Equilibrium of Non-Concurrent Forces; (The Law of Moments)

Object:

To study the principles of the Law of Moments, and the equilibrium of parallel forces.

Apparatus:

Meter stick, fulcrum with knife-edge, scale, rigid support, known masses with a pair of looped threads, unknown weight, and weighting scales (pan balance).

Theory:

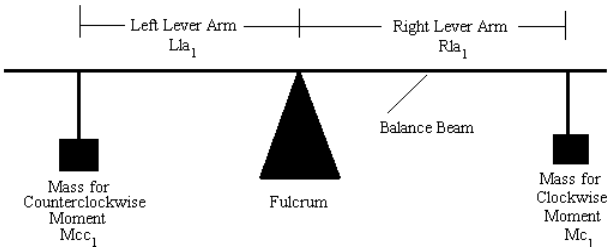

Figure 1

The Law of Moments allows us to determine when an object is balanced. It has important applications in aviation because pilots need to know if their aircraft will fly straight and level. The law of moments says that an object such as a scale will be in equilibrium (will not tip in either direction) when the *Counterclockwise Moment* is equal to the *Clockwise Moment*. The moments are defined as

$$\text{Counterclockwise Moment} = \sum_i (Mcc_i \; x \, Lla_i) \text{ g}$$

$$\text{Clockwise Moment} = \sum_i (Mc_i \; x \, Rla_i) \text{ g}$$

(Refer to figure1. for the definitions of Mcc, Rla, Mc, and Lla.) When a system is in equilibrium, the Law of Moments can be stated mathematically as

$$\sum_i (Mcc_i \; x \, Lla_i) = \sum_i (Mc_i \; x \, Rla_i)$$

For the situation pictured in figure 1 this would reduce to

$$(Mcc_1) \text{ x } (Lla_1) = (Mc_1) \text{ x } (Rla_1)$$

If the fulcrum is not located at the center of mass of the balance beam it can be shown that the situation is the same as if a mass equal to the mass of the beam was located at the beam's center of mass.

Procedure:

Part A

The conditions of equilibrium: Place the meter stick in the sliding knife-edge support so that the (unloaded) stick will balance horizontally, and note the position of the knife-edge on the stick. When adjusting the position of the knife-edge, gently secure the meter stick with the setscrew. Do not drive it into the wood! Place a 100 gram weight at the 10 cm mark and a 200 gram weight at the opposite side of the fulcrum in such a position that the loaded stick balances horizontally.

Repeat with different weights and distances. In each case, note the reading of the spring balance. Record data and results in table I.

Part B

To find the weight of the meter stick, by use of moments: Side the meter stick in the knife-edge clamp to the 30 cm mark. Place 300 grams at the 10 cm mark and a 100 gram weight to the opposite side of the fulcrum, to make the loaded meter stick balance horizontally, repeat with different weights at different distances. Finally, weigh the meter stick on a scale. Record the data and results in table II.

Part C

To find an unknown weight, by use of moments: Support the meter stick at the center of gravity. Hang the unknown weight at the 80 cm mark and balance with suitable known weights on the other side of the fulcrum. Repeat with different known weights and positions. Weigh the unknown weight on a scale. Record data and results in a table similar to table I.

Part D

Principle of weighing with an unequal arm balance: Support the meter stick at the center of gravity. Hang the unknown weight at the 90 cm mark and balance with known weights placed at the 20 cm mark. Should the two weights be equal? Now, reverse the positions of the unknown weight and the known weights, i.e., place the unknown at 20 cm and balance with known weights placed at 90 cm. How is the unknown weight computed from the two sets of known weights, without using the moment arms?

Repeat, for another pair of Unequal moment arms. Record data and results in a table similar to table I.

Question:

1) The balancing position of the meter stick is typically not at 50cm. Why is this the case?

Table I

Position of Fulcrum:_____

Weight of knife-edge and unloaded meter stick as measured by scale:_____

Weight on right side		
Lever arm right side		
Weight on left side		
Lever arm left side		
Clockwise moment		
Counterclockwise moment		
Percent difference		
Reading of scale		

Note: All moments should be expressed as N-m

Table II

Position of fulcrum:_____ Center of gravity of meter stick:_____

Weight on left side		
Lever arm left side		
Weight on right side		
Lever arm right side		
Counterclockwise moment of weights		
Clockwise moment of weights		
Difference: moment due to weight of stick		
Computed weight of stick		
Known weight of stick from scales		
Percent difference		