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**Lab 3: The Force Table**

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PHYS 261 – 005

With:

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**Objective**

The objective of this lab was for us to familiarize ourselves with the mingling of force vectors using a force table. In doing so, we would learn to add a series of vectors together by a variety of methods to find the resultant and the equilibrant vectors in the set.

**Theory**

Vectors are a mathematical tool used to describe objects or phenomena that can be identified by a given direction and magnitude. In this lab, that phenomena are going to be force and its vector nature. When two vectors are added together, the sum of the two vectors is going to be dependent on the sums of that vectors axial components, as opposed to the general magnitudes themselves. Therefore, the direction of the vectors is important: the magnitude on a vector may not be negative but the components can be.

When a set of vectors are added together, and the vector sum is returned, the result is called, accordingly, the resultant. When the addend vectors are set in place on the force table, the resultant vector will pull the system in an identifiable direction. The idea is that for every vector, including this resultant, there exists a vector that, when added together, result in equilibrium. This vector is also named quite conveniently the equilibrant.

For every vector *F* at some angle *θ*, the axial components of the vector can be found with the following formulae:

Eq. 3-1

Eq. 3-2

The axial components of a resultant vector are simply found as follows:

Eq. 3-3

Eq. 3-4

The resultant can then be calculated using the Pythagorean Theorem:

Eq. 3-5

And the angle of the resultant can be found using the components in an inverse tangent:

Eq. 3-6

**Procedure**

The procedure for this lab involved arriving at experimental results for an equilibrant vector using a force table. In this lab, there were five different sets of setups for the force table which defined specific masses and angles at which to position the arms therefor. After placing the defined weights, our task was to experimentally determine the angle and magnitude of the equilibrant on a trial-and-error basis using the remaining arm of the force table. The components of the experimentally determined equilibrant were compared to the components of the theoretically determined to verify the theory described above.

**Data**

For each set of the experiment, a table of force vector properties was given with certain information filled out. In the tables below, the information in bold marks the information provided from which the rest of the information in the tables was derived.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Vector Set 1 | |  |  |  |  |
|  | *Mass (kg)* | *Weight (N)* | *Angle (°)* | *x component* | *y component* |
| *A* | **0.15** | 1.47105 | **0** | 1.47105 | 0 |
| *B* | **0.2** | 1.9614 | **90** | 0 | 1.9614 |
| *A+B* |  |  |  | 1.47105 | 1.9614 |
| *E* | 0.24 | 2.3544 | -53.01 | -1.41659 | -1.88055 |
|  |  |  | *Total* | 0.05446 | 0.08085 |

**Table 3-1.** The table of information for the first set of vectors. The angle and mass of each arm on the force table was given, and the equilibrant was calculated through trial and error. The totals at the bottom represent the discrepancy between the theoretical and the actual equilibrant.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Vector Set 2 | |  |  |  |  |
|  | *Mass (kg)* | *Weight (N)* | *Angle (°)* | *x component* | *y component* |
| *A* | **0.15** | 1.47105 | **45** | 1.040189 | 1.040189 |
| *B* | **0.2** | 1.9614 | **135** | -1.386919 | 1.386919 |
| *A+B* |  |  |  | 0.34173 | 2.4271087 |
| *E* | 0.24 | 2.3544 | -82.2 | -0.319529 | -2.332617 |
|  |  |  | *Total* | 0.022201 | 0.0944917 |

**Table 3-2.** The table of information for the second set of vectors. The given information is similar to table 3-1 except for the defined angles. The methodology for filling out the table was the same.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Vector Set 3 | |  |  |  |  |
|  | *Mass (kg)* | *Weight (N)* | *Angle (°)* | *x component* | *y component* |
| *A* | **0.15** | 1.47105 | **30** | 0.49035 | 0.849311 |
| *B* | **0.2** | 0.9807 | 90 | **0** | 0.9807 |
| *A+B* |  |  |  | 1.274356 | 1.71645 |
| *E* | 0.22 | 2.1582 | -125.1 | -1.240976 | -1.795731 |
|  |  |  | *Total* | 0.03338 | -0.049281 |

**Table 3-3.** The table of information for the third set of vectors. For vector B, no angle was given. Instead, the angle was derived using the inverse of Eq. 3-1.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Vector Set 4 | |  |  |  |  |
|  | *Mass (kg)* | *Weight (N)* | *Angle (°)* | *x component* | *y component* |
| *A* | **0.1** | 0.9807 | **60** | 0.49035 | 0.849311 |
| *B* | **0.2** | 1.9614 | **200** | -1.843113 | -0.670838 |
| *A+B* |  |  |  | -1.352763 | 0.178473 |
| *E* | 0.14 | 1.37298 | -6.5 | 1.364134 | -0.155426 |
|  |  |  | *Total* | 0.011391 | 0.023047 |

**Table 3-4.** The table of information for the fourth set of vectors. This table is similar to tables 3-1 and 3-2 in terms of the given information and the derivation methodology.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Vector Set 5 | |  |  |  |  |
|  | *Mass (kg)* | *Weight (N)* | *Angle (°)* | *x component* | *y component* |
| *A* | **0.25** | **2.45** | **156.5** | **-2.247** | **0.977** |
| *B* | 0.17 | **1.67** | 93.981 | **-0.116** | **1.667** |
| C | **0.22** | **2.16** | **356.5** | **2.156** | **-0.132** |
| *A+B+C* |  |  |  | -0.207 | 2.512 |
| *E* | **0.25** | 2.45175 | 240 | -1.225875 | -2.123278 |
|  |  |  | *Total* | -1.432875 | 0.388722 |

**Table 3-5.** The table of information for the fifth set of vectors. This table is quite different from the others. Vectors A and C were entirely defined, but even more wild is that Vector B had no given weight, while the equilibrant vector did. The angle for Vector B was found using an inverse of Eq. 3-1, and then the angle of the equilibrant was determined on as normal with the set weight.

**Analysis**

For each of the resultant vectors calculated, the experimentally determined equilibrant was slightly off from the theoretical equilibrant. The theoretical equilibrants will be determined using Eq. 3-5 and Eq. 3-6. Comparing the theoretical resultants, and the experimental ones, which will be determined by inverting the found equilibrants:

Eq. 3-7

A percent error will be calculated between the angles and the magnitudes of the resultants of each set.

Eq. 3-8

**Set 1**

The theoretical resultant for Set 1 is determined as follows:

Thus, the percent errors:

**Set 2**

The theoretical resultant for Set 2 is determined as follows:

Thus, the percent errors:

Something acute to notice here is that the resultant vector for this vector set is very similar to the resultant for set 1, even though the components are very different. This is because the addend vectors, A and B, are the same magnitude in sets 1 and 2, and they are in both sets 90 degrees apart.

**Set 3**

The theoretical resultant for Set 3 is determined as follows:

Thus, the percent errors:

**Set 4**

The theoretical resultant for Set 4 is determined as follows:

Thus, the percent errors:

**Set 5**

The theoretical resultant for Set 4 is determined as follows:

2.160037

Thus, the percent errors:

An important thing to mention, though it wasn’t needed here, is that using Eq. 3-6 would not work if the angle of a vector was 90 degrees. This is because a vector with an angle of 90 degrees would have an x component of zero, which would have let to a divide-by-zero issue when using in a tangent function. The workaround is to use an inverse of Eq. 3-1 or Eq. 3-2 where you use an inverse sin or inverse cosine function to solve for theta. When using Eq. 3-6, you can tell which quadrant the vector points based on the signs of the components. A positive x would mean either quadrant 1 or 4, and a positive y would mean either quadrant 1 or 2. The opposite signs mean the opposite side of the cartesian plane.

**Conclusions**

For sets 1, 2, and 4, the percent errors were standard. There was no significant error between the theoretical and actual resultant angles or magnitudes in these cases. However, when looking at sets 3 and 5, something is obviously not right. The error in set 5 was somewhat expected: during the lab, we found ourselves having to compromise on the angle we found for the equilibrant force, even though that angle did not match up with a calculated angle using Eq. 3-6 on the equilibrant components. We decided to use the experimental angle, because the purpose of the lab was to find an experimental equilibrant. Therefore, set 5 is at peace with us. However, the error in set 3 is a surprise. It has caught me completely off guard, and I am not very sure why the error on the angle for the resultant is so off. It could dumb luck, but I believe it is possible that we made a mistake when reading the force table, so we are now faced what is possibly inaccurate data.

Whatever the case, the theory holds for sets 1, 2, and 4, and for holds in terms of the magnitude of the resultant for the remaining. The same cannot be said for the angles of sets 3 and 5 for obvious reasons. It is probably not best to say that the results of this lab do a good job of validating the vector nature of forces, but in most of the cases presented here, the theory applied quite fittingly.