College Of Engineering
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Dept. of Chem. & Petrochemical Engineering
Subject : Physics
First Stage

Physics

Chapter-4 Static Equilibrium and Elasticity

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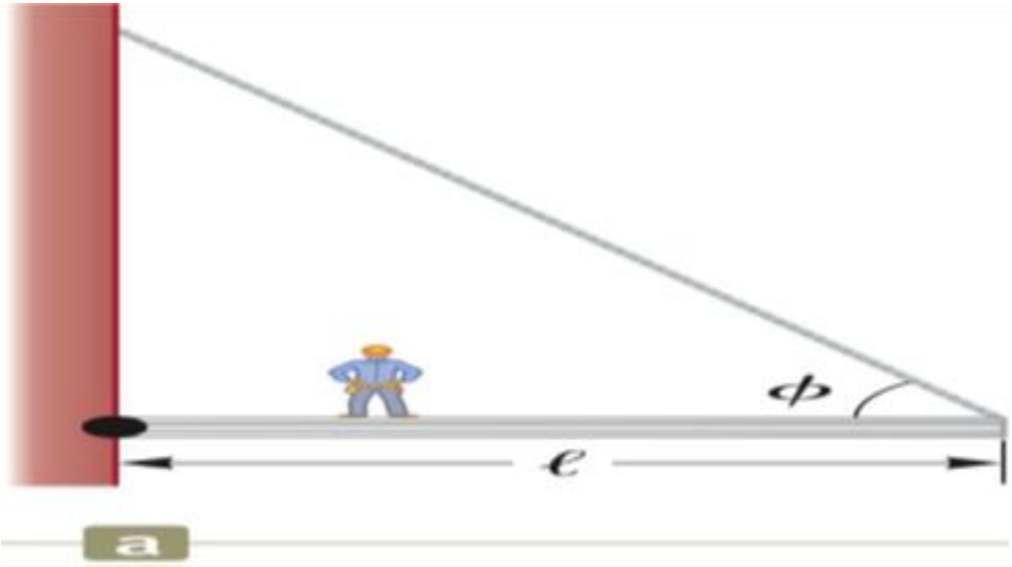
Horizontal Beam Example

Conceptualize

- The beam is uniform.
- So the center of gravity is at the geometric center of the beam.
- The person is standing on the beam.
- What are the tension in the cable and the force exerted by the wall on the beam?

Categorize

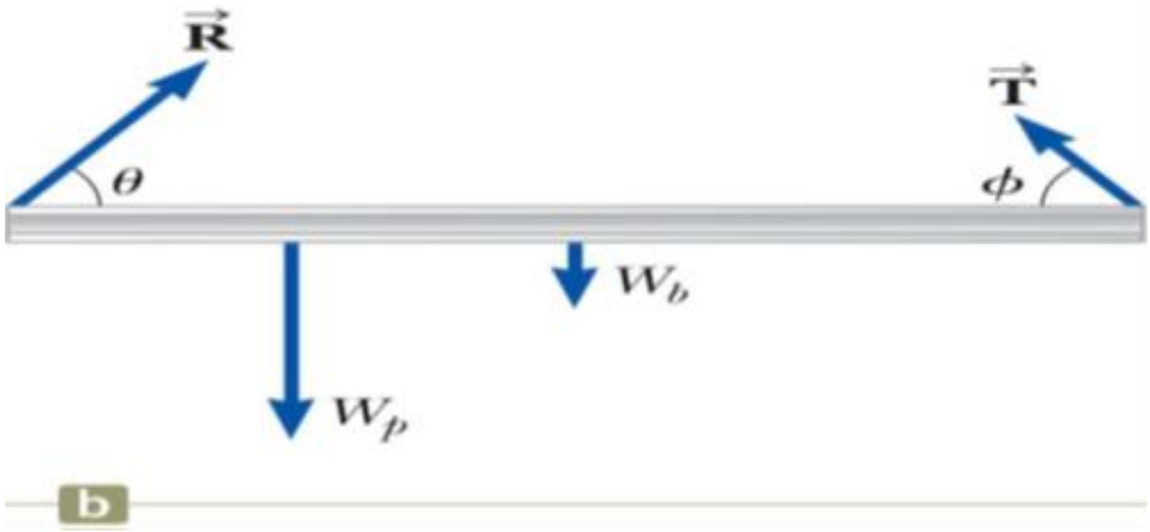
- The system is at rest, categorize as a rigid object in equilibrium.



Horizontal Beam Example, 2

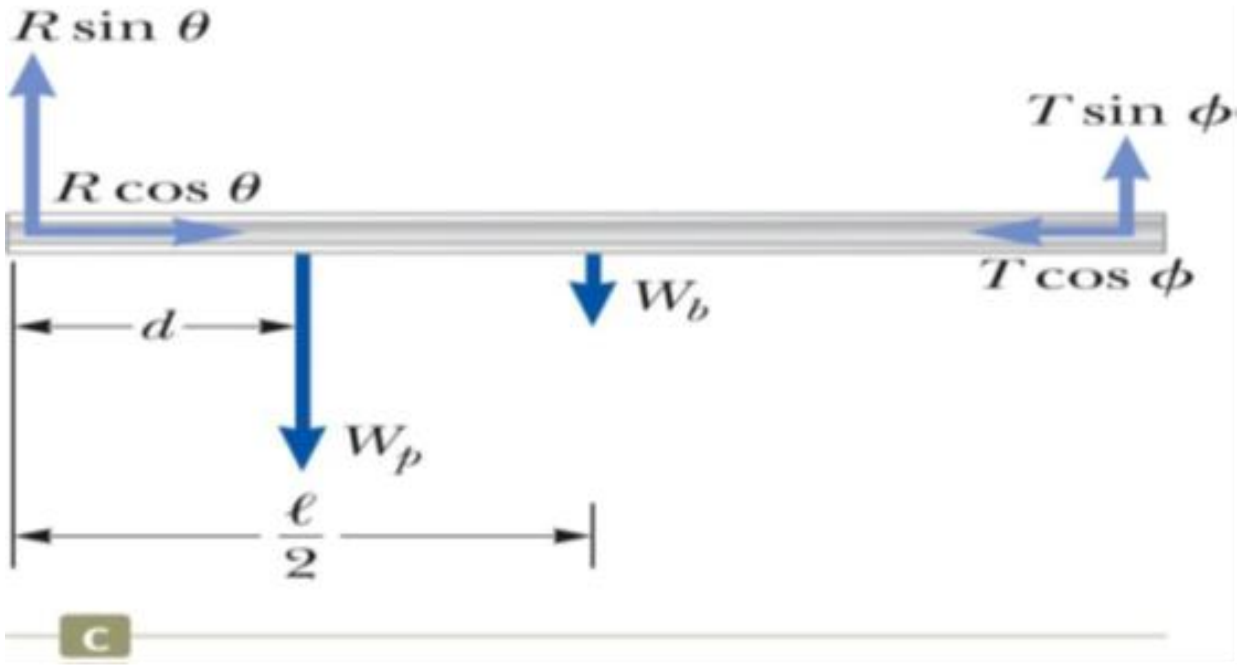
Analyze

- Draw a force diagram.
- Use the pivot in the problem (at the wall) as the pivot.
- This will generally be easiest.
- Note there are three unknowns (T, R,).



Analyze, cont.

- The forces can be resolved into components.
- Apply the two conditions of equilibrium to obtain three equations.
- Solve for the unknowns.



Finalize

- The positive value for θ indicates the direction of R was correct in the diagram.

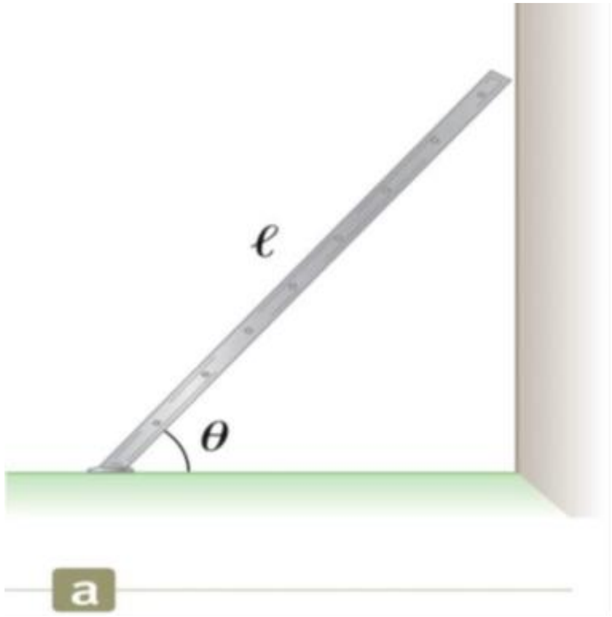
Ladder Example

Conceptualize

- The ladder is uniform.
- So the weight of the ladder acts through its geometric center (its center of gravity).
- There is static friction between the ladder and the ground.

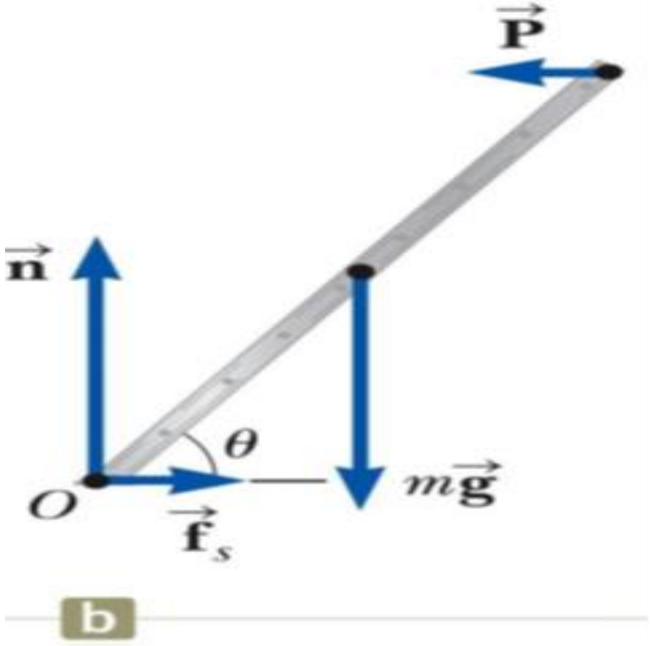
Categorize

- Model the object as a rigid object in equilibrium.



Analyze

- Draw a diagram showing all the forces acting on the ladder.
- The frictional force is $f_s = \mu_s n$.
- Let O be the axis of rotation.
- Apply the equations for the two conditions of equilibrium.
- Solve the equations.



Elasticity

So far we have assumed that objects remain rigid when external forces act on them.

- Except springs

Actually, all objects are deformable to some extent.

- It is possible to change the size and/or shape of the object by applying external forces.

Internal forces resist the deformation.

Stress

- Is proportional to the force causing the deformation
- It is the external force acting on the object per unit cross-sectional area.

Strain

- Is the result of a stress
- Is a measure of the degree of deformation

Elastic Modulus

The elastic modulus is the constant of proportionality between the stress and the strain.

- For sufficiently small stresses, the stress is directly proportional to the stress.
- It depends on the material being deformed.
- It also depends on the nature of the deformation.

The elastic modulus, in general, relates what is done to a solid object to how that object responds.

$$\text{elastic modulus} \equiv \frac{\text{stress}}{\text{strain}}$$

Various types of deformation have unique elastic moduli.

Young's Modulus: Measures the resistance of a solid to a change in its length
Shear Modulus: Measures the resistance of motion of the planes within a solid parallel to each other
Bulk Modulus: Measures the resistance of solids or liquids to changes in their volume

Young’s Modulus

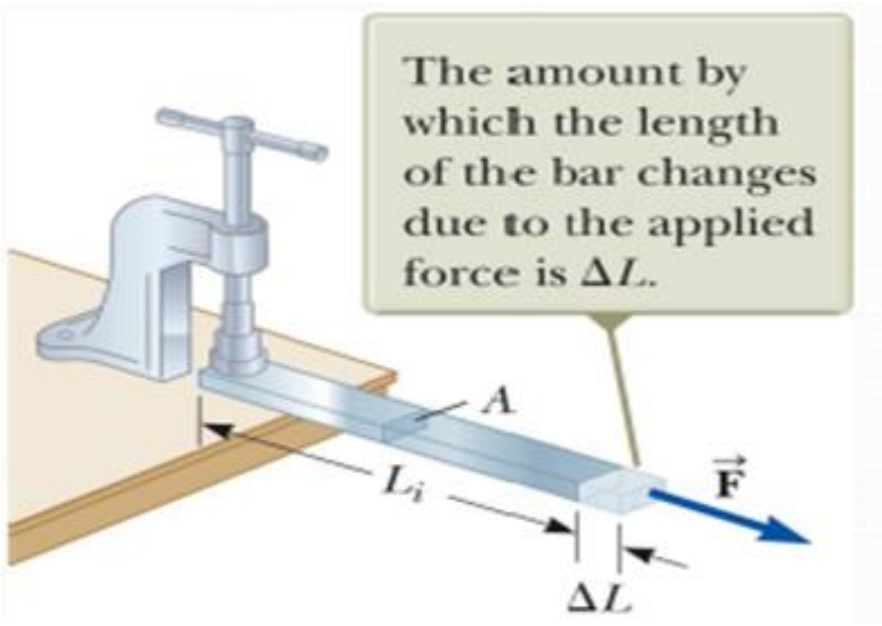
The bar is stretched by an amount DL under the action of the force F.

The **tensile stress** is the ratio of the magnitude of the external force to the cross-sectional area A.

The **tension strain** is the ratio of the change in length to the original length.

Young’s modulus, Y, is the ratio of those two ratios:

$$Y \equiv \frac{\text{tensile stress}}{\text{tensile strain}} = \frac{F/A}{\Delta L/L_i}$$

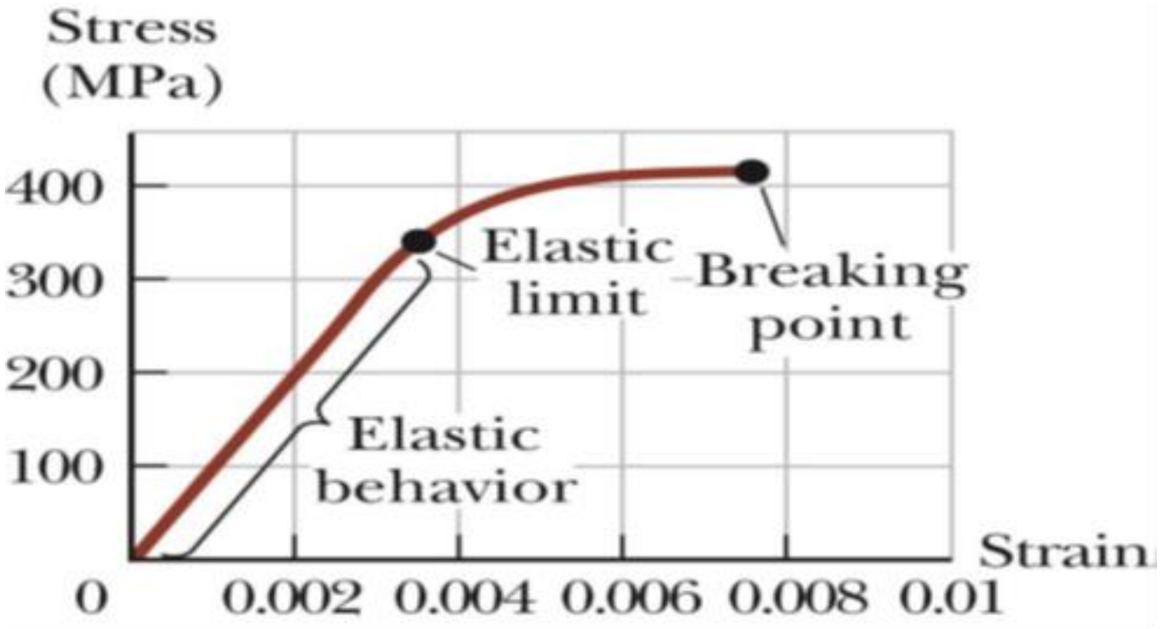


Units are N / m2

Experiments show that for certain stresses, the stress is directly proportional to the strain. This is the elastic behavior part of the curve.

When the stress exceeds **the elastic limit**, the substance will be permanently deformed.

With additional stress, the material ultimately breaks.



Shear Modulus

Another type of deformation occurs when a force acts parallel to one of its faces while the opposite face is held fixed by another force.

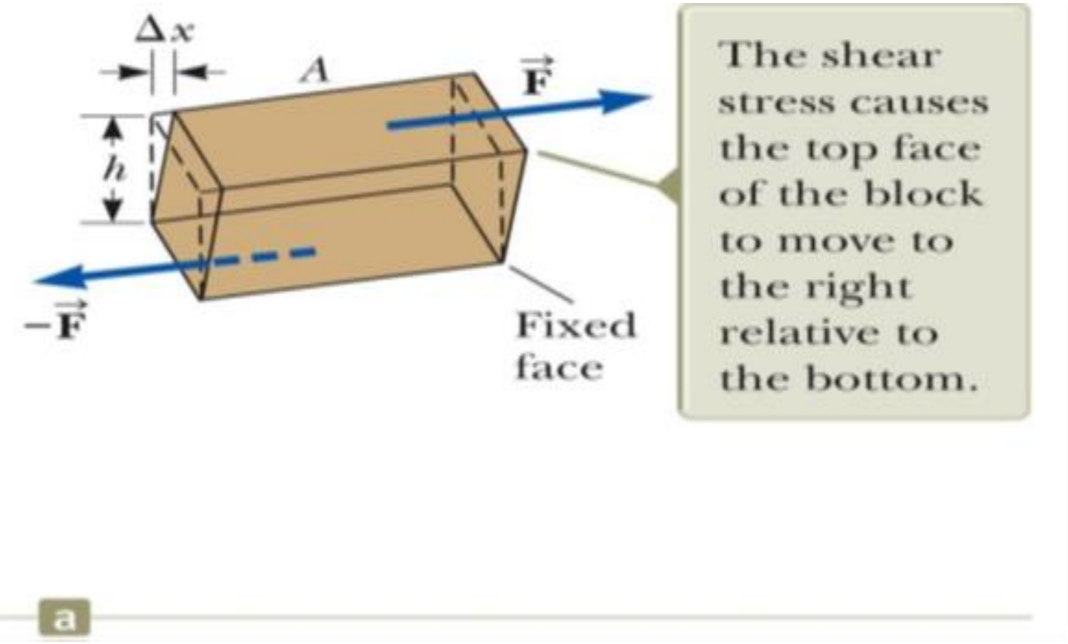
This is called a ***shear stress.***

For small deformations, no change in volume occurs with this deformation.

□ A good first approximation

The shear strain is x / h.

□ x is the horizontal distance the sheared face moves.



- h is the height of the object.

The shear stress is F / A.

- F is the tangential force.
- A is the area of the face being sheared.

The shear modulus is the ratio of the shear stress to the shear strain.

$$S = \frac{\text{shear stress}}{\text{shear strain}} = \frac{F/A}{\Delta x/h}$$

Units are N / m^2

Example: Shear stress on the spine

Between each pair of vertebrae of the spine is a disc of cartilage of thickness 0.5 cm. Assume the disc has a radius of 0.04 m. The shear modulus of cartilage is 1 107N=m2. A shear force of 10 N is applied to one end of the disc while the other end is held fixed. (a) What is the resulting shear strain? (b) How far has one end of the disc moved with respect to the other end?

Solution: (a) The shear strain is caused by the shear force,

$$\begin{aligned} \text{strain} &= \frac{F}{AS} \\ \text{strain} &= \frac{10 \text{ N}}{\pi(0.04 \text{ m})^2(1 \times 10^7 \text{ N/m}^2)} \\ \text{strain} &= 1.99 \times 10^{-4}. \end{aligned}$$

• (b) A shear strain is dined as the displacement over the height,

$$\begin{aligned} \text{strain} &= \frac{\Delta x}{h} \\ \Delta x &= h \times \text{strain} \\ \Delta x &= (0.5\ \text{cm})(1.99 \times 10^{-4}) \\ \Delta x &= 0.99\ \mu\text{m}. \end{aligned}$$