How many licks does it take to get to the center of a Tootsie Pop?

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I. INTRODUCTION

Our goal was to find how many licks it would take to get to the center of a tootsie pop. This program was inspired by pure interest in an unsolved question from our childhood. With basic experimentation and mechanics, we were able to measure and calculate the number of licks required to reach the center of our tootsie pop. These calculations can be further used (with respective assumptions) to calculate how meteoroids and comets are disintegrated in different planetary atmospheres.

II. PROCEDURE

For accuracy, we took actual measurements of frictional force against the tootsie pop for a constant frictional force. By measuring the angle at which we had our "lab-rat" lick the tootsie pop, we were then able to measure the difference in radii from the center of our pop. These measurements were used to find our coefficient of static friction. By laying the tootsie pops on a tongue, we allow gravity to slide the candy off the tongue. During the experiment, the angle at which gravity allowed the candy to slide was at approximately 5°. On a dry tongue, we measured an angle of 40° from 90° normal to the ground. We used these measurements to calculate the coefficient of static friction with the equation:

$$F_f = \mu F_N, \quad \text{where} \quad \mathrm{N} = mg\cos\theta \tag{1}$$

By now, we measured that the average has 18.13g of candy around the central stick. We also assumed that it would take the same amount of time to remove one side as it would on the other side of the tootsie pop. We then said our entire volume we were concerned with was:

$$\frac{2}{3}\pi r_a^2 \tag{2}$$

Where R_a was the initial radius and R_b is the radius where one lick has removed a surface off of the candy. To do this for a computer, we made it integrate each surface that one lick removes from the volume of the candy. This was done by approximating how many surfaces make up the density of one tootsie pop. For visualization, we integrated the volume of a hemisphere (3d integral for volume of hemisphere) from a radius of 0.028m to 0.

III. CALCULATIONS

For our calculations, we are only concerned with removing half of the tootsie pop's volume. This lick applies a force onto the candy so that a surface is removed from half of the candies volume. Proportionality constant K represents seconds per kilogram. As a function of time we found a function for the change in radius per lick was:

$$dr = KF_f dt \tag{3}$$

We the used dr as a dependent variable being subtracted from our initial radius. This gives us the next radius after one surface is removed. In our code, we named this newRadius which is represented here as:

$$R_b = R_a - dr. \tag{4}$$

Since we made calculations for a dry tongue and a wet tongue, we will change the change the friction constant according to what tongue is dissolving the candy. Finally, we use the new radius, R_b, to calculate the difference in volume lost by the lick. The new volume, V, is:

$$V = \frac{2}{3}\pi R_a^2 - \frac{2}{3}\pi R_b^2. \tag{5}$$

For randomness (since there is no way to average the type of lick anybody uses to enjoy a tootsie pop), we added a random number generator to represent different type of licks. This random number was our input for our proportionality constant K in equation (3).

IV. FINDINGS AND CONCLUSION

From running our code, we found that the approximate average amount of licks to get to the center of a tootsie pop, with a range of 80-120 $\frac{s}{kg}$, was from 636 - 957 licks. Unit analysis shows that the licks are found by how many changes in radii are made to get to the center of the tootsie pop. With a varying time constant, you can idealize the type of lick that is being used to enjoy the candy. The constant is interestingly enough scaling how long it takes to apply enough force to remove a surface from our tootsie pop.