Dynamic Bungee Experiment

Taylor Dockery and Julia Mayol

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Physics 113

Section 03

Professor Cumming

“Oh my honor, I have neither given nor received any unacknowledged aid on this lab report.”
Introduction

In this lab, the goal was to test the relationship between the length of an un-stretched bungee to the maximum length of a bungee and mass when they are dropped. The purpose was to figure out the relationship between the bungee’s stretch when attached to a falling mass and the bungee’s static length. Knowing the dynamic properties of the bungee will make it easier to determine the proper length of elastic for the egg drop.

The equation used to relate the potential energy of the object to the kinetic energy is

\[(Equation \#1)\]

\[mgh = \frac{1}{2}kx_{\text{max}}^2\]

\[m = \text{mass of hanger}\]
\[g = \text{gravitational acceleration}\]
\[k = \text{“bungee constant”}\]
\[x_{\text{max}} = \text{maximum length of bungee stretch}\]

With the information presented in this equation, the potential energy of the mass can be related to the elastic potential energy of the mass attached to the bungee when the mass reaches its lowest point.

Figure #1: Setup

Setup

The un-stretched length of the bungee was first measured by placing the bungee over a horizontal tape measure. The cord was straightened for accurate measurement, but was not stretched. After measuring the un-stretched length of bungee, the mass hanger (100 g) was attached to the bungee with a tight knot. One individual held the mass as portrayed by the “Before Drop” position in Figure #1, while the other individual positioned an iPhone equipped with a slow motion camera perpendicular to the height that the mass hanger was expected to fall to. If it was determined that the camera was not perfectly level with the mass at the lowest point of the drop, the camera was repositioned and the drop was re-done. Paper was also placed behind
the drop zone so that it would be easier to see on the camera where the bungee reaches during the fall.

**Procedure**

The mass was dropped at least four times for each length of bungee. The distance that the bungee fell was recorded as height, which is the un-stretched length (L) plus x (the difference in length of the bungee’s dynamic stretch length and static length). Height (h) was measured from the bungee support to the lowest point the that attached the mass hanger reached with each drop. High speed footage was analyzed to see where on the measuring tape (that was hung from the top of rod that the bungee was attached to) the knot reached. The reason why this measurement technique was chosen is so the experimental values and conclusions can be applied to different sized masses on the end of the bungee. Two centimeters were subtracted from the determined h because of the overlap between the rod and the tape. A total of six lengths were tested, and the relationships were recorded.

**Results**

**Figure #2: Results**

<table>
<thead>
<tr>
<th>L(cm) +- .1 cm</th>
<th>L+x (cm) +- .2 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.5</td>
<td>62.5</td>
</tr>
<tr>
<td></td>
<td>61.8</td>
</tr>
<tr>
<td></td>
<td>61.1</td>
</tr>
<tr>
<td></td>
<td>61</td>
</tr>
<tr>
<td>36.5</td>
<td>103.7</td>
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<td>104.2</td>
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<td></td>
<td>31.8</td>
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<tr>
<td></td>
<td>32.2</td>
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</table>

<table>
<thead>
<tr>
<th>L (m) +/- .001 m</th>
<th>xmax (m) +/- .002 m</th>
<th>av h (L+x) (m) +/- .002 m</th>
<th>GPE (J) +/- .002 J</th>
</tr>
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<tbody>
<tr>
<td>0.110</td>
<td>0.191</td>
<td>0.301</td>
<td>0.29498</td>
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<td>0.161</td>
<td>0.299</td>
<td>0.460</td>
<td>0.451045</td>
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<td>0.215</td>
<td>0.381</td>
<td>0.596</td>
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<td>0.365</td>
<td>0.651</td>
<td>1.016</td>
<td>0.99568</td>
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<td>0.434</td>
<td>0.761</td>
<td>1.195</td>
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<tr>
<td>0.556</td>
<td>1.007</td>
<td>1.563</td>
<td>1.531495</td>
</tr>
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</table>

**Figure #3: Averaged heights**
Taylor Dockery
Bungee #2

<table>
<thead>
<tr>
<th>16.1</th>
<th>32.3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>48.2</td>
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<tr>
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<td>48.8</td>
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<tr>
<td></td>
<td>47.5</td>
</tr>
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<td>47.6</td>
</tr>
</tbody>
</table>

Figure #4: Un-stretched length correlated with length

Figure #5: Potential energy vs Length
**Results, Continued**

The mass was dropped at least four times for the six masses on the hangar, and recorded in Figure #2. The four values for each mass were then averaged and recorded in Figure #3.

The results of our trials were linearized on two separate graphs. The first graph, Figure #4, shows the relationship between $x_{\text{max}}$ and height vs the un-stretched length. Both lines were linear, and had a negligible y-intercept. Because the y-intercept is negligible, the graph was adjusted with zero as the y-intercept. Note that the height and $x_{\text{max}}$ are proportional to each other.

The initial purpose of the experiment was to determine a $k$ value in relation to $\frac{1}{2} x^2$ (as explained in Equation 1). However, the value of $x_{\text{max}}$ is proportional to the height and length. Because of this relationship, length can be related to $k$. Length was graphed in Figure #5 with a relation to gravitational potential energy ($gmh$). The graph was linear, so there was no need to raise $L$ to an exponent for linearization to figure out a value for $k$. After some algebraic manipulation, a new equation was formulated to determine the height of a bungee with a set mass and an un-stretched length:

\[
(Equation \#2) \quad h = \frac{kL}{(mg)}
\]

$h$: total height of bungee fall  
$k$: “bungee constant”  
$m$: mass of hanger  
$g$: gravitational constant

This equation was derived from the graphical relationship between $mgh$ (gravitational potential energy) and $L$. Unlike Equation #1 for a normal spring, the elastic potential energy for the bungee is not based on the squared value of displacement. An equation that will display the relationship between $L$ and $h$ is more useful in determining the proper length for the bungee to use for an egg drop.

In testing the proposed equation, the equation yielded an average of %1.2 error, which is less than the %3 percent experimental uncertainty, so this experiment is accurate.
**Discussion**

This experiment was helpful in determining what length of bungee to use for a mass to drop a certain distance. Equation #2 accurately measures this length within experimental uncertainty. The most important information gathered from this experiment is the linear relationship between the $x_{\text{max}}$ and Length, which made it simple to formulate Equation #2. Although the bungee doesn’t follow Hooke’s Law, the bungee has physical properties that are very similar.

Uncertainty arose from multiple sources during the experiment. One of most obvious sources of uncertainty came from the knots that were tied to attach the bungee to the mass hangar and to the suspending apparatus. The knot was tied as tightly as possible, but the fact that the knot contributed to some of the stretch length of the bungee is still significant. This stretch was most evident in the slow motion video, which is why we decided to measure to the top of the knot. However, there was no way to make the same adjustment for the top of the bungee. There is also no way to guarantee that the bungee cord retained constant elasticity throughout the experiment. The masses were removed from the cord to give it a rest after every drop to minimize this issue.

In conclusion, this experiment was useful in determining a workable equation to formulate the necessary length of bungee to drop a specified mass a certain distance without it touching the ground. Our experiment was conducted in the best way to minimize uncertainties, and was accurate.