LOOPING PENDULUM

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ABSTRACT

In this paper we will witness that by tying both ends of a string to unequal weights, lifting the end tied to the smaller weight with a specific angle would conclude in a small fraction of the string wrapping around the bar, thus stopping the larger weight from falling on the ground. On some conditions we observe that the light load spins around the rod because of the friction between rod and thread and prevent the heavy load from hitting the floor.

(This is just a short explanation)

1 Introduction

By connecting two loads, one heavy and one light, with a string over a horizontal rod and lifting up the heavy load by pulling down the light one we can observe that release the light load will cause its sweeping around the rod, which keeps the heavy load from falling to the ground (iypt.org). So to investigate this phenomenon several experiments are done . Accordingly, we will consider two major physical principles; Archimedes Spiral and Newton's Law of Motion . By experiments we came to the conclusion that the effective parameters are: weights' masses, angle, width of the bar, length and material of the string (Fig. 1).

In order to study the phenomenon, we designed a setup to investigate the effective parameters. A bar, a string and two unequal weights make up the main parts of our setup.

1) We commence by analyzing the effect of its amplitude on the smaller weight's turn around the bar.

2) The bar's width and surface .

3) The string's height difference after multiple turns around the bar.

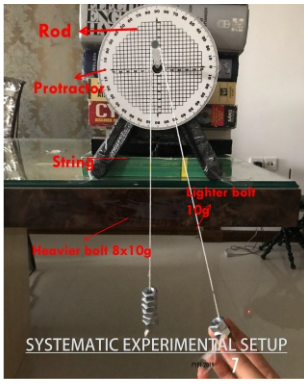


Fig. 1: Experimental setup

2 Experiments and Theory

Parameters in this experiment are:

- Difference between the two bolts
- Releasing angle
- Heavier bolts' distance from the ground
- Friction between the string and rod

There are 4 forces acting on the light mass:

- Gravitation force ,
- Centripetal force,
- Tension force and
- Coriolis force

We can find the motion of the light load according to the equation (1) and (2).

$$\ddot{x} = -\left[\frac{g-\frac{m_2}{m_1}(g\sin\theta+\ell\dot{\theta}^2)e^{\mu(\theta+\frac{\pi}{2})}}{1+\frac{m_2}{m_1}e^{\mu(\theta+\frac{\pi}{2})}} + r\ddot{\theta}\right] \quad (1)$$

$$\ddot{\theta} = \frac{g\cos\theta - v\theta^2 - 2\dot{\ell}\dot{\theta}}{\ell} \quad (2)$$

Because of the initial angle that the lighter load has in the beginning of the experiment, it spins around the rod and the friction between the thread and rod causes the lighter load to stop the heavy load from hitting the ground. The tension force of the thread can be calculated by equation (3).

$$T_1 = T_2 e^{\mu\theta} \quad (3)$$

In our experiment we started from 10 g mass and when the mass in both sides are equal the movement is observed.

According to free body diagram (Fig. 2) we can find T_1 and T_2 (Eq. 4 and 5).

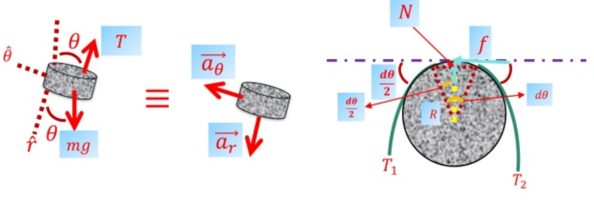


Fig. 2: Free diagram in our experimental setup

$$T_1 = \frac{2m_1m_2g}{m_1e^{\mu\alpha} + m_2\cos\theta} \quad (4)$$

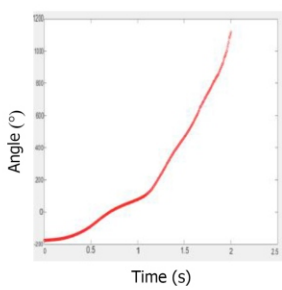
$$T_2 = \frac{2m_1m_2e^{\mu\alpha}}{m_1e^{\mu\alpha} + m_2\cos\theta} \quad (5)$$

For doing this experiment, we need two different loads, a thread and a horizontal rod. We connect two loads with a thread and hang it on the rod. We lift up the heavy load and hold the light load with a yarn and cut it for starting the experiment. We wait till the heavy load is constant and release the lighter load. We tested with 4 to 1 mass ratio, 85° angle, 75 cm thread length and 0.35 friction coefficient. We see the light load spinning around the rod and prevent the heavy load from hitting the floor. The experiment was recorded with 240 fps slow motion as the mobile camera is in the direction of the rod from side. Different thread lengths, mass ratios and initial angle were measured .

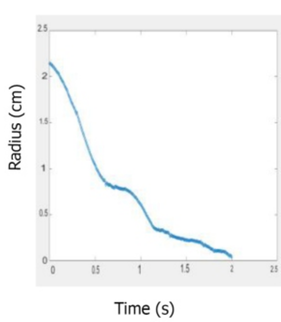
3 Results and Conclusion

After a series of experiments we found, the light load turns around the bar in a form of a spiral then friction and its velocity stop the heavy mass. Hence, the motion is divided into two phases, phase 1: rotation and falling and phase 2: rotation (when the heavy mass no longer falls). It has shown that by increasing the ratio of the masses the velocity of the light load increases but the number of loops decreases. And also if the light mass is released from a higher angle it laps faster and makes more turns because its potential energy is more.

By reducing the length of the string (radius of rotation), rotation velocity increases so the string sweeps around the rod and causes the heavy load stops. If the angle, mass ratio, and the length of string is not big enough the light load doesn't have much force to sweep and the heavy load falls down (Fig. 3 a and b)



(a)



(b)

Fig. 3: a) angle versus time (light load) , b) radius versus time (light load)

According to the comparison between theory and experiment (Fig.4) , our experiment is correct. The angle shows the number of spins, so 1000° shows 3 spins with 4 to 1 mass ratio. We have a two-phase motion, which means the light load stops the heavy load but the heavy load starts falling and stops again when the light load keeps spinning.

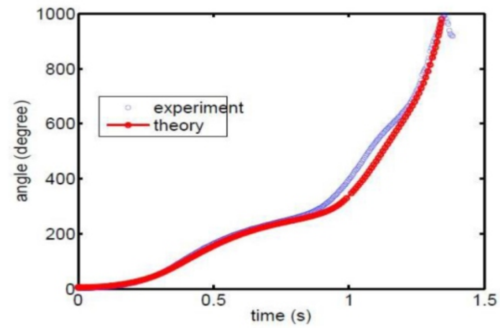


Fig. 4: Comparison between theory and experiment

References

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