Lab Report 3

Physics 261-005

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**Objective:** The objective of the lab is to understand the fundamentals of forces and the vector components that we use to describe and apply that understanding to the end of learning to find the sum of vectors through graphical, algebraic, and experimental methods. A force table is used to accomplish obtaining data about vector sums through experimental location of the point of equilibrium, which is then compared to calculated results for the theoretical vector sum.

**Theory:** A force table is a device that is used to experimentally determine at what angles forces of different magnitudes come into equilibrium. The magnitude of each of the forces is quantified by the amount of weight that is added to the arms of the force table, and the equilibrium can be determined by changing the angular position of the participating forces. Equilibrium can be identified when the ring to which all the arms are attached is pulled to the center of the table. The x and y components of the forces can be determined using the following formulae:

Eq.(1)

Eq.(2)

Where *x* and *y* are the x and y components of a vector respectively, *N* is the magnitude of the force in Newtons, and *Θ* is the angular position of the force. The x and y components of the equilibrant can be determined by negating the sum of the x and y components of the addend vectors:

Eq.(3)

Eq.(4)

In this experiment, the magnitude of the forces will be represented by weights hung from strings which are the arms of the force table.

**Procedure**: For each set in this procedure, certain data was provided to us in the lab manual. Initially, we used the given data about to the forces to calculate the derivable information for the vectors for which enough data was given. After calculations were made and theoretical information was yielded, the given information about the forces was applied on the force table. Each string on the force table was assigned to one of the vectors in the set. After the known data was given its representations on the force table, the unknowns were determined experimentally by changing the position and weight as needed of the respective table arm until equilibrium between all the forces was identified. The experimentally obtained measurements were then compared to the calculated theoretical results. ma

**Data:** In each of the experiment sets, some data is provided, which is used to derive theoretical data. Data obtained from theoretical or experimental calculations are emboldened to highlight the results.

Below is the table of results from Set 3-1.



Table 1. The results of the first experiment set.

The results in Table 1 do not stand out for any reason, and the margin of error is normal for this type of experiment. This was the simplest set out of the five, so for analysis it will help to use this set as a control for comparing the other four experiment sets to.



Table 2. The results of the second experiment set. With respect to data given, the only difference is that the angles of force A and force B have changed by 45 degrees.

There is hardly any difference between the results in Table 2 and that in Table 1 other than the magnitude of the error margin, which is still within expectations. The difference in angular position will be discussed in the analysis.



Table 3. The results of the third experiment set. In this set, the angle of force B was unknown, but the x component of the force was given.

There is more variance in the given data for the set in Table 3 than previously encountered. Both the weights and the angles of the addend forces are different, and so the results for the negating force will differ in more ways than just angular position. Also notice that the angle for force B is not given, but the x component is.



Table 4. The results of the fourth experiment set. In this set, the angle of force B does not cleanly fit in a 45 or 30 degree increment pattern.

The results in Table 4 are more like the sets in Table 2 and Table 1 in that the mass of the arms’ weights are given alongside their angular positions, but we see similar variance to that in Table 3 because both the given masses and angles differ from the originals. The angle for force B is also at an odd increment, so the resulting axial components will be more diverse.



Table 5. The results of the fifth experiment set. In this set, the mass of the negating force vector is given, whereas the mass of one of the addend forces is unknown. However, the weight and axis components is given for all of the addend force vectors.

Table 5 is the curveball set. The mass component of the negating force vector is given, but the weight and angle of force B are unknown. The angle of derived x and y components of the equilibrant could not be calculated until the components for force B were determined.

**Analysis:** For those sets where the weight of an arm was not known but the mass was known, the weight was simply calculated by using the formula:

Eq.(5)

Where g is earth’s gravitational constant, 9.81 m/s2. In the inverse case, such as force B in Table 5, the mass component was derived by dividing the weight by 9.81 m/s2.

In Table 3, the angular position of force B was not given, but the x component of the vector was. With that in mind, the angular position of force B could derived using the inverse of Eq.(1):

Eq.(5)

The angle for force B in Table 5 was determined in a similar fashion.

All the sets’ totals represent the error in the experimental calculation of the equilibrant. The source of this error is that the angle of the equilibrant was only estimable to one decimal point due to the markings on the force table, and the weight was only estimable to the smallest weights available, which in some cases ranged from 10 grams to 50. To quantify and visualize the margin of error and verify that the seen margin is normal, the percent error formula was implemented:

Eq.(6)

Where *theoretical* is a calculated equilibrant vector angle or magnitude and *actual* is an experimentally determined one for a set of addend vectors. The theoretical angle is determined for the equilibrant:

Eq.(7)

Where *N* is the weight of the force vector. The weight of the vector can be found using Pythagorean’s Theorem on the axial component vectors:

Eq.(8)

When plugging in the theoretical axial components of each into Eq.(7), and comparing that angle with the angle calculated for each experimentally derived equilibrant using Eq.(6), the following percent errors were recorded:

Set 1: 5.12%

Set 2: 0.05%

Set 3: 1.67%

Set 4: 0.01%

Set 5: N/A: Angle was given

Percent errors for equilibrant magnitudes, using the magnitudes calculated with Eq.(8) for Eq.(7) above, are as follows:

Set 1: 0.01%

Set 2: 0.02%

Set 3: 5.19%

Set 4: 0.01%

Set 5: 0.02%

The experimentally determined equilibrants in set 1 and set 2 are equal in magnitude, even though their angles and axial components are quite different. The reason for this is due to the fact that, between set 1 and set 2, force A and force B maintain a 90 degree angle with each other, so the magnitude of the force to bring the resultant to equilibrium will have the same magnitude at a different angular position.

If the x-component of an angle is equal to 0, Eq.(7) cannot be used. Doing so will cause a divide by zero error, which we should avoid. We are in luck, though, because finding the angle of a vector with an x-component of 0 is quite simple. Vectors with an x-component of 0 and a positive y-component will point straight up; having an angle of 90 degrees. If in such a case the y-component were negative, the angle would be -90 degrees. The quadrant of an angle that would be found in Eq.(7) can be predetermined by looking at the signs on the components of the vector. If the x-component is positive, the vector will point to the right. Likewise, if the y-component is positive, the vector will point up. The opposite is true for both if the respective components are negative.

**Conclusions:** According to the data collected, the equilibrant of a set of vectors is the negating vector to the sum of all addend vectors; if you add the axial components of a set of vectors, the axial components of the equilibrant will be the opposite of those totals. The small margins of error that arose during this experiment are a result of the limits of the precision in measurement that the force table and weights provide, as well as the need for “eyeballing” equilibrium. The human eye is not quite precise enough to make such judgement. Overall, I think the goal of the experiment, to be able to understand and apply the fundamentals of vector addition, was reached. It might be interesting to see how much more precise the experiment could be if the force tables restricted placement of the weight clamps only to certain places on the table separated at constant small intervals.