Lecture 3: Equilibrium

An object is said to be in equilibrium when _____ _____. That is, according to Newton's first law, the body will _____.

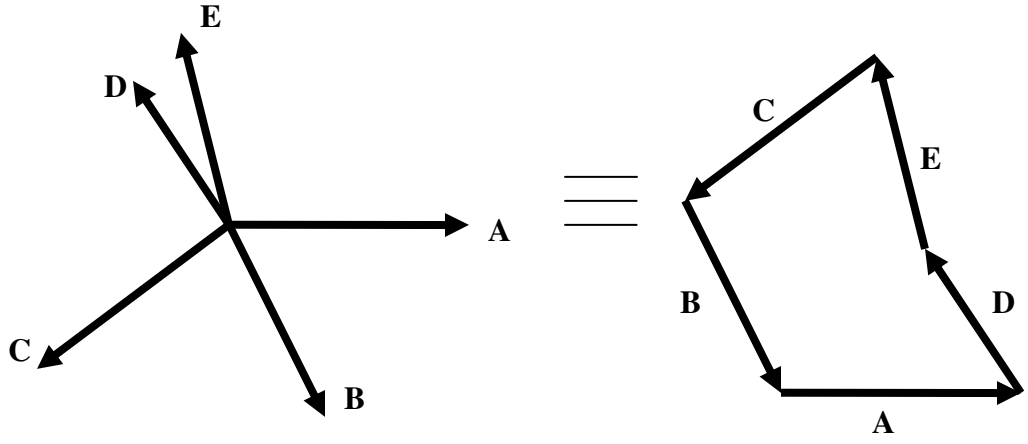
Newton's laws of motion state that

1. A particle remains at rest or continues to move with a constant velocity unless an unbalanced force acts on it.
2. Force = mass x acceleration
3. The forces of action and reaction between bodies are always equal in magnitude, in the opposite directions and collinear (lie in the same line in space).

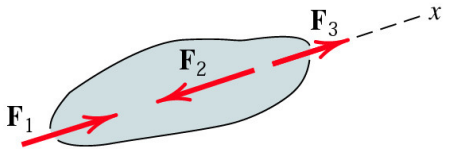
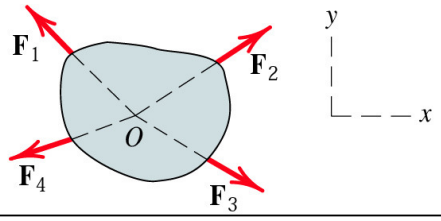
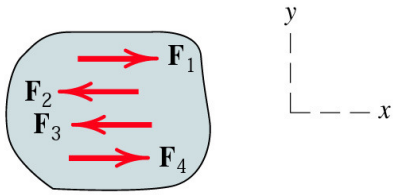
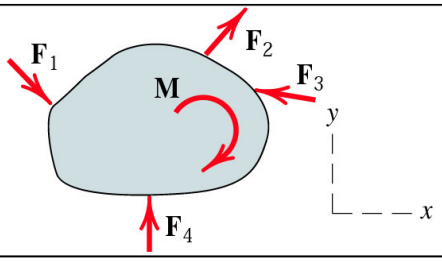
From the first law, it can be deduced that an object in equilibrium must have zero resultant force and zero moment acting on it. For a general case of an object in a three dimensional space, the conditions for equilibrium can be given as

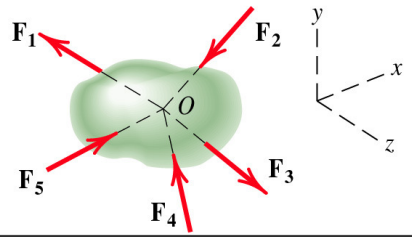
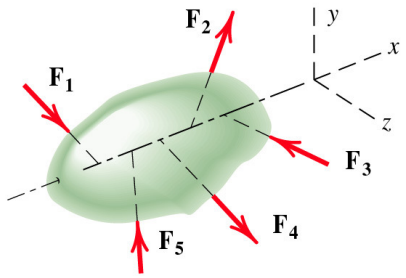
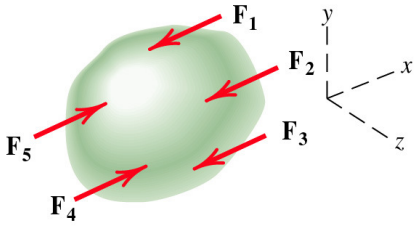
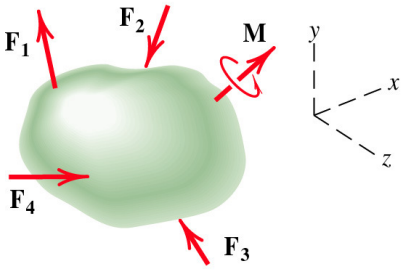
$$\sum F_x = \sum F_y = \sum F_z = \sum M_x = \sum M_y = \sum M_z = 0$$

Graphically, all forces in a system in equilibrium must form a _____.



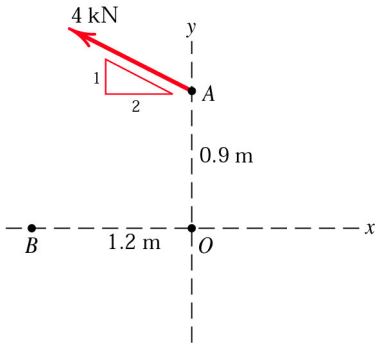
The following tables demonstrate the equilibrium conditions in two- and three-dimensional systems.

CATEGORIES OF EQUILIBRIUM IN TWO DIMENSIONS		
Force System	Free-Body Diagram	Independent Equations
1. Collinear		$\Sigma F_x = 0$
2. Concurrent at a point		$\Sigma F_x = 0$ $\Sigma F_y = 0$
3. Parallel		$\Sigma F_x = 0$ $\Sigma M_z = 0$
4. General		$\Sigma F_x = 0$ $\Sigma M_z = 0$ $\Sigma F_y = 0$

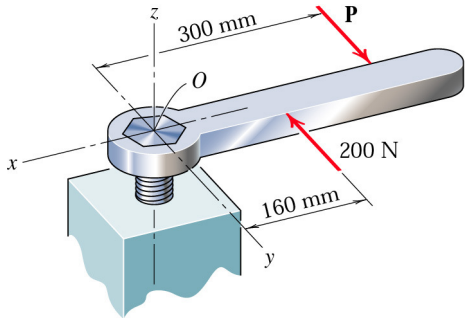
CATEGORIES OF EQUILIBRIUM IN THREE DIMENSIONS		
Force System	Free-Body Diagram	Independent Equations
1. Concurrent at a point		$\Sigma F_x = 0$ $\Sigma F_y = 0$ $\Sigma F_z = 0$
2. Concurrent with a line		$\Sigma F_x = 0$ $\Sigma M_y = 0$ $\Sigma F_y = 0$ $\Sigma M_z = 0$ $\Sigma F_z = 0$
3. Parallel		$\Sigma F_x = 0$ $\Sigma M_y = 0$ $\Sigma M_z = 0$
4. General		$\Sigma F_x = 0$ $\Sigma M_x = 0$ $\Sigma F_y = 0$ $\Sigma M_y = 0$ $\Sigma F_z = 0$ $\Sigma M_z = 0$

Exercises

1. [2/54 Meriam] Replace the 4 kN force acting at point A by a force-couple system at
   (a) point O
   (b) point B



2. [2/67 Meriam] The wrench is subjected to the 200 N force and the force **P** as shown. If the equivalent of the two forces is a force **R** at O and a couple expressed as the vector $\mathbf{M} = 20\mathbf{k}\ \ N \cdot m$, determine the vector expressions for **P** and **R**.



3. [2/117 Meriam] The right-angle pipe OAB is shown here. Given that the cable carries 750 N tensile force, replace it with a force-couple system at point O.