Statics - TAM 211

Lecture 41

April 30, 2018

Announcements

- Check ALL of your grades on Compass2g. Report issues
  - Exam grades are now posted
- There will be Discussion Sections this week
- Upcoming deadlines:
  - 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

http://knowledge.wharton.upenn.edu

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

"Work-Energy Method" for deriving equations of equilibrium.

$$\delta U = \sum(\vec{F} \cdot \delta \vec{r}) + \sum(\vec{M} \cdot \delta \vec{\theta}) = 0$$

Throughout this course, we have been using the "Force-Balance Method" for deriving E of E.

$$\Sigma \vec{F} = 0, \quad \Sigma \vec{M} = 0$$

Virtual work (Work-Energy Method) is particularly useful for structures with many members, whereas F-B method needs multiple eqns ($\Sigma \vec{F} = 0$, $\Sigma \vec{M} = 0$) per member.

Recap: 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,

virtual work

$$\delta U = 0$$

super, super small → 0

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

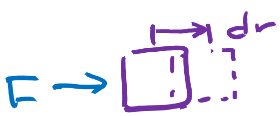
For 2D:

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

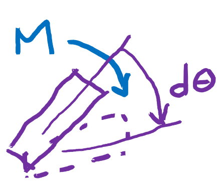
(↑ x, y) (↑ z)

Positive Work: Force/moment are in the same direction as displacement

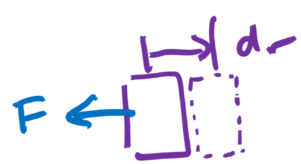
Negative Work: F/M are opposite direction as disp.



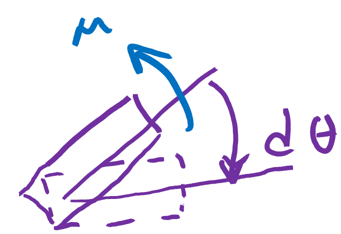
+Fdr



+Mdθ



−Fdr

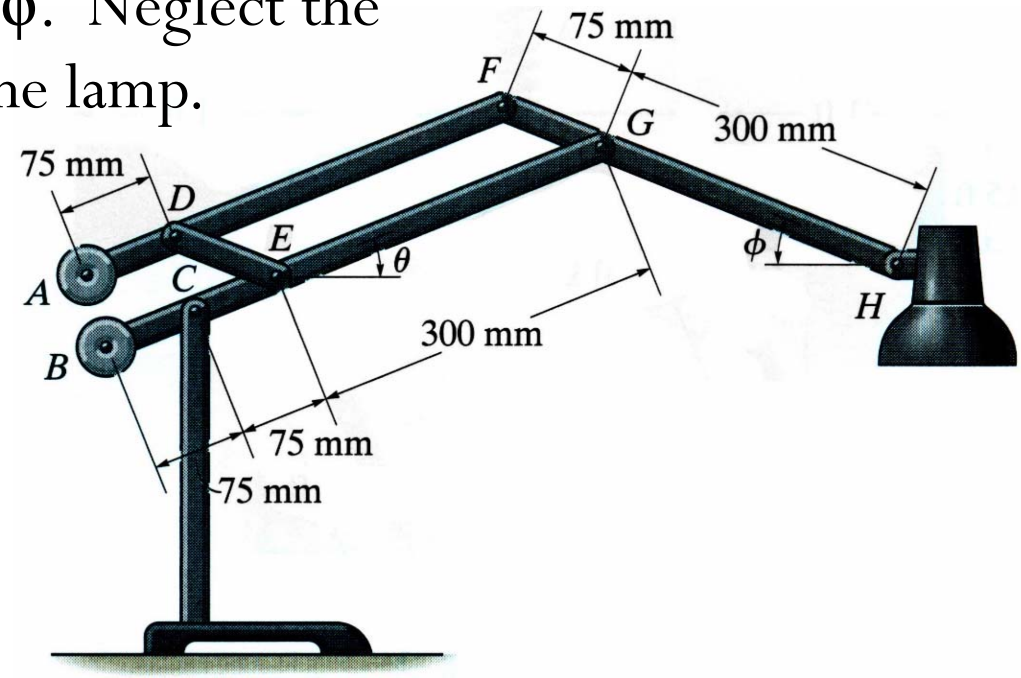


−Mdθ

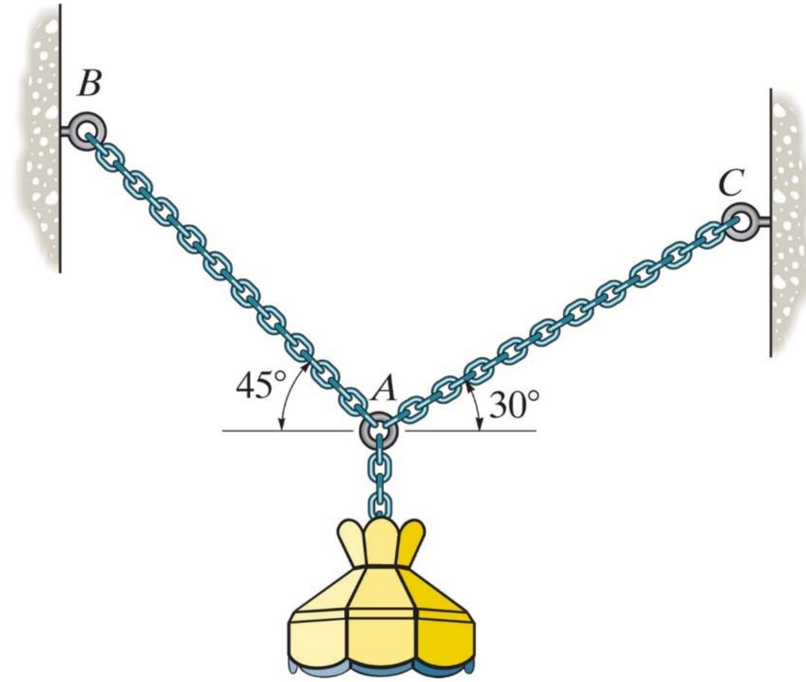
Procedure for Analysis

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 <u>fixed</u> point and select the parallel line of action component and <u>remove forces that do no work</u>
4. <u>Differentiate</u> 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

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. Assume that pins are frictionless.



Determine the tension in the cable *AC*. The lamp weighs 10 lb.



The scissors jack supports a load **P**. Determine axial force in the screw necessary for equilibrium when the jack is in the position shown. Each of the four links has a length L and is pin-connected at its center. Points B and D can move horizontally.