PHYS 1443 – Section 003
Lecture #19

Wednesday, Nov. 12, 2003
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1. Conditions for Mechanical Equilibrium
2. Center of Gravity in Mechanical Equilibrium
3. Elastic Properties of Solids
   - Young's Modulus
   - Shear Modulus
   - Bulk Modulus

Today's homework is homework #10 due noon, Wednesday, Nov. 19!!

Conditions for Equilibrium

What do you think does the term "An object is at its equilibrium" mean?

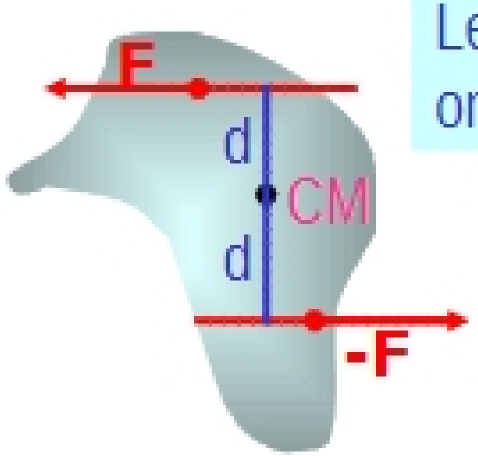
The object is either at rest (Static Equilibrium) or its center of mass is moving with a constant velocity (Dynamic Equilibrium).

When do you think an object is at its equilibrium?

Translational Equilibrium: Equilibrium in linear motion $\sum \vec{F} = 0$

Is this it?

The above condition is sufficient for a point-like particle to be at its static equilibrium. However for object with size this is not sufficient. One more condition is needed. What is it?



Let's consider two forces equal magnitude but opposite direction acting on a rigid object as shown in the figure. What do you think will happen?

The object will rotate about the CM. The net torque acting on the object about any axis must be 0. $\sum \vec{\tau} = 0$

For an object to be at its static equilibrium, the object should not have linear or angular speed. $v_{CM} = 0 \quad \omega = 0$

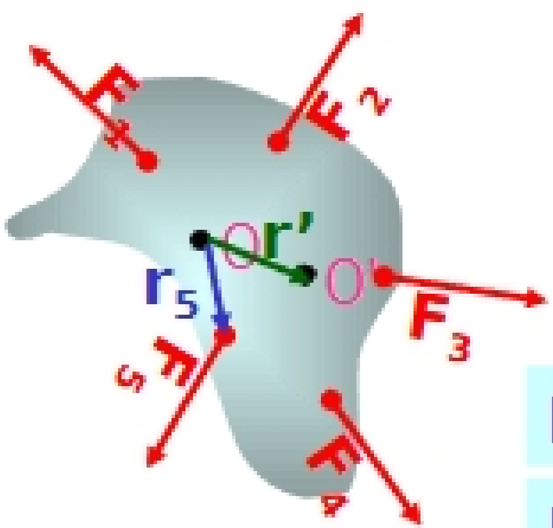
More on Conditions for Equilibrium

To simplify the problems, we will only deal with forces acting on x-y plane, giving torque only along z-axis. What do you think the conditions for equilibrium be in this case?

The six possible equations from the two vector equations turns to three equations.

$$\sum \vec{F} = 0 \quad \sum F_x = 0 \quad \sum F_y = 0 \qquad \sum \vec{\tau} = 0 \quad \sum \tau_z = 0$$

What happens if there are many forces exerting on the object?



If an object is at its translational static equilibrium, and if the net torque acting on the object is 0 about one axis, the net torque must be 0 about any arbitrary axis.

Net Force exerting on the object $\sum \vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \cdots = 0$

Net torque about O $\sum \vec{\tau}_O = \vec{r}_1 \times \vec{F}_1 + \vec{r}_2 \times \vec{F}_2 + \vec{r}_3 \times \vec{F}_3 + \cdots = \sum \vec{r}_i \times \vec{F}_i = 0$

Position of force **F**$_i$ about O' $\vec{r}_i' = \vec{r}_i - \vec{r}'$

Net torque about O' $\sum \vec{\tau}_{O'} = \vec{r}_1' \times \vec{F}_1 + \vec{r}_2' \times \vec{F}_2 + \cdots = (\vec{r}_1 - \vec{r}') \times \vec{F}_1 + (\vec{r}_2 - \vec{r}') \times \vec{F}_2 + \cdots = \sum \vec{r}_i \times \vec{F}_i - \vec{r}' \times \sum \vec{F}_i$

$$\sum \vec{\tau}_{O'} = \sum \vec{r}_i \times \vec{F}_i - \vec{r}' \times 0 = \sum \vec{\tau}_O = 0$$