PHY 107
Equilibrium/Elasticity

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OUTLINE

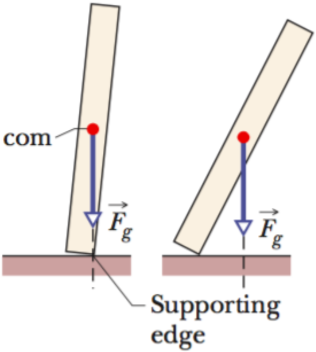
- What is equilibrium?
- Requirements of Equilibrium
- Center of gravity
- Examples of Static Equilibrium
- Elasticity

Equilibrium

Two conditions to be met for equilibrium:
1. The linear momentum $\overrightarrow{P}$ of its center of mass is constant.
2. Its angular momentum $\overrightarrow{L}$ about its center of mass, or about any other point, is also constant.

Static equilibrium: Constants are zero
No motion in any way

Equilibrium



The two requirements for a body to be in equilibrium are:

1. The vector sum of all the external forces that act on the body must be zero.
2. The vector sum of all external torques that act on the body, measured about any possible point, must also be zero.

Center of gravity

The gravitational force on a body effectively acts at a single point called the center of gravity (cog) of the body.

The net force and the net torque (about any point) acting on the body would not change.

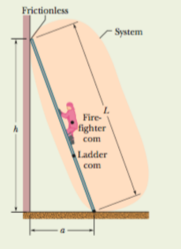
If g is the same for all the elements of a body, then the body's center of gravity (cog) is coincident with the body's center of mass (com).

g **varies little along the Earth's surface and decreases in size with altitude!**

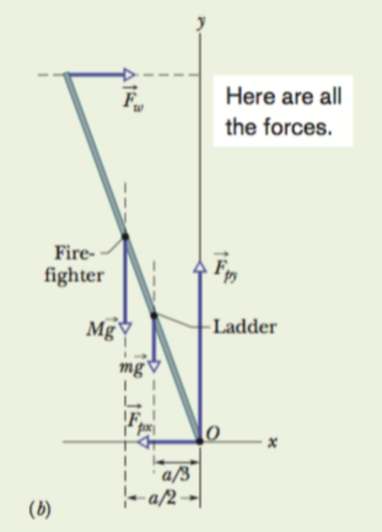
Example on static equilibrium

Balancing a leaning ladder

A ladder of length L =12m and mass m = 45 kg leans against a slick wall (that is, there is no friction between the ladder and the wall). The ladder's upper end is at height h = 9.3 m above the pavement on which the lower end is supported (the pavement is not frictionless). The ladder's center of mass is L/3 from the lower end, along the length of the ladder. A firefighter of mass M = 72 kg climbs the ladder until her center of mass is L/2 from the lower end. What then are the magnitudes of the forces on the ladder from the wall and the pavement?



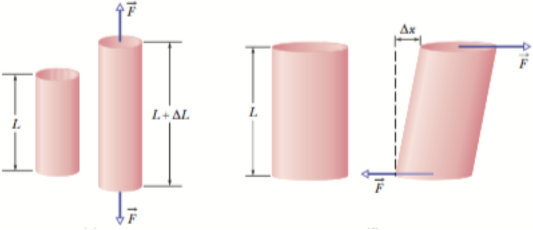
Solution:



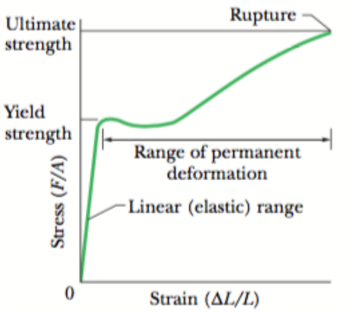
$\tau_{net,z} = 0$; Force Balancing Equation ; Geometry

Elasticity

All real 'rigid' bodies are to some extent elastic, which means that we can change their dimensions slightly by pulling, pushing, twisting, or compressing them.
Stress (deforming force per unit area) produces a strain (unit deformation).



Modulus of elasticity= Stress/ Strain



Tension and Compression: $\frac{F}{A} = G\frac{\Delta L}{L}$
Shearing stress: G=E

Example: One end of a steel rod of radius R = 9.5 mm and length L = 81 cm is held in a vise. A force of magnitude F = 62 kN is then applied perpendicularly to the end face (uniformly across the area) at the other end, pulling directly away from the vise. What are the stress on the rod and the elongation L and strain of the rod?

Solution:

$Stress = \frac{F}{\pi R^2}$

$\frac{\Delta L}{L} = \frac{(F/A)}{E}$

Problems of importance

Reference book (Extended 9th edition):
Some examples of static equilibrium: 3
Elasticity: 43

Reference

Fundamentals of Physics by Halliday and Resnik