

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, spring balance, rigid support (retort stand), known weights with a pair of looped threads, metal arm pendulum clamp with a brass hook (to hang a light spring on it), unknown weight, and weighing scales (pan balance).

Theory:

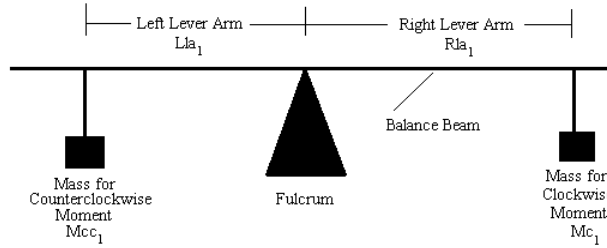


Figure 1

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 (won't tip in either direction) when the *Counterclockwise Moment* is equal to the *Clockwise Moment*. The moments are defined as

$$\text{Counterclockwise Moment} = \sum_i (Mcc_i \times Lla_i)$$

$$\text{Clockwise Moment} = \sum_i (Mc_i \times Rla_i)$$

(Refer to figure 1 for the definitions of Mcc, Rla, Mc, and Lla.) When a system is in equilibrium the Law of Moments can be stated mathematically as

$$\sum_i (Mcc_i \times Lla_i) = \sum_i (Mc_i \times Rla_i)$$

For the situation pictured in figure 1 this would reduce to

$$(Mcc_1) \times (Lla_1) = (Mc_1) \times (Rla_1)$$

If the fulcrum is not located at the center of mass of the balance beam it can be shown that the situation is exactly 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! Hang the knife edge from the spring balance, which is attached to the support on the table. 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. Slide 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, so as to make the loaded meter stick balance horizontally, Repeat with different weights at different distances. Finally, weigh the meter stick on a scale (pan balance). 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.

Report:

Tables I and II may be substituted for “Tabulated Results” on the cover sheet. Save the last hour of the period for the problems and for writing conclusions.

Questions:

1) What is the purpose of the spring balance? What conclusion may be drawn from its readings? (Refer to Table I).

Table I

Position of Fulcrum: _____

Weight of knife edge and unloaded meter stick by spring balance: _____

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

Table II

Position of fulcrum: _____

Center of gravity at: _____

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		

Note: All moments should be expressed as: N-m.