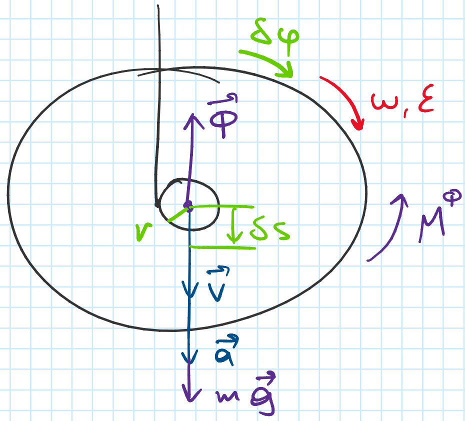
TM Big HW 2 Anton Buguev B19-RO-01

R.O.: yo-yo - planar motion



Force analysis: $G = mg$

Solution:

1) Let us find acceleration of yo-yo using Lagrange-d'Alambert principle:

$$\sum \delta A + \sum \delta A^{\Phi} = 0$$

$$\sum \delta A = A^{G} = mg\,\delta s$$

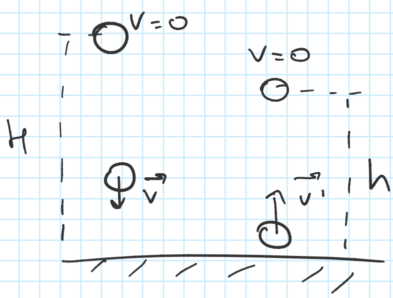
$$\sum \delta A^{\Phi} = \delta A^{\Phi} + \delta A^{M^{\Phi}} = -ma\,\delta s - J\varepsilon\,\delta\varphi$$

we can write $v = \omega r \Rightarrow \omega = \frac{v}{r} \Rightarrow \delta\varphi = \frac{\delta s}{r}$, $\varepsilon = \frac{a}{r} \Rightarrow$

$$mg\cancel{\delta s} - ma\cancel{\delta s} - J \cdot \frac{a}{r} \cdot \frac{\cancel{\delta s}}{r} = 0$$

$$\boxed{a = \frac{mg}{m + \frac{J}{r^2}}}$$ where $J = m \cdot \rho^2$

2) Let us make analogy that yo-yo is ordinary ball that falls from some height without initial velocity and bounces from the floor and flies up on some height that is less than initial height.



3) We can write that $v' = k v_p$ where

v' - velocity right after bounce from the floor, m/s

k - coefficient, $k \leq 1$

v_p - velocity right before bounce from the floor, m/s

There is equation $S = \frac{v^2 - V_0^2}{2a}$.

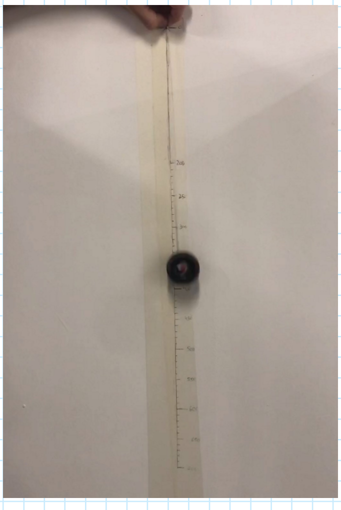
We assume that the only

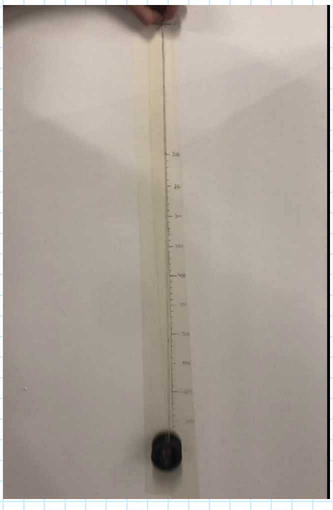
Since initial height and velocity are H and 0, we can write $V_p = \sqrt{2aH}$

Since final velocity after bounce is 0, we can write $v' = \sqrt{2ah}$

So we can find $k = \frac{V'}{V_P}$ for first bounce and then using this value predict velocity after each bounce and therefore height after each bounce and therefore approximate number of oscillations.

4) We made 5 experiments with different initial heights and each experiment was made 3 times:





initial heights are:

0,3 m, 0,4 m, 0,5 m, 0,6 m, 0,7 m

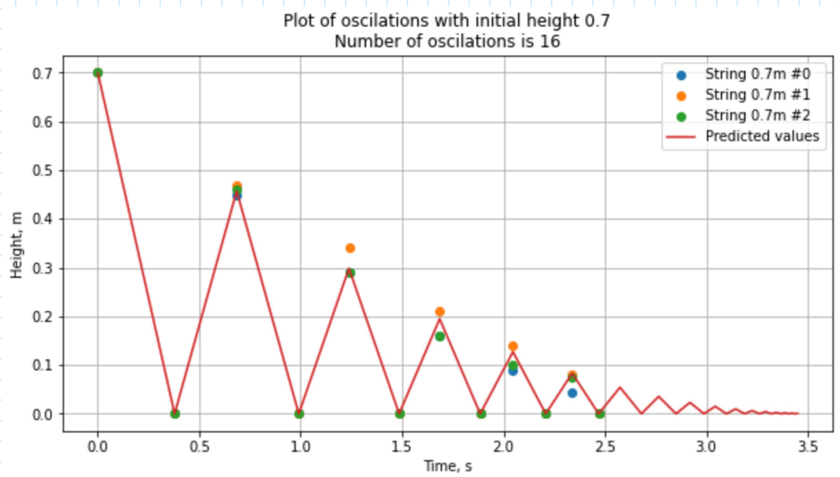
so considering first bounce for each initial height we can train machine learning model to predict the height of the flight after first bounce and use it to calculate k.

5) After we find k for given height we can calculate heights after bounces until height becomes very small and therefore we can find number of oscillations.

6) After calculations using Python we have:

initial string length, m	number of oscillations	max height, m
0,3	9	0,15
0,4	11	0,22
0,5	13	0,3
0,6	14	0,38
0,7	16	0,46
Mean	12,6	0,302
STD	2,42	0,11

This is one of resulting plots. This plot is for initial length 0,7m. Colourful points are experiment results, red line - calculated result.



As we can see, calculated results are close to experimental results and therefore we can conclude that our predicted model is indeed correct and can be used to calculate number of oscillations.