**Lecture 5**
GEN_ENG 205-2: Engineering Analysis 2
Winter Quarter 2018
Prof. James P. Hambleton
Chapter 3: §3.1 Forces[1]

Acknowledgements

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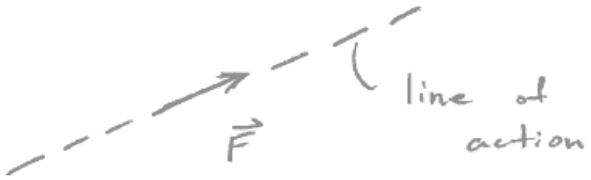
## Forces in Equilibrium

The next four chapters focus on equilibrium[2]:

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

$$\sum \vec{M} = 0 \quad \leftarrow \text{moments introduced in Chapter 4}$$

## Force basics




The line of action is the line collinear with the force vector.

[1] Bedford, A., & Fowler, W. (2008). *Engineering Mechanics: Statics and Dynamics* (5th ed.). Upper Saddle River, NJ: Pearson Prentice Hall.
[2] An object is in equilibrium only if each point of the object has the same (constant) velocity. This velocity is measured with respect to an inertial reference frame, which we assume is fixed with respect to the earth.

A system of forces is simply a set of forces.

A system of forces is coplanar, or two-dimensional (Section 3.2), if the lines of action of all the forces lie in a plane. Otherwise, it is three-dimensional (Section 3.3).

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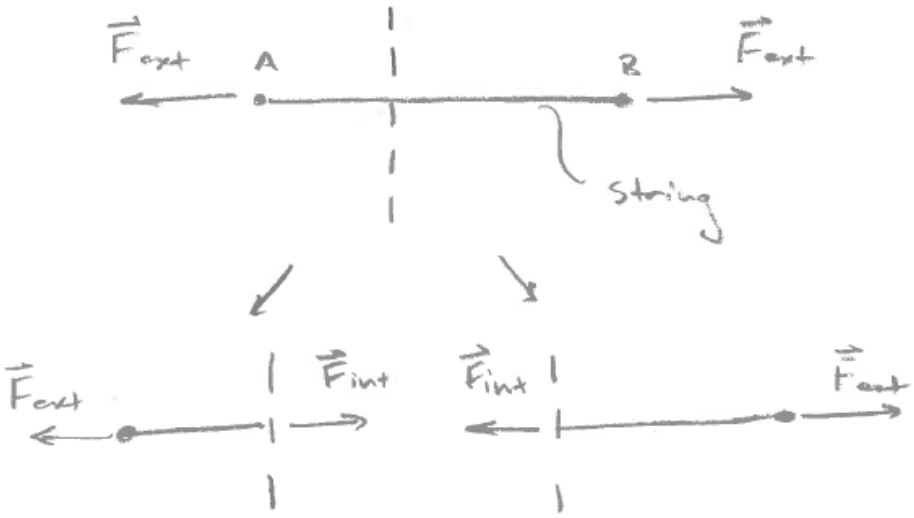
An external force is a force exerted on a particular object by a different object.

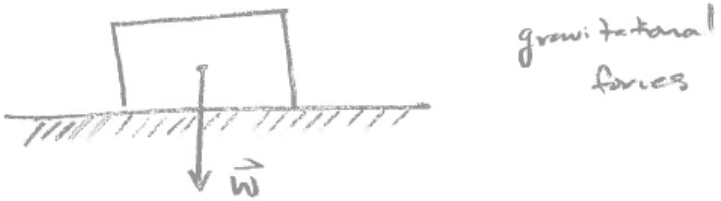
An internal force is a force exerted by a different part of the same object.



A <u>body force</u> acts over the volume of an object. A <u>surface force</u> acts on its surface.

<u>Types of forces</u>

Gravitational forces




$$\left|\vec{W}\right| = mg$$

where $m$ is the mass and we assume $g$ = 9.81 m/s$^2$ or 32.2 ft/s$^2$.

Contact forces


Forces are equal in magnitude and opposite in direction (Newton's 3rd law).

$\vec{F} = \vec{N} + \vec{f}$

$\vec{N}$ component of force normal to the surface, or <u>normal force</u>

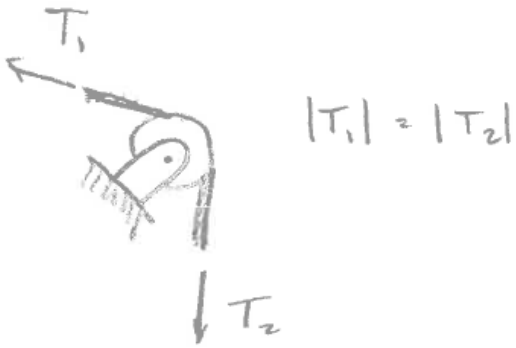
$\vec{f}$ component of force tangent (or parallel) to the surface, or <u>friction force</u>

$\vec{f} = 0$ means <u>smooth</u>

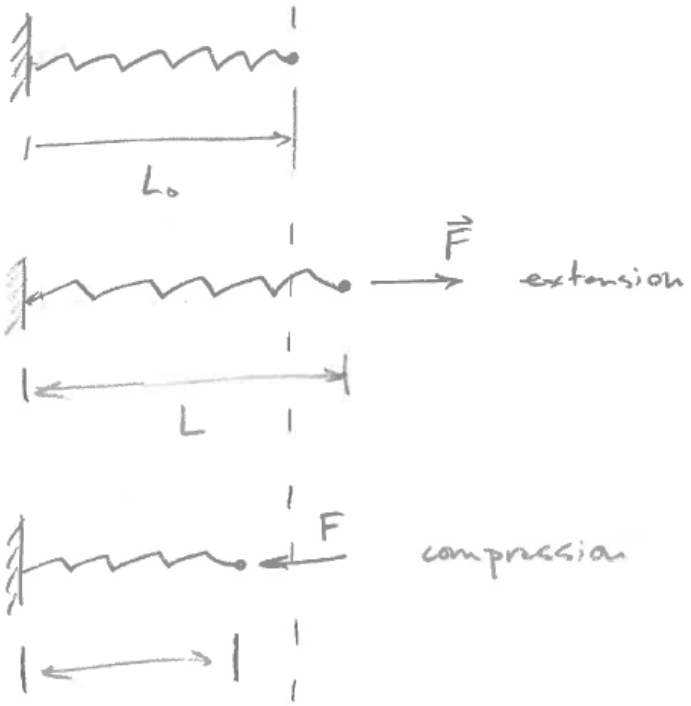
$\vec{f} > 0$ means <u>rough</u>

Forces in ropes and cables

We assume that ropes and cables are weightless and <u>carry only tension</u>. Furthermore, we assume that <u>tension is the same on each side of a pulley</u>.




Spring forces




$$\left|\vec{F}\right| = k\left|L - L_0\right|$$

$k$ is the spring constant with units [$k$] = forces/length (e.g., N/m)

$L$ is the stretched length

$L_0$ is the unstretched (relaxed) length

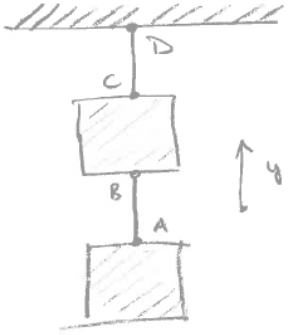
## Free-body diagrams

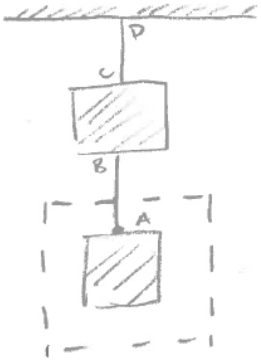
Steps in drawing a free-body diagram:

1. Identify the object you want to isolate.
2. Sketch the object isolated from its surroundings.
3. Draw the external[3] forces acting on the object, labeled appropriately.

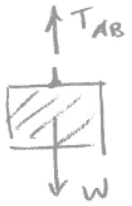
[3] External is now defined with respect to the object that has been isolated, or freed, from its surroundings.

Example (one-dimensional)



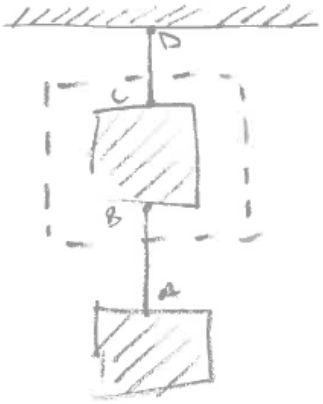




2 blocks of equal weight W




$\Sigma F_y = 0: \quad T_{AB} - W = 0$

$\Rightarrow \boxed{T_{AB} = W}$

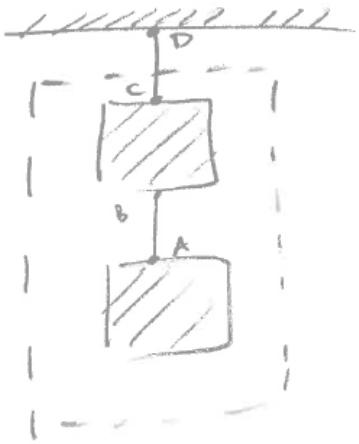




$\Sigma F_y = 0: \quad T_{CD} - T_{AB} - W = 0$

$T_{CD} - W - W = 0$

$\boxed{T_{CD} = 2W}$





$\Sigma F_y = 0: \quad T_{CD} - 2W = 0$

$\boxed{T_{CD} = 2W}$