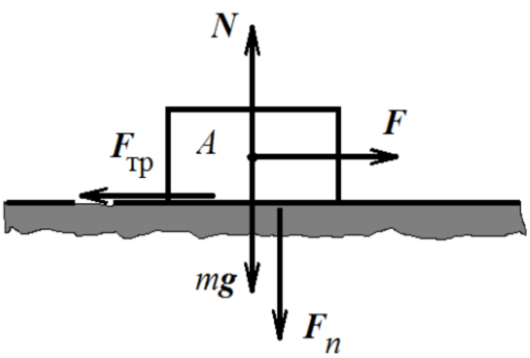
Laboratory work № 1.6
Determination of sliding friction coefficient

Objective: definition of the coefficient of sliding friction by «drawing rule».
Instruments and equipment: board, drawing rule, the body having two surfaces covered with different materials, ruler.

Theoretical introduction

The phenomenon of the friction occurs at the border between different contiguous bodies. Friction forces occur only when you try to displace one body relative to another (static friction - the friction of rest) or by moving the bodies relative to each other (dynamic sliding friction, rolling friction and viscous friction). Frictional forces are electromagnetic in nature and are determined by the nature of the interaction of atoms and molecules in adjoining layers.

Let the body A (for example, a bar) lies on a fixed base. Let us act on the body A by the external force F, continuously increase it. First, the bar will remain stationary. This means that the external force F is balanced by a force F_{fr}, tangential to the friction surfaces and directed oppositely to the force F.



The friction that may exist between objects, not moving relative to each other is called a static friction. As long as the external force is less than a maximum value F_{max}, the relative sliding of the bodies does not arise, because the force of static friction "automatically" is set to compensating the action of an external force.
When an external force module (and hence the module of the static friction force) exceed F_{max} value, the body begins to slide on the base. This frictional force continues to act on the body A – it is called in this case, the force of sliding friction. The friction force between bodies moving relative to each other, called the force of sliding friction. Module force of sliding friction depends on the relative velocity and is approximately F_{max}.
The main empirical laws of dry friction received French physicists G. Amontons and S. Kulon. It was found that the maximum static friction force does not depend on the area of contact between bodies and proportional to the modulus of normal pressure forces the F_n , pressing the friction surfaces to each other

$$\boldsymbol{F_{max} = \mu_0 F_n} \qquad (1)$$

Here $\boldsymbol{\mu_0}$ - the coefficient of static friction, depending on the properties of the contacting surfaces. The characteristic values of the rest friction coefficients $\boldsymbol{\mu_0}$ are shown in Table 1

1st material	steel	steel	steel	metal	rubber	wood
2nd material	ice	steel	plastic	wood	asphalt	wood
$\boldsymbol{\mu_0}$	0.015	0.15	0.3	0.5	0.55	0.65

A similar relationship holds for the force of sliding friction

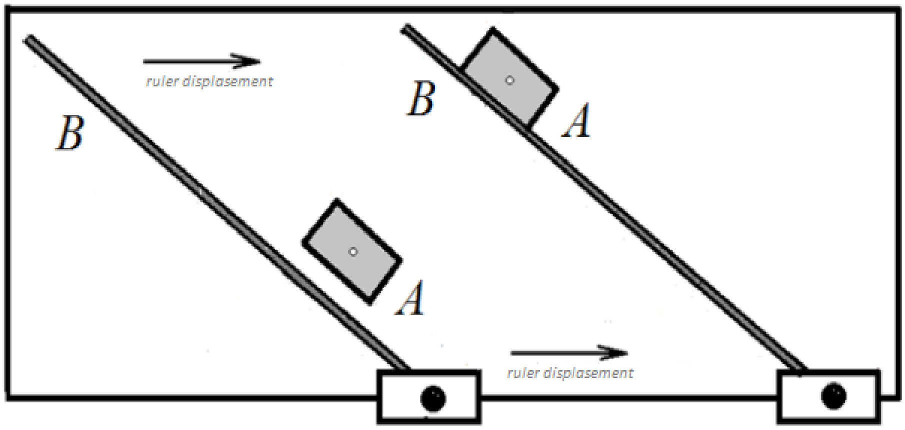
$$\boldsymbol{F_{fr} = \mu F_n} \qquad (2)$$

ere μ - coefficient of sliding friction.
According to Newton's third law down force module (Fig. 1) is equal to the normal reaction power module N. Therefore, base frequently is recorded as

$$F_{fr} = \mu N \tag{3}$$

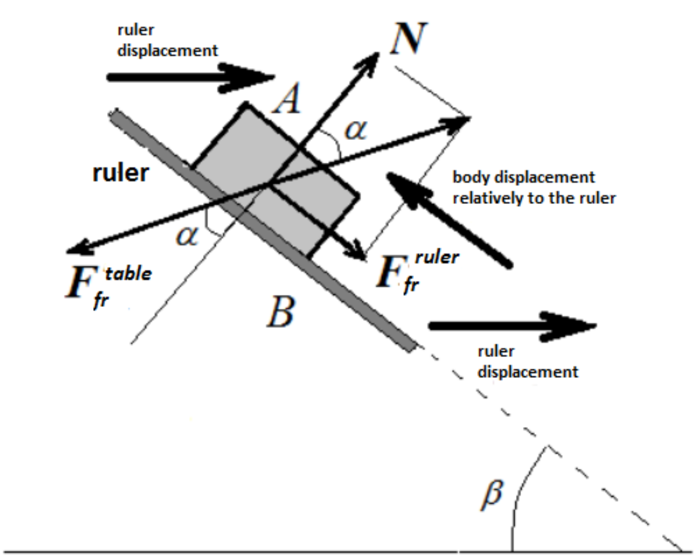
Description of the facility and theoretical information

Facility base is horizontal board, the lower edge of which, as direction track, can move the slider with the fixed ruler at a certain angle. The line (drawing rule), set on the rib, can be moved progressively on the horizontal surface of the board (Fig. 2). Attach to the plane of the line body A so that line and the body surface touch each other. The body is a parallelepiped lying on a horizontal base board and the side surface abuts the line.



If the line B is evenly move the right it pushes the body A is evenly moved upward along the ruler (Fig.2).

The work defines the coefficient of sliding friction between the ruler B and body A. In Fig. 3 shows the forces acting on the body, pressed to the ruler. Body rubs on ruler and on a horizontal surface of the table on which it lies. Two friction force is therefore considered:



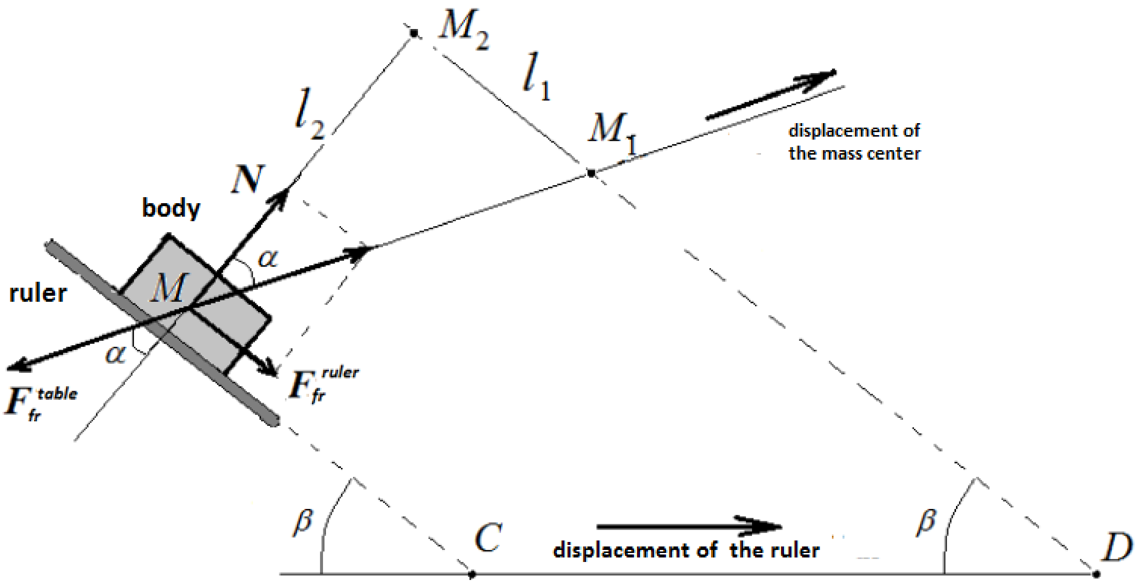
F_{fr}^{ruler} - sliding frictional force between the body A and ruler B. This force is directed opposite to the velocity of the body relative to the ruler. F_{fr}^{table} - sliding frictional force between the body and the horizontal surface of the table on which the body moves with the ruler. This force is directed in the opposite direction relative to the table body speed, i.e. 90α at an angle to the line.

We denote by N the normal force of reaction of the ruler. If A moves evenly, then the sum of all forces acting on a body is equal to zero. Because the

$$F_{fr}^{ruler} = \mu N, \text{ so } \mu = \frac{F_{fr}^{ruler}}{N}, \text{ so, from fig.3 follows } \mu = \frac{F_{fr}^{ruler}}{N} = tg\ \alpha$$

Define tg α, for this line will move from left to right at a distance of CD (Fig. 4). The center of mass of the body is moved from the point M to the point M1. If MM2 determines the direction normal to the line, then

$$tg\,\alpha = \frac{M_1M_2}{MM_2} = \frac{l_1}{l_2}$$



Finally, we have a working formula for the determination of the coefficient of sliding friction

$$\mu = tg\,\alpha = \frac{l_1}{l_2} \quad (4)$$

The angle between the edge of a ruler and a direction track denoted by β. In various experiments, it can be changed. In the center of movable body is a hole. Inserting the pencil into the hole, it is possible to mark the position of the body at the beginning of the motion (point M) and the end of the motion (point M1) (Figure 4). One side surface of the body is brass, and to the other is glued rubber layer. The line is made of dural. Thus, when the ruler pushes the body, and it starts to slide along the ruler, arises a frictional force between the brass and dural, or between the rubber and the dural - depends on which surface slides the body ruler.

The order of the work

1. On board surface put a piece of paper and fix it. Put the drawing rule on the paper. Make sure that the slider is free to move left and right along the direction track, which coincides with an edge of the board.
2. Place drawing rule, so that edge of ruler makes an angle β = 45° with drawing rule (board edge).
3. Put the body on the paper close to the ruler surface (eg, the touching surfaces of duralumin - duralumin) and carefully mark the initial position of the body M through the hole in the body.
4. Pressing the slider to the edge of the board, smoothly and evenly move the slider to the right until it stops.
5. Carefully, without moving the body, mark the new position of the body M1.
6. Remove the body and through the obtained point M1 draw a straight line parallel to ruler. From the starting point of M drop a perpendicular MM2 on received line. Connect the points M

and M1 straight MM1.
7. Measure the distance $M_1M_2 = l_1$and $MM_2 = l_2$, with the help of measuring ruler. The results are written in table 1. Determine the coefficient of friction for a given pair of materials according to the formula (4).
8. Changing the original position of the body relative to the board, to repeat the experiment at least five times. Find the average value of the coefficient of friction for a given pair of material duralumin - duralumin.
9. The measurement results are written in Table 1.

Pair of material	№ of experiment	β	l_1	l_2	μ	$< \mu >$
duralumin - duralumin	1	45°				
	2					
	3					
	4					
	5					
Rubber - duralumin	1					
	2					
	3					
	4					
	5					

11. Turn the body to the other side so that the contacting surfaces become and duralumin gum. For this pair of materials perform studies similar to given for a pair of material duralumin - duralumin. The data record in Table 2, similar to Table 1

Control tasks

1. What kind of friction you know?
4. Which fundamental interaction determines the appearance of friction forces?
3. How do you determine the coefficient of friction in this work?
7. What is the role of friction forces in nature?
8. What is the difference between sliding friction and rolling friction?