Statics - TAM 211

Lecture 40

April 27, 2018

Announcements

- Check ALL of your grades on Compass2g. Report issues
  - Exam grades will be posted later this week
- There will be Discussion Sections next week
- Upcoming deadlines:
  - Quiz 6
    - CBTF (W-F: 4/25-27)
    - CoG thru 3D Rigid Bodies: Lectures 29-36
  - Tuesday (5/1)
    - PL HW 15
  - Wednesday (5/2)
    - Written Assignment 6
  - Quiz 7
    - CBTF (Thurs-Tues: 5/3-8)
    - 50 minutes
    - Fluid Pressure - Virtual Work

Chart of centroid locations for different geometries - Attachment in CBTF quiz

Chapter 11: Virtual Work

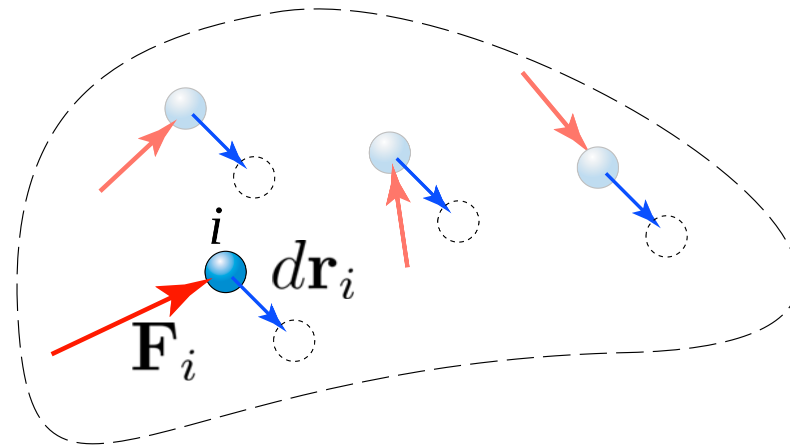
Goals and Objectives

- Introduce the principle of virtual work
- Show how it applies to determining the equilibrium configuration of a series of pin-connected members

Recap: Definition of Work (U)

Work of a force

A force does work when it undergoes a displacement in the direction of the line of action.

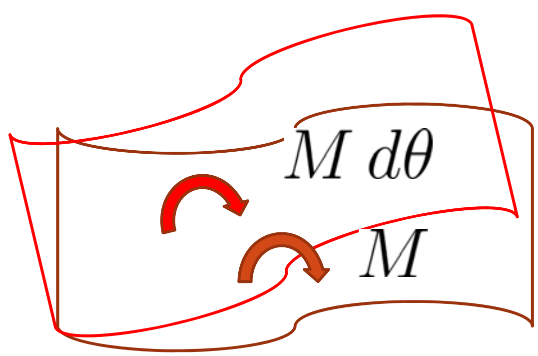


The work dU produced by the force $\boldsymbol{F}$ when it undergoes a differential displacement $d\boldsymbol{r}$ is given by

$$dU = \mathbf{F} \cdot d\mathbf{r}$$

Work of a couple moment

$$dU = M\mathbf{k} \cdot d\theta\,\mathbf{k} = M\,d\theta$$



Virtual Displacements

A *virtual displacement* is a conceptually possible displacement *or* rotation of all *or* part of a system of particles. The movement is assumed to be possible, but actually does not exist. These "movements" are first-order differential quantity denoted by the symbol δ (for example, δr and $\delta\theta$.

Principle of Virtual Work

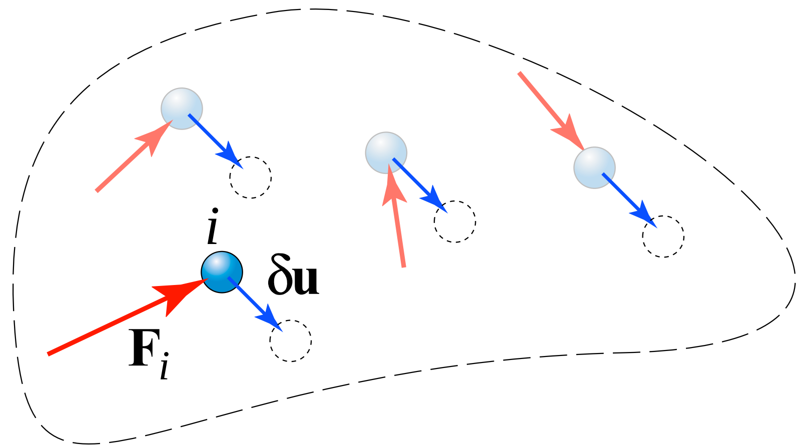
The principle of virtual work states that if a body is in equilibrium, then the algebraic sum of the virtual work done by all the forces and couple moments acting on the body is zero for any virtual displacement of the body. Thus,

$$\delta U = 0$$

$$\delta U = \Sigma(\boldsymbol{F} \cdot \delta \boldsymbol{u}) + \Sigma(\boldsymbol{M} \cdot \delta \boldsymbol{\theta}) = 0$$

For 2D:

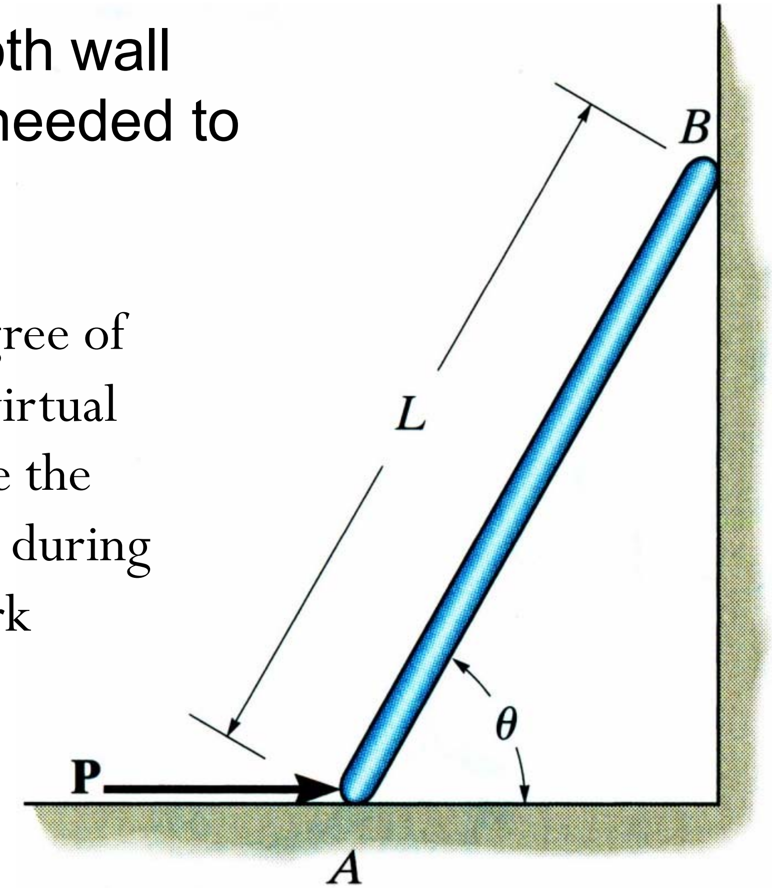
$$\delta U = \Sigma(\boldsymbol{F} \cdot \delta \boldsymbol{u}) + \Sigma(M\, \delta \theta) = 0$$



Procedure for Analysis

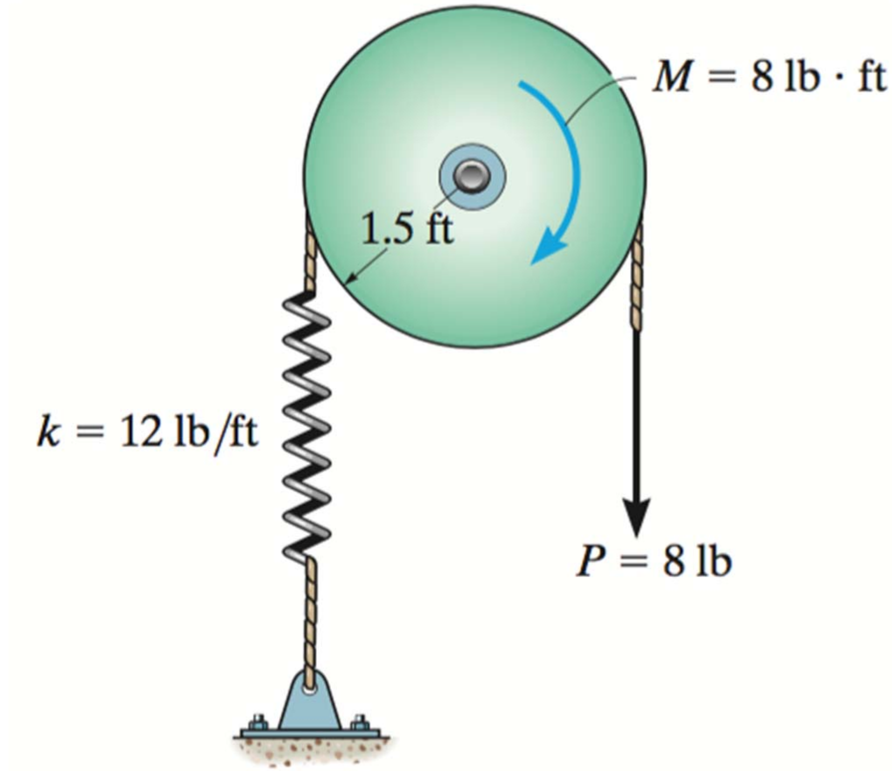
1. Draw FBD of the entire system and provide coordinate system
2. Sketch the "deflected position" of the system
3. Define position coordinates measured from a fixed point and select the parallel line of action component and remove forces that do no work
4. Differentiate position coordinates to obtain virtual displacement
5. Write the virtual work equation and express the virtual work of each force/ couple moment
6. Factor out the comment virtual displacement term and solve

The thin rod of weight W rests against the smooth wall and floor. Determine the magnitude of force P needed to hold it in equilibrium.



Use the principle of virtual work. This problem has one degree of freedom, which we can take as the angle θ. Let $\delta\theta$ be the virtual rotation of the rod, such that the rod slides at A and B. Since the contact at A and B are smooth, the only forces that do work during the virtual displacements are P and W. Then the virtual work becomes:

Disk of 10 lb is subjected to a vertical force P = 8 lb and a couple moment M = 8 lb ft. Determine disk's rotation θ if the end of the spring wraps around the periphery of the disk as the disk turns. The spring is originally unstretched.



Determine the mass of A and B required to hold the 400 g desk lamp in balance for any angles θ and ϕ. Neglect the weight of the mechanism and the size of the lamp.