Lab Report 6 – FORCE TABLE

XUAN MAI TRAN

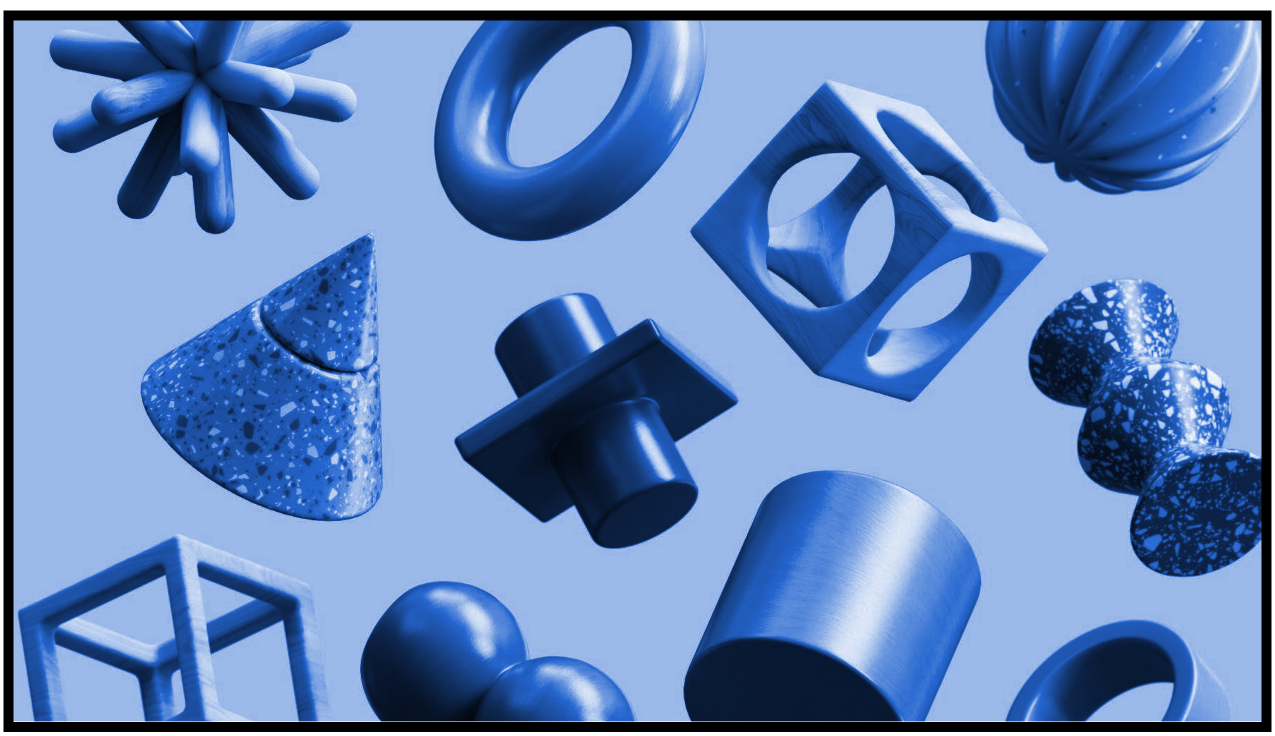
02/20/2025

-

PHYS 2125

-

DR. JOSEPH BARCHAS



Objectives

To confirm experimentally the vector nature of forces and vector addition.

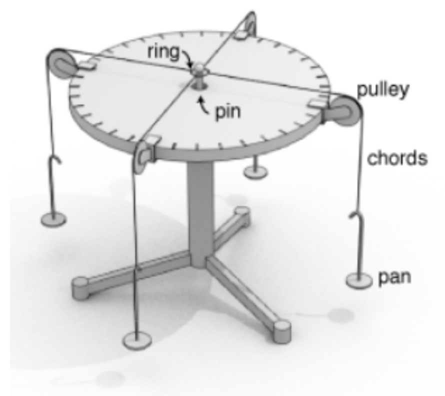
Equipments

The list of equipments used in this experiment is:

- Force Table (table, ring, pin)
- Pulleys
- String
- Hanging Masses

Theory and Equations

1. Net Force



A force table is a circular table with a 360 degree protractor scale on which an arrangement of pulleys, string, and hanging masses may be placed as in the picture here.

We neglect the ring's weight and focus on the tension forces acting on the ring in the horizontal plane.

With the magnitude and direction known for each tension, we can decompose each tension into a x- and y-component in the (horizontal) x-y plane:

$$T_i = m_i g \quad , \quad T_{ix} = T_i cos\theta_i \quad , \quad T_{iy} = T_i sin\theta_i \qquad \text{(Eq. 1 a, b, c)}$$

Where i = 1, 2, 3, or 4 (meaning mass 1, tension 1, etc.)

We can then calculate the net force component equations on the ring:

$$\sum_{i=i}^{N} F_{ix} = T_{ix} + T_{2x} + ... + T_{nx} \qquad \text{(Eq. 2)}$$

$$\sum_{i=i}^{N} F_{iy} = T_{iy} + T_{2y} + ... + T_{ny} \qquad \text{(Eq. 3)}$$

Where n is the number of masses/strings attached to the ring fit (it will be 2, 3, or 4 for our experiment).

The magnitude of the net force can also be calculated:

$$F_{net} = \sqrt{(\sum_{i=1}^{n} F_{ix})^2 + (\sum_{i=1}^{n} F_{iy})^2} \qquad \text{(Eq. 4)}$$

In theory, the net force should be 0 if the ring is in equilibrium:

$$\sum_{i=1}^{n} F_{ix} = 0 \qquad \sum_{i=1}^{n} F_{iy} = 0$$

2. Percentage Error

$$\text{(Modified Percentage Error)} = (\frac{F_{net}}{T_{max}}) * 100\%$$

Summary of Procedures

First, we set up a stable surface with those above equipment tools and the force table seen in the picture above. We are interested in producing an equilibrium state for the ring (net force of 0). The ring will float in place without touching the pin when the ring is in balance. We arrange the position of the pulleys to create balance for the ring based on different scenarios of hanging masses. If the mass is 0, we remove the hanger so that the tension is 0 in that string. Then, we record each situation with the angle (direction) corresponding to each hanging mass in each case below.

A	(100g, 100g, 0 , 0)
B	(100g, 100g, 100g, 0)
C	(100g, 100g, 100g, 100g)
D	(100g, 150g, 200g, 0)
E	(150g, 200g, 250g, 0)
F	(50g, 100g, 150g, 200g)

Data and Observations

The mass of the hook included is 5 grams.

Scenario	Mass 1 (g)	Mass 2 (g)	Mass 3 (g)	Mass 4 (g)

A	105	105	0	0
angle (degrees)	0	180		
B	105	105	105	0
angle (degrees)	0	120	240	
C	105	105	105	105
angle (degrees)	0	90	180	270
D	105	155	205	0
angle (degrees)	225	148	0	
E	155	205	255	0
angle (degrees)	130	215	0	
F	55.0	105	155	205
angle (degrees)	190	250	140	0

Data Analysis

Sample Calculation:

Scenario A:

- $T_1 = m_1 * g = 105g * 9.800m/s^2 * 10^{-3} = 1.03\ (N)$
- $T_{1x} = T_1 * cos(\theta) = 1.03N * cos(0) = 1.03$ (N)
- $T_{1y} = T_1 * sin(\theta) = 1.03N * sin(0) = 0.00$ (N)
- $Total\ F_x = T_{1x} + T_{2x} = 1.03N + (-1.03N) = 0.00\ (N)$
- Total $F_y = T_{1y} + T_{2y} = 0.00N + 0.00N = 0.00\ (N)$
- $F_{Net} = \sqrt{(Total\ F_x)^2 + (Total\ F_y)^2} = \sqrt{(0.00N)^2 + (0.00N)^2} = 0.00\ (N)$

g (m/s^2)	9.800

Scenario	Force	T1 = M1*g (N)	T2 = M2*g (N)	T3 = M3*g (N)	T4 = M4*g (N)
A	Ti (N)	1.03	1.03		
	Tx (N)	1.03	-1.03		

	Ty (N)	0.000	0.000		
	Total Fx (N)	0.000			
	Total Fy (N)	0.000			
	F-net (N)	0.000			
B	Ti (N)	1.03	1.03	1.03	
	Tx (N)	1.03	-0.51	-0.51	
	Ty (N)	0.000	0.89	-0.89	
	Total Fx (N)	0.000			
	Total Fy (N)	0.000			
	F-net (N)	0.000			
C	Ti (N)	1.03	1.03	1.03	1.03
	Tx (N)	1.03	0.00	-1.03	0.00
	Ty (N)	0.000	1.03	0.000	-1.03
	Total Fx (N)	0.000			
	Total Fy (N)	0.000			
	F-net (N)	0.000			
D	Ti (N)	1.03	1.52	2.01	
	Tx (N)	-0.728	-1.29	2.01	
	Ty (N)	-0.728	0.805	0.000	
	Total Fx (N)	-0.00680			
	Total Fy (N)	0.0773			
	F-net (N)	0.0776			
E	Ti (N)	1.52	2.01	2.50	
	Tx (N)	-0.976	-1.65	2.50	
	Ty (N)	1.16	-1.15	0.000	
	Total Fx (N)	-0.123			
	Total Fy (N)	0.0113			
	F-net (N)	0.124			
F	Ti (N)	0.539	1.03	1.52	2.01
	Tx (N)	-0.531	-0.352	-1.164	2.009
	Ty (N)	-0.0936	-0.967	0.976	0.000
	Total Fx (N)	-0.0374			
	Total Fy (N)	-0.0841			
	F-net (N)	0.0921			

Results

Sample Calculation:

Scenario A:

- Modified Percentage Error $= (\frac{F_{net}}{T_{max}}) * 100\% = (\frac{F_{net}}{Max(T1, T2)}) * 100\%$

$$= (\frac{0.000N}{Max(1.03N, 1.03N)}) * 100\% = 0.000\ \%$$

Scenario	Force	T1 = M1*g (N)	T2 = M2*g (N)	T3 = M3*g (N)	T4 = M4*g (N)	Modified Percent Error (%)
A	Ti (N)	1.03	1.03			
	Tx (N)	1.03	-1.03			
	Ty (N)	0.000	0.000			
	Fx (N)	0.000				
	Fy (N)	0.000				
	F-net (N)	0.000				0.000
B	Ti (N)	1.03	1.03	1.03		
	Tx (N)	1.03	-0.51	-0.51		
	Ty (N)	0.000	0.89	-0.89		
	Fx (N)	0.000				
	Fy (N)	0.000				
	F-net (N)	0.000				0.000
C	Ti (N)	1.03	1.03	1.03	1.03	
	Tx (N)	1.03	0.00	-1.03	0.00	
	Ty (N)	0.000	1.03	0.000	-1.03	
	Fx (N)	0.000				
	Fy (N)	0.000				
	F-net (N)	0.000				0.000
D	Ti (N)	1.03	1.52	2.01		
	Tx (N)	-0.728	-1.29	2.01		
	Ty (N)	-0.728	0.805	0.000		
	Fx (N)	-0.00680				

	Fy (N)	0.0773				
	F-net (N)	0.0776				3.86
E	Ti (N)	1.52	2.01	2.50		
	Tx (N)	-0.976	-1.65	2.50		
	Ty (N)	1.16	-1.15	0.000		
	Fx (N)	-0.123				
	Fy (N)	0.0113				
	F-net (N)	0.124				4.95
F	Ti (N)	0.539	1.03	1.52	2.01	
	Tx (N)	-0.531	-0.352	-1.164	2.009	
	Ty (N)	-0.0936	-0.967	0.976	0.000	
	Fx (N)	-0.0374				
	Fy (N)	-0.0841				
	F-net (N)	0.0921				4.58

Discussion / Conclusion

In general, we can see that the ring reaches the equilibrium when the total forces acting on it approximate to 0 ($F_x = 0$ and $F_y = 0$).

As we can see from the data analysis above, for the first 3 cases, based on the theory of Eq. 2 and Eq. 3, we easily guess the angular of the hanging masses to set up the string correctly so that the ring achieves the perfect equilibrium state. That's why $F_x = 0$ and $F_y = 0$ as in theory. It leads to the Modified Percentage Error equals 0%. Additionally, the scenarios A and C show symmetrical mass distribution. In Scenario A, two equal masses (105 g) are placed at 0° and 180°, creating balance. Similarly, Scenario C has four equal masses (105 g) placed at 90° intervals, ensuring symmetry and balance.

However, in the last 3 cases, we have to manually adjust the string to get the equilibrium state of the ring with the different hanging masses. Scenarios with more mass (like Scenario F) show a more complex distribution of forces. The different masses and angles show how different configurations can still achieve equilibrium, even when the masses are not equal, but hard to get the perfect equilibrium as in other cases.

Post-Lab Question

Question 1

In the original percentage error formula as below, we compare between the experimentally determined measure (exp) and the accepted value (acc). And there are 2 types of accepted values which are theoretical value which is predicted from theory and empirical value which is collected from a reliable source.

$$\text{Percentage Error} = \left|\frac{(exp) - (acc)}{(acc)}\right| * 100\% = \left|\frac{(F - net_{exp}) - (F - net_{acc})}{(F - net_{acc})}\right| * 100\% \quad \text{(Eq. 5)}$$

In theory, the $\sum_{i=1}^{N} F_{ix} = 0$ and $\sum_{i=1}^{N} F_{iy} = 0$.

It leads to $F - net_{acc} = \sqrt{(\sum_{i=1}^{N} F_{ix})^2 + (\sum_{i=1}^{N} F_{iy})^2} = \sqrt{(0N)^2 + (0N)^2} = 0\ (N)$

Following to Eq. 5 above, we have:

$$\text{Percentage Error} = \left|\frac{(F - net_{exp}) - (F - net_{acc})}{(F - net_{acc})}\right| * 100\% = \left|\frac{(F - net_{exp}) - 0\ N}{0\ N}\right| * 100\% = \textbf{undefined}$$

(as the dominator = 0)

That's why we have to modify the normal formula of Percentage Error.

Question 2

With 7 equal masses attached with the string and the ring in the equilibrium status, we can calculate the angular based on the Eq. 2 and Eq. 3 above. Particularly,

$$\sum_{i=i}^{7} F_{ix} = T_{1x} + T_{2x} + ... + T_{7x} = 0 \qquad \text{(Eq. 6)}$$

While we also have from Eq. 1 a, b, c that:

$$T_{1x} = T_{2x} = T_{3x} = T_{4x} = T_{5x} = T_{6x} = T_{7x} = m * g * \cos(\theta_i) = T*\cos(\theta_i) \qquad \text{(Eq. 7)}$$

Combining Eq. 7 into Eq. 6, we have:

$$\sum_{i=1}^{7} F_{ix} = \mathrm{T} * \sum_{i=1}^{7} \cos(\theta_i) = 0$$

Similarly, we have:

$$\sum_{i=1}^{7} F_{iy} = \mathrm{T} * \sum_{i=1}^{7} \sin(\theta_i) = 0$$

Assuming 7 forces equally distributed and separated, we have:

$$\theta_i = \frac{360^0}{7} = 51.4^0$$

Since the angles are distributed symmetrically around the unit circle, their sums in both the x- and y-directions cancel out completely.