Physics 203 – Lab 2: Vectors (Force Table)
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Section: ST5
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I. Introduction

In this experiment, vector addition and equilibrium using a force table was studied. A vector is a physical quantity that possesses both magnitude and direction, such as force or velocity. By adjusting the directions and magnitudes of forces acting on a central ring, we can experimentally verify the principles of vector addition and equilibrium. The goal of this lab is to understand how multiple forces combine to produce a resultant and how to determine the equilibrant which is the force that balances the system. This concept has practical everyday applications in engineering and everyday life, such as balancing forces on bridge supports, cranes, and aircrafts in flight.

II. Procedure

A force table was used to simulate forces acting in different directions. Each force was created by hanging a mass from a pulley positioned at a specific angle. The mass experienced a tension equal to its weight ($F = mg$). The direction of each force was adjusted by rotating the pulley around the table.

Equilibrium was tested by checking whether the central ring remained centered when the pin was removed.

- **Experiment 1:** Determined the sensitivity of the table by balancing equal masses (50 g each) at 0° and 180°, then increasing one side until imbalance occurred.
- **Experiment 2:** Created a symmetric two-force setup with random directions, then found a third balancing mass experimentally and compared it with the simulated prediction.
- **Experiment 3:** Analyzed one vector (50 g at 35°) and calculated its x- and y-components using trigonometry, then confirmed equilibrium by balancing those components with new masses.
- **Experiment 4:** Combined three known vectors and calculated a fourth force that would balance the system using component algebra, then verified equilibrium experimentally.

III. Data and Calculations

Table 1 – Measured and Calculated Forces

Vector	Added Mass (g)	Tray Mass (g)	Total Mass (g)	Mass (kg)	Force (N = m×g)	Direction (° CCW)
A	30	50	80	0.080	0.784	55°
B	40	50	90	0.090	0.882	145°
C	25	50	75	0.075	0.735	210°

Table 1: This table lists the added and tray masses for each force, converts them to Newtons, and shows their corresponding directions used on the force table.

Sample Calculation :

$$\boldsymbol{F = mg = 0.080 \times 9.80 = 0.784}\ \mathrm{N}$$
$$\boldsymbol{F_x = F\cos(55°) = 0.784 \times 0.5736 = 0.450}\ \mathrm{N}$$
$$\boldsymbol{F_y = F\sin(55°) = 0.784 \times 0.8192 = 0.642}\ \mathrm{N}$$

Table 2 – Force Components

Vector	(Fx)(N)	(Fy)(N)
A (55°)	**+0.450**	**+0.642**
B (145°)	**−0.723**	**+0.510**
C (210°)	**−0.637**	**−0.368**

Table 2: Each force is resolved into its x- and y-components using trigonometric functions. Positive and negative signs indicate direction along the x or y axis.

Table 3 – Resultant and Equilibrant Force Calculations

Quantity	Expression / Calculation	Result (N)
ΣF_x	$0.450 - 0.723 - 0.637$	-0.910
ΣF_γ	$0.642 + 0.510 - 0.368$	$+0.784$
D_x, D_γ	$(-\Sigma F_x, -\Sigma F_\gamma)$	$(+0.910, -0.784)$
$\lvert D \rvert$	$\sqrt{(D_x^2 + D_\gamma^2)}$	1.20 N
Direction	$\tan^{-1}$	D_γ / D_x
Equivalent Total Mass	$\lvert D \rvert / g$	0.122 kg = 122 g
Added Mass (excluding tray)	Total − 50 g	≈72 g

Table 3: Summarizes the calculation of the resultant vector from forces A, B, and C, and determines the equilibrant D that balances the system. The equilibrant's components ($D_x = +0.910$ N, $D_\gamma = -0.784$ N) correspond to a magnitude of 1.20 N directed at 319° CCW, equivalent to 122 g of total hanging mass.

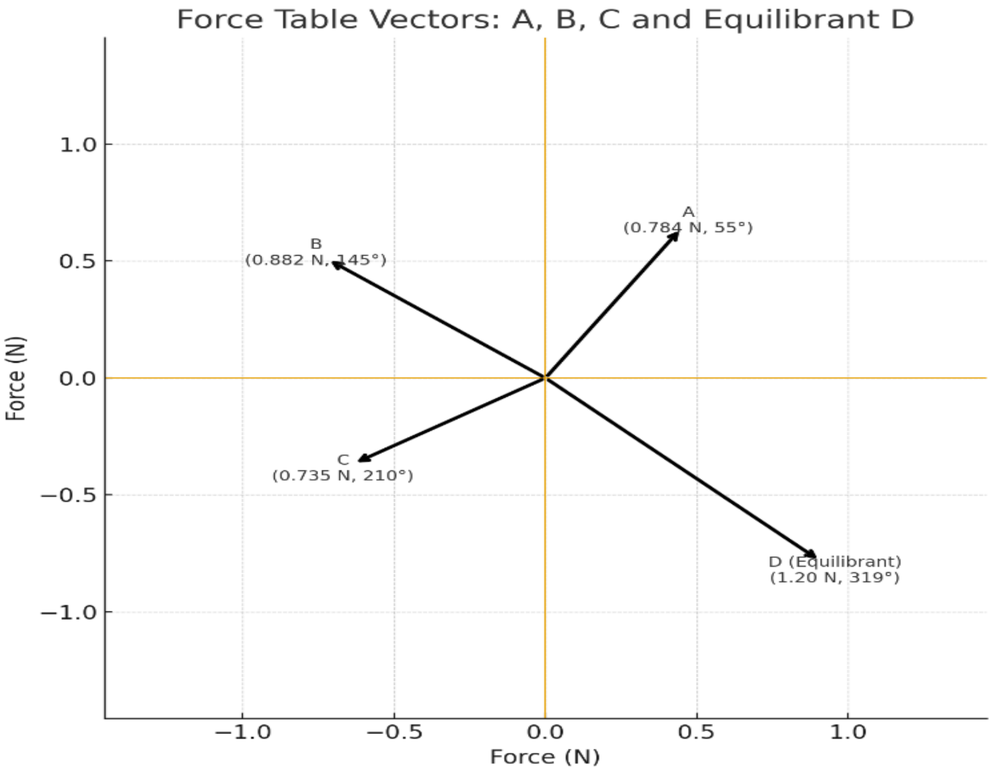

Figure 1: A vector diagram illustrating how forces A (30 g at 55°), B (40 g at 145°), and C (25 g at 210°) combine to yield a resultant balanced by the equilibrant D (1.20 N at 319°).

IV. Questions

1. What factors could contribute to this sensitivity?

The sensitivity of the force table (14 g in this case) can be affected by several factors: small frictional forces in the pulleys, the non-radial alignment of strings, and minor imperfections in leveling the table. Additional contributors may include slack in the rope, variations in pan mass, and the precision of visually judging whether the ring is centered or not. These mechanical and observational limitations combine to determine the smallest weight difference detectable before equilibrium is visibly disturbed.

2. Report the difference between what you've experimentally measured and what the simulation predicted. Are they within the expected sensitivity of the instrument?

Experimentally, the mass required to balance the system was **80.0 g**, while the simulation predicted **75.0 g**, giving a difference of **5 g**. Since this 5 g difference is well within the instrument's measured sensitivity of **14 g**, the experimental and simulated results are consistent. This confirms that the force table's accuracy is reasonable for the range of forces tested.

3. Include the results and work of this calculation in the lab report. Also, draw a graphical vector diagram that shows how the system should be in equilibrium.

For a 50 g mass at **35°**, the total force $F_1 = mg = 0.50N \times 9.8m/s^2 = 0.490N$.
Using trigonometry:

$$F_{1x} = F_1 \cos{(35°)} = 0.401N$$
$$F_{1y} = F_1 \sin{(35°)} = 0.281N$$

To achieve equilibrium, equal and opposite component forces must act at **180°** (to balance F_{1x}) and **270°** (to balance F_{1y}).
The vector diagram would show one vector at 35°, with two balancing vectors along the x- and y-axes forming a closed triangle, indicating equilibrium.

Vector Components and Equilibrium for a Single Force

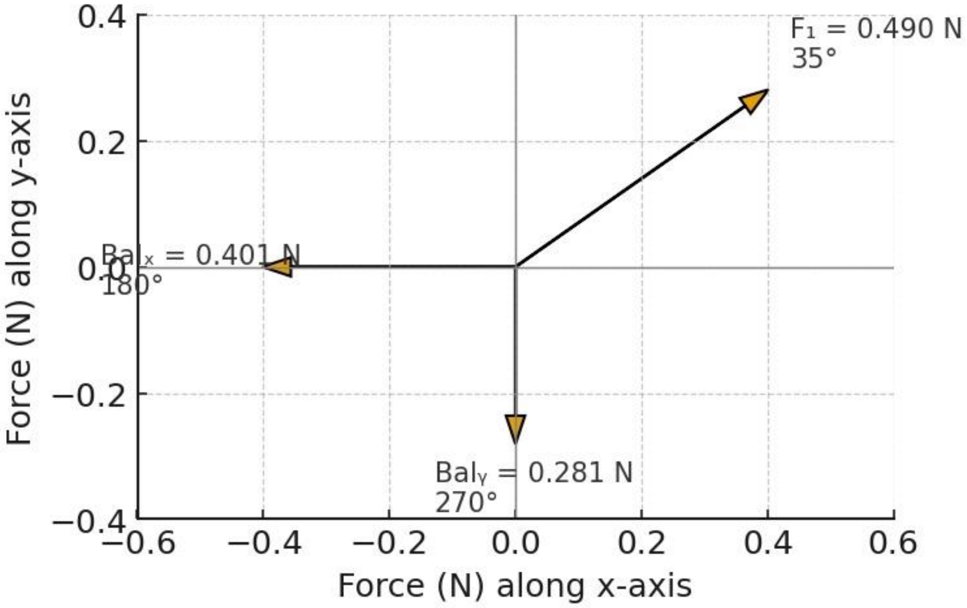

Figure 2: Vector diagram illustrating the decomposition of force F_1 (50 g at 35°) into its x- and y-components. The diagram shows F_1 = 0.490 N at 35°, with balancing component forces Bal_x = 0.401 N (180°) and Bal_y = 0.281 N (270°), demonstrating how the system reaches equilibrium when each component is counteracted by an equal and opposite force.

4. Give the details of this calculation and compare your analytical results with the experimental results. Draw a vector diagram that shows the table arrangement.

Given:

- $A = 30g@55°$
- $B = 40g@145°$
- $C = 25g@210°$

Converting to Newtons ($g = 9.8m/s^2$):

$$F_A = 0.294N,\ F_B = 0.392N,\ F_C = 0.245N$$

Decomposing into x and y components, summing, and solving for the fourth vector $\vec{D}$that brings the net force to zero yields:

$$D_x = 0.910N,\ D_y = -0.784N$$

The resultant magnitude and direction are:

$$|\vec{D}| = \sqrt{(0.910)^2 + (-0.784)^2} = 1.20N$$

$$\theta_D = \tan^{-1}\left(\frac{-0.784}{0.910}\right) \approx 319^\circ$$

When this predicted vector was applied experimentally, the system balanced, confirming agreement between analytical and experimental results within the table’s sensitivity.
The vector diagram would display the three known vectors and the fourth equilibrant forming a closed polygon, demonstrating equilibrium.

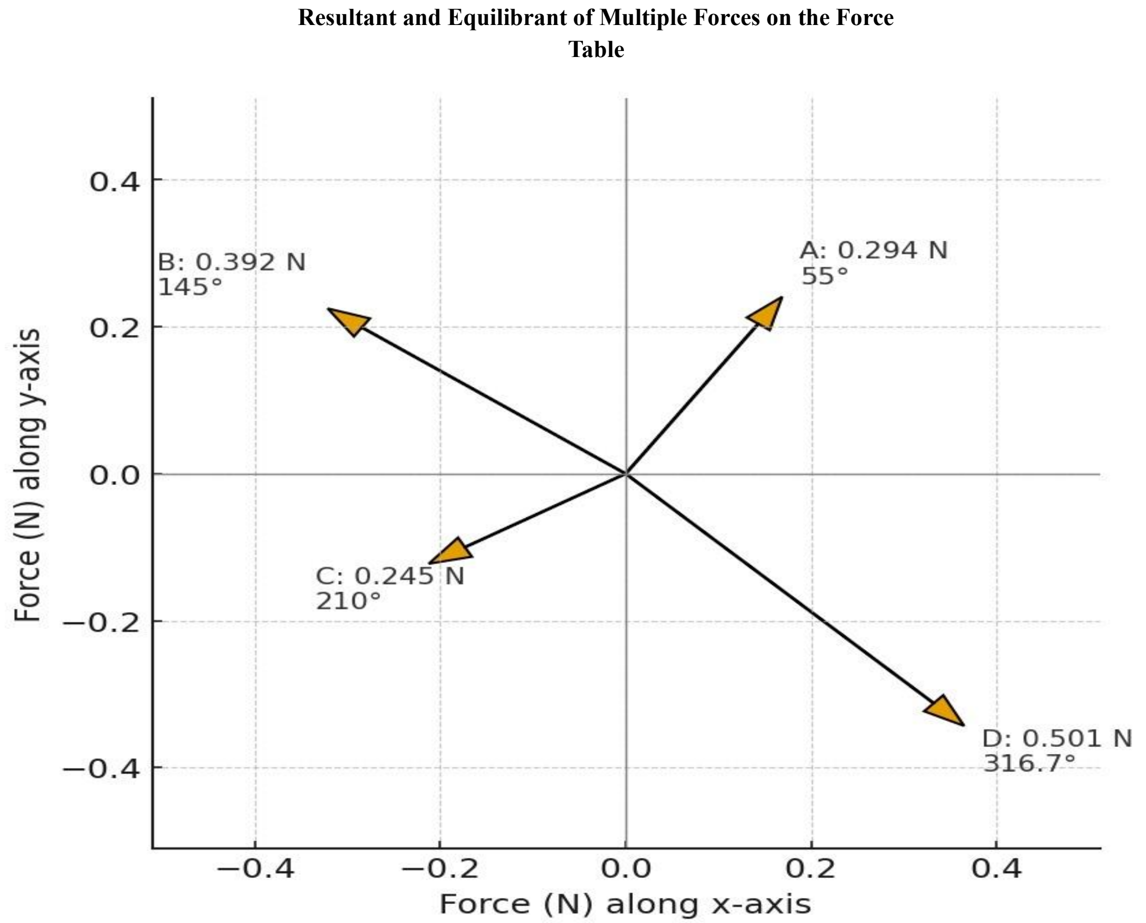

Figure 3: Vector diagram showing forces A (30 g at 55°), B (40 g at 145°), and C (25 g at 210°), and their analytical equilibrant D. The calculated components yield $D_x = 0.365$ N and $D_y = -0.343$ N, corresponding to a resultant magnitude of 0.501 N directed at 316.7°. This fourth vector closes the polygon, confirming equilibrium (ΣF = 0).

V. Conclusion

In this experiment, the force tables was used to investigate and test the principles of vector addition and equilibrium. By balancing multiple known forces with an equilibrant, it was shown that the vector sum of all forces acting on a point in equilibrium is zero, consistent with Newton’s First Law as discussed in the course. The graphical and analytical methods both produced results that closely matched the experimental observations, with minor differences well within the instrument’s sensitivity (±14 g). Small discrepancies between the calculated and measured equilibrant forces likely arose from pulley friction, non-radial string alignment, and limits in visually judging when the ring was perfectly centered. Overall, the results confirmed the accuracy of the component methods for adding vectors and demonstrated that both the magnitude and direction of each force must be considered to achieve equilibrium. This lab successfully linked the theoretical concept of vector addition with its practical realization on the force table, reinforcing the relationship between analytical prediction and experimental verification in physics.