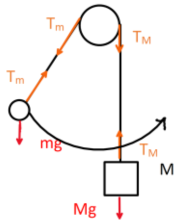
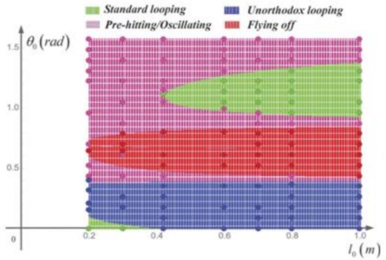
Looping Pendulum

Step 1: Idea





Source: Wen Q, Huang X, Zhang Y et al. (2021).
Looping pendulum:
Theoretical and experimental studies. *Eur. J. Phys.* **42** *045006*

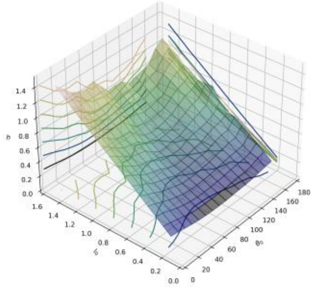
A small pendulum mass gets accelerated by a significantly heavier mass, increases ist angular speed due to momentum conservation, wraps around a pole and ultimatively stops the heavier mass from falling: Following the Capstan equation, the wrapping provides exponentially growing friction.

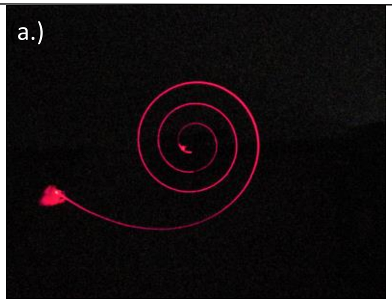
Altough the underlying mechanical principles are simple, the exact outcome depends on chaotic factors: The motion exhibits two distinct phases of description (slipping and non-slipping), and only slight differences in starting parameters induce substantially different progressions.

Step 3: Simulation & Results

We set up a numerical simulation of the motion, with the intent of using our actual experiment's result for its calibration. The aim: Comparing with the findings of a precursor project.

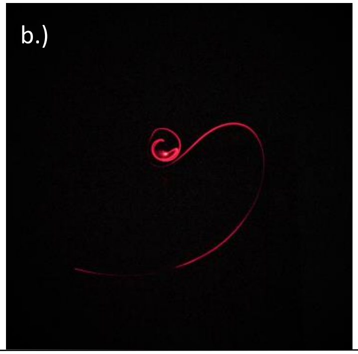
Ultimatively, we had to abandon this goal, but we managed to calculate a prediction for the fall height of the larger mass, depending on the initial parameters. The result can be seen below.





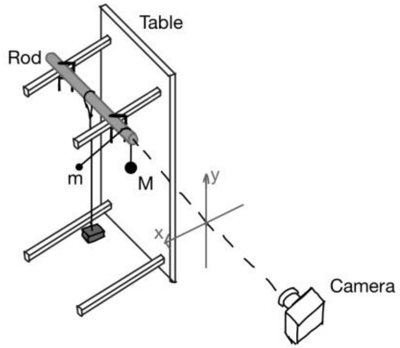
The following shows some of our pictures we took. The photo on the left (a.) shows a standard loop with a regular curve.

However, not all our data were perfect. The picture on the right (b.) shows a funny behavior of the small mass, where it reverted its direction of looping mid flight.



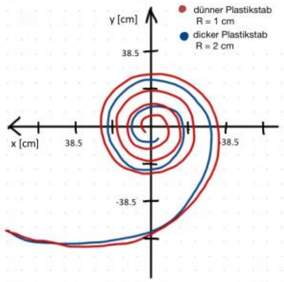
Step 2: Setup

For our experiment we used the following setup: We put a table sideways and fixed a rod to the upper table legs using screw clamps. We aligned the optical axis of the camera with the rod's central axis.
We fixed LED's to the smaller mass and let it swing at an inital angle. We then darkened the room to take long exposure pictures with the camera to track the trajectory of the smaller mass.



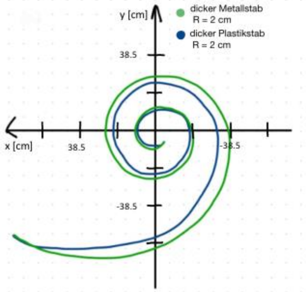
In the picture on the left we can see the grid we used to make our measurements. With this we could repeat our measurements for approximately the same initial conditions so that we could compare certain properties and explore our set up more.

Step 4: Data Analysis



To analyse our data, we traced some of our pictures by hand, to make the trajectory more visible, since most of them were quite dark. This enabled us to compare different loops, as can be seen in the two pictures here. Using an online angle measuring program we figured out the starting angles of our masses, and knowing the initial length of our rope, we were able to create a coordinate system. This gave our data more quality.
Using this method we compared the impact of different rod thickness and materials on the trajectory.

The graphic above (a.) compares different rod thicknesses. One can observe that for a thinner rod the small mass loops more times than the thicker one.
For different rod materials, as can be seen in (b.), we observe very similar loops, though the metal rod leads to a slightly bigger loop than the plastic one.
Both these phenomena can be explained by increased friction.



Angle-measuring website:
https://www.ginifab.com/feeds/angle_measurement/online_protractor.de.php

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