a b c
The volume of a cylinder is $V_C =$ where
d h

Data of measurements

Table 1

No.	a, mm	b, mm	c, mm	V_p, mm^3	Δa, mm	Δb mm	Δc mm	ΔV_p, mm^3
1								
2								
3								
4								
5								
Average								

The values of ________are measured by a vernier caliper with accuracy _______ mm, and the values of_________ are measured by a micrometer caliper with accuracy ________ mm.

Table 2

No.	D, mm	h, mm	V_C, mm^3	ΔD, mm	Δh, mm	ΔV_C, mm^3
1						
2						
3						
Average						

Error analysis

Errors in direct measurements

1. Calculate the average value of a (the number of measurements n = 5)

$\bar{a} =$

2. Calculate the standard deviation for these measurements

$\sigma_{\bar{a}} =$

3. Calculate the random error $\Delta\bar{a}_r =$

where α = ______________________________ $t_{\alpha n}$ ________________________

Find $t_{\alpha,n}$ from the table of Student's coefficients

with α = 0.95 and n = 5 $t_{\alpha,n} =$

4. Calculate the error of individual measurement

$\Delta\bar{a}_{i.m} =$ where ℓ_a

____

The value of $\bar{a}$ is __________________ so $\ell_a =$ _______________ mm.

In a similar manner, calculate averages of $b, C, D,$ and h.

Error in individual measurement

b

1. The average for $n = 5$ is

   $\bar{b} =$

2. The standard deviation is

   $\sigma_{\bar{b}} =$

3. The random error is

   $\Delta\bar{b}_r =$

   α =

   $t_{\alpha,n} =$

4. The error in individual measurement is $\Delta\bar{b}_{i.m} =$

where $\ell_{\bar{b}} =$

$\bar{b}$ is measured by ____________________,

hence $\ell_{\bar{b}} =$ ___________ mm.

5. The total error is

$\Delta\bar{b} =$

D

1. The average for $n = 3$ is

   $\bar{D} =$

2. The standard deviation is

   $\sigma_{\bar{D}} =$

3. The random error is

   $\Delta\bar{D}_r =$

   α =

   $t_{\alpha,n} =$

4. The error in individual measurement is $\Delta\bar{D}_{i.m} =$

where $\ell_{\bar{D}} =$

$\bar{D}$ is measured by ____________________,

hence $\ell_{\bar{D}} =$ ___________ mm.

5. The total error is

$\Delta\bar{D} =$

C

1. The average for $n = 5$ is

   $\bar{C} =$

2. The standard deviation is

   $\sigma_{\bar{C}} =$

h

1. The average for $n = 3$ is

   $\bar{h} =$

2. The standard deviation is

   $\sigma_{\bar{h}} =$

3. The random error is

$\Delta\bar{C}_r =$

$\alpha =$

$t_{\alpha,n} =$

4.The error in individual measurement is $\Delta\bar{C}_{i.m} =$

where $\ell_{\bar{C}} =$

$\bar{C}$ is measured by ____________________,

hence $\ell_{\bar{C}} =$ ___________ mm.

5. The total error is

$\Delta\bar{C} =$

3. The random error is

$\Delta\bar{h}_r =$

$\alpha =$

$t_{\alpha,n} =$

4. The error in individual measurement is $\Delta\bar{h}_{i.m} =$

where $\ell_{\bar{h}} =$

$\bar{h}$ is measured by ____________________,

hence $\ell_{\bar{h}} =$ _____________ mm.

5. The total error is

$\Delta\bar{h} =$

Relative error

(according to tutor's instruction)

Parallelepiped

$$\frac{\Delta\bar{V}_p}{\bar{V}_p} = \sqrt{\left(\frac{\Delta\bar{a}}{\bar{a}}\right)^2 + \left(\frac{\Delta\bar{b}}{\bar{b}}\right)^2 + \left(\frac{\Delta\bar{c}}{\bar{c}}\right)^2}, \text{ where}$$

$\Delta\bar{a}$, $\Delta\bar{b}$, and $\Delta\bar{c}$ are the total errors in direct measurements of $\bar{a}$, $\bar{b}$, and $\bar{c}$

$\Delta\bar{a} =$ mm with $\alpha =$

$t_{\alpha,n} =$

$\Delta\bar{b} =$ mm with $\alpha =$

$t_{\alpha,n} =$

$\Delta\bar{c} =$ mm with $\alpha =$

$t_{\alpha,n} =$

$$\varepsilon = \frac{\Delta\bar{V}_p}{\bar{V}_p}$$

$\Delta\bar{V}_p =$

Cylinder

$$\frac{\Delta\bar{V}_c}{\bar{V}_c} = \sqrt{\left(\frac{2\Delta\bar{D}}{\bar{D}}\right)^2 + \left(\frac{\Delta\bar{h}}{\bar{h}}\right)^2}, \text{ where}$$

$\Delta\bar{D}$ and $\Delta\bar{h}$ are the total errors in direct measurements of $\bar{D}$, $\bar{h}$.

$\Delta\bar{D} =$ mm with $\alpha =$

$t_{\alpha,n} =$

$\Delta\bar{h} =$ mm with $\alpha =$

$t_{\alpha,n} =$

$$\varepsilon = \frac{\Delta\bar{V}_c}{\bar{V}_c}$$

$\Delta\bar{V}_c =$

The final result with confidence level $\alpha = 0.95$

(by the rule of rounding off)

$\bar{V}_P \pm \Delta\bar{V}_P =$ mm^3

$\bar{V}_C \pm \Delta\bar{V}_C =$ mm^3

Conclusions

Test questions

1. What errors are called systematic? Give some examples.
2. What errors are called the calibration ones?
3. Give the definition of uniform distribution parameter l_x for a physical quantity x.
4. Indicate possible sources of random errors. Can these errors be eliminated while performing an individual measurement?
5. Write the formula of a normal distribution and explain the meaning of all its parameters. How can these parameters be evaluated?
6. Indicate conditions at which the end points of confidence interval measurement errors are specified with the help of the Student distribution.
7. Give the general formula that expresses the error in indirect measurements of a certain quantity $Z(y_1, \ldots, y_m)$ in terms of errors in direct measurements of quantities $y_1, \ldots, y_m$.
8. Describe the procedure of measuring with a vernier caliper.
9. Describe the procedure of measuring with a micrometer caliper.

Report on laboratory experiment No. 2
Measuring the free fall acceleration

The objective is to measure the acceleration due to gravity g_{φ} in Tomsk, to calculate g_0, and to compare it with the theoretical estimate.

THEORY

A reference frame is ____

____

Noninertial reference frames are called

____

____

A laboratory system is

____

____

____

The net force that acts on a body in a laboratory coordinate system is

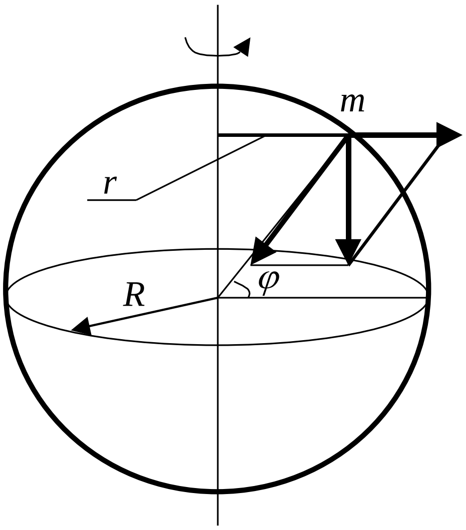
where

F_{gr} = is the force of________________________________

F_{cp} = is the force of ________________________________

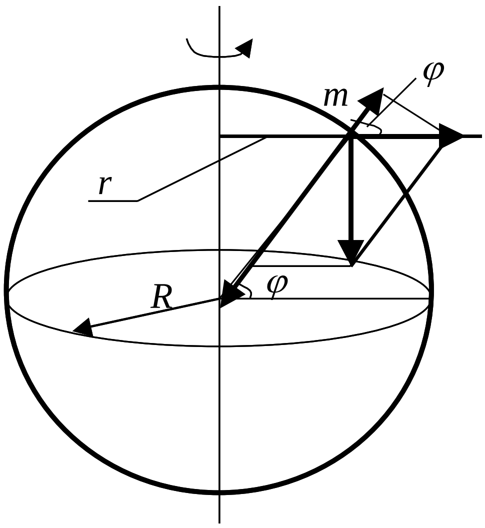
F_{cor} = is the force of ________________________________

Forces acting on a body in a noninertial reference frame at latitude φ



The axis of the Earth's rotation

The acceleration of a body on the Earth's surface at latitude φ



The axis of the Earth's rotation

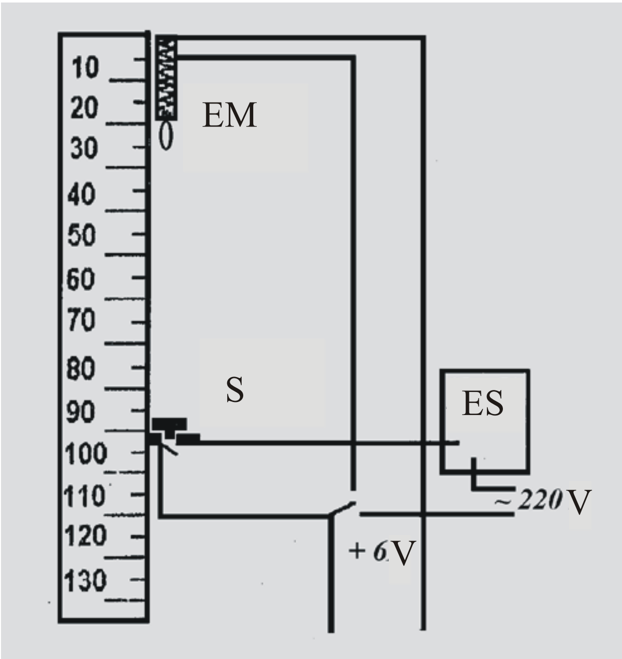
$mg_{\varphi} =$
where____________________________

$g_{\varphi} - g_0 =$
$a_{cp} = \omega r =$
$g_{\varphi} =$

Calculation formulas

$g_{\varphi} =$
where _______________________________________
$g_0 =$
where___________________________________

Experimental Setup



EM _______________________________
____
S _________________________________
____
ESW_______________________________
____

Data of measurements

h, m	Time t, s															t_{av}, s	g_{φ}, m/s
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		

CALCULATIONS

Evaluation of the free fall acceleration from the experimental data

$g_{\varphi} =$

Calculation of the theoretical value

g_0 =

Initial data for calculation

$\gamma = 6.6720 \cdot 10^{-11}$ N·m^2 / kg $R_{earth} = 6.371 \cdot 10^6$ m $M_{earth} = 5.98 \cdot 10^{24}$ kg.

Conclusions

Test questions

1. What reference frames are called noninertial?
2. What inertial forces do you know?
3. What is the direction of Coriolis force?
4. How do you estimate the accuracy of this method of measuring the free fall acceleration?
5. Write the formula for Δg.
6. In what direction will the body fall if the value of *h* is not small? Take into account all the forces.
7. What is the time delay?
8. Is there any difference between the weight of a body at poles and in the equator? Why?
9. Is it possible to use Newton's second law if the reference frame is the Earth itself?

Report on laboratory experiment No. 3
Determining the coefficient of sliding friction

The objective is to evaluate the coefficient of sliding friction *k*.

THEORY

The types of friction are____

____

The force of sliding friction acts if____

____

____

The friction coefficient depends on____

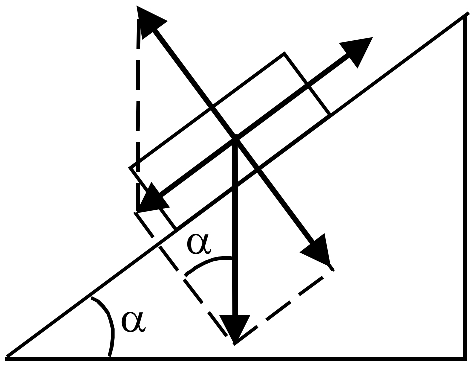
____

The method of limiting angle is used to evaluate *k*. The method is based on the following physical phenomenon:________________________

____

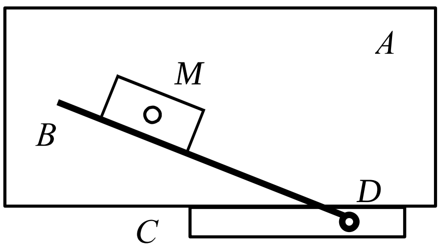
____

____



The force of sliding friction F_{sl} (for homogeneous solid materials in contact) is approximately equal to the maximum static frictional force $F_{sl} = kN$

k = ____



Experimental Setup

Here

A ____________________________________

B ____________________________________

C ____________________________________

D ____________________________________

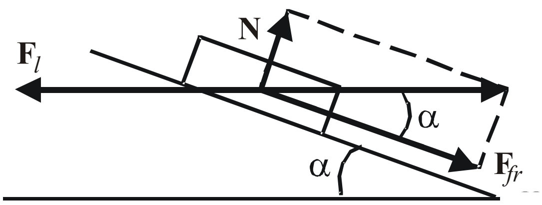


Diagram of the experiment

Here

N __________________________________

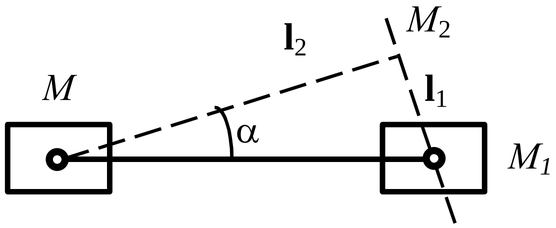
F_{sl} _________________________________

F_l __________________________________

Directions of forces **N** and $\mathbf{F}_{fr}$ are fixed, but the direction of $\mathbf{F}_l$ is variable and

depends on____

____



Here
M ____________________________
M_1 ____________________________
M_1M_2 ____________________________
MM_2 ____________________________
MM_1 ____________________________

Calculation formulas

The coefficient of sliding friction is $k =$ where

ℓ_1 ____

ℓ_2 ____

The average coefficient of sliding friction is $\bar{k} =$

Data of measurements

Table 1

Materials in contact	No.	Mass of the load, kg	α, deg	ℓ_1, cm	ℓ_2, cm	k	$\bar{k}$
Duralumin-brass	1						
	2						
	3		45				
	4						
	5						
	1						
	2						
	3	0.2	45				
	4						
	5						
Duralumin-rubber	1						
	2						
	3		50				
	4						
	5						
	1						
	2						
	3	0.2	50				
	4						
	5						

Conclusions

____

____

____

____

Error analysis

Calculate the absolute and relative errors in measuring the coefficient of sliding friction *k* for materials in contact by the formulas

$$\sigma_{\bar{k}} = \sqrt{\frac{\sum_{i=1}^{n}(\bar{k}-k_i)^2}{n(n-1)}} =$$

$$\Delta\bar{k}_r = t_{\alpha,n} \cdot \bar{\sigma}_{\bar{k}}$$

where $t_{\alpha,n} = 2.26$ at $\alpha = 0.95$ and $n = 10$ (from the table).

$\bar{k} \pm \Delta\bar{k}_r =$ with confidence level $\alpha = 0.95$.

$$\varepsilon_{\bar{k}} = \frac{\Delta\bar{k}_r}{\bar{k}} =$$

Test questions

1. What factors determine the magnitude of friction force?
2. What is the direction of friction force?
3. What physical parameters can affect the force of sliding friction?
4. Compare the coefficient of sliding friction with that of static friction.
5. Why two specimens having surfaces machined in equal quantity have different coefficients of dry sliding friction?
6. When does the rolling friction force act?
7. What is the static and sliding friction?
8. What is the mechanism of energy losses in friction?
9. When does the empirical law of dry friction ($F = kN$) violate?

____

Report on laboratory experiment No. 4
Studying the distribution function of random variables

The objective is____

____

THEORY

Very often random variables are distributed according to the Gauss law

____

Here the average $\tilde{x}$ is evaluated by the formula

____

where n is ____

The standard deviation is

____

The confidence level $\Delta\tilde{x}$ is ____

Here $t_{\alpha,n}$ is called ____________________________________ which depends on

____

and

____

In our case, $n = 150$ and $t_{\alpha,n}$ = ________ with confidence level α = ________.

Data of measurements and calculations

____

1.Try to record the time interval x = 1s by an electric timer. The number of measurements is n = 150. Taking into consideration that 1 revolution of the timer arm equals 1 s or 100 timer scale divisions, put the data in Table 1 in units of scale divisions.

2. Calculate $\tilde{x}$, $(x_i - \tilde{x})^2$, and σ and put them in Table 1.

Table 1

n	X_i	$(x_i - \tilde{x})^2$	N	x_i	$(x_i - \tilde{x})^2$
1			76		
2			77		
3			78		
4			79		
5			80		
6			81		
7			82		
8			83		
9			84		
10			95		
11			86		
12			87		
13			88		

14			89		
15			90		
16			91		
17			92		
18			93		
19			94		
20			95		
21			96		
22			97		
23			98		
24			99		
25			100		
26			101		
27			102		
28			103		
29			104		
30			105		
31			106		
32			107		
33			108		
34			109		
35			110		
36			111		
37			112		
38			113		
39			114		
40			115		
41			116		
42			117		
43			118		
44			119		
45			120		
46			121		
47			122		
48			123		
49			124		
50			125		
51			126		
52			127		
53			128		
54			129		
55			130		
56			131		
57			132		

58			133		
59			134		
60			135		
61			136		
62			137		
63			138		
64			139		
56			140		
66			141		
67			142		
68			143		
69			144		
70			145		
71			146		
72			147		
73			148		
74			149		
75			150		
				$\tilde{x} =$	$\sigma =$

2. Divide the total range of x_i variables into 10 arbitrary intervals and count the number of data N_i in each subinterval. Here Δx is the length of the intervals, and $\bar{x}_i$ are their centers.

3. Calculate the probability density $f_i = \frac{N_i}{n\Delta x}$.

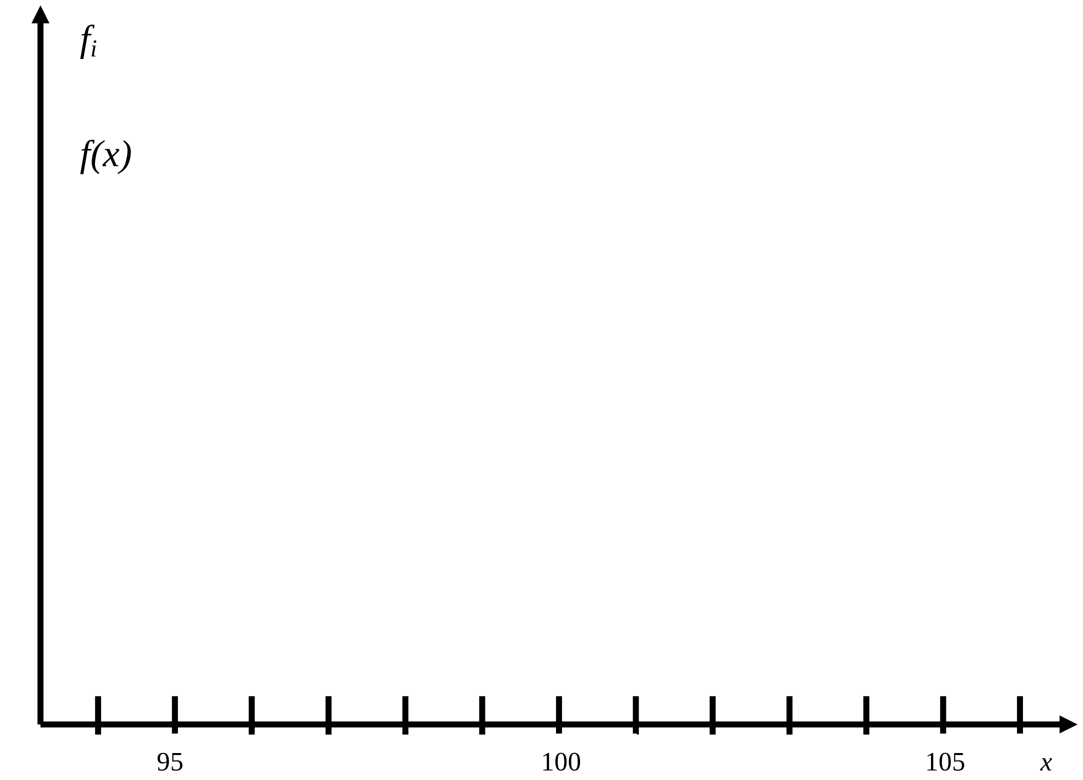
4. Evaluate the parameters of the Gauss distribution $f(x) = \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{(\tilde{x}-x_i)^2}{2\sigma^2}}$ for the points $\bar{x}_i$.

Put all the calculated values in Table 2.

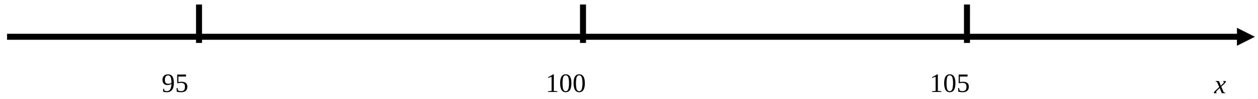
Table 2

Serial No. of interval	Δx	N_i	f_i	$f(x)$
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

5. Using the data of Table 2, construct the histogram and the Gauss distribution.



6. Take arbitrarily 3, 5, and 10 successive measurements. (Three times for each series in different parts of the distribution.) Evaluate $\tilde{x}$ and the confidence level $\Delta\tilde{x}$. Compare these values with those for n=150.



Conclusions

Test questions

1. What random physical variables do you know?
2. What is the mathematical meaning of the distribution function?
3. Write the Gauss distribution function and explain the meaning of its parameters σ, x, and $\tilde{x}$.
4. Find the width of the Gauss distribution function (the distance between the points at opposite edges at half maximum). Express this quantity in terms of σ.
5. What can you conclude while looking at the rectangles $x = \bar{x} \pm \Delta x$ found in the experiment?

Report on laboratory experiment No. 5
Elastic and inelastic collisions of balls

The objective of the experiment is____
____
____

THEORY

The impact in mechanics is____
____

The impact is called a**)** central when_______________________________________
____
b) completely elastic when____
____
The head-on central impact is called perfectly inelastic when ___________________
____

The coefficient of restitution is ____
____

When one ball is initially at rest, the law of conservation of momentum has the form
____
____
____

Calculation formulas

Speed of the moving ball before impact is v_1 =
where
____
____
____
____
____
Speeds of bolls after impact are

u_1 = where ____________________________________

u_2 = where ____________________________________

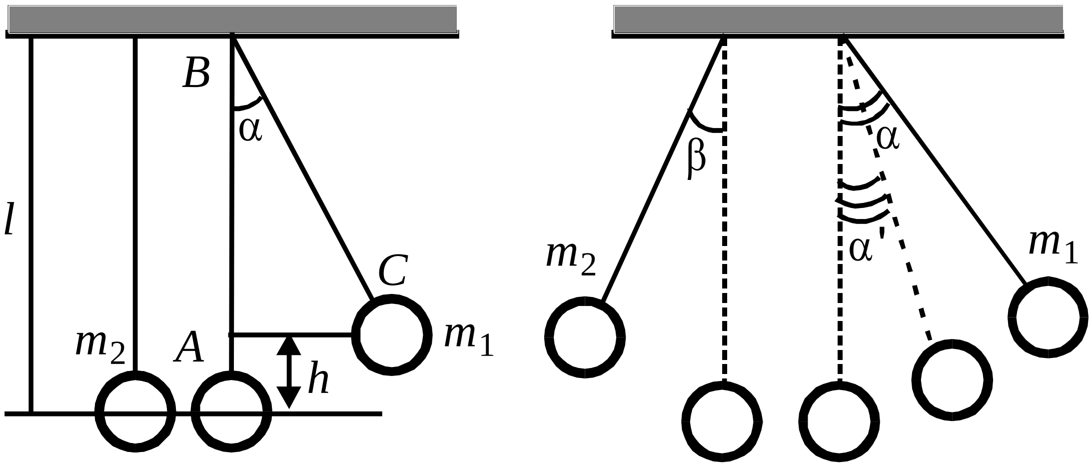
The coefficient of restitution is k =

To check the validity of the law of conservation of momentum, the following relations must be tested:

____for an elastic impact

____ for an inelastic impact

Experimental Setup



h = ______________________________

l = ______________________________

α = ______________________________

β = ______________________________

α = ______________________________

α′ = ______________________________

β = ______________________________

Data of measurements

1) For the fist pair of balls

m_1 = m_2 =

Table 1

No.	α	$\sin\frac{\alpha}{2}$	$\sin^2\frac{\alpha}{2}$	α'	$\sin\frac{\alpha'}{2}$	$\sin^2\frac{\alpha'}{2}$	β	$\sin\frac{\beta}{2}$	$\sin^2\frac{\beta}{2}$	***k***
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
Average										

Checking of the law of conservation of momentum

$$m_1 \sin\frac{\alpha}{2} = -m_1 \sin\frac{\alpha'}{2} + m_2 \sin\frac{\beta}{2} \quad (1)$$

____

____

Conclusions

____

____

____

2) For the second pair of balls

m_1 =____________________ m_2 =______________________

Table 2

No.	α	$\sin\frac{\alpha}{2}$	$\sin^2\frac{\alpha}{2}$	α'	$\sin\frac{\alpha'}{2}$	$\sin^2\frac{\alpha'}{2}$	β	$\sin\frac{\beta}{2}$	$\sin^2\frac{\beta}{2}$	*k*
1										
2										
3										
4										

5										
6										
7										
8										
9										
10										
Average										

Checking of the law of conservation of momentum

$$m_1\, sin\frac{\alpha}{2} = -m_1\, sin\frac{\alpha'}{2} + m_2\, sin\frac{\beta}{2} \qquad (2)$$

____

____

Conclusions

____

____

____

____

3) For the third pair of balls (inelastic collision)

m_1=____________________ m_2=____________________

Table 3

No.	α	$\sin\frac{\alpha}{2}$	β	$\sin\frac{\beta}{2}$
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
Average				

Checking of the law of conservation of momentum

$$m_1 \sin\frac{\alpha}{2} = (m_1 + m_2)\sin\frac{\beta}{2} \qquad (3)$$

Conclusions

Error analysis

Calculate the random error in measuring the coefficient of restitution k from the data in Tables 1 and 2 (according to tutor's instruction).

1. Calculate the average value of k

   $\bar{k} =$

2. Calculate the standard deviation of $\bar{k}$

   $\sigma_{\bar{k}} =$

3. Calculate the random error

   $\Delta\bar{k}_r = t_{\alpha,n} \cdot \sigma_{\bar{k}} =$ where $\alpha =$

   $t_{\alpha,n} =$ (from the table)

$\bar{k} \pm \Delta\bar{k}_r =$ with confidence level $\alpha = 0.95$.

The relative measurement error is

$$\varepsilon_k = \frac{\Delta \bar{k}_r}{\bar{k}} =$$

Test questions

1. What types of impacts do you know?
2. How do you understand the terms absolutely elastic collision, elastic collision, inelastic collision, and perfectly inelastic collision?
3. Why is it necessary to center the balls?
4. What is the elasticity coefficient?
5. Does this coefficient depend on collision angles?
6. What factors determine the values of the elasticity coefficient?
7. How do Eqs. (1) and (2) change when the collision is perfectly inelastic?
8. Describe the process of collision. What forces do act in this process? What is the elastic deformation?
9. Formulate the law of conservation of energy for the perfectly inelastic collision.
10. What is your opinion concerning Eq. (3)? Is it correct or not?

Report on laboratory experiment No. 6
Studying dynamics laws with Athwood's machine

The objective of the experiments is____

____

____

THEORY

The fundamental laws used in this work are ________________________________
The acceleration is ____

____

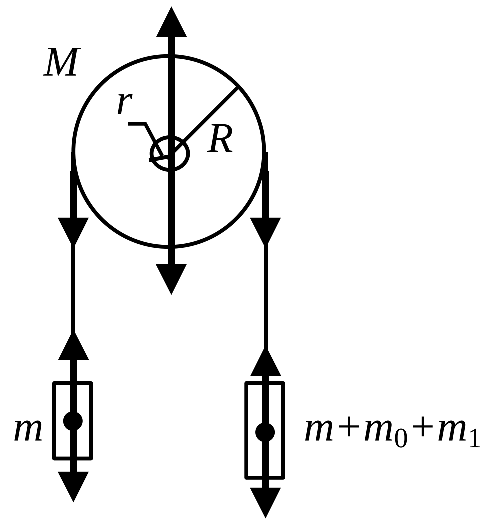
The force is ____

____

Newton's second law (for translational motion) ______________________________

____

The basic law of rotational motion is _______________________________________



____

Draw the diagram of forces acting upon the bodies shown in the figure and analyze their motion.

1) For uniform motion of bodies, equations have the form

____

____

The torque produced by the friction force is________________________________

____

2) For uniformly accelerated motion of bodies, the equation of motion has the form

____

____

The friction force is ____
________________________________when _______________________________
The acceleration of bodies is ____

____

____

3) On the other hand, using the laws of kinematics, the acceleration can be found if

___________and _______________ are specified, i.e., _______________________

Calculation formulas

(explain the physical meaning of every quantity)

Problem 1

Compare the magnitude of acceleration calculated in accordance with laws of kinematics from the formula

$a = \frac{2S}{t^2}$, where S ____

t ____

and that calculated in accordance with the law of dynamics from the formula

$a = \frac{m_1 g}{2m + \frac{M}{2}}$, where m_1 is ____

m is ____

M_p ____

Problem 2

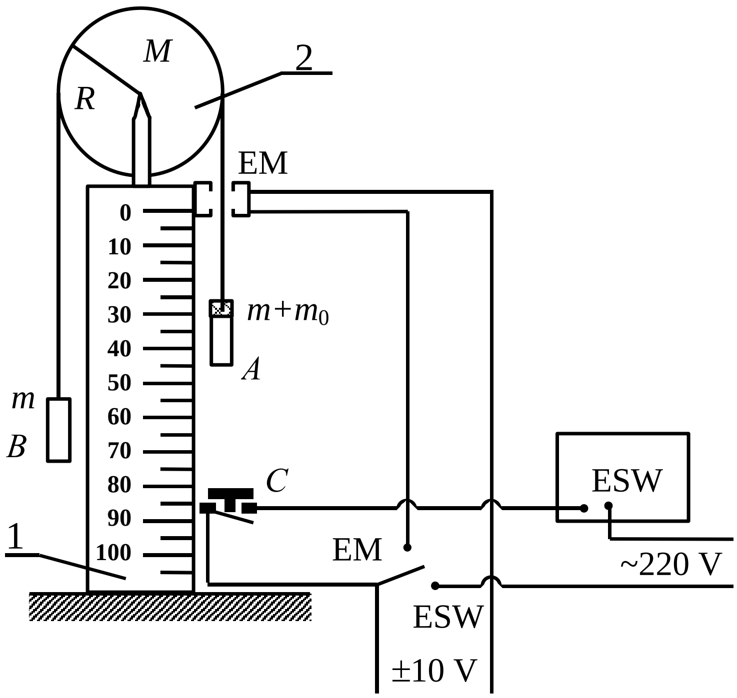
Check the relation

$\frac{a_1}{a_2} = \frac{F_1}{F_2}$, where a_1 is ____

a_2 is ____

$F_1 = P_2 - P_1 = (m_2 - m_1)g$, where m_1 is ________________________________

$F_1 = P_2 + P_1 = (m_2 + m_1)g$, m_2 is ________________________________



Experimental Setup

where

A is____________________

C is ____________________

B is ____________________

ESW is ________________

EM is __________________

1 is ____________________

2 is ____________________

Experimental data

Problem 1 Table 1

No.	m_1, g	$2m$, g	M_p, g	S, cm	t, s	t_{av}, s	$a = \frac{2S}{t^2}$, cm/s^2	$a = \frac{m_1 g}{2m + \frac{M}{2}}$ cm/s^2
1 2 3 4 5								
1 2 3 4 5								

Calculations

1) Calculate the acceleration in accordance with the laws of kinematics from the formula

$$a = \frac{2S}{t^2}, \qquad a =$$

Calculate the acceleration in accordance with the laws of dynamics from the formula

$$a = \frac{m_1 g}{2m + \frac{M}{2}}, \qquad m_1 = \qquad a =$$

Compare the results obtained.

Conclusions

____

____

2) For the second extra mass $m_1 =$

$$a = \frac{2S}{t^2}, \qquad a =$$

$$a = \frac{m_1 g}{2m + \frac{M}{2}}, \qquad a =$$

Conclusions

____

____

Problem 2 Table 2

No.	m_1, g	m_2, g	$k_1 = \frac{F_1}{F_2}$	S, cm	t_1, s	t_{1av}, s	t_2, s	t_{2av}, s	$k_2 = \frac{a_1}{a_2}$
1									
2									
3									
4									
5									

Calculations

Find the ratio of forces

$$k_1 = \frac{F_1}{F_2} = \frac{m_2 - m_1}{m_2 + m_1}, \qquad k_1 =$$

Find accelerations a_1, a_2 and their ratio

$$a_1 = \frac{2S}{t_{1\,av}^2}, \qquad a_1 =$$

$$a_2 = \frac{2S}{t_{2\,av}^2}, \qquad a_2 =$$

$$k_2 = \frac{a_1}{a_2}, \qquad k_2 =$$

Compare k_1 and k_2 $\qquad k_1 =$

$k_2 =$

Conclusions

____

____

____

____

____

Test questions

1. How does the rotation friction force depend on the masses attached to each end of the cord?
2. What should be done to overcome the rotational friction force?
3. Under what conditions does the torque produced by the rotational friction force equal to that produced by tension in the cord?
4. Write the formula for the magnitude of rotational friction torque. On what quantities does the friction coefficient depend?
5. What conditions are needed to neglect the rotational friction force?
6. Write the equetion of motion of bodies when $a << g$, $m_1 << m$, and $m_0 << m$.
7. Write the equation describing the motion of masses.
8. How can we verify that the motion of bodies is uniform or uniformly accelerated?
9. Write the kinematics equation of motion of bodies.
10. What is the magnitude of rotational friction force when the bodies move with acceleration?

Report on laboratory experiment No. 7
Determining the mean free path and the effective diameter of a molecule

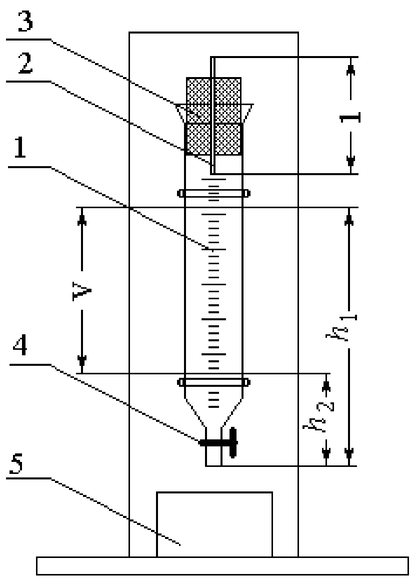
The objective of the experiments is____
____
____

THEORY

Transport phenomena are ____
____
The mean free path is____
____
The effective diameter of a molecule is _____________________________________
____

Calculation formulas

The mean free path is $\bar{\lambda}$ =
where ____
The pressure difference along the pipe is $\Delta P =$
where h_1 ____
h_2 ____
r is the radius of a capillary, *r* =
The effective molecule diameter D_{eff} =
where____



Experimental Setup

Where
1________________________________
2________________________________
3________________________________
4________________________________
5________________________________
*l*________________________________
h_1 (measured)______________________
h_2 (measured)______________________
V (measured)_______________________

Data of measurements

1) Estimation of the accuracy of the microscope and calculation of the capillary radius.

Table 1

	1	2	3	ΔN_{av}
N_1				
N_2				
$\Delta N = N_2 - N_1$				

The accuracy of the microscope is

$$x = \frac{2\text{ mm}}{\Delta N_{\text{av}}},$$

$x =$

Table 2

	1	2	3	$\Delta N'_{av}$
N'_1				
N'_2				
$\Delta N' = N'_2 - N'_1$				

The capillary diameter is

$$d = \Delta N'_{\text{av}} \cdot x$$

and its radius $r = \dfrac{d}{2}$.

$d =$

$r =$

Put the data in Table 3

Table 3

No	h_1, m	t, s	h_2, m	l, m	ΔP, Pa	V, m^3	T, K	P, Pa	r, m	λ, m	D, m
1 2 3											

Reference data for calculations

R = 8.31 J/mol·K, μ = 0.029 кg/mol, $K = 1.38\cdot10^{-23}$ J/K,

1 mm Hg = 133.3 Pa, g = 9.8 m/s^2, $\rho_{water} = 10^3$ kg/m^3.

CALCULATIONS

Calculate the mean free path $\bar{\lambda}$

$\lambda_1 =$

$\lambda_2 =$

$\lambda_3 =$

$$\bar{\lambda} = \frac{\lambda_1 + \lambda_2 + \lambda_3}{3} =$$

Calculate the effective diameter of an air molecule

$D_{eff} =$

Compare the measured and theoretical values.

Theoretical value

for air under standard conditions

$\bar{\lambda} \cong 6.95\cdot10^{-8}$ m

$D_{eff} \cong 0.35$ nm $= 3.5\cdot10^{-10}$ m

Measured value

$\bar{\lambda} =$

$D_{eff} =$

Conclusions

Calculate the error in measuring $\bar{\lambda}$ by the method of evaluating the indirect measurement error.

Derive the formula for calculating

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

Error analysis

$$\bar{\lambda} \pm \Delta\bar{\lambda} =$$ with confidence level $\alpha = 0.95$.

The relative error is

$$\delta_{\bar{\lambda}} = \frac{\Delta\bar{\lambda}}{\bar{\lambda}} =$$

Test questions

1. What are the causes of transport phenomena?
2. What transport phenomena do you know?
3. Why the transport phenomena are rather “slow”?
4. What is D_{eff} ?
5. What physical phenomenon provides the basis for experimental determination of $\bar{\lambda}$ and D_{eff} ?
6. Give the relation between $\bar{\lambda}$ and D_{eff}.

7. Explain why $p_1 > p_2$. Here p_1 is the air pressure at the upper end of the capillary, and p_2 is the air pressure at the bottom of the capillary.
8. Explain why the term $\frac{h_1 + h_2}{2}$ is used .
9. Give the formulas for $\Delta\bar{\lambda}$ and ΔD_{eff}.
10. Explain the procedure of measuring the capillary radius by a microscope.