Experiment 1: Static Equilibrium with Unequal Angles

Equipment Needed	Suggested Part
• (2) Tension Protractors	ME-6855
• (2) Large Table Clamps	ME-9472
• (3) 90 cm Steel Rods	ME-8738
• (2) Multi Clamps	SE-9442
• Hooked Mass Set	SE-8759
• Braided Physics String	SE-8050
• Balance	SE-8723

Purpose

The purpose of this experiment is to verify that the vector sum of the forces acting on an object in equilibrium is zero.

Pre-lab Question

If an object is suspended by two strings at two different angles, as shown in Figure 1.1, which string will have the greater tension?

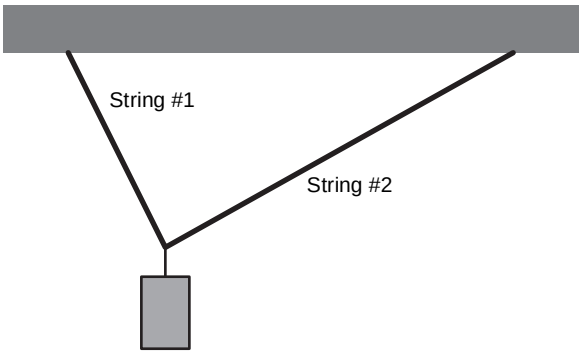

Figure 1.1

Theory

The vector sum of the forces acting on an object in equilibrium is zero:

(eq. 1-1) $$\sum_i \vec{F}_i = 0$$

This requires that the sum of the force components in the x- and y-directions must each separately be zero:

(eq. 1-2) $$\sum_i \vec{F}_{ix} = 0$$

(eq. 1-3) $$\sum_i \vec{F}_{iy} = 0$$

For example, if three forces are acting on an object (as shown in Figure 1.2), Equation 1-2 yields

(eq. 1-4) $$F_{2x} - F_{1x} = 0$$

(eq. 1-5) $$F_2\cos\theta_2 - F_1\cos\theta_1 = 0$$

This can also be interpreted as requiring the magnitudes of the x-components of the forces to be equal and opposite:

(eq. 1-6) $$F_{2x} = F_{1x}$$

(eq. 1-7) $$F_2\cos\theta_2 = F_1\cos\theta_1$$

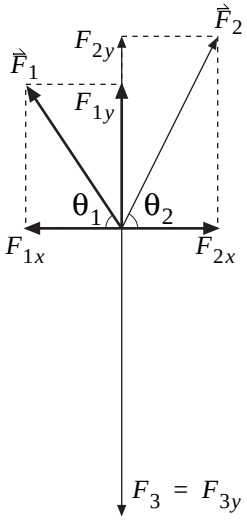

Figure 1.2

Similarly, Equation 1-3 yields

(eq. 1-8) $$F_{1y} + F_{2y} - F_{3y} = 0$$

(eq. 1-9) $$F_1 \sin\theta_1 + F_2 \sin\theta_2 - F_3 = 0$$

Or, the sum of the magnitudes of the forces up must equal the sum of the magnitudes of the forces down:

(eq. 1-10) $$F_{1y} + F_{2y} = F_{3y}$$

(eq. 1-11) $$F_1 \sin\theta_1 + F_2 \sin\theta_2 = F_3$$

Procedure

1. Clamp two rods (90 cm long) vertically to the table, approximately 80 cm apart. Attach two Tension Protractors (oriented with zero degrees horizontal) to a cross rod, and clamp this rod between the vertical rods as shown in the Figure 1.3 (but don't attach the mass yet).

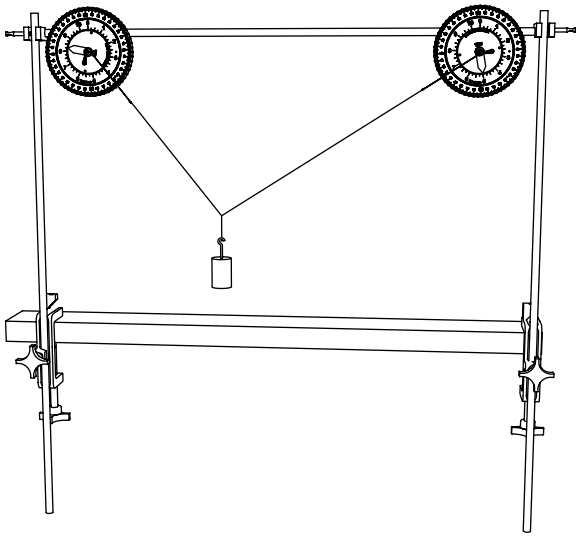

Figure 1.3: Set-up

2. Zero the force scale of each Tension Protractor: Without anything attached to the Tension Protractor string, adjust the thumb screw in the back until the force scale reads zero.

3. Zero the angle scale of each Tension Protractor: Hang a small mass (10 g) from the hook. Rotate the outer ring to align the 90° mark with the string (Figure 1.4).

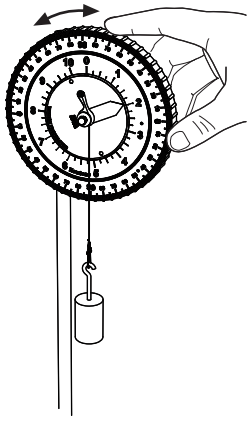

Figure 1.4: Zero the angle scale

4. Cut a string about 60 cm long. Tie a loop about 25 cm from one end so that the string length on one side of the loop is about 20 cm and the string length on the other side of the loop is 35 cm. Tie one end of the string to the wire hook on one of the Tension Protractors and tie the other end of the string to the wire hook of the other Tension Protractor. Hang a 500 g mass from the string loop (Figure 1.3).

5. Read the magnitude of force and the angle for each string and record them in Table 1.1.

6. Remove the hooked mass and use a balance to find its exact mass. Record it in Table 1.1.

Table 1.1: Data

	Magnitude of Force (N)	Angle (°)	Hanging Mass (kg)
Tension 1			
Tension 2			

Analysis

1. Calculate the weight of the hanging mass and record it in Table 1.2.

2. Calculate the x- and y-components of the tension of each string. Record them in Table 1.2.

Table 1.2: Calculations

Weight of Hanging Mass	
x-component of Tension 1	
x-component of Tension 2	
y-component of Tension 1	
y-component of Tension 2	

3. Calculate the sum of the forces to the left and the sum of forces to the right. Calculate the percent difference between them. Record these values in Table 1.3.

4. Calculate the sum of the upward forces and the sum of the downward forces. Calculate the percent difference between them. Record these values in Table 1.3.

Table 1.3: Results

			Percent Difference
Sum of x-components	Left		
	Right		
Sum of y-components	Upward		
	Downward		

5. Estimate the precision of the tension and angle measurements. Are the resulting forces being compared the same within the range of the precision?