I. Objectives

1. Calculate the resultant for two given forces, and determine the magnitude and direction of the third force needed to balance the resultant of the two given forces using a force table.

II. Introduction

This lab utilizes masses. You must wear closed-toed shoes during this entire lab.

A force table is a circular platform used to demonstrate that vector equations can be used to confirm how forces behave in everyday situations. The force table is a horizontal platform, graduated in degrees, with a center ring from which three masses can be attached and balanced. The *x*-axis of the force table is measured along the line connecting 180^o and 0^o and the *y*-axis of the force table is measured along the line connecting 90^o and 270^o.

III. Equipment and Materials

Force table, pulleys, slotted weight set, washers, thread, electronic balance, protractor, ruler

IV. Calculations

We begin by calculating the resultant force $\mathbf{F_R}$ from the forces $\mathbf{F_1}$ and $\mathbf{F_2}$:

$$\mathbf{F_R} = \mathbf{F_1} + \mathbf{F_2}$$

Because these are vectors we need to add their components:

$$F_{Rx} = F_{1x} + F_{2x}$$

$$F_{Rx} = m_1 g \cos\theta_1 + m_2 g \cos\theta_2$$

$$F_{Ry} = F_{1y} + F_{2y}$$

$$F_{Ry} = m_1 g \sin\theta_1 + m_2 g \sin\theta_2$$

The magnitude of the resultant force is:

$$F_R = \sqrt{F_{Rx}^2 + F_{Ry}^2}$$

and the angle of the resultant force is:

$$\theta_R = \tan^{-1}\left(\frac{F_{Ry}}{F_{Rx}}\right)$$

A force can be converted to a mass by dividing by *g*, the acceleration of gravity. The balancing force $\mathbf{F_B}$ requires the same mass as the resultant force $\mathbf{F_R}$ but in a direction 180^0 from $\mathbf{F_R}$:

$$\mathbf{F_B} = -\mathbf{F_R}$$

or:

$$\text{angle } \mathbf{F_B} = \text{angle } \mathbf{F_R} + 180^o$$

V. Procedure

1. Complete Table 2, Table 3, and columns B, C, and D of Table 4. **Use three significant figures in all of your calculations and answers**. Hints for Table 3: add 180 to any **negative** results for column E. If your calculator displays an error message for one of your calculations for column E, what does that indicate about the angle? For what angle is arctan undefined?

2. Be careful when adding or removing masses from the pulleys! Hold them in place and do **not** allow the strings to fly off the pulleys.

3. Place the pulleys at the positions indicated in Table 1.

4. Place the number of kilograms indicated in Table 1 on the pulleys.

5. Place the third pulley with the balancing force 180^0 from the resultant force $\mathbf{F_R}$

6. Place the number of kilograms necessary on the third pulley to balance the forces. Make any adjustments by adding or subtracting mass to balance the ring around the center of the force table.

7. Complete Table 4.

8. Select any one of the trials, hand draw vectors $\mathbf{F_1}$, $\mathbf{F_2}$, $\mathbf{F_R}$ and $\mathbf{F_B}$ to scale using the graph paper on the last page of this lab. **Label all of the vectors with their magnitudes. Be sure to indicate which trial you selected**.

VI. Data

Table 1 Masses and Angles

A	B	C	D	E
Trial	First mass m_1 in kg	First angle θ_1 in degrees	Second mass m_2 in kg	Second angle θ_2 in degrees
1	0.100	0.00	0.100	120
2	0.100	30.0	0.100	150
3	0.100	0.00	0.150	90.0
4	0.100	0.00	0.150	120
5	0.100	0.00	0.150	150

Table 2 Forces

A	B	C	$D = \sqrt{B^2 + C^2}$	E	F	$G = \sqrt{E^2 + F^2}$
Trial	First force x component $F_{1x} = m_1 g \cos\theta_1$ in N	First force y component $F_{1y} = m_1 g \sin\theta_1$ in N	First force magnitude F_1 in N	Second force x component $F_{2x} = m_2 g \cos\theta_2$ in N	Second force y component $F_{2y} = m_2 g \sin\theta_2$ in N	Second force magnitude F_2 in N
1						
2						
3						
4						
5						

Table 3 Resultant Forces

A	B	C	$D = \sqrt{B^2 + C^2}$	$E = \tan^{-1}\left(\frac{C}{B}\right)$
Trial	Resultant force x component $F_{Rx} = F_{1x} + F_{2x}$ in N	Resultant force y component $F_{Ry} = F_{1y} + F_{2y}$ in N	Resultant force magnitude F_R in N	Angle of resultant force $\mathbf{F_R}$ in degrees $\theta_R = \tan^{-1}\left(\frac{F_{Ry}}{F_{Rx}}\right)$
1				
2				
3				
4				
5				

Table 4 Balancing Forces

A	B	C	D = C/g	E	F = Eg	G = | C – F |
Trial	Angle of balancing force $\mathbf{F_B}$ in degrees = angle $\mathbf{F_R}$ + 180^o	Calculated weight added to third pulley, $F_R = F_B$ in N	Calculated mass added to the third pulley in kg	Actual mass added to third pulley in kg	Actual weight added to the third pulley in N	Difference between calculated and actual weights in N
1						
2						
3						
4						
5						

VII. Discussion Questions

1. Explain how and why the first two trials are similar.

2. What comparisons can be made among the last three trials? Explain how and why the results differ.

3. Compare your experimental, calculated, and graphical results. Are they the same or different? Other than mathematical errors what could account for any differences?