Name ___________________________________ Date _________________

Partners ____

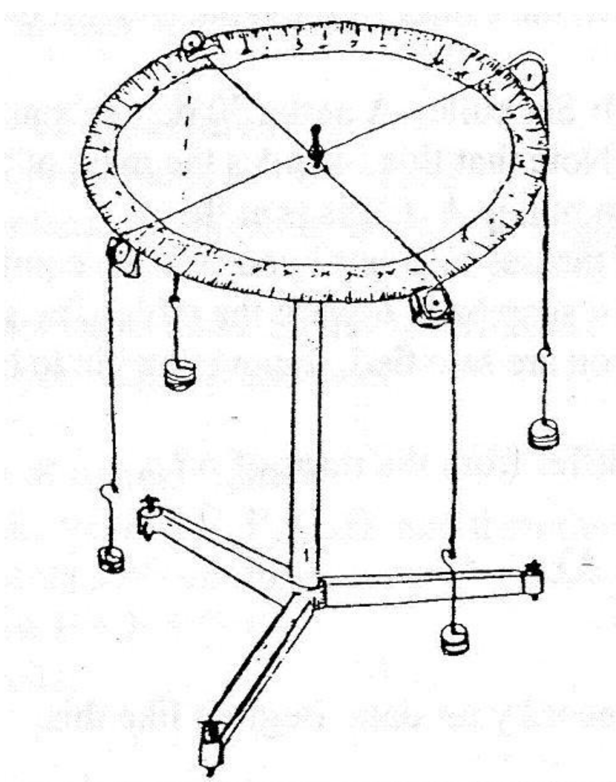
Force Table: Lab #5
By M.L. West

Objective: to clarify the idea that forces are vectors. To experience the conditions for equilibrium of coplanar forces, and to become fluent with the concept of vector addition on a hands-on as well as on an intellectual level. To use a graphical method of analysis.

Equipment: Force table, level, ring/strings, pin, four pulleys, four small mass hangers, set of slotted masses, ruler, protractor, graph paper

Setup: The force table is a circular metal plate mounted on a vertical metal rod supported on a tripod with leveling screws. The rim of the plate is engraved with a 0 to 360 degree scale. Pulleys can be clamped along this scale, and then strings can be hung over them. The strings can be attached to a ring which is placed at the center of the plate and secured by a thick steel pin. A mass hanger holding slotted masses can be attached to the other end of each string. Several forces can be applied to the ring at once.

When the forces provided by the various masses are in equilibrium, the ring will be at the exact center of the table, and then the pin may be removed briefly (for purposes of celebration).

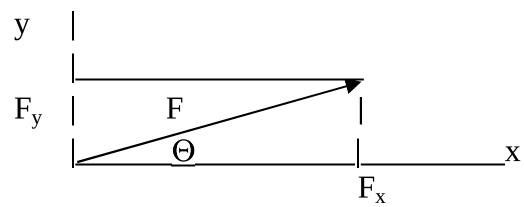


Theory: A set of concurrent forces acting on the same point of a body is **in equilibrium** if the vector sum of the forces is zero. This means that the vectors representing the forces, when placed end to end, will form a closed polygon (displacement = 0).

$$\Sigma F = 0$$

Any vector can be decomposed into components along two perpendicular axes. If Θ (theta) is the angle upwards from the positive x axis, then the forces in the component directions are

$F_x = F \cos(\Theta)$
$F_y = F \sin(\Theta)$



Since the components are independent of each other, then for a set of forces which are in equilibrium, the x- components and the y-components each sum to zero by themselves.

$\Sigma F_x = 0$

and also $\Sigma F_y = 0$

In this experiment the forces are weights, 9.8 m/s^2 times the masses, but for simplicity we will just use the masses to represent the forces.

Procedure:

0. Getting started: Use the carpenter's level to make sure that the top of your force table is horizontal. Insert the thick pin in the center of the table and put the ring over it.

1. Experiment 1 (two pulleys): Set pulley A at the 30 degree mark. Pull one string over the pulley and load it with 300 grams. Note that this includes the mass of the hanger itself.

Set pulley B exactly opposite to pulley A. (This is at the ________ degree mark.) Pull another string over this pulley and add masses to B until you achieve equilibrium. Check by pulling up the ring slightly and letting it snap back toward the table. The strings should appear to meet at the center of the table. When you are satisfied, remove the pin to be sure nothing moves. The mass of B is ________ grams.

By what percentage does this differ from the mass of A?

$$\% \text{ difference} = \frac{100\,(B - A)}{A} = \_$$

Open an Excel spreadsheet to record your data. Begin it like this:

Force Table Lab		U. Physics I	
Your name	*Partner's name*	*Partner's name*	*Partner's name*
Date			
Experiment	Force Vector	Angle (degrees)	Mass (grams)
1 (two pulleys)	A	30	300
	B		
		mass % difference:	

2. Experiment 2 (three pulleys): Remove pulley A, but leave pulley B in place. Set pulley C at 0 degrees, and pulley D at 90 degrees. Add masses to pulley C and to pulley D until you achieve equilibrium. Record the angles and masses in your data spreadsheet.

3. Numerical analysis of experiment 2:
Calculate the x- and y-components of A.
Compare A_x to C and find the % difference.
Compare A_y to D and find the % difference.
Record these values in your data spreadsheet.

4. Graphical analysis of experiment 1 and 2:
On graph paper draw the vectors A, B, A + B.
On a fresh diagram draw B, C, D, C + D, B + C + D.
Comment on the drawings, especially how C + D compares to A.

5. Experiment 3 (four pulleys): Arrange three pulleys arbitrarily such that none are at 0 degrees, 90 degrees, 180 degrees or 270 degrees on the table. Also put them so that no two pulleys are at 90 degrees to each other or opposite each other. Call these pulleys E, F, and G, and load them with masses between 150 and 350 grams. Record these angles and masses in your data spreadsheet.

Now attach a fourth pulley H and load it with masses to achieve equilibrium. If H requires more than 500 grams reduce the other three hangers somewhat, please. (We do not want to break the string.) Record H in your spreadsheet.

6. Numerical analysis of experiment 3:
Calculate the x- and y-components of the vectors.
Compare the total positive x components to the total negative x components and find the % difference.
Compare +y to -y components and find the % difference.
Record these values in your data spreadsheet.

7. Graphical analysis of experiment 3:
On graph paper draw the vectors E, F, G, H, and then their components.
Measure their components and sum them.
On a fresh diagram draw E + F + G + H.
Comment on these results.

8. Experiment 4 (four pulleys again): Design an experiment with three pulleys with masses on them, and a fourth pulley empty as a challenge to another lab group. How long did it take them to achieve equilibrium? Add these data to your spreadsheet.

Summarize how they attacked the problem.

Accept a challenge from another lab group.
How long did you take to solve it? _________
Add these data to your spreadsheet.
Summarize how you and your partners attacked the problem.

9. Conclusions:

10. Further Research: Make several suggestions as to further use for this equipment.