Statics - TAM TAM 211

Lecture 6

September 21, 2018

Announcements

- Zhaoyu Xu (TA) has office hours on Fridays 1-3 pm in Library Cafe.
- Use the Blackboard Discussion Board if you have questions.
- Videos with more practice of resultant forces have been uploaded to Blackboard
- No class on Monday September 24 (Mid-Autumn Festival)

- Upcoming deadlines:
- Friday (Sept 21)
  - Written Assignment 1
- Tuesday (9/26)
  - Prairie Learn HW2
- Thursday (9/28)
  - Note different day!
  - Quiz 1
  - 6-7 pm
  - Computer Lab
  - No personal calculator, must use computer

Chapter 3: Equilibrium of a particle

Goals and Objectives

- Practice following general procedure for analysis.
- Introduce the concept of a free-body diagram for an object modeled as a particle.
- Solve equilibrium problems using the equations of equilibrium.
  - 3D, 2D planar, idealizations (smooth surfaces, pulleys, springs)

Recap: General procedure for analysis

1. Read the problem carefully; write it down carefully.
2. MODEL THE PROBLEM: Draw given diagrams neatly and construct additional figures as necessary.
3. Apply principles needed.
4. Solve problem symbolically. Make sure equations are dimensionally homogeneous
5. Substitute numbers. Provide proper units *throughout*. Check significant figures. Box the final answer(s).
6. See if answer is reasonable.

Most effective way to learn engineering mechanics is to ***solve problems!***

Recap: Equilibrium of a particle

3-Dimensional forces: equilibrium requires

$$\sum \boldsymbol{F} = \sum F_x \, \boldsymbol{i} + \sum F_y \, \boldsymbol{j} + \sum F_z \, \boldsymbol{k} = \boldsymbol{0} \quad \Longrightarrow \quad \begin{aligned} \sum F_x &= 0 \\ \sum F_y &= 0 \\ \sum F_z &= 0 \end{aligned}$$

Planar forces: if all forces are acting in a single plane, such as the "xy" plane, then the equilibrium condition becomes

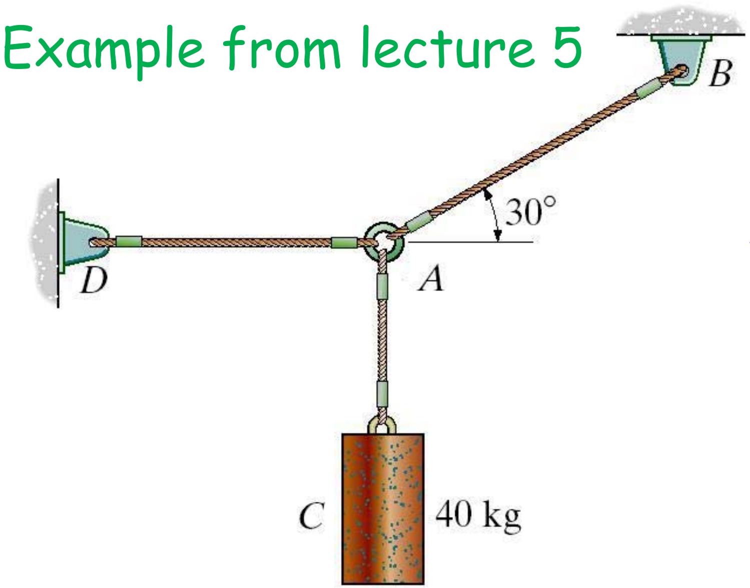
$$\sum \boldsymbol{F} = \sum F_x \, \boldsymbol{i} + \sum F_y \, \boldsymbol{j} = \boldsymbol{0} \quad \Longrightarrow \quad \begin{aligned} \sum F_x &= 0 \\ \sum F_y &= 0 \end{aligned}$$

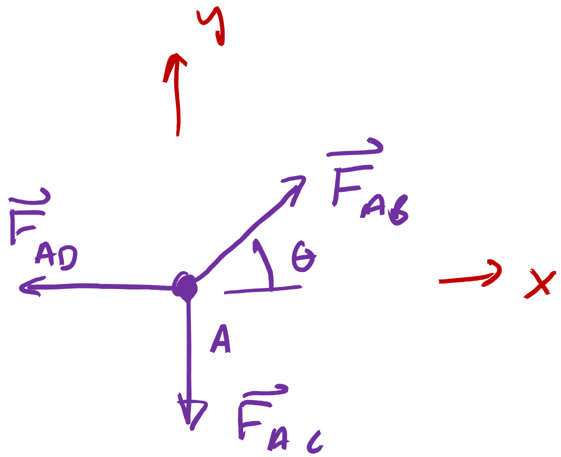
Recap: Free body diagram

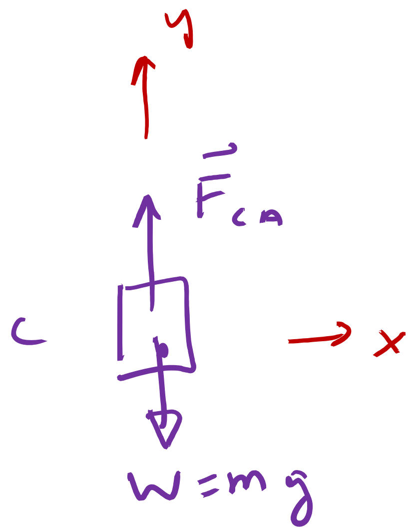
Drawing of a body, or part of a body, on which all forces acting on the body are shown.

- ❑ Draw Outlined Shape: image object free of its surroundings
- ❑ Establish x, y, z axes in any suitable orientation
  - ❑ Show positive directions for translation and rotation
- ❑ Show all forces acting on the object at points of application
- ❑ Label all known and unknown forces
- ❑ Sense ("direction") of unknown force can be assumed. If solution is negative, then the sense is reverse of that shown on FBD

Example from lecture 5



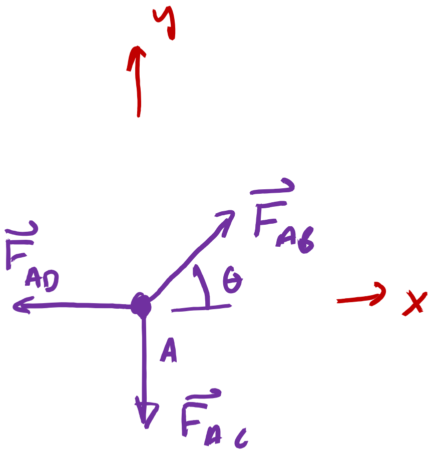




Recap: Equations of equilibrium

- Use FBD to write equilibrium equations in x, y, z directions
  - $\sum \overrightarrow{\boldsymbol{F_x}} = 0, \sum \overrightarrow{\boldsymbol{F_y}} = 0,$ and if 3D $\sum \overrightarrow{\boldsymbol{F_z}} = 0,$
  - If # equations ≥ # unknown forces, **statically determinate** (can solve for unknowns)
  - If # equations < # unknown forces, **indeterminate** (can **NOT** solve for unknowns), need more equations
- Get more equations from FBD of other bodies in the problem

@ Pt. A:



$\sum F_x = 0$

(1) $-F_{AD} + F_{AB}\cos\theta = 0$

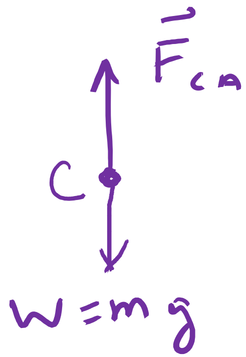
$\sum F_y = 0$

(2) $-F_{AC} + F_{AB}\sin\theta = 0$

3 unknowns, 2 eqns

⇒ Indeterminate

@ Pt. C:



$\sum F_y = 0$

(3) $F_{CA} - mg = 0$

1 unknown, 1 eqn

(4) Note that $F_{CA} = -F_{AC}$

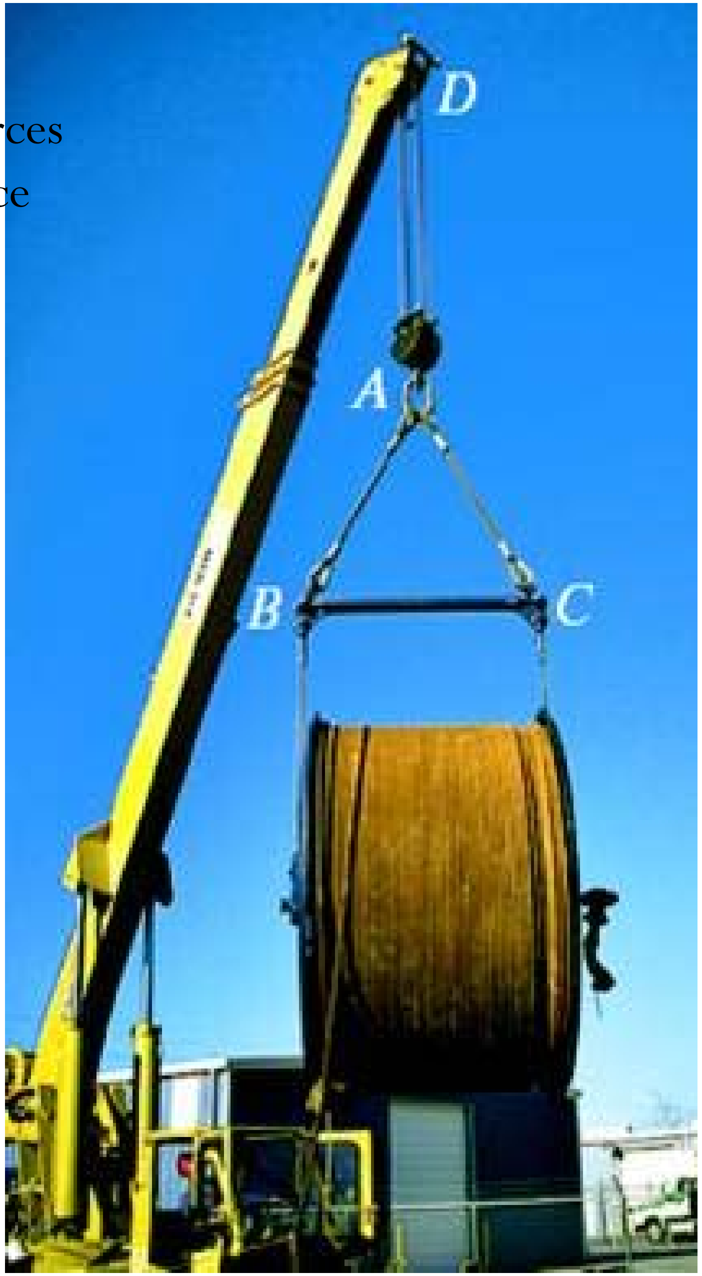
1 eqn

⇒ 4 eqns, 4 unk

⇒ Statically Determinate

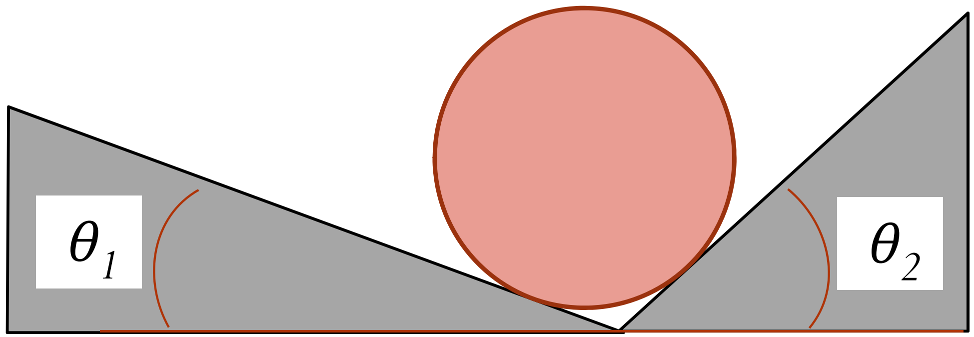
Find the forces in cables AB and AC?

- ❑ Draw Outlined Shape
- ❑ Establish x, y, z axes
- ❑ Show all forces acting on object
- ❑ Label known and unknown forces
- ❑ Assume sense of unknown force



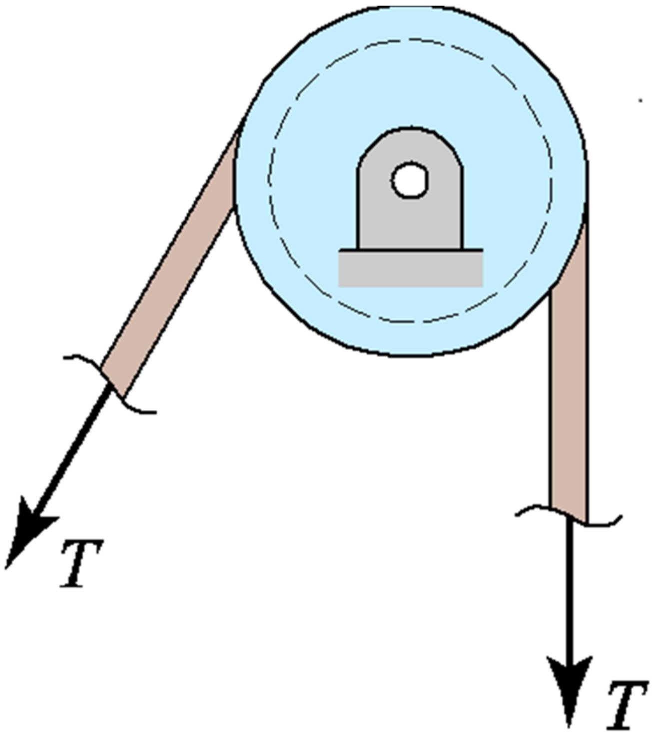
Idealizations

Contact force on a **smooth surface** (with no friction) will be a normal force (i.e., perpendicular to the surface at the point of contact.



Idealizations

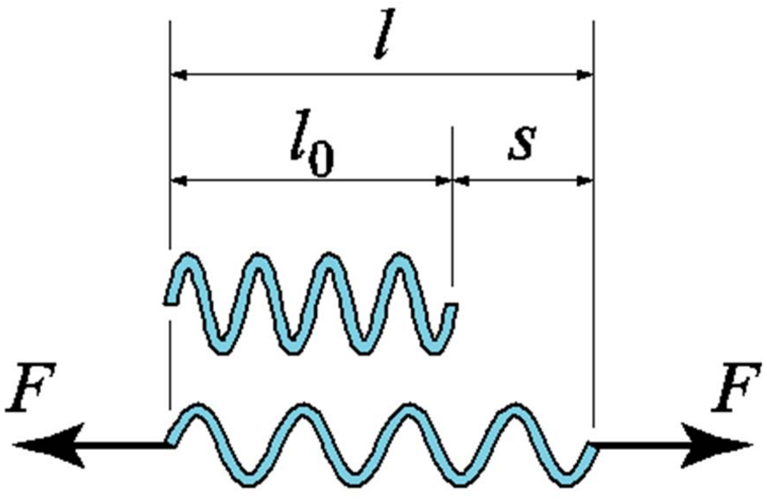
Pulleys are (usually) regarded as frictionless; then the tension in a rope or cord around the pulley is the same on either side.



Frictionless pulley

Idealizations

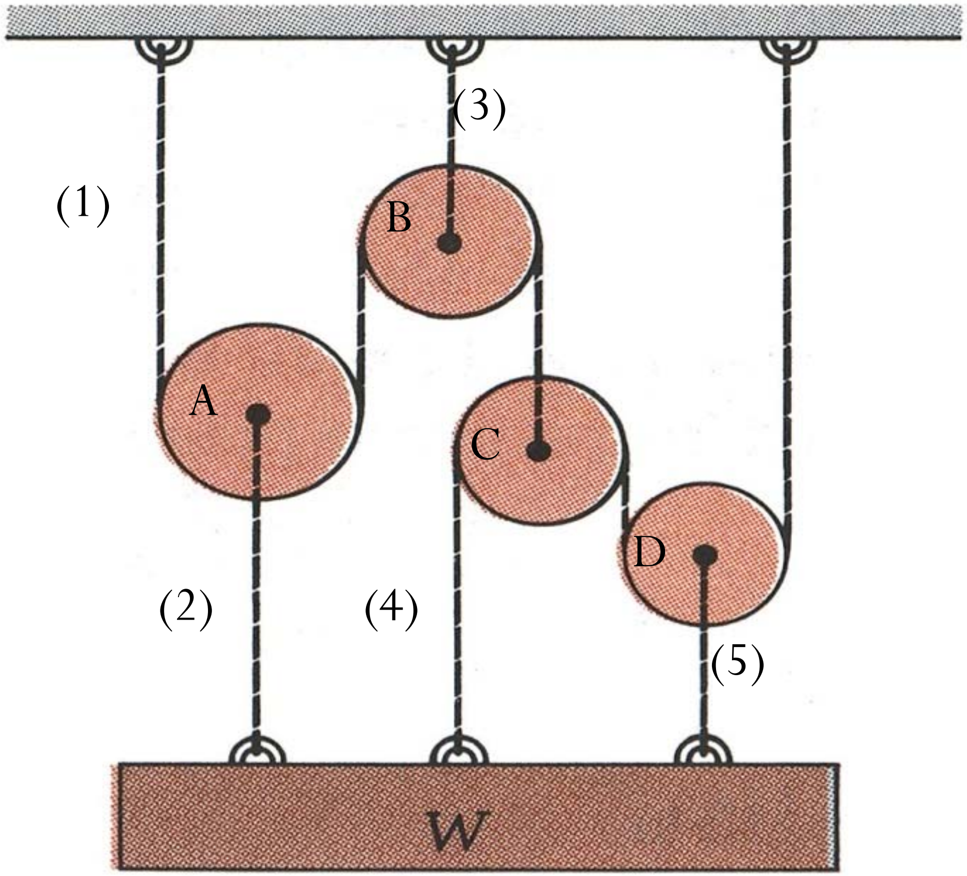
Springs are (usually) regarded as linearly elastic; then the tension is proportional to the *change* in length s.

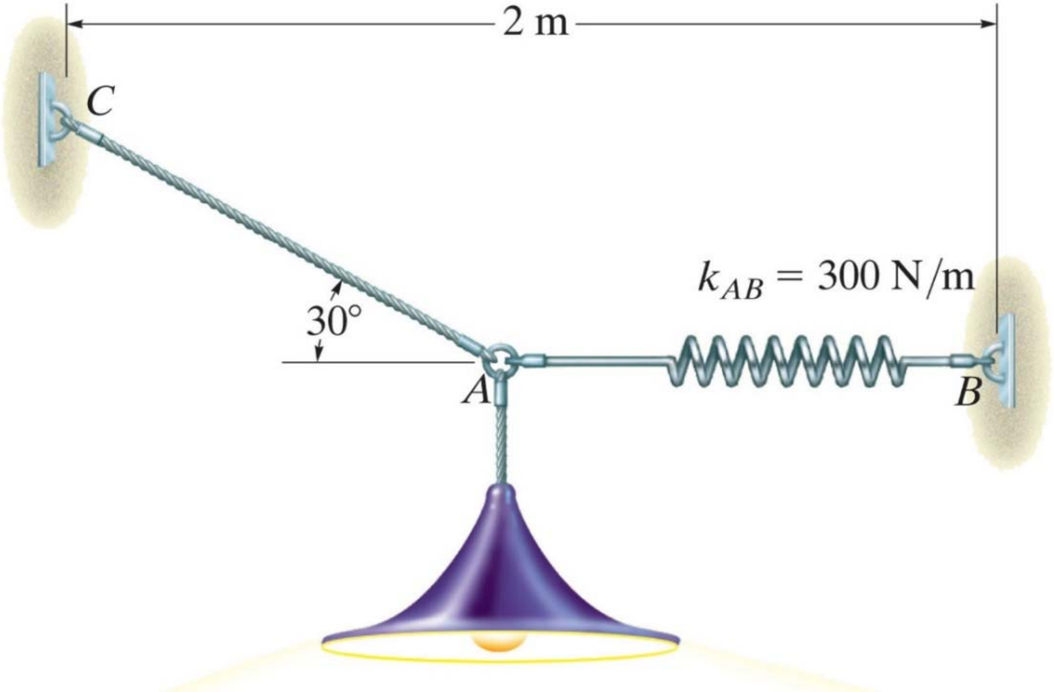


$$F = ks = k(l - l_0)$$

Linearly elastic spring

The five ropes can each take 1500 N without breaking. How heavy can *W* be without breaking any?



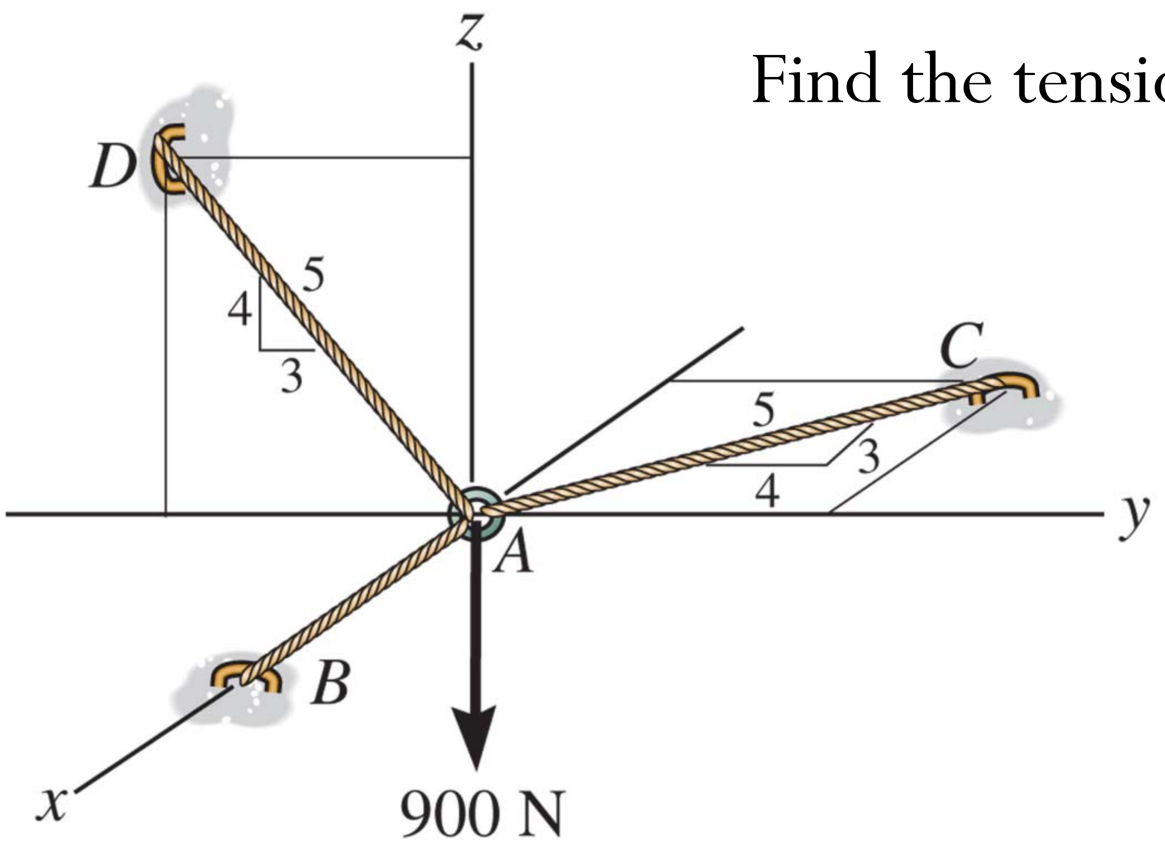


Determine the required length of cord AC so that the 8-kg lamp can be suspended in the position shown. The undeformed spring length is 0.4 m and has a stiffness of 300 N/m.

3D force systems

Use $\sum \overrightarrow{F_x} = 0, \sum \overrightarrow{F_y} = 0, \sum \overrightarrow{F_z} = 0$

Find the tension developed in each cable



Example – 3D

Determine the stretch in each of the two springs required to hold the 20-kg crate in the equilibrium position shown. Each spring has an unstretched length of 2 m and a stiffness of $k = 360$ N-m.