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Force Table (5)

PHYS 211L – H02 Tuesday 10:05 am – 12:05 pm

Due: 9/13/16

**Abstract**

We investigated the concept of vector addition using a force table with pins, pulleys, weight hangers, varying masses, and protractors. We measured the vector components of several forces and how they sum to create an equilibrium. This was done by placing pulleys and weights at varying angles around a circular force table and observing how it affected the equilibrium of the ring at the center of the system. In practice, our results were almost entirely accurate with our calculations; with some testing we found that on average our results could be 6.667 degrees or 11.667 kilograms off while still maintaining equilibrium.

**Introduction/Background**

The origins of vector addition are so ancient that its origin is unknown and has been lost in time. There are some speculations that it may have made its first appearance in the works of Aristotle1. However, vectors as we know them today were studied in-depth beginning in the 19th and 20th century2. Using vector addition, we are able to break down certain abstract quantities such as velocity into their components and analyze the way it interacts with the physical world. Our experiment provides examples of force vectors being added to create an equilibrium on a central object that is being acted upon by the forces, a ring.

**Procedure**

For this lab we had a force table set up with three adjustable string pulleys. The force table was marked with degrees 0 through 360 so that measurements could be made about the angles of the pulleys and their respective exerted forces. For the first portion of the experiment, we tested the outcome of two pulleys 180 degrees from one another at 37 degrees and 217 degrees with unequal mass; one pulley had 100 grams and the other had 150 grams. We observed that equilibrium at the center of the force table was impossible and the system was only being held together by the rod holding the ring in place. However, once we equalized the masses, the ring was balanced in the center even without the aid of the rod. Using a protractor, a diagram of the system was drawn on a sheet of paper.

System 1

37°

100g

217°

100g

Next, we tested the effects of three pulley forces as opposed to two. Setting each of the three pulleys 120 degrees apart from each other, we gave each device an equal mass of 100 grams. The ring, once the rod was removed, was suspended in equilibrium at the center of the table.

120°

150g

240°

150g

0°

150g

System 2

To test the range of error, we moved one of the pulleys until the equilibrium was disturbed. This angle was recorded as ΔΘ. We also tested the error for mass. Mass was added to one of the pulleys until equilibrium was disturbed. This was mass was recorded as Δm. Using a protractor, a diagram of the system was drawn on a sheet of paper.

For the next portion of the lab, we tested a system that was not symmetric. We placed a pulley at 90° with 90 grams, one at 0° with 120 grams, and one at 217° with 150 grams. The system gained equilibrium at the center. Using a protractor, a diagram of the system was drawn on a sheet of paper. A separate vector diagram was drawn so that each vector was placed head to tail. The result was a triangle that led back to itself resulting in a 0 vector sum. This 0 vector sum represents the idea that the system is in equilibrium because all of the forces acting on the object total to be 0 in both the x and y plane.

217°

150g

90°

90g

0°

120gg

System 3

Using trigonometry, the x and y components of all the systems were recorded. In each case, the sum of the components was 0 in both directions. Next, we moved the mass that currently is placed at 217° to a position of 225°. With the equilibrium disturbed, we added and removed masses from the other two pulleys to restore balance. We found that with a new mass 105 grams on both the 90° and 0° pulley, equilibrium was obtained.

225°

150g

90°

105g

0°

105gg

System 4

For this system, ΔΘ and Δm were calculated as before. It was found that ΔΘ = 8° and Δm = 15 grams.

**Results/Analysis/Physics**

This experiment primarily dealt with the idea of vector summation along with the principle of forces and equilibrium. In every case where equilibrium was obtained, it was calculated that the summation of the vector components was 0. Each force, when added together, canceled out one another. Because there was no *net* force, there was no acceleration on the mass (ring). With a velocity and acceleration of 0, the ring was able to be held in place without the help of the metal rod. These ideas fall in line with Newton’s principles. The object that was at rest remained in rest because no outside net forces were acting on the object.

In this experiment, gravity was used to exert forces on the x and y plane using pulleys. The forces exerted on the ring were equal to the force of gravity acting on the masses on the pulleys. The force of gravity in this experiment agreed with the idea that force is equal to mass multiplied by acceleration.

System 1

|  |  |  |  |
| --- | --- | --- | --- |
| **Vector** | **Magnitude** | **X Component** | **Y Component** |
| 37 degrees | 100g | 79.8636g | 60.1815g |
| 217 degrees | 100g | -79.8636g | -60.1815g |

System 2

|  |  |  |  |
| --- | --- | --- | --- |
| **Vector** | **Magnitude** | **X Component** | **Y Component** |
| 0 degrees | 150g | 150g | 0g |
| 120 degrees | 150g | -75g | 129.9038g |
| 240 degrees | 150g | -75g | -129.9038g |

System 3

|  |  |  |  |
| --- | --- | --- | --- |
| **Vector** | **Magnitude** | **X Component** | **Y Component** |
| 0 degrees | 120g | 120g | 0g |
| 90 degrees | 90g | 0g | 90g |
| 217 degrees | 150g | -120g | -90g |

System 4

|  |  |  |  |
| --- | --- | --- | --- |
| **Vector** | **Magnitude** | **X Component** | **Y Component** |
| 0 degrees | 105g | 105g | 0g |
| 90 degrees | 105g | 0g | 105g |
| 225 degrees | 150g | -105g | -105g |

**Conclusions**

[*What was learned*]From this experiment we were able to derive that vectors can be added and subtracted from one another in the physical world rather than simply abstractly. We learned that, in order to accomplish this, vectors must be broken into their components so that they can be added to one another. Once this is done, the remaining components can be put together using the Pythagorean theorem to obtain the resulting vector. [*Uncertainties*] The forces and variables measured during this experiment were very accurate to the calculated results. Any discrepancy was within the margin of uncertainty wherein the system could be altered and still achieve equilibrium. [*First universal question*] All of our results were to be expected from the experiment. The existing area of uncertainty is caused by the fact that this experiment was not performed in a perfect vacuum. Static frictional forces very possibly played a role in maintaining equilibrium in the system despite the force components not exactly equaling 0.

[*Second universal question*] This concept is present in every day occurrences. For example, when we drive cars on the road, we have a velocity vector that is opposed by other vector forces such as kinetic friction and wind resistance. The net force in the system is still positive in the direction of the car until the brakes are applied in the opposite direction. Once the car has come to a complete stop, the net force acting on the vehicle is 0; thus, the car is at rest and at an equilibrium. Another instance that this concept is present is during a game of tug-of-war. When one side pulls on the rope, it exerts a force on the system in that direction. If the other team pulls with an equal force, the net force acting on the rope is 0 and it will remain stagnant in equilibrium until one team pulls harder than the other.

[*Lab questions*] When an object is in equilibrium, the net force acting in the system on the object is 0 newtons. When you resolve a vector into components, you’re using trigonometry to find the magnitude of that vector that is in the x and y direction. If the ring was stationary but not around the pin, then the system would still be in equilibrium. If it is stationary, there are is no acceleration which implies there is no net force acting on the ring. If the table were moving with a constant velocity, the results of this lab would not be affected. To be affected, a force would have to be exerted on the lab. Because there is no acceleration in a constant velocity, there could not be a force by the law that force equals mass times acceleration. If the table were accelerated horizontally, the lab would be affected. It would be altered because the acceleration would be greater than 0 which exerts a force on the system. This would change the sum of the velocity components in the direction of the acceleration.

**References**

1. "History of Vectors." Vectors. N.p., n.d. Web. 12 Sept. 2016.