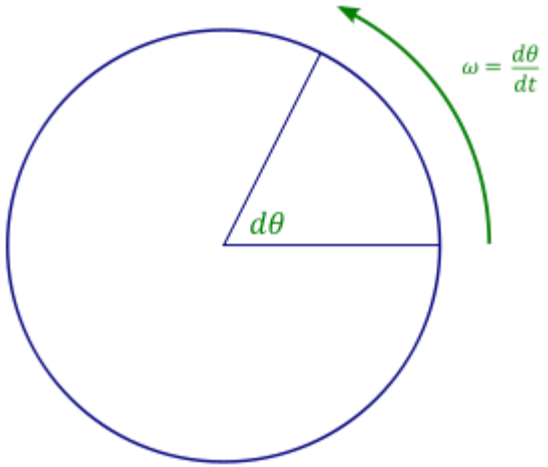
# 2nd Newton's Law for Rotation

| Linear motion | Rotation |
|---|---|
| Coordinate: x | Angle (in radians): $\theta = l/R$ |
| Velocity: $v = \Delta x/\Delta t$ | Angular velocity: $\omega = \Delta\theta/\Delta t$ |
| Mass: m | Moment of Inertia: $I$ |
| Acceleration: $a = \Delta v/\Delta t$ | Angular acceleration: $\alpha = \Delta\omega/\Delta t$ |
| Force, F | Torque, $T = F \times l$ |

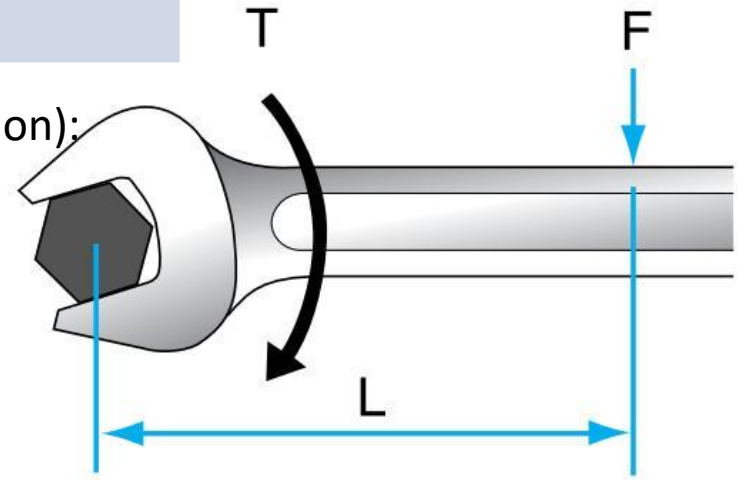



2nd Newton's Law:

$$F = ma$$

2nd Newton's Law (for rotation):

$$T = I\frac{\Delta\omega}{\Delta t} = I\alpha$$



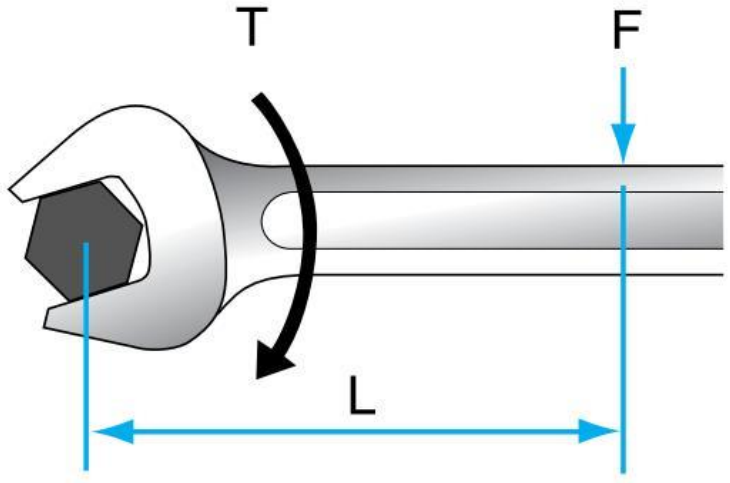

Torque T = F (Force) × L (Length)

# Statics

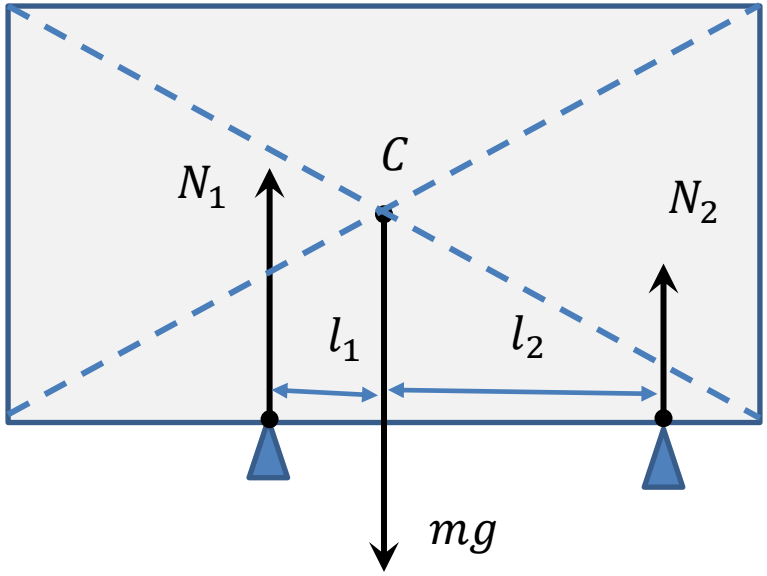
Consider a rigid object in equilibrium. Since it has zero acceleration , and no rotation, the sum of all forces and torques applied should be 0:

$$\sum \vec{F} = 0$$

$$\sum \vec{T} = 0$$




Example: whiteboard on two holders:




- Total force = 0:

$$-mg + N_1 + N_2 = 0$$

- Total torque = 0.

$$N_2 l_2 - N_1 l_1 = 0$$

The torque is with respect to point C (center), thus $mg$ produces zero torque (no lever). "Counter−clockwise" is positive rotation. Solving above equations:

$$mg = N_1 + N_2 = N_1(1 + l_1/l_2)$$

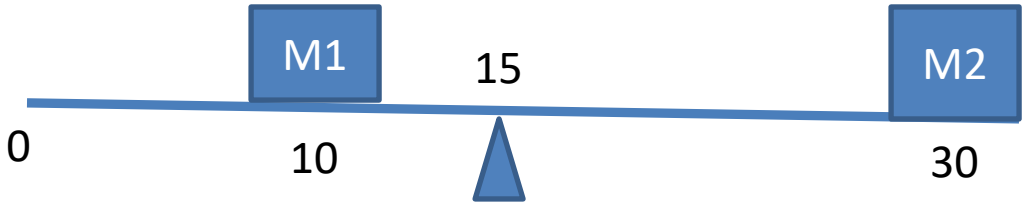
$$N_1 = mgl_2/(l_1 + l_2)$$

$$N_2 = mgl_1/(l_1 + l_2)$$

# Homework

**Problem 1**

A ruler is used to balance two weights as shown in figure 1. The ruler total length is 30 cm , it is supported at its center (at 15 cm mark). Mass M1=30 g, is located at 10 cm mark. The other mass, M2 is at 30 cm mark. Find M2




**Problem 2 (experimental)** Use a ruler and a pencil to find the ratio of masses of US quarter and US penny. You may use other two coins if you wish, Its OK to use several identical coins. Make a picture of your experiment, describe procedure and give your results.