Lab 3.1

Equilibrium in Forces

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Lab 3.1
Equilibrium in Forces

Problem: To examine the first condition for static equilibrium: the balance of forces.

Hypothesis: The sum of the vertical forces and the sum of horizontal forces will equal zero to acquire static equilibrium.

Apparatus:
Force table or peg force board
Protractor (360^{o}) mounted on square background
3 pulleys
Masses (with hangars)
Small builder's level
String or fishing line

Procedure:
1. A data table was set up in the notebook.
2. The force board was set up with the two pulleys about 30 cm apart.
3. One string was placed across the two pulleys and a mass, m_1 and m_2, were fastened on each end such that they balanced. The pulleys were placed at a level that achieved balance.
4. A second piece of string was tied to the horizontal string between the two pulleys and a third mass was hung, creating a Y shape. The masses and the pulley positions were adjusted such that the system reached static equilibrium.
5. The circular protractor was moved to a point behind the strings. The angles were measured between the strings. The builder's level was used to ensure that the top of the protractor was horizontal.
6. The masses of m_1, m_2, and m_3, were recorded in the data table.
7. Masses m_1 and m_2 were changed only. The apparatus was rearranged to static equilibrium and all of the masses and angles were recorded in the data table.
8. A third pulley was applied to the string attached to the middle mass. The pulley was held in place by hand and the angles were measured (including the new one in the middle string) and masses being used when in static equilibrium. All observations were recorded in the data table.

Observation:

Table 1: Two Pulleys

	Masses (g)			Angles (degrees)				
	m_1	m_2	m_3	Θ_1	Θ_2	Θ_3	Θ_4	Θ_5
1.	242	242	200	22	68	67	23	113
2.	295	295	200	21	69	68	22	112

	Forces (left/right) by masses (N)				Sum of all Forces (N)		Force (middle mass)	
	$F_{1(v)}$	$F_{1(h)}$	$F_{2(v)}$	$F_{2(h)}$	$F_{t(v)}$	$F_{t(h)}$	$F_{3(v)}$	$F_{3(h)}$
1.	0.888	2.199	0.926	-2.183	1.815	0.016	1.960	0
2.	1.036	2.699	1.083	-2.680	2.119	0.019	1.960	0

Table 2: Three Pulleys

Masses (g)			Angles (degrees)				
m_1	m_2	m_3	Θ_1	Θ_2	Θ_3	Θ_4	Θ_5
242	242	200	31	55	70	24	130

Forces (left/right) by masses (N)				Sum of all Forces (N)		Force (middle mass)	
$F_{1(v)}$	$F_{1(h)}$	$F_{2(v)}$	$F_{2(h)}$	$F_{t(v)}$	$F_{t(h)}$	$F_{3(v)}$	$F_{3(h)}$
1.225	2.033	0.965	-2.166	2.19	-0.133	1.842	0.67

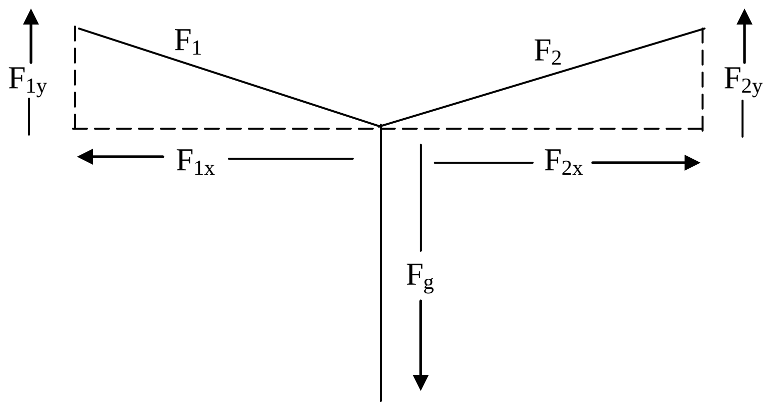
Discussion Question:

1. In each case, the sum of the vertical components is very similar to the force of gravity on the middle mass, within experimental uncertainty. The gravitational forces of the third mass are approximately equal to the sum of the vertical forces of the other two masses. This is due to the fact that the sum of all the force vectors must be zero when they act through the centre of mass for static translation equilibrium. The force of gravity [down] is cancelled out by the normal forces [up].

2. The sum of the horizontal components is approximately zero, considering the uncertainties. The forces acting on the masses to the left is counter balanced by the forces acting on the masses to the right. For static equilibrium, the sum of the horizontal forces should equal zero.

3. The sum of the vertical and horizontal forces from the outer two masses compared to the vertical and horizontal forces on the middle mass in step 8 is approximately equal.

4. Free Body Diagram



$$\Sigma \vec{F}_y = 0 \qquad \Sigma \vec{F}_x = 0$$

Conclusion:

The results in our experiment prove the first condition for static equilibrium. The sum of the vertical forces and the sum of horizontal forces does approximately equal zero, considering the uncertainties. The vertical components of the first mass and the second mass counter balance the force of gravity on the third mass for the first and second experiment. Even when the third pulley is added, the vertical component of the third mass equals the vertical components of the first and second mass. These two different types of experimental results can be stated for the horizontal components as well. No matter how heavy an object is, static equilibrium can be acquired through the first condition for static equilibrium.