THE SLEDGE PROJECT

Teaching Physics Innovatively Conference

Budapest, 17-19. Aug. 2015.

Who are we?

- Teacher and senior students at Trefort Ágoston Bilingual Technical High School, Budapest
- Members of **„The sledge project"** mentor class:

Csilla Fülöp and students:Tamás Berényi, Balázs Simó, Roland Szabó




- *I chose the peripatetic way of education for the implementation*

Topic flag & typical responses

- In physics classes and science competions this question is often asked: **„Why is it easier to pull a sledge horizontally than to pull it on a slope upwards?"**
- Some typical answers:
  - „exert a force against friction (both cases) + against gravity (only on a slope)"
  - „mechanical work must be done to support „height", „positional", „potential", „gravitational" energy also, not only to dissipate energy in friction"

Studying the answers

1.) „*exert a force against friction (both cases)* +

against gravity (only on a slope)"

Problem: The force against gravity is increasing, whereas the force against friction is decreasing as the tilt angle is increasing, since it is $F_{friction}=\mu\cdot G\cdot\cos\alpha$

2.) „*besides the energy dissipated in friction, extra mechanical work must be done to give „height", „positional", „potential", „gravitational" energy*"

Problem: work and force are different notions, the distance should be studied too

The Newtonian analysis

We used for the theoretical analysis of the case Newton's laws, which are also well known as basics of classical dynamics

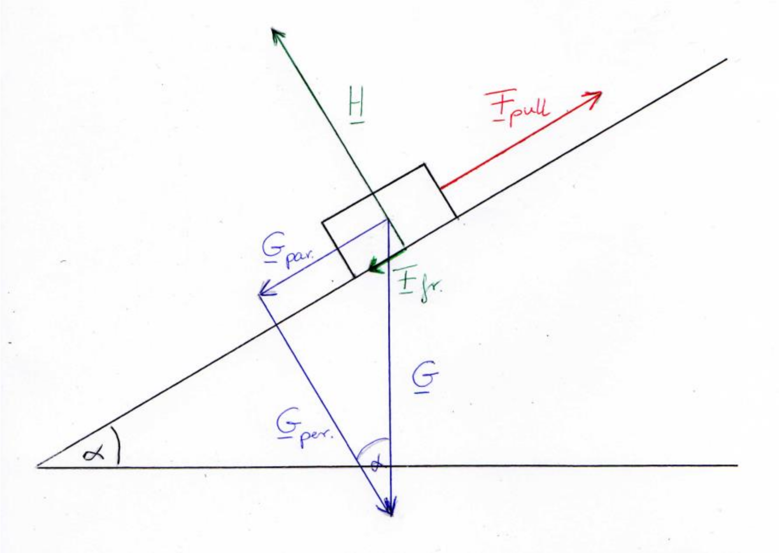
We denote the notions used in the analysis in dynamics by the symbols used in SI system: F, m, a, μ, α

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

- … in case of pull on level ground is

  $*\underline{F}_{pull} = - *\underline{F}_{friction}$ (since $\sum *\underline{F} = \underline{0}$) , so $*F_{pull} = \mu \cdot m \cdot g$

- … in case of pulling up on a slope is



1.) $\underline{H} = - \underline{G}_{perp.}$ $H = m \cdot g \cdot \cos\alpha$

2.) $F_{friction} = \mu \cdot H$ $F_{friction} = \mu \cdot m \cdot g \cdot \cos\alpha$

3.) $\underline{L} = \underline{G}_{parallel}$ $L = m \cdot g \cdot \sin\alpha$

A function of two variables

- The force of pull is $\underline{\boldsymbol{F}}_{pull} - \underline{\boldsymbol{F}}_{friction} - \underline{\boldsymbol{L}} = \underline{\boldsymbol{0}}$, which gives us that

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

$$\infty$$

- To compare the force of pull in these cases we formed a function: $\psi = F_{pull} - {}^{*}F_{pull}$
- We received that $\psi = m \cdot g \cdot (\mu \cdot \cos\alpha + \sin\alpha - \mu)$
- If we study the sgnψ function, we can figure if our original statement is true or false.
- Problem!!! : analysing a function like sgnψ is not in the secondary school curriculum

Numerical analysis

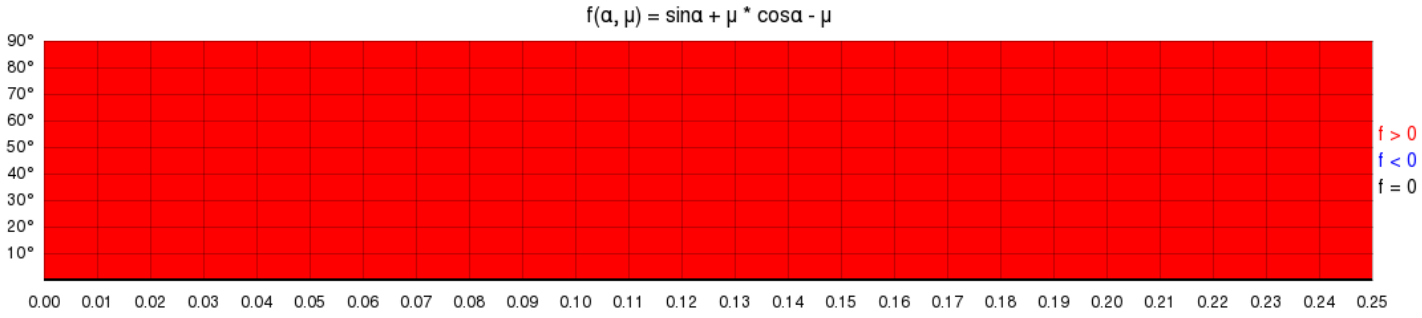
a study of the sgnψ function

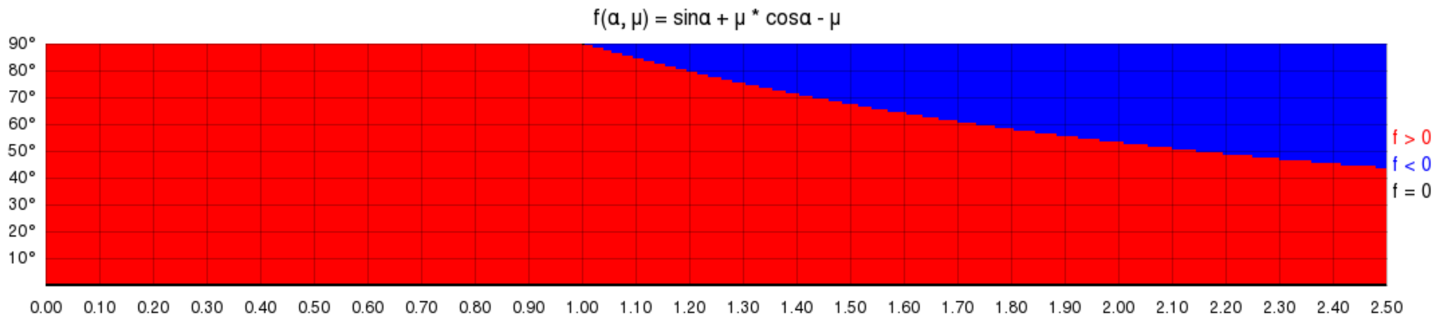
Our programme for studying the sgnψ function

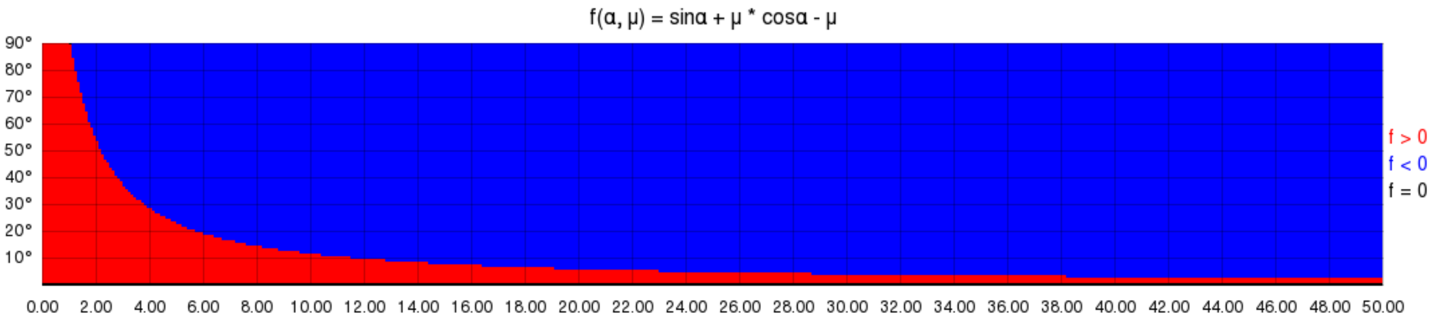
- We wrote a programme in C++ using SDL (1000x180 pixels)
- Since $0° \leq \alpha \leq 90°$ on the vertical axis we can easily represent the tilt angle(α) if $1°=2$ pixels
- So on the horizontal axis we can represent μ. With a multiplier we can adjust the maximum value to what we want to study.
- Our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

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

Our results in the numerical analysis







Hands-on measurements

What are the typical values for μ and α when playing the sledge?

Measuring the friction constant

- We pulled the sledge on level ground at constant speed
- We used
  - a 80213-141 Kamasaki digital scale bought in a fishing shop (dynamometer)
  - a bathroom scale and a sledge

- We measured 3 different occasions, that means different circumstances. We decided to note 3 readings each time. We formed the mean value by calculating the arithmetic mean.

Our results for „μ”

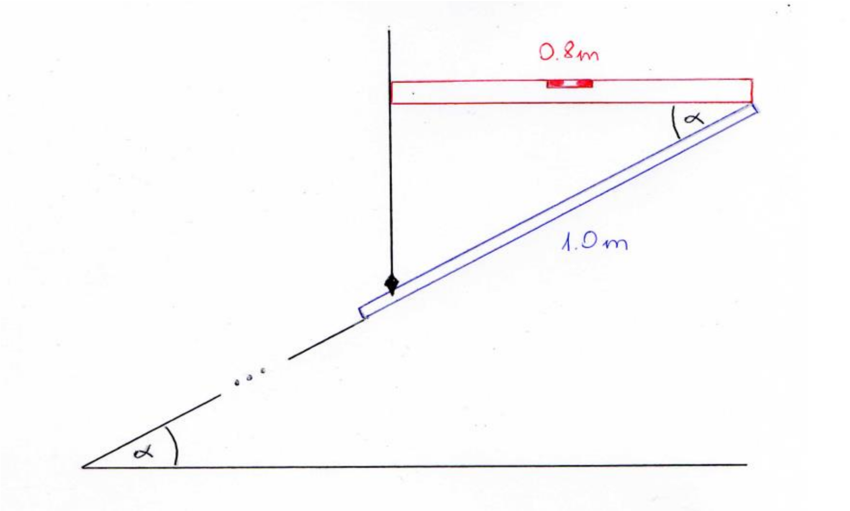
	F gravity (N)	Pull (N)	$\mu = F_{pull}/F_{gravity}$	μ_{mean}
1. measurement (late evening, with a girl on, 9th Febr. 2015.)	351+51.7= 403	45.15	0.112	0.118
		49.46	0.123	
		47.88	0.119	
2. measurement (afternoon,10th Febr. 2015.)	51.7	9.88	0.191	0.178
		9.20	0.178	
		9.45	0.166	
3. Measurement (early morning16th Febr. 2015.)	51.7	4.90	0.095	0.092
		5.10	0.098	
		4.35	0.084	

- In journal „Kömal” we found that $0.02 \leq \mu \leq 0.3$.

Our results match those in the literature.

Measuring tilt angles 2 ways

- We didn't have an inclinometer
- Our conventional method with
  - a bubble level (0.8m)
  - a 1meter rod,
  - a pendulum (string & load).



- We also used applied apparatus: the GPS system
- We made our measurements on 23rd June 2015.

Our results for „α"

	spot	$L_{projection}$ (cm)	cosα	α_{actual}	α_{mean}	*$\alpha_{act\ 1}$	*$\alpha_{act\ 2}$	*α_{mean}
Slope 1 (Petőfi u. 2. 1095)	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°				
Slope 2 (Kékvirág u. 2. 1091)	2/1	80.5	0.9938	6°	**11°**	11°	14°	**12°**
	2/2	81.5	0.9816	11°				
	2/3	83.0	0.9639	15°				
Slope 3 (Bihari u. 3-5. 1107)	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 result ranges from 6° to 20° , and the mean value is 14°.

Incorporating the results…

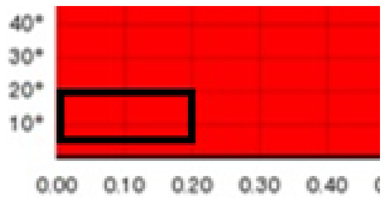
… of our theoretical and
the practical studies

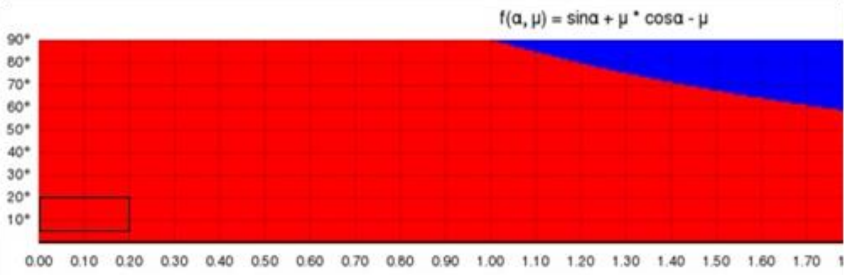
„Why is it easier to pull a sledge on level ground than to pull it up a slope? „

- Since $\mu<1$, from the theoretical study we can learn, that there is no need to give a typical value to α.

  A correct answer is: **As the typical $\mu<1$**, it is easier to pull a sledge on lever ground than to pull it up a slope.

- We studied the area denoted by the typical values based on our measurement





  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.**

THANK YOU FOR YOUR ATTENTION

Feel free to ask or share your comments