Textbook Chapter Link

https://openstax.org/books/university-physics-volume-1/pages/12-introduction

Topic List

1. Equilibrium
2. Elasticity

Key Equations

- $\sigma = \frac{F}{A}$
- $\varepsilon = \frac{\Delta L}{L}$
- $Y = \frac{\sigma}{\varepsilon}$

Equilibrium

- From previous lectures
  - Equilibrium occurs when $\sum \vec{F} = 0$
  - Two types of equilibria
    - Static equilibrium: no motion
    - Dynamic equilibrium: motion
- Requirements for equilibrium
  - $\sum \vec{F} = 0$
  - $\sum \vec{\tau} = 0$
- Strategy to solve equilibrium problems

1. **Model the system with simple shapes**
2. **Draw all the force vectors that are applied on the system *where they are being applied***
3. **Pick a pivot point**
   Best to choose a point where all distances are measured from, or where equations simplify
4. **Apply conditions for equilibrium**

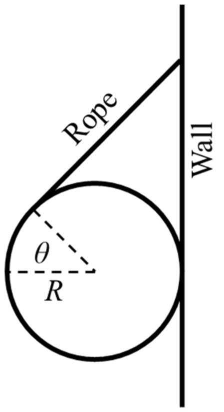
- **Example**: A 3.0-m-long massless horizontal bar is being pushed upward by a 40. N force on one end and a 60. N force on the other end. You quickly counteract this with a 100 N force downward, 1.0 m from the 60. N force. Is this system in equilibrium?

- **Example**: Three masses are attached to a uniform 150 g meter stick, where m_1 = 50. g is placed at 0 cm, m_2 = 75 g is at 30. cm, and m_3 is at the 100. cm mark. If the fulcrum is positioned at the 70. cm mark, find m_3 and the normal force at the fulcrum when the system is balanced.

- **Activity**: A uniform, 5.0-m ladder rests against a slippery vertical wall. The inclination angle between the ladder and the rough horizontal floor is 53°. If the ladder weighs 400.0 N, show that the coefficient of static friction that just prevents the ladder from slipping is 0.38.

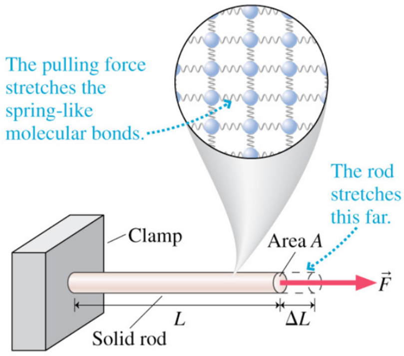
- **Activity**: A horizontal log with a length of 15.0 m and weight of 4.9 kN is supported partially by a tree stump on one end. A cable is also holding up the log and is positioned 2.0 m from the other end. If the tension measured in the cable is 4.0 kN and the log is not uniform, where is the log's center of mass?

- **Activity**: A cylinder with mass M and radius R is held up by a rope connected to a rough wall and the wall itself, as shown in the figure. The rope is tangent to the surface of the cylinder and connected to a point θ parallel to the cross-sectional area as measured from the horizontal. What is the lowest possible value for the coefficient of static friction between the cylinder and the rough wall, such that equilibrium is maintained?



- **Activity**: A solid cube with sides of length a and mass m is placed on a rough surface. You are instructed to push horizontally on one of the cube's top edges with just enough force F such that the block starts to tip over. Assuming that the static friction force is large enough such that the block will not start to slide across the surface, determine
  - This minimum force F.
  - The lowest possible value for the coefficient of static friction.

Elasticity



- Molecular bonds can be treated as small springs[1]
  - Applying a force to the system stretches these springs
- Stress
  - Indicates how the force applied is distributed across the bonds

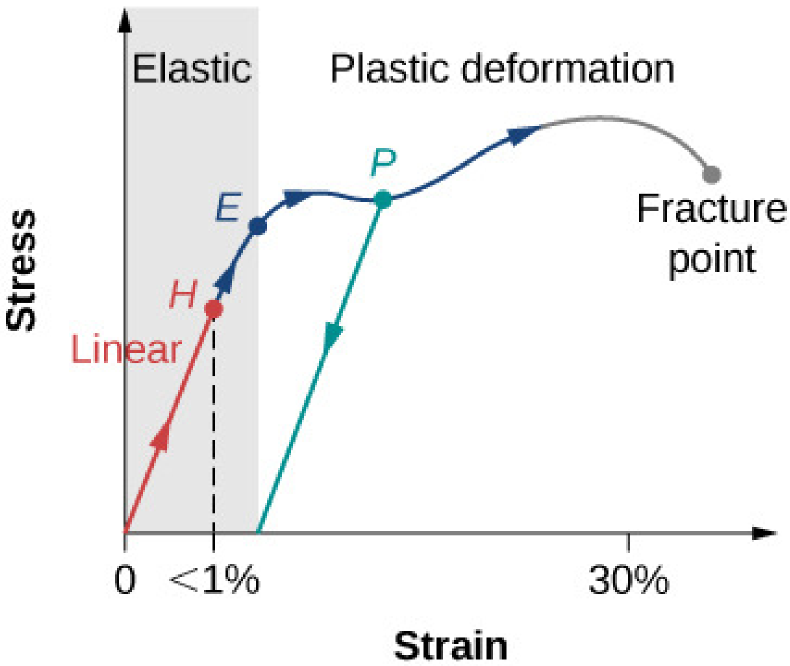
$$\sigma = \frac{F}{A}$$

- Strain
  - Represents the fractional extent of deformation

$$\varepsilon = \frac{\Delta L}{L}$$

- Young's Modulus
  - Measure of how well material can withstand tension

$$Y = \frac{\sigma}{\varepsilon}$$



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- **Example**: A human anterior cruciate ligament (ACL) with a length of 2.7 cm and a steel rod that has a length equal to 54 cm are subjected to the same stretching force. Both have the same cross-sectional area. Find the ratio of the change in length of the ACL to the change in length of the steel rod. Use $Y_S = 2.0\times10^{11}$ N/m^2 and $Y_{ACL} = 1.0\times10^8$ N/m^2.

- **Activity**: A 2.0-m-long, 1.0-mm-diameter wire is suspended from the ceiling. Hanging a 4.5-kg mass from the wire stretches the wire by 1.0 mm. Using the Young's Modulus of the wire, determine what the material is composed of by using Table 12.1 in Section 12.3 of the textbook.

- **Activity:** A typical cross sectional area of a human ACL is 4.4×10^{-5} m^2. What applied stretching force is required to cause a 0.10% change in length? For ACL, $Y = 1.0\times10^8$ N/m^2