Determination of the coefficient of friction on an inclined plane (Item No.: P1253000)

Curricular Relevance

Area of Expertise: Physik

Education Level: Klasse 7-10

Topic: Mechanik

Subtopic: Kräfte, einfache Maschinen

Experiment: Bestimmung der Reibungszahl mit der geneigten Ebene

Difficulty

Intermediate

Preparation Time

10 Minutes

Execution Time

20 Minutes

Recommended Group Size

1 Student

Additional Requirements:

Experiment Variations:

Keywords:

Principle and equipment

Principle

Demonstrate that one can determine the coefficient of friction μ on an inclined plane without measuring any forces.

Equipment

Position No.	Material	Order No.	Quantity
1	Demo Physics board with stand	02150-00	1
2	Inclined plane f.demonstr.board	02152-00	1
3	Optical disk, magnet held	08270-09	1
4	Friction block	02240-01	1
5	Scale for demonstration board	02153-00	1
6	Holding pin	03949-00	1
7	Slotted weight, black, 50 g	02206-01	2

Set-up and procedure

Set-up

- Place the protractor disk onto the demonstration board.
- Attach the plane on the protractor disk in such a mann er that its lower edge passes through the centre of the protractor disk.
- Beginning with a slight angle of inclination a between the plane and the horizontal line on the protractor disk, place the friction block onto the inclined plane with its larger wooden surface downwards (Fig. 1).

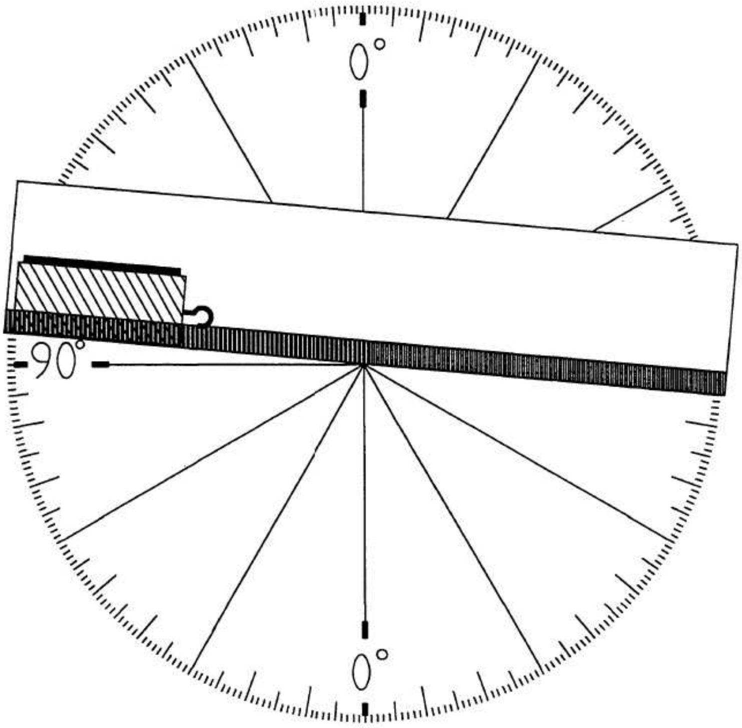

Fig. 1

Procedure

- Increase the size of the angle of slope α gradually, in such a manner that the plane rotates around the centre of the protractor disk.
- Read the angle α_h which is required so that the contact frictional force $\overrightarrow{F_h}$ is just overcome and the block begins to slide; read α_h.
- Without changing the angle α_h place the block onto the inclined plane several times and carefully observe its movement.
- Record α_h and your observations (1).
- Return the inclined plane to its initial position, increase the angle of slope α as before, but now before the angle α_h is reached, determine the angle α at which the friction block slides down the inclined plane after being pushed lightly by trial and error; observe the block carefully; note the value of α (in Table 1) and your observation (2).
- With the aid of the holding pin, first load the friction block with one of the slotted weights, then with both of them. Determine the angle α in each case and record it.

Observations and evaluation

Observations

1. After overcoming the contact frictional force, the block slides increasingly rapidly down the inclined plane.
2. Table 1

Table 1

Friction block	$\alpha / 1^\circ$
Without load	10
Loaded with 50 g	10
Loaded with 100 g	10

The block slides - whether unloaded or loaded - down the slope with uniform movement after being pushed lightly.

Evaluation

The following is true for the inclined plane:

$F_H = \frac{F_G * h}{l} = F_G * \sin\alpha$ (cf. Fig. 2)

If a body slides down the inclined plane uniformly (with constant velocity), the movement against the opposing frictional force $\overrightarrow{F_r}$, which equal to the downslope driving force $\overrightarrow{F_h}$ in magnitude. Therefore, the following is valid:

$\overrightarrow{F_H} = \overrightarrow{F_r} = F_G * \sin\alpha$.

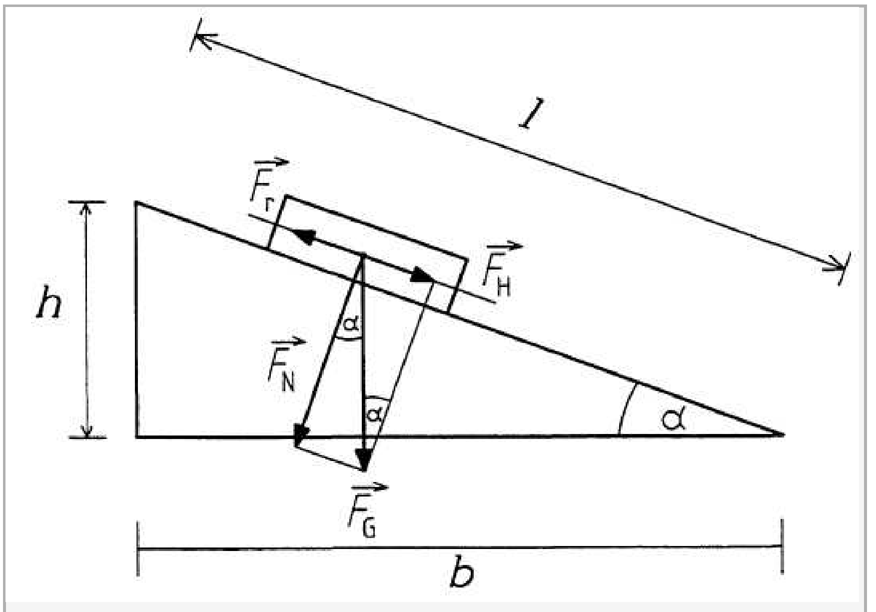

Fig. 2

In addition, the following is true for the (sliding) frictional force:

$\overrightarrow{F_r} = \mu * \overrightarrow{F_N}$

where $\overrightarrow{F_N}$ indicates the normal force, which acts perpendicular to the inclined plane as a component of the weight $\overrightarrow{F_G}$.

Consequently, $F_G * \sin\alpha = \mu * F_G * \cos\alpha$ (cf. Fig. 2). From this it follows that $\mu = \tan\alpha$, a result which generally surprises the student because, according to it, μ is not a function of the normal force.

With the equation $\mu = \tan\alpha$, an easily applied measuring equation for the determination of the coefficient of friction is available. The last part of the experiment, which should only serve to confirm the equation $\mu = \tan\alpha$, establishes that μ is independent of the weight $\overrightarrow{F_G}$ and thus of the normal force $\overrightarrow{F_N}$.

The results of the first part of the experiment show that the static frictional force is larger than the sliding frictional force since $F_H > F_r$. And because the downslope driving force is larger in this case than that required to compensate the sliding frictional force, the movement is accelerated.

Remarks

If the students do not have any previous trigonometric knowledge, then *h* and *b* can be measured and as a result of $\frac{F_h}{F_G} = \frac{h}{b}$ (cf. Fig. 2), the relationship $\mu = \frac{h}{b}$ instead of $\mu = \tan\alpha$ can be used to determine μ. Logically, this changes nothing in the recognition that μ is independent of F_N.

While turning the inclined plane, one must avoid jerky changes. Otherwise, the determination of the angle α_h and α becomes more difficult. If one changes the position of the plane progressively (each step 1°) in the vicinity of α_h and α, and in each case replaces the frictional block, the experimental procedure is usually facilitated.

If one desires to have larger angles α_h and α, the block must be placed with its rubberised side downwards.

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