AP Physics Study Guide

Statics and Torque

From Simple Studies, https://simplestudies.edublogs.org & @simplestudiesinc on Instagramv

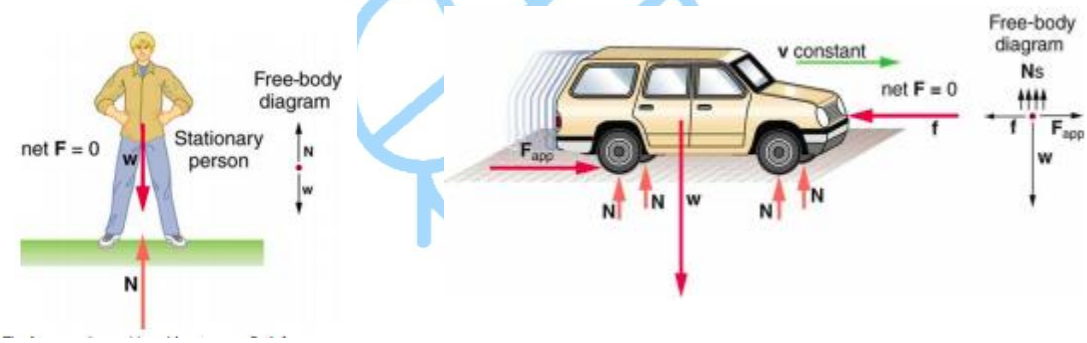
All images are from the Openstax college physics textbook

Statics is the study of forces in equilibrium, a large group of situations that makes up a special case of Newton's second law

- There are forces acting, but they are balanced

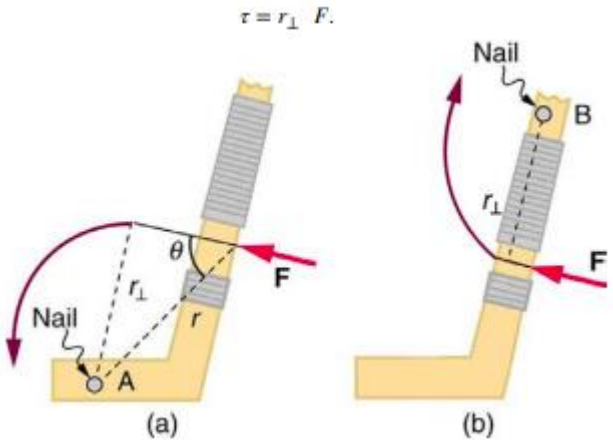
The first condition of equilibrium is that the net external force on the system must be zero

- Net F = 0
- The net external force in *any* direction is zero (along x and y-axis)
- An object in **static equilibrium** is motionless
- An object in **dynamic equilibrium** is moving with constant velocity



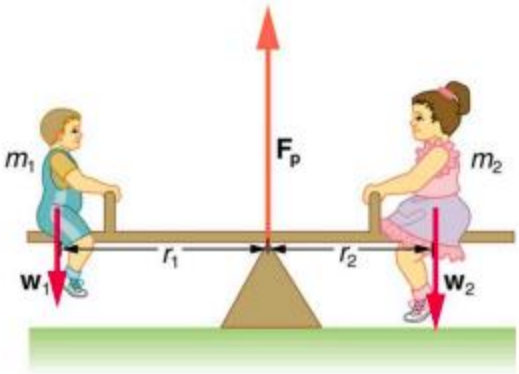
The second condition of equilibrium involves avoiding accelerated motion (so you want to maintain a constant angular velocity)

- A rotating body or system can be in equilibrium if its rate of rotation is constant and remains unchanged by the forces acting on it
- **Torque** is the rotational equivalent of a force
    - It is a measure of the effectiveness of a force in changing or accelerating a rotation
    - $\tau = rF\ sin\theta$
        - R is the distance from the pivot point to the point where the force is applied
        - $\theta$is the angle between the force and the vector directed from the point of application to the pivot point
    - An alternate expression for torque is given in terms of the **perpendicular lever arm**
        - $\tau = \boldsymbol{r}_{\perp}\boldsymbol{F}$
    - The **SI unit of torque** is newtons times meters (N x m)
    - Torque is always calculated with reference to some chosen pivot point
        - Torque is either clockwise or counterclockwise relative to the chosen pivot point



The third condition necessary to achieve equilibrium is that the net external torque on a system must be zero

- An external torque is one that is created by an external force



A system is said to be in **stable equilibrium** if, when displaced from equilibrium, it experiences a net force or torque in a direction opposite to the direction of the displacement

- Ex: an object experiencing a restoring force

A system is in **unstable equilibrium** if, when displaced, it experiences a net force or torque in the same direction as the displacement from equilibrium

- Ex: a ball resting on top of a hill that is displaced

A system is in **neutral equilibrium** if its equilibrium is independent of displacements from its original position

- Ex: a marble on a flat horizontal surface

These are the steps to take for solving static equilibrium problems**:**

- Determine whether or not the system is in **static equilibrium**
    - The acceleration of the system is zero and accelerated rotation does not occur
- Draw a free body diagram for the system of interest
    - Label all forces and note their relative magnitudes, directions, and points of application
- Apply either or both of the conditions for equilibrium
    - net F = 0 and net τ= 0
- Check the solution to see if it is reasonable
    - Examine the magnitude, direction, and units of the answer

Mechanical advantage is the ratio of output to input force magnitudes for any simple machine

- $MA = F_o/F_i$