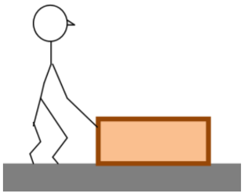
Friction

Introduction

Friction is a physics concept that denotes the resistive force that occurs when two surfaces slide over each other, while they are being pressed together.

We have 3 different kinds of friction, give an example of each:

- rolling friction: ....
- sliding friction: ....
- air resistance: ....



Friction can lead to *deformation* and *heat production* .

Like with every force, frictional force causes an "acceleration". Because the frictional force is always opposite to the direction of relative motion, friction always causes a "negative acceleration" or deceleration. A moving object that undergoes no other force but friction will move ever more slowly until it stops.

In the following experiments for the students, we will talk about sliding friction. We want to test the laws below on their accuracy.

<u>The laws of friction</u>

- 1st law:
  The resistance you notice when you shove away an object is independent of the size of the contact area.

- 2nd law:
  The frictional resistance is proportional to the normal reaction force : the heavier the moving object is, the larger the frictional force.

- 3rd law:
  The frictional resistance is dependent on the finishing and the nature of the contacting surfaces. A chair is easy to move on a slippery floor, difficult to move on a rough concrete floor.

	Static friction coefficient		Kinetic friction coefficient	
Contact surfaces	Dry	Lubricated	Dry	Lubricated
Steel on steel	0,80-0,15	0,23-0,11	0,57-0,03	0,20-0,03
Steel on (cast) iron	0,35-0,20	0,20-0,10	0,27-0,13	0,13-0,03
Wood on wood	0,60-0,20	0,16	0,40-0,20	0,08
Rubber on asphalt	0,90-0,60	0,45	0,50	0,40
Steel on wood	0,50-0,20	0,65	0,50	0,22-0,08

Experiments for the students

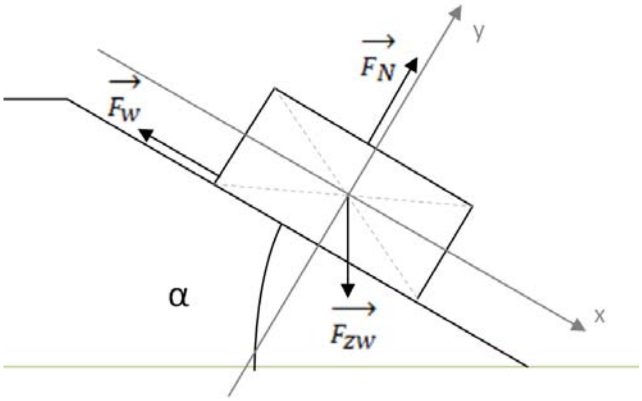


Fig1.7 friction: sliding friction

Purpose

In this experiment you put a block on a slope. Increase the incline by using an NXT motor (see picture next page). In this experiment you need a motor in order to slowly raise the incline with the help of a gear wheel and tooth rack. With an ultrasonic sensor, you detect when the block starts sliding down. It may happen that the sensor does not detect the block. In that case just try again.

What you need

- LEGO NXT box
- LEGO education box (9648)
- abrasive paper
- normal white paper
- weights (100g - 300g)

Set-up

You place the block as close to the NXT ultrasonic sensor as possible, without it being detected by it.. From the moment the block slides down, the ultrasonic sensor will detect it and the motor will stop. Now, you can measure the angle. This way you can test the three laws.

Design a construction like in these pictures below.

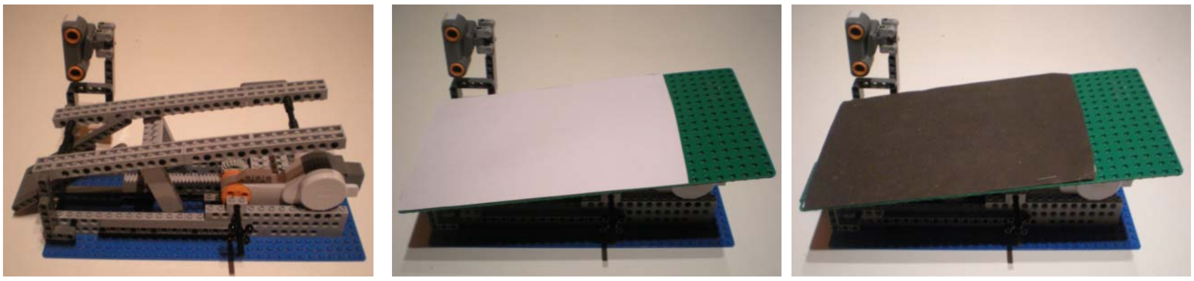
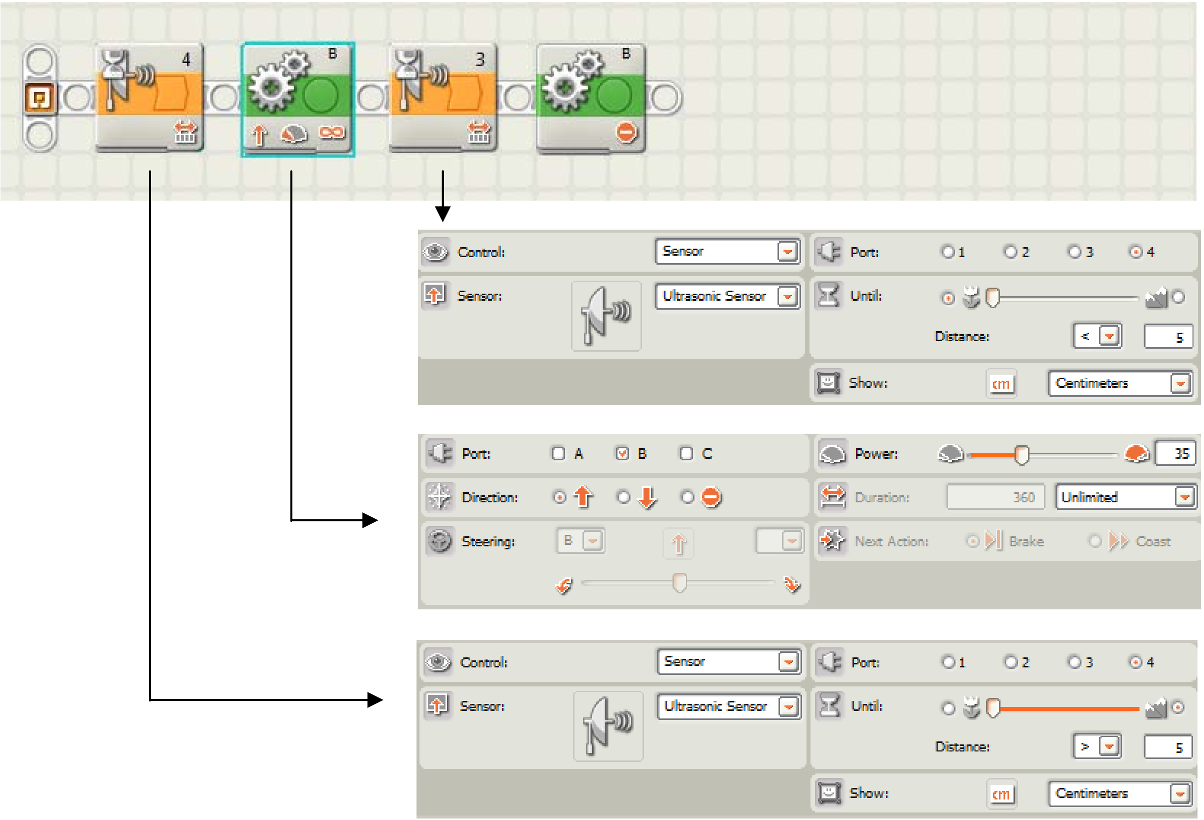


Fig1.8 friction: set-up

Program the NXT as follows:



<u>Formulas</u>

- The frictional force $F_{WS} = f_s \cdot F_N$ with: F_{WS} static frictional force
  f_s coefficient of static friction
  F_N normal reaction force

You can calculate the coefficient of friction f_s with the formula $f_s = \tan\alpha$. You can also find the coefficient of friction between certain materials in your book of tables page 31.

- The gravity $F_{zw} = m \cdot g$ with: F_{zw} gravity $[N]$
  m mass $[kg]$
  g earth acceleration $[m/s^2]$

- The normal reaction force $\overline{F_N} = \overline{F_{zw_y}}$

You can calculate the component of gravity in the y-axis direction with the formula $F_{zw_y} = \cos\alpha \cdot F_{zw}$.

Experiment 1

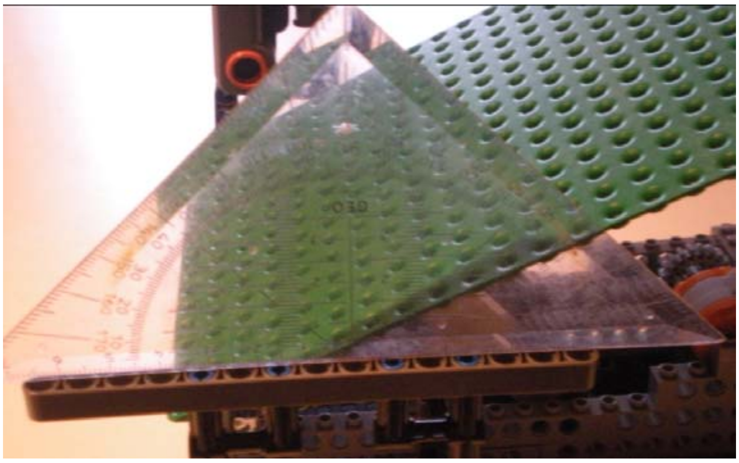
Make a black block in the form of a cuboid. Black blocks are easily noticeable for the ultrasonic sensor. In this block you include two “ballast” bricks (heavy bricks). Each of them weighs 55g.

The one time you place the cuboid on one of its larger sides, the other time on one of the small sides so that the contacting surface changes. Each time make sure you place the cuboid on exactly the same spot. Take care not to put it right in front of the ultrasonic sensor, because otherwise the incline will not raise.

Conduct each experiment 10 times, measure the angle every time and calculate the average value.

We measure the angle as demonstrated in the picture below.

Fig##friction: “ballast” block



Fig## friction: how to measure the angle

Measurement 1: two “ballast” bricks, cuboid on large side

Power: *40*

Mass : *110 g*

We conduct the experiment 10 times:

1st try: ....*31°*............

2nd try: ....*30°*............

3rd try: ....*28°*............

4th try: ....*30°*............

5th try: ....*30°*.........

6th try: ....*29°*.........

7th try: ....*28°*.........

8th try: ....*27°*.........

9th try: ....*29°*.........

10th try: ....*27°*.........

Average value of the angle: *28,9°*

Measurement 2: two “ballast” bricks, cuboid positioned upright on its small side

Power: *35*

Mass : *110 g*

We conduct the experiment 10 times:

1th try: ....*30°*...........

2nd try: ....*27°*...........

3rd try: ....*26°*...........

4th try: ....*29°*...........

5th try: ....*32°*.........

6th try: ....*30°*.........

7th try: ....*27°*.........

8th try: ....*28°*.........

9th try: ....*27°*.........

10th try: ....*32°*.........

Average value of the angle: *28,6°*

Conclusion :

> The resistive force you experience when you slide an object is independent of the size of the contact surfaces. (law n°1)

Fill in the table underneath and calculate the frictional force.

Normal white paper						
m (g)	α (°)	f_s	F_{ZW} (N)	F_{ZW_y} (N)	F_N (N)	F_{WS} (N)
110	*28,6*	*0,34*	*1,079*	*0,947*	*0,947*	*0,322*

Experiment 2

Construct a black cuboid like in experiment 1. For this experiment we will use four “ballast” bricks in measurement 1 and for measurement 2 we won’t use any.

Conduct the experiment 10 times, measure the angle every time and calculate the average value.

Measurement 1: four “ballast” bricks

Power: *45*

Mass : *0.220 kg*

We conduct the experiment 10 times:

1th try: ....*28°*...........

2nd try: ....*30°*...........

3rd try: ....*28°*...........

4th try: ....*31°*...........

5th try: ....*29°*........

6th try: ....*32°*........

7th try: ....*28°*........

8th try: ....*27°*........

9th try: ....*32°*........

10th try: ....*28°*........

Average value of the angle: *29,3°*

Measurement 2: no “ballast” bricks

Power: *35*

Mass: 0,022 kg.

We conduct the experiment 10 times:

1th try: ....*30°*...........

2nd try: ....*34°*...........

3rd try: ....*28°*...........

4th try: ....*29°*...........

5th try: ....*28°*........

6th try: ....*29°*........

7th try: ....*33°*........

8th try: ....*32°*........

9th try: ....*29°*........

10th try: ....*31°*........

Average value of the angle: *30,3°*

- Conclusion :

Compare the angles.

- *Measurement 1* : results in an average angle value of 29,3° with the cuboid containing four “ballast” LEGO bricks.

- *Measurement 2* : results in an average angle value of 30,3° with the cuboid without any “ballast” LEGO bricks.

Fill in the table below and calculate the frictional force in both cases.

Normal white paper						
m (g)	α (°)	f_s	F_{ZW} (N)	F_{ZW_y} (N)	F_N (N)	F_{WS} (N)
220	29,3	0,56	2,158	1,882	1,882	1,056
22	30,3	0,58	0,216	0,186	0,186	0,109

The heavier the object to be moved, the larger the frictional force. (law n° 2) Theoretically the angle doesn't change when using a heavier object. In the experiment above the difference is negligible.

Experiment 3

In this experiment we use normal white paper and abrasive paper for the contacting surfaces. We conduct this experiment with 1, 2, 3 and 4 "ballast" bricks successively. Each time we measure the angle and calculate the frictional force.

Normal white paper						
m (g)	α (°)	f_s	F_{ZW} (N)	F_{ZW_y} (N)	F_N (N)	F_{WS} (N)
55	33°	0,65	0,540	0,453	0,453	0,294
110	35°	0,70	1,079	0,884	0,884	0,619
165	34°	0,67	1,619	1,342	1,342	0,905
220	33°	0,65	2,158	1,810	1,810	1,175

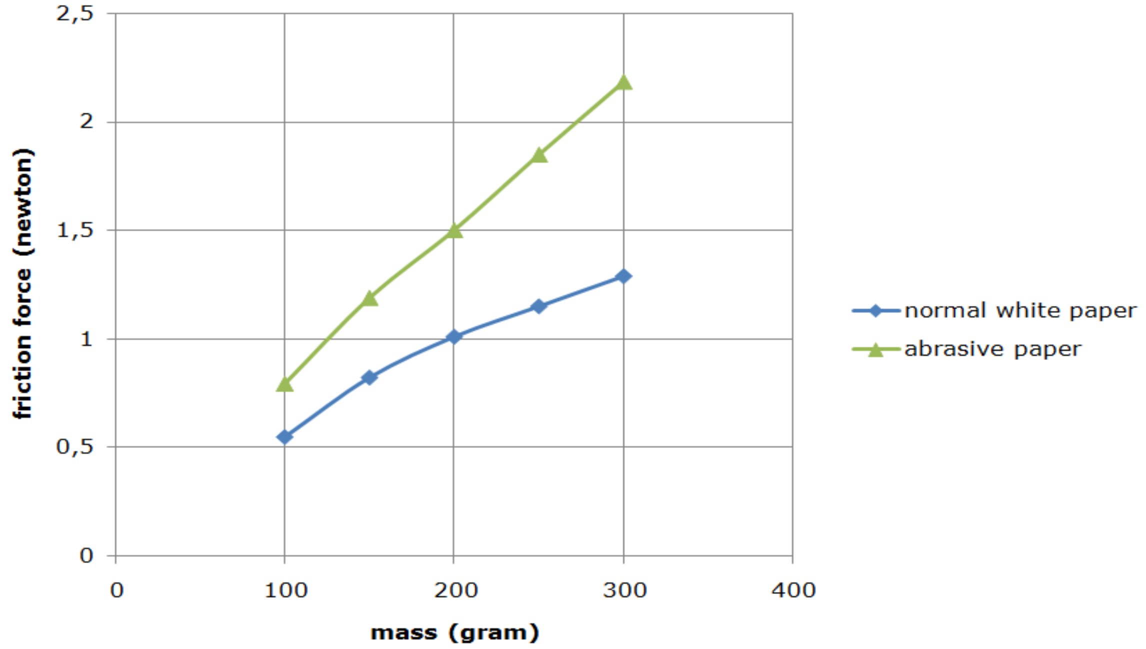
Abrasive paper						
m (g)	α (°)	f_s	F_{ZW} (N)	F_{ZW_y} (N)	F_N (N)	F_{WS} (N)
55	42°	0,90	0,540	0,401	0,401	0,361
110	43°	0,93	1,079	0,789	0,789	0,736
165	43°	0,93	1,619	1,184	1,184	1,104
220	42°	0,90	2,158	1,604	1,604	1,444

Conclusion:

With abrasive paper, we measure a larger angle than with normal paper.
(law n° 3)
The heavier the object to be moved, the larger the frictional force. (law n° 2)

Is there a linear relation between the mass and the frictional force?

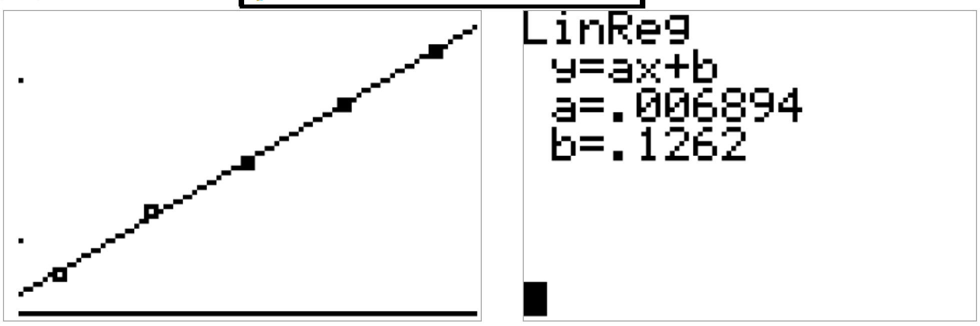
We note down the points in a graph and link them with each other.



We clearly notice a linear relation.

With the calculator, we can conduct a linear regression on the established results.

Abrasive paper: $y = 0{,}006894x + 0{,}1262$



Normal white paper: $y = 0{,}00362x + 0{,}2408$