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Physics Experiment: Friction

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Introduction

Friction is the force which opposes the tendency of motion between two surfaces in contact. This existing force exists because of the irregularity of surfaces in real objects. Therefore, surfaces which are supposed to be well polished, still posses small peaks which enter in contact when one of the objects intends to move over the other one.

Analytically, the force done by the friction when an object is moving over a surface, is given by:

$$F_\mu = \mu N \tag{1}$$

In the formula (1), N is the normal force, which is perpendicular to the plane or surface where the object is placed. Concretely, in this very experiment, our sliding object was resting over a horizontal plane, where $\overrightarrow{N}$ is exactly the opposite of the force exerted by $m\overrightarrow{g}$.

Thus, assuming that there is no acceleration in any vertical direction, since the object is moving along the horizontal, the frictional force can be redefined as:

$$F_\mu = \mu m g \tag{2}$$

Admittedly, by Newton's Second Law, if the object was pushed or pulled by a force which made a non-zero angle with respect to the horizontal, the resultant force would be affected by that concrete angle. Hence, the formula (2) could be written, in a more general manner, as:

$$F_\mu = \mu m g \cos\theta \tag{3}$$

Furthermore, the coefficient of friction can be defined in terms of acceleration along the horizontal axis and acceleration of gravity. That is, if there are no forces acting in any vertical direction, then $F_\mu = \mu m g$. Accordingly, by substitution on the $x-axis$ formulas, and knowing that $-F_\mu = m a_x$, is given that:

$$\mu = -a/g \tag{4}$$

Once the concept of friction (as well as the coefficient of friction) has been well defined and mathematically stated, the experiment can be executed in order to compare theoretical results against real analysis.

Description of the experiment

The experiment was meant to find the coefficient of friction and the frictional force exerted by the contact between a sliding object and a polished surface. The experiment took place in a normal environment, with an ordinary floor surface (supposed to be well polished) and a sliding object, which was a waste basket of light weight.

The materials used during the experiment were a motion detector, which tracks all the changes in position and time into the *Logger Pro* computer software.

The experiment consisted of three main stages:

Initial measurements: The team set up the motion detector on the floor. Afterwards, the object was pushed away from the motion detector. This was necessary, since pushing the object towards to the motion detector leads into negative values and hence more complicated post analysis. This stage took about half an hour, since many measurements have to be done in order to achieve a suitable one to analyze the experiment.

Preliminary graph analysis: After the first measurements, the team studied the graphs and tried to analyze what happened from the moment when the object is pushed until it stops.

Further analysis: In this stage, the team defined a new data column in the computer software where was included the formula for the coefficient of friction μ. Subsequently, the team drew the graph of the coefficient of friction on the same screen where the other graphs were displayed, thus comparing the results from once graph to another.

Consequently, the team proceeded to analyze all the results by fitting the most straight line in every single graph. Otherwise, information from results would be fuzzy.

Results

The first noticeable from the results was that there were unexpected peaks in the graphs, probably coming from the irregularities assumed in the polished surface, as well as the slightly deformed bottom of the sliding object. Consider table 1, containing a sample of the results obtained during the experiment:

Time (s)	**Position** (m)	**Velocity** (m/s)	**Accel.** (m/s^2)	μ
0.65	0.400	0.561	9.306	-0.950
0.75	0.542	1.458	3.466	-0.354
0.85	0.689	1.392	-1.047	0.107
0.95	0.822	1.252	-1.547	0.158
1.05	0.939	1.086	-1.592	0.162
1.15	1.039	1.039	-1.497	0.153
1.25	1.125	0.783	-1.552	0.158
1.35	1.196	0.625	-1.504	0.153
1.45	1.251	0.482	-1.397	0.143
1.55	1.292	0.344	-1.402	0.143
1.65	1.319	0.207	-1.228	0.125
1.75	1.333	0.098	-0.846	0.086

Table 1: Measurements from the beginning until the body stops.

According to the list of values in table 1, the object behaves as expected. That is, rapidly increasing at the beginning (due to the given impulse) and then decreasing progressively due to frictional force, which acts in opposite direction to the velocity of the sliding object.

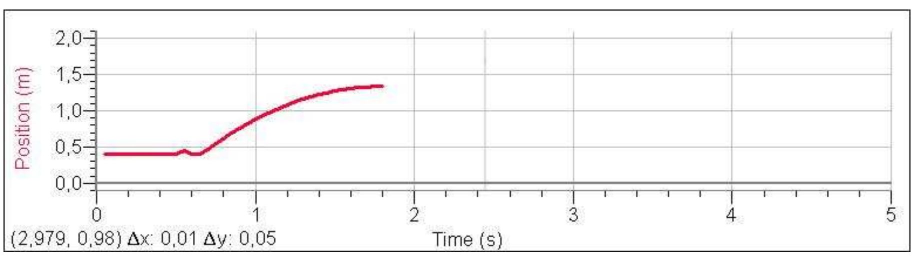

Figure 1: Change in position.

As seen from figure 1, the position is increasing more quickly at the beginning than in the end, according to the graph and perfectly true, considering the mathematical description of position respect to velocity and acceleration.

According to figure 2, the velocity increases from 0 to $1.5m/s$ in about $200ms$. Afterwards, it decreases at a constant rhythm, very progressively, until the body stops. Notice that there is a small bump, which the team suspected as a erroneous measurement from the motion detector before the experiment was started.

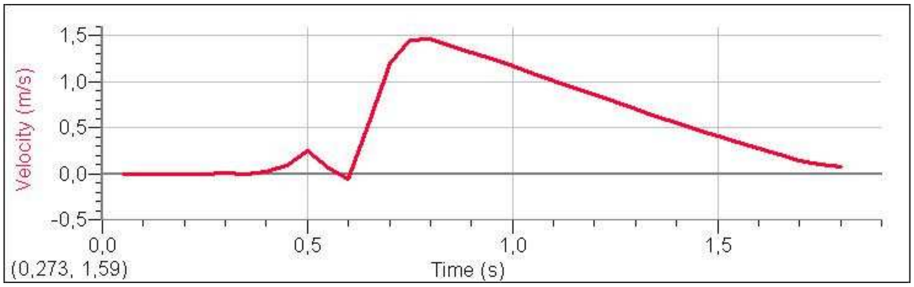

Figure 2: Change in velocity.

In order to obtain proper results, the team fitted the sample set between two points which defined a straight line. That would be from $t = 0.9s$ to $t = 1.6s$ in figure 2, and thus obtaining a highly accurate result for the change in velocity.

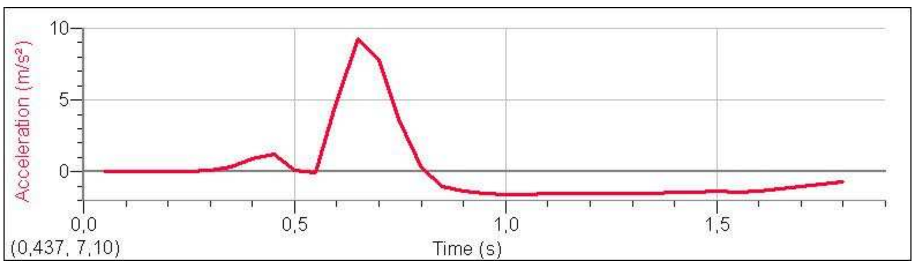

Figure 3: Change in acceleration.

In figure 3, it turns out that the acceleration is positive and increasing during the same period of time when the velocity is increasing, which is logical. Right after, the acceleration decreases until it reaches zero, crossing the $x - axis$. Admittedly the acceleration starts to be negative at the point when the initial impulse is not affecting anymore and only the frictional force is acting on the body, which is negative against the velocity of the object.

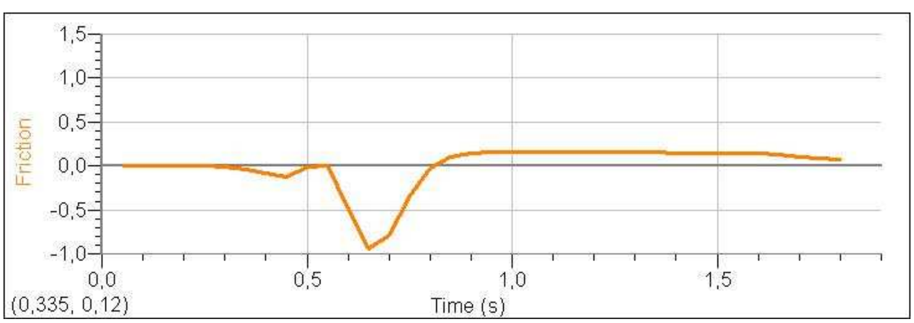

Figure 4: Change in coefficient of friction.

Figure 4 shows the change in coefficient of friction. Eventually, the team decided to create a new column in the software tool, by defining the formula $\mu = -ag$, and then plot the graph to compare with the rest of calculations. Data in figure 4 represents the value of the **coefficient of *kinetic* friction**.

Finally, in order to achieve an accurate value for the coefficient of friction (μ) and in the same way the team dealt with the change in velocity, the straight line from $t = 1.0s$ to $t = 1.6s$ was selected to represent the data set for the calculations. Thus, the value for the coefficient of friction would be accurate enough for the success of the experiment. So far, it turned out to be $\mu = 0.1523 \pm 0.015$.

Notice that the coefficient of kinetic energy changes with the other values as well. By and large, the coefficient of static friction is a fixed value for objects which are at rest and are intended to be moved with respect to a surface. However, the kinetic coefficient of friction seems to increase and decrease in function of the velocity and also in function of the acceleration.

Conclusion

By the means of education, this experiment was interesting, but entertaining at the same time. When the team decided to calculate mathematically on paper and then check on the table of results, it turned out that, sometimes, the results are not what it was expected. Nevertheless, the results are mostly what they should be.

A clear confirmation for the fitting of the results with reality and mathematics is that the graphs describe the expected path, except for some small parts of the graphs where there are some peaks, possibly because of the measuring accuracy of the tools.

As a final note, just to say that the experiment was an enriching experience for the team and personally for me. Also, it was the first experiment the team performed and it was more difficult to get use to the tools than performing the experiment itself. Nevertheless, the team looks forward to the next experiment and hopefully it will be more interesting and even more challenging.