IT Promoting Physics Projects

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Abstract- **STEM (S-Science, T-Technology, E-Engineering, M-Mathematics) is in crisis. Research in didactics is done to find a way out. In physics education research IT plays an important role. Students are fond of new technology, and are familiar with informatics. Surely, cutting edge science research is in need of using IT. Obviously, teaching new contents in most topics can't miss out using some kind of, but simplified tools or programs.**

IT can call to life projects in the field of classical physics, too. In our project we analyzed a simple motion on a slope the classical way, which led us to a function of two variables. For a numerical analysis we needed computing skills. Our group achieved surprising results in the study.

Key words: classical physics, mentor class, numerical analysis in high school

I. Introduction

We have to be aware of the fact that STEM (S-Science, T-Technology, E-Engineering, M-Mathematics) is in crisis. Students don't like these areas, and less and less choose a profession from it as carrier.

Research is done in didactics how to make these fields more enchanting and understandable for the future generation.

Using applied or high-tech apparatus, or combining information technology or computing in our projects helps to attract students to a decision to participate according to the experience.

In physics education research one of the biggest tasks is to develop projects and methodological tools for new content. One of the goals is to teach the latest achievements of science research. As IT is an essential tool in the research itself, surely it plays a determinative role in the education, too. Particle physics, environmental science chaos theory and similar content have to build on IT even in the popularization of these topics. If we are talking about special classes or projects for those who have special talent or pay interest in science (we call these mentor classes or mentored projects), even more of IT we need to rely on.

We present "The sledge project" (Ref. [1].) as an example of a partly different project from what we discussed above. We made a deeper study of a question from the fields of classical physics. After a few steps we got to a function of two variables. Analyzing it is not in the secondary school curriculum. But programming made it possible to answer our questions.

A. Topic flag

Travelling home from a physics competition with eager students, we discussed some issues that arose during the event. A well-known question came into our focus: "Why is it easier to pull a sledge horizontally than to pull it on a slope upwards?"(See Fig. 1.)

FIGURE 1.
PULLING A SLEDGE

Some of the students paid special attention to the problem and showed interest to participate in a deeper study.

B. A study of the typical qualitative answers

We met answers that are similar to this reasoning: "In both cases we need to exert a force against friction, plus on the slope we must exert force against a component of gravity as well."

The problem is as follows: We agree that the force against gravity is an increasing value as the tilt angle of the slope is increasing, whereas the force against friction is a decreasing one. When we add up these two, the sum is not necessarily an increasing function.

Some of the answers we know of are similar to this: "Besides energy dissipated in friction, extra mechanical work must be done to give „height"/ „positional"/ „potential"/ „gravitational" energy."

When talking about an "easier pull" we associate it with forces rather than with energy. Work, energy, and force are different notions. If we want to make a connection, we need to study distance as well.

C. The Newtonian analysis

We used Newton's laws, which are also well known as basics of classical dynamics for the theoretical analysis of the case. We denote the notions used in the analysis in dynamics by the symbols used in SI system: F, m, a, μ, α, etc..

Based on Newton's 2nd law the force needed for a uniform motion…

- … in case of pull on level ground (denoted by *) is as follows:

$$ {}^{*}\boldsymbol{F}_{\text{pull}} = -{}^{*}\boldsymbol{F}_{\text{friction}} \tag{1} $$

, since $\sum * \boldsymbol{F} = 0$, (2)

so $* \boldsymbol{F}_{\text{pull}} = \mu \cdot m \cdot g$ (3)

➢ … in case of pulling up on a slope (see Fig. 2.) is as discussed below:

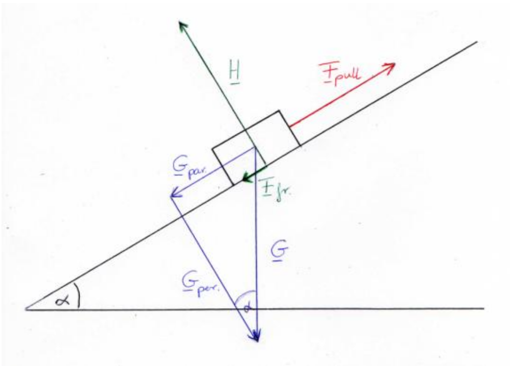

FIGURE 2.
A STUDY OF THE FORCES ON A SLOPE

- The force that is exerted by the slope is H.

$$\mathbf{H} = -\mathbf{G}_{\text{perpendicular}} \quad (4)$$

, therefore

$$\mathrm{H} = \mathrm{m} \cdot \mathrm{g} \cdot \cos\alpha \quad (5)$$

- We can calculate friction, since

$$\mathrm{F}_{\text{friction}} = \mu \cdot \mathrm{H} \quad (6)$$

, so $\mathrm{F}_{\text{friction}} = \mu \cdot \mathrm{m} \cdot \mathrm{g} \cdot \cos\alpha$ (7)

- The component of gravity can be given as

$$\mathbf{L} = -\mathbf{G}_{\text{parallel}} \quad (8)$$

, that means

$$\mathrm{L} = \mathrm{m} \cdot \mathrm{g} \cdot \sin\alpha \quad (9)$$

Based on Newton's 2nd law the force of pull is

$$\mathbf{F}_{\text{pull}} - \mathbf{F}_{\text{friction}} - \mathbf{L} = \mathbf{0} \quad (10)$$

, which gives us that

$$F_{pull} = \mu \cdot \mathrm{m} \cdot \mathrm{g} \cdot \cos\alpha + \mathrm{m} \cdot \mathrm{g} \cdot \sin\alpha \quad (11)$$

$$F_{pull} = \mathrm{m} \cdot \mathrm{g} \cdot (\mu \cdot \cos\alpha + \sin\alpha) \quad (12)$$

To compare the force of pull in these cases we formed a function

$$\psi = \mathrm{F}_{\text{pull}} - * \mathrm{F}_{\text{pull}} \quad (13)$$

We received that

$$\psi = \mathrm{m} \cdot \mathrm{g} \cdot (\mu \cdot \cos\alpha + \sin\alpha - \mu) \, . \quad (14)$$

If we study the sgnψ function, we can figure out if our original statement is true or false. We need to face a problem: analysing a function like sgnψ is not in the secondary school curriculum. A few decades ago we could not have coped with a task like this analysis.

D. *Numerical analysis, a study of the sgnψ function*

Two of the students participating in the project are students of IT software.

So we wrote a programme in C++ using SDL (1000x180 pixels). Since $0^\circ \leq \alpha \leq 90^\circ$ on the vertical axis we can easily represent the tilt angle, α if $1^\circ = 2$ pixels. So, on the horizontal axis we can represent μ. With a multiplier we can adjust the maximum value to what we want to study. Our programme works in two cycles. This means 90,000 data-pairs to calculate with. We presented the results according to our purpose in a colour code (Table 1.)

TABLE 1.
COLOR CODE OF SGNΨ FUNCTION IN SDL

Pull on slope	Pull on level ground	sgnψ	Colour code
bigger	smaller	+	red
smaller	bigger	-	blue

We were very excited to see the results. If blue area appears, it means that the original statement is not necessarily true in all circumstances. Our results in the numerical analysis:

1.) For all possible angles, if $0 \leq \mu \leq 0.25$, see Fig. 3.

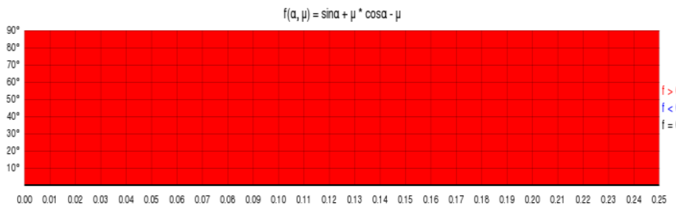

FIGURE 3.
Sgnψ, if $0 \leq \mu \leq 0.25$

2.) For all possible angles if $0 \leq \mu \leq 2.5$ we present the result in Fig. 4.

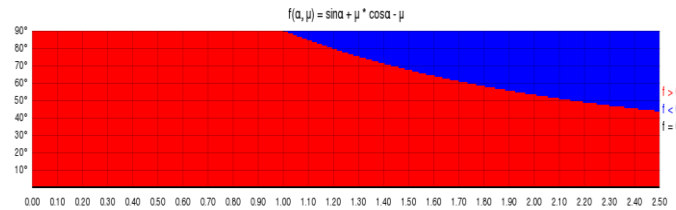

FIGURE 4.
Sgnψ, if $0 \leq \mu \leq .2.5$

The fact that a blue area appears on the figure means that the statement is not even necessarily true.

3.) For all possible angles, we allowed μ up to 50, you can check Fig. 5.

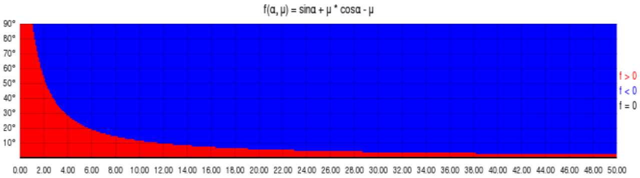

FIGURE 5.
Sgnψ, if $0 \le \mu \le 50$

We can conclude that α and μ are the main quantities that define motion on a slope.

E. Hands-on" measurements

We wanted to see what the typical values (for μ and α) are, when playing the sledge.

- <u>Measuring the friction constant</u>

We pulled the sledge on level ground at constant speed. We used an 80213-141 Kamasaki digital scale (dynamometer) that we bought cheap in a fishing shop. We also needed a bathroom scale and a sledge. We made measurements 3 different occasions, which means 3 different circumstances. We decided to note 3 readings each time. We formed the mean value by calculating the arithmetic mean. Our results are in Table 2.

TABLE 2.
OUR RESULTS FOR FRICTION CONSTANT

measurement (Budapest XXI. ÁMK)	$F_{gravity}$ (N)	F_{pull} (N)	$F = \frac{F_{pull}}{F_{gravity}}$	μ_{mean}
9th Febr. 2015. late evening	351+51.7= 403	45.15	0.112	0.118
		49.46	0.123	
		47.88	0.119	
10th Febr. 2015. afternoon	51.7	9.88	0.191	0.178
		9.20	0.178	
		9.45	0.166	
16th Febr. 2015. early morning	51.7	4.90	0.095	0.092
		5.10	0.098	
		4.35	0.084	

In journal "KÖMAL" (, which is a mathematics and physics journal in Hungary for higher primary and secondary school students) we found that the friction constant measured with a different method is $0.02 \le \mu \le 0.3$. Our results match those we found in the literature (Ref.[2].).

- <u>Measuring tilt angles</u>

Our first problem was that we could not get an inclinometer. Since this instrument is not cheap, we worked out a conventional method for α. We needed a bubble level (0.8m), a 1meter rod, and a pendulum (string & load). Fig.6 and 7. demonstrate how we used our tools.

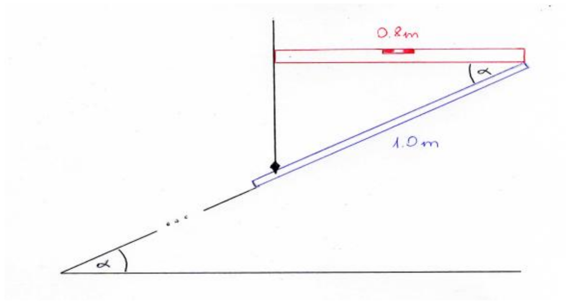

FIGURE 6.
OUR HAND-MADE APPARATUS

We also used applied apparatus to measure tilt angles, the GPS system. We worked with the two versions that were available free. See Fig. 7./b.

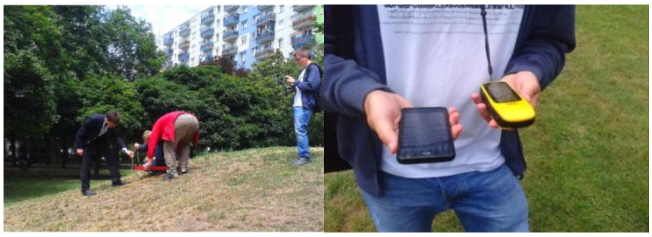

FIGURE 7.
IN-SITU MEASUREMENTS

We made our measurements in different playgrounds in Budapest (Bp.) on 23rd June 2015. We visited 3 playgrounds:

- Slope 1. is Bp. 1095 Petőfi utca 2.
- Slope 2. is Bp. 1091 Kékvirág utca 2.
- Slope 3. is Bp. 1107 Bihari utca 3-5.

Table 3. includes our results. We denote by * our results with the GPS system.

TABLE 3.
TILT ANGLES OF SLEDGING SLOPES

slope	spot	l_{pro} (cm)	cosα	α_{act}	α mean	*α act1	*α act2	*α mean
S1	1/1	84.0	0.9524	18°	**15°**	16°	13°	**15°**
	1/2	85.0	0.9512	20°				
	1/3	80.5	0.9938	6°				
S2	2/1	80.5	0.9938	6°	**11°**	11°	14°	**12°**
	2/2	81.5	0.9816	11°				
	2/3	83.3	0.9639	15°				
S3	3/1	83.5	0.9581	17°	**17°**	15°	14°	**15°**
	3/2	85.0	0.9412	20°				
	3/3	82.5	0.9697	14°				

Our results range from 6° to 20°, and the mean value is 14°.

F. Incorporating the results of our theoretical and practical studies

„Why is it easier to pull a sledge on level ground than to pull it up a slope?"

We provide two answers:

1.) Since μ<1, from the theoretical study we learned that there is no need to give a typical value to α. (Fig. 8.)

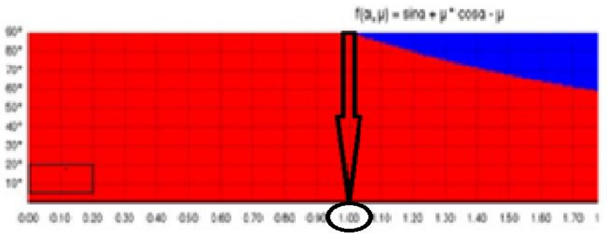

FIGURE 8.
WHEN THE FRICTION CONSTANT IS BELOW 1

A correct answer is: As the typical μ < 1, it is easier to pull a sledge on level ground than to pull it up a slope.

2.) We studied the area denoted by the typical values based on our measurements (Fig. 9.).

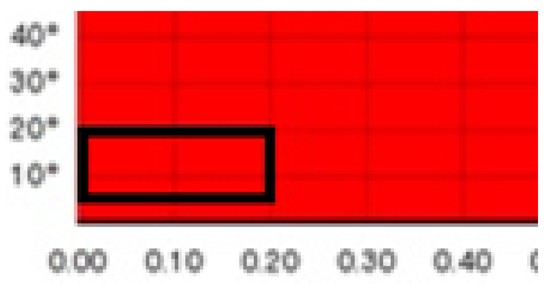

FIGURE 9.
REAL SLEDGING

Another correct answer is: It is easier to pull a sledge on level ground than to pull it up a slope, because of the real values of α and μ.

CONCLUSION

In science methodology revolution can break out as in research IT is becoming a new tool in education.

In "The Sledge project" we studied an often-asked question in classical mechanics. This topic has been studied before only in a qualitative way in primary and secondary school science education. We have found that the typical answers in this case are not correct. We faced a big problem: reasons were asked for, whereas the statement is not obvious, furthermore: the statement is not necessarily true in all physical conditions.

Easily we got to a function of two variables. From this point on computing skills were needed to carry on with the project. Our peripatetic mentor class turned into an interdisciplinary forum of science. We made quantitative analysis. We could find real answers for a classical physics question, where the qualitative answer based on experience opposed the scientific truth.

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