Equilibrium: Force Table

Objective

This exercise will make use of the fact that if a particle is not accelerating, then the vector sum of the forces on it must be zero.

Materials

1. Force table
2. Force table pulleys
3. Set of slotted weights
4. Slotted-weight hangers (x3)
5. String and scissors for room
6. Triple-beam balance

Introduction

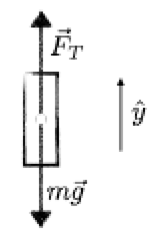

Figure 1: *From a free-body diagram of the stationary mass m, it is apparent that the tension in the string F_T is equal to the weight of the mass.*

We will not consider at this time the conditions for rotational equilibrium. The “particle" will be a small ring at the center of a circular table. Forces can be applied to the particle by means of strings that pass over pulleys to hanging masses. To the extent that pulley friction and string mass are negligible, such a hanging mass will cause a force whose magnitude is equal to its weight, F = mg (see Figure 1). For example a hanging mass of 0.250 kg will cause a force of 2.45 N. Be sure to include the mass of the hanger!

Procedure

Part A: Components of a Vector

Consider the +x direction to be at 0° on the built-in protractor of the force table, and the +y direction at 90° to +x. (Note that some force tables may have angles that progress clockwise rather than the usual counterclockwise; you will need to take this into account.) Use a randomly selected mass (not less than 200 g) to apply a force somewhere between 0° and 90°. Apply an equal magnitude oppositely directed force to put the ring in equilibrium. Verify that the ring is indeed in equilibrium. Compute the x and y components of the original force:

$$F_x = F \cos \theta$$

$$F_y = F \sin \theta$$

where θ is the angle between the force and the +x direction.

Now replace this original force by a force of magnitude F_x in the +x direction and F_y in the +y direction. The line from 0° to 180° is the traditional x-axis and the line from 90° to 270° is the y-axis. You should hang masses along the x- and y-axes that will generate forces equal to F_x and F_y. Verify that these two forces are balanced by the same force that balanced the original force. This exercise should make it clear that any force can be replaced by its components.

Part B: Resultant of a Force

Arbitrarily apply two forces to the ring. A force of this magnitude in the opposite direction (a.k.a. equilibrant) should produce equilibrium when applied to the ring simultaneously with these two forces. Verify that this is indeed the case. To make the problem more interesting, avoid angles that are multiples of 45° or 90°. Compute the magnitude and direction of the resultant (the vector sum) of these two forces ($F_1 = m_1 g$ and $F_2 = m_2 g$) by using equations such as:

$F_{1x} = F_1 \cos\theta$ and $F_{1y} = F_1 \sin\theta$
$F_{2x} = F_2\ cos\ \theta$ and $F_{2y} = F_2\ sin\ \theta$

Magnitude of resultant force in x direction $F_x = F_{1x} + F_{2x}$
Magnitude of resultant force in y direction $F_y = F_{1y} + F_{2y}$

Magnitude of resultant force $F_R = \sqrt{{F_x}^2 + {F_y}^2}$

Direction of resultant force $\theta = \tan^{-1}\frac{F_y}{F_x}$