Lab 103: Translational Static Equilibrium -- Force Table

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1. OBJECTIVE AND BACKGROUND

The objective of Lab 103 is to further expand the students' knowledge of static translational equilibrium where the vector sum of forces is zero. Furthermore, another objective is to experimentally test the vector nature of force and to practice manipulating the vectors to attain a better understanding of vectors. Lastly, the final objective is to find unknown tensions and directions in a system of strings connected to a central ring. For this lab, it was essential to keep in mind Newton's Second law $\sum F = ma$ where F is equal to the force, *m* is equal to the mass, and *a* is equal to the acceleration. Another mathematical concept that comes in handy is the Law of Sines, $\frac{sinA}{a} = \frac{sinB}{b} = \frac{sinC}{c}$, and the Law of Cosines, $a^2 = b^2 + c^2 - 2ab(cosA)$.

2. EXPERIMENTAL PROCEDURE

This lab experiment has many steps to it, but it is crucial that all of them are done correctly. Before starting anything, the equipment and tools should be checked in order to verify that everything needed for the lab is there. Three knotted strings are placed around the centering pin for the force table, each string being set to a certain angle on the force table. Then weights are hung at the end of the nots which run over the pulley at different locations/angles around the force table. In the first lab, we were given θ_a, θ_b, θ_c along with the T_a and had to determine T_b and T_c. Using Newton's Law, it was quite simply to calculate T_b and T_c. However for the second part, we were given everything but T_c and θ_c. Once again, we used Newton's second law to find T_c, but used Law of Sines to calculate θ_c. In the final part, we were given everything but θ_b and θ_c. Once again, Newton's second law was used to calculate the tensions, but the Law of Cosines was used to calculate the angles θ_b and θ_c.

3. RESULTS: Calculations

Case 1:

$m_a = 120\ g = 0.12\ kg$; $\theta_a = 0°$; $\theta_b = 120°$; $\theta_c = 240°$

$T_a = ma = (0.12\ kg)(9.8\ m/s^2) = 1.176\ N$

Due to the fact that tension is a force, Newton's Second Law, $\sum F = ma$ *to solve for tension.*

$T_a = T_b = T_c$
$T_b = 1.176\ N$
$T_c = 1.176\ N$

Because the angular difference between each vector is the same at 120, the tension of all three vectors is the same, and the mass of the three vectors is the same.

$$\%\ Error = \left|\frac{Theoretical\ Tension - Experimental\ Tension}{Theoretical\ Tension}\right|(100) = \left|\frac{1.176\ N - 1.176\ N}{1.176\ N}\right|(100) = 0\%$$

Percent error for both the tension of vector A and the tension of vector B as well.

Case 2:

Vector a: $m_a = 60\ g = 0.06\ kg$; $\theta_a = 0°$
Vector b: $m_b = 80\ g = 0.08\ kg$; $\theta_b = 90°$

$T_a = ma = (0.06\ kg)(9.8\ m/s^2) = 0.588\ N$
$T_b = ma = (0.08\ kg)(9.8\ m/s^2) = 0.789\ N$

Since tension is a force, we can use Newton's Second Law, $\sum F = ma$ *to solve for tension.*

$$\%\ Error = \left|\frac{Theoretical\ Tension - Experimental\ Tension}{Theoretical\ Tension}\right|(100) = \left|\frac{0.98\ N - 0.98\ N}{0.98\ N}\right|(100) = 0\%$$
$$\%\ Error = \left|\frac{Theoretical\ Angle - Experimental\ Angle}{Theoretical\ Angle}\right|(100) = \left|\frac{233.13° - 233.0°}{233.13°}\right|(100) = 0.056\%$$

Case 3:

Vector a: $m_a = 100\ g = 0.1\ kg$; $\theta_a = 0°$
Vector b: $m_b = 240\ g = 0.24\ kg$
Vector c: $m_c = 260\ g = 0.26\ kg$

$T_a = ma = (0.1\ kg)(9.8\ m/s^2) = 0.980\ N$
$T_b = ma = (0.24\ kg)(9.8\ m/s^2) = 2.352\ N$
$T_c = ma = (0.26\ kg)(9.8\ m/s^2) = 2.548\ N$

Due to the fact that tension is a force, Newton's Second Law, $\sum F = ma$ *to solve for tension.*

$$\%\ Error = \left|\frac{Theoretical\ Angle - Experimental\ Angle}{Theoretical\ Angle}\right|(100) = \left|\frac{90° - 90°}{90°}\right|(100) = 0\%$$
$$\%\ Error = \left|\frac{Theoretical\ Angle - Experimental\ Angle}{Theoretical\ Angle}\right|(100) = \left|\frac{247.38° - 246°}{247.38°}\right|(100) = 0.558\%$$

4. Discussion

Throughout this lab, my group was exposed to many different physics theories and principles in real life. The primary principles/theories we learned in this lab was Newton's Second Law and how to manipulate vectors to attain a better understanding of vectors. Newton's second law was the core of this lab and without it, we could not have solved for the theoretical tensions and angles. When the lab was done, the percent error calculated by myself was 0% for case 1, a very similar 0.05% for case 2, and 0.56% for case 3. From this, it can be concluded that our theoretical results were consistent with the experimental data and that our data confirms the static equilibrium condition. These are incredibly low percent errors which means that we did the experiment correctly, but still not all of them were perfect, meaning there were still errors to an extent and these errors could have been due to countless reasons. For one, there was no way to position the string accurately onto the degree tick mark and this all came down to the accuracy of the human eye . Another possible error in play could have been the masses used to hang on the strings because the masses looked old and worn out, meaning that it is possible they weigh slightly less than advertised.

5. Conclusions

Similar to the labs in the past, much has been learned from this experiment as expected. I learned that if the components of the vectors add up to be 0, then the ring will appear to be in a levitation state, known as equilibrium. Another thing I learned is that if the angle of one of the vectors is changed, then mass can be added or removed in order to still keep the system in equilibrium. Additionally, one of the biggest things I observed was that this force table lab yielded the lowest percent error, meaning that this lab is generally the most accurate compared to others. One thing that could have been improved was the force table because the labeling of the angles was only listed as whole angles, and it could have been more accurate by going to the tenths. Another thing that could have been improved were the weights because some of them had a slight rust on them or the labeling of how heavy the weight is had worn off.

6. Reference

"Addition of Forces." *The Physics Classroom*,
www.physicsclassroom.com/class/vectors/Lesson-3/Addition-of-Forces.

"Lab 1 - Force Table." *Volumetric Glassware*,
www.webassign.net/labsgraceperiod/ncsulcpmech2/lab_1/manual.html.

7. Raw Data

Case	Quantity Given	Quantity to be determined	Theoretical Answer	Measured Value	% diff
1	Ta = 1.176 N θ_a = 0	Tb	1.176 N	1.176 N	0
	θ_b = 120 θ_c = 240	Tc	1.176 N	1.176 N	0
2	Ta = 0.588 N θ_a = 0	Tc	0.98 N	0.98 N	0
	Tb = 0.789 N θ_b = 90	θ_c	233.13	233	0.056
3	Ta = 0.98 θ_a = 0	θ_b	90	90	0
	Tb = 2,352 N Tc = 2.548 N	θ_c	247.38	246	0.558