**BME 460: Quantitative Analysis Description**

**Quantitative Analysis**. Document a quantitative analysis of a pertinent aspect of your project. This analysis will account for 25% of the total lab notebook score. This analysis should be performed individually, not as a team. Total score of [10] based on:

[ ] a. (5) Problem description, execution, and conclusions clear, appropriate, well explained?

[ ] b. (5) Statistical analysis: appropriate, clearly presented and described?

Minimum requirements: Graph of experimental data showing mean/std. dev. for each point, with best-fit and correlation coefficient, OR hypothesis testing analysis.

Start with a clear explanation, and a figure to show the overall theoretical and/or experimental setup. Provide thoughtful conclusions.

NOTE: *Team members may perform QA on the same aspect of their projects; however, each QA must be performed and reported individually.*

**QA Example: Shopping Aid for Wheelchair**

This project involved a basket attached to a custom tray, mounted in front of the client.

Notes:

* Measuring forces using a spring scale or digital force gage often provides a basis for a meaningful QA (spring scale in lab; DFG available – ask)
* This QA compares theory with experiment -- not absolutely necessary, but makes for an especially strong QA
* Should have shown the std. deviations on the experimental graphs
* Should have included a graph comparing theory with experiment
* Should have included a best fit line, with correlation coefficient
* Problem, theory, and experiments are well explained
* Conclusions are appropriate

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**APPENDIX C: QUANTITATIVE ANALYSIS**

The objective of the quantitative analysis is to estimate and measure the amount of horizontally applied force necessary to tip the basket in order to assess the effectiveness of the device in real situations where heavy objects may be accidentally dropped into the basket. In addition, the effectiveness of the Velcro strips added to prevent tipping can be measured and analyzed. First, we estimated the applied force necessary for basket tipping without Velcro. Then, a spring scale was used to measure the experimental applied force as various weights were loaded into the basket to simulate a load of groceries during shopping.

**Theory**

The basket and board are considered the system in this problem. The basket is at equilibrium if the net forces and net moments sum to zero. Under low applied forces, the system may be in equilibrium, as there are no moments acting on the system and the forces sum up to zero. This is displayed in a free-body diagram in Figure C-1, which shows a side view of the basket and Horizontal Basket Tray.

y

*Fapplied*

*FNormal*

Basket

A

x

*Fpegs*

Support Board

*Fgravity*

*Figure C-1: Free Body Diagram of System at Rest*

ΣFx = Fapplied + Fpegs = 0

ΣFy = FNormal + Fgravity = 0

ΣM = 0

As shown in Figure C-1, when the applied force is low, the torques applied to the center of gravity from the pegs and the applied force cancel. The forces also cancel each other out. However, as the basket begins to tip, a theoretical pivot point is created at point “A”. The sum of the forces still cancels out, as the Fapplied is now cancelled by the force in the x-direction applied by the pivot point. The force of gravity (the weight of the basket) Fgravity is also balanced by the force in the y-direction from the pivot joint.

At the pivot joint, there are two significant moments. One is caused by the center of gravity of the basket and its groceries, while the other is caused by Fapplied. These moments are shown in Figure C-2.

x

y

rgravity

Center of gravity

*Fapplied*

rapplied

A

*Fgravity*

*Figure C-2: Free Body Diagram of System Tipping*

The moment equation thus becomes as follows:

ΣM = Fapplied(rapplied) + Fgravity(rgravity)

When the moment resulting from Fapplied overwhelms the moment generated from the weight of the system, the basket begins to tip. The critical value of Fapplied was calculated using weights of five pound increments, starting from two pounds, as the empty basket weighs two pounds. The theoretical values of Fapplied are listed in Table C-1. The theoretical moment arm rapplied is the height of the basket, which is 10.5”, while the theoretical moment arm rgravity is roughly assumed to be half of the Horizontal Basket Tray width, which is 3.5”.

|  |  |
| --- | --- |
| **Weight of Basket (lbs)** | **Fapplied (lbs)** |
| 2 | 0.7 |
| 7 | 2.3 |
| 12 | 4.0 |
| 17 | 5.7 |
| 22 | 7.3 |

*Table C-1: Calculated Values of Fapplied Required to Tip the Basket for Various Weights*

**Experimental Results**

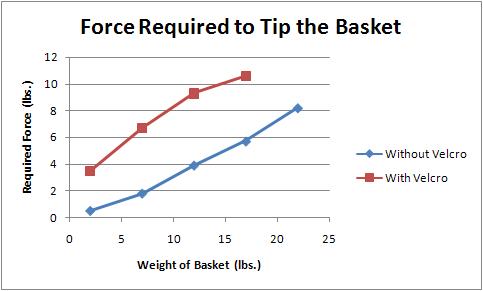
Next, we measured the Fapplied necessary to tip the basket at the corresponding weights, both with and without the Velcro strips in use. Five trials were done at each weight both with and without using the Velcro strips. The averages and standard deviations of Fapplied are listed in Table C-2.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Without Velcro** | | **With Velcro** | |
| Weight (lbs) | Mean (lbs) | Standard Deviation (lbs) | Mean (lbs) | Standard Deviation (lbs) |
| 2 | 0.5 | 0 | 3.5 | 0.35 |
| 7 | 1.8 | 0.27 | 6.7 | 0.76 |
| 12 | 3.9 | 0.22 | 9.3 | 0.67 |
| 17 | 5.7 | 0.27 | 10.6 | 0.42 |
| 22 | 8.2 | 0.76 | >16 | -- |

*Table C-2: Experimental Values of Fapplied to Tip the Basket for Various Weights*

As can be seen by comparing values from Tables C-1 and C-2, the actual applied force necessary to tip the basket without Velcro is fairly close to the theoretical value. The error can be attributed to a few factors. First, the measurement error of the spring scale, which has increment marks of 0.5 lbs. and has a range from 0-50 lbs., can be fairly large. Therefore, there may be some error even after repeated trials. This factor also limited our ability to obtain an accurate reading with 2 lbs. of weight, as 0.5 lbs. is roughly the smallest reading possible using the spring scale. In addition, the actual moment arms may be slightly different from the theoretical values used. The direction of experimentally applied force also may not be perfectly horizontal. Lastly, the basket is not a rigid object, and the sides of the basket tended to tilt towards the direction of the force without any movement from the bottom surface of the basket, adding some error to the results.

The application of the Velcro strips greatly increases the applied force necessary to tip the basket, shown in Figure C-3. At a weight of 22 pounds, the maximum force that we could generate by pulling on the spring scale with one arm did not tip the basket. The required force for tipping was also fairly high at weights of 12 and 17 pounds.



*Figure C-3: Experimental Values of Fapplied to Tip the Basket for Various Weights*

**Discussion**

Practical situations that may result in the tipping of the basket include the dropping of heavy items like laundry detergent onto the basket, as well as accidental collision with a rigid object or person. These events generate forces that are somewhat different from the experimental applied force considered in our analysis. First of all, it is very unlikely that a bottle of laundry detergent dropped into the basket will generate a force equivalent to a concentrated force at the very top of the basket. Instead, the moments generated will tend to be distributed along the basket wall with moment arms less than the height of the basket. It is also highly improbable that the item is traveling significantly fast in the horizontal direction unless thrown. In addition, the sides of the basket are not rigid, so the basket may just angle off slightly rather than tip. Also, the experiment does not take into account the instantaneous extra weight that a heavy object will add to the weight of the basket while generating a horizontal force. Taking all of these considerations into account, a case of laundry detergent weighing roughly 7 pounds will generate much less than the equivalent of a Fapplied of 7 pounds, which means that it is probably not a concern unless the basket is nearly empty. If that is the case, then the basket may tip, but the consequences incurred would then be very small, as there would probably be very little weight in the basket for causing injury. Of course, the heavy item just dropped may pose a threat for injury, but no more so than if someone were to drop the same item in another situation.

The case of collision does not pose as significant of a danger, as the speeds encountered in a grocery store while shopping with our clients did not come generate the force necessary to tip the basket at any significant weight. The exceptional case may be if a person were to fall onto the device after tripping. Compensating for this case would require much better preventative tipping measures. However, there is a large risk of injury if this situation were to occur, regardless of whether or not the device tipped or not, and installing preventative measures for this case can be deemed impractical.

To conclude, the analysis has shown that the Velcro strips on the basket provide significantly better tipping prevention than the rubber pegs alone. With the Velcro strips applied, the basket is safe from tipping in almost all realistic cases, save for the case where an empty basket may be tipped by a very heavy item, resulting in an outcome almost identical to the dropping of the heavy item alone.