

Statics - TAM 211

Lecture 15

October 22, 2018

Announcements

- ❑ Students are encouraged to practice drawing FBDs, writing out equilibrium equations, and solving these by hand using your calculator.
- ❑ Upcoming deadlines:
 - Tuesday (10/23)
 - Prairie Learn HW5
 - **Quiz 2, Wednesday (10/24)**
 - During class time (9:00 am)
 - Computer Lab (D211 for ME, D331 for CEE)
 - Chapter 5
 - Friday (10/26)
 - Written Assignment 5
 - **Friday (11/2) all in Teaching Building A418-420**
 - 8:00 am: Quiz 3, Chapter 6. On paper.
 - 9:00 am: Lecture 17
 - 10:00 am: Discussion section for ALL students
 - No class
 - Friday October 26 (Sports Meeting day)
 - Monday October 29
- ❑ PrairieLearn incorrect software issues:
 - ❑ Negative sign symbol (- vs. −)
 - ❑ Space between negative sign (-12 vs. - 12)
 - ❑ Solutions:
 - ❑ Always type in the negative sign symbol (-) into your PL answers for HW or Quiz.
 - ❑ Do not add space between negative symbol and number
 - ❑ All students with these errors will be provided updated grades on Quiz 1. No credit for Quiz 2 and beyond.

Chapter 5: Equilibrium of Rigid Bodies

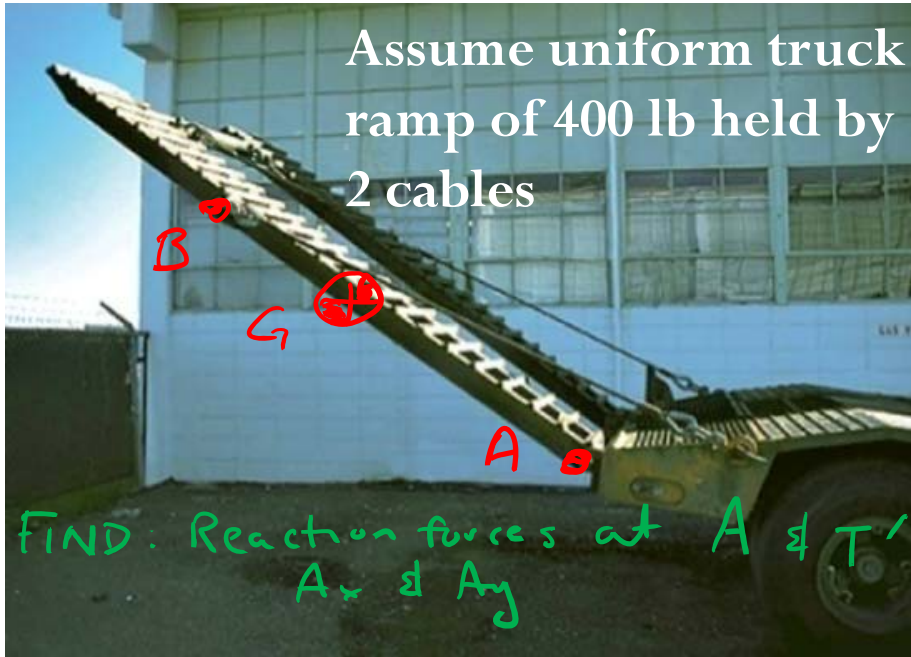
Goals and Objectives

- Introduce the free-body diagram for a rigid body
- Develop the equations of equilibrium for a 2D and 3D rigid body
- Solve rigid body equilibrium problems using the equations of equilibrium in 2D and 3D

- Introduce concepts of
 - Support reactions for 2D and 3D bodies
 - Two- and three-force members
 - Constraints and statical determinacy

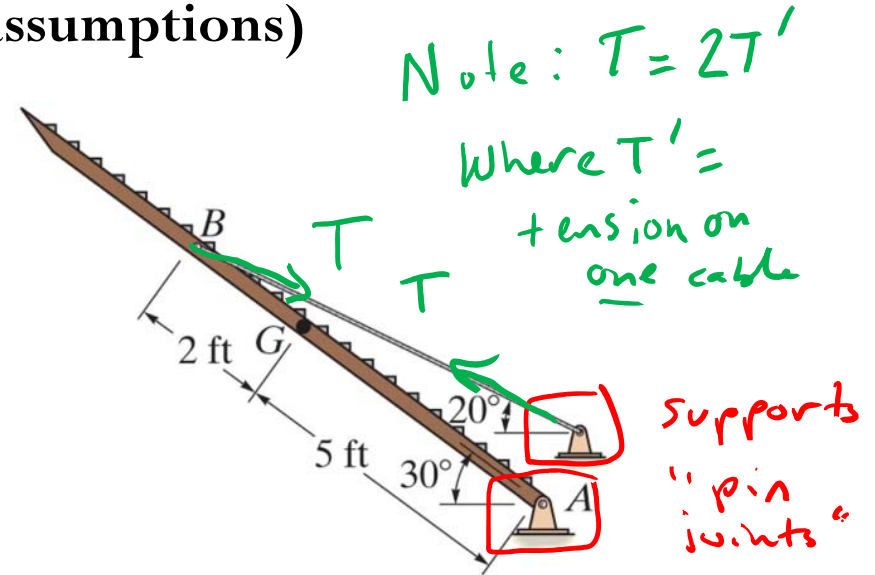
Process of solving rigid body equilibrium problems

See Example 5.11 in text for full derivation



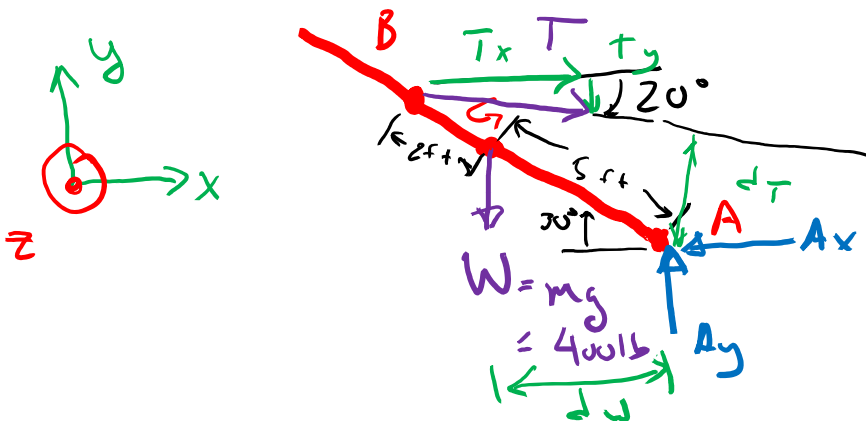
1. Create idealized model (model and assumptions)

Center of Gravity or Center of mass



2. Draw free body diagram showing ALL the external (applied loads and support reactions)

FBD of RAMP only



3. Apply equations of equilibrium

$$\vec{F}_R = \sum \vec{F} = 0$$

$$\rightarrow \sum F_x: -A_x + T \cos 20^\circ = 0 \quad (1)$$

$$\uparrow \sum F_y: A_y - W - T \sin 20^\circ = 0 \quad (2)$$

$$(\vec{M}_R)_A = \sum \vec{M}_A = 0$$

Let's sum moments about pt A. Pick pt to sum moments that eliminates as many unknowns as possible.

$$\uparrow \sum M_A: +W(d_w) - T(d_T) = 0 \quad (3)$$

3 Unknowns (A_x, A_y, T), 3 equations (1-3)
 \Rightarrow Determinate system \therefore Can solve.

This slide presents the basic approach for problem solving for this course (previous slide). Understand how to do this approach!

Recap: Equilibrium in two-dimensional bodies (Support reactions)

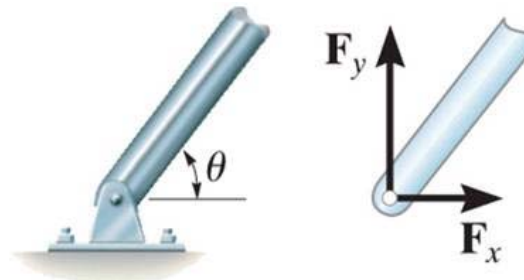
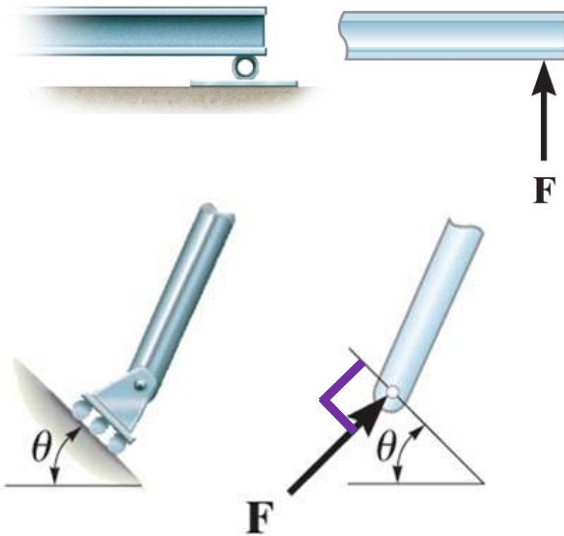
Roller



Smooth pin or hinge

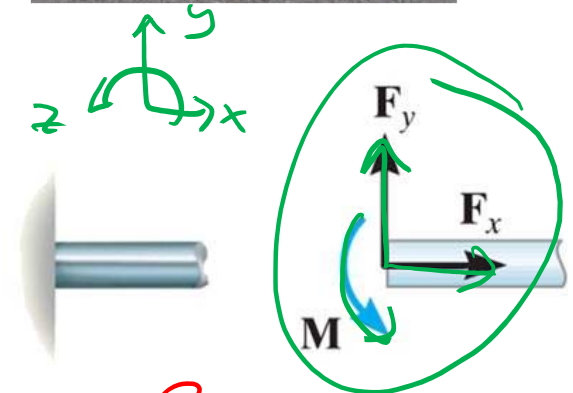


Fixed support



Reaction Forces

on the body



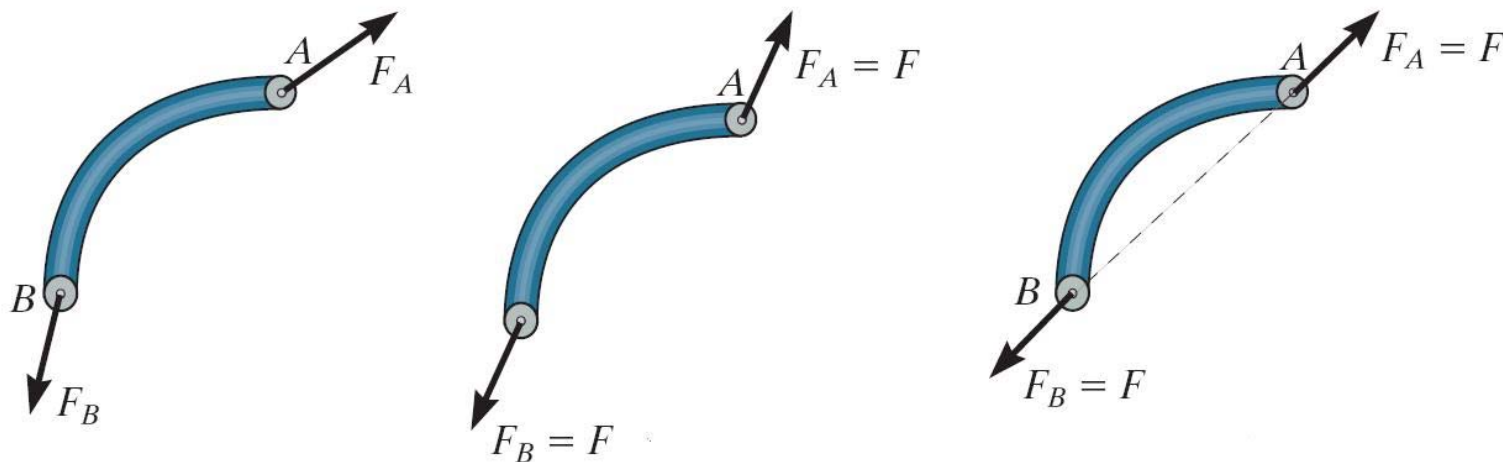
Reaction
Moment

- If a support prevents the translation of a body in a given direction, then a force is developed on the body on that direction
- If a rotation is prevented, a couple moment is exerted on the body

Two-force members

As the name implies, two-force members have forces applied at only two points.

If we apply the equations of equilibrium to such members, we can quickly determine that **the resultant forces at A and B must be equal in magnitude and act in the opposite directions along the line joining points A and B.**

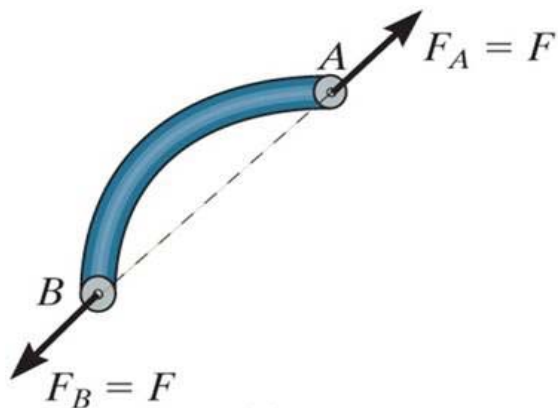


Two-force member: the two forces at ends are equal, opposite, collinear

Examples of two-force members



In the cases above, members AB can be considered as two-force members, provided that their weight is neglected.

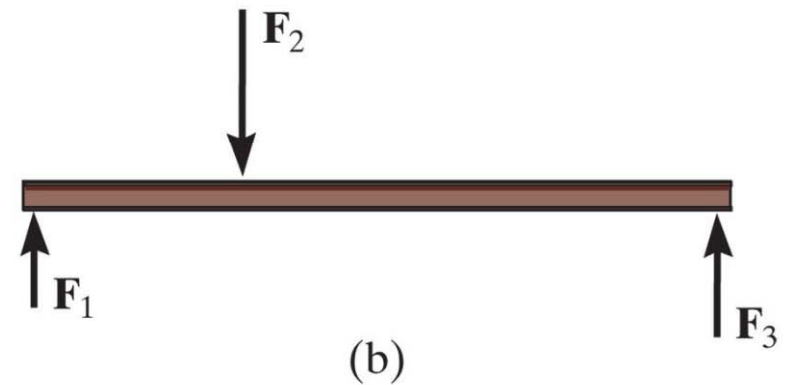
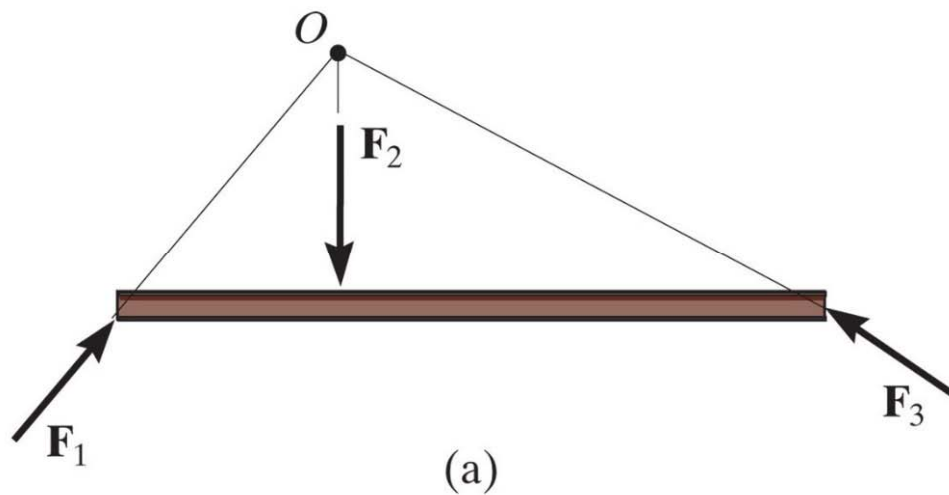


Two-force members **simplify** the equilibrium analysis of some rigid bodies since the **directions of the resultant forces at A and B are thus known** (along the line joining points A and B).

Three-force members

As the name implies, three-force members have forces applied at only three points.

Moment equilibrium can be satisfied only if the three forces are concurrent or parallel force system



Three-force member: a force system where the three forces
(a) meet at the same point (point O), or
(b) are parallel

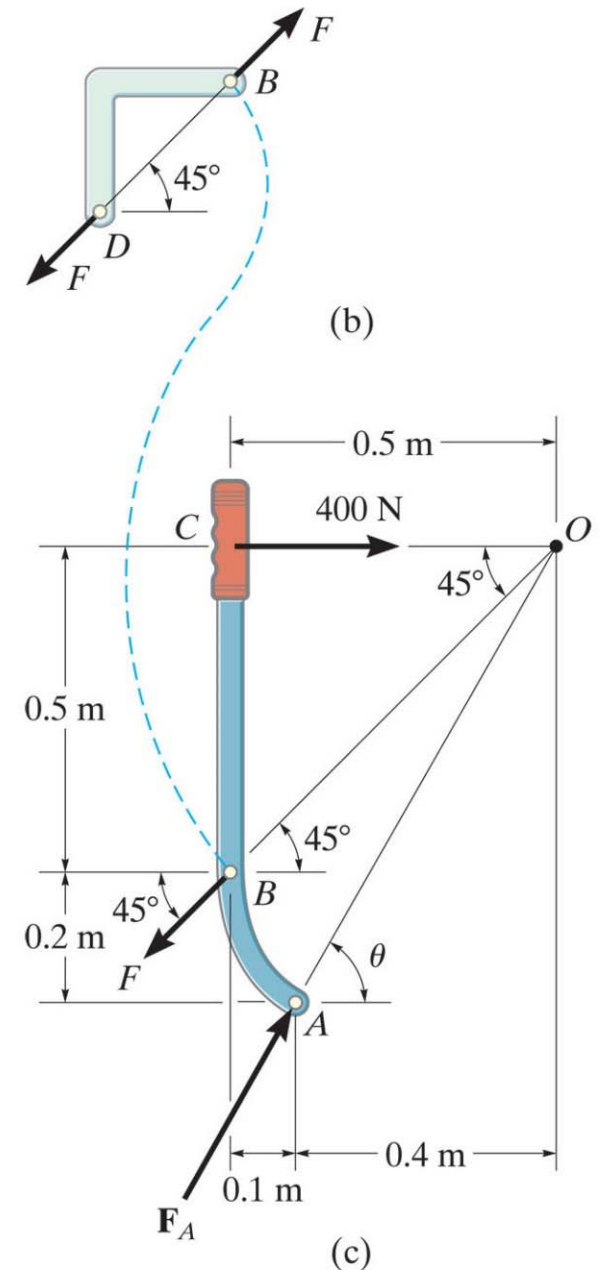
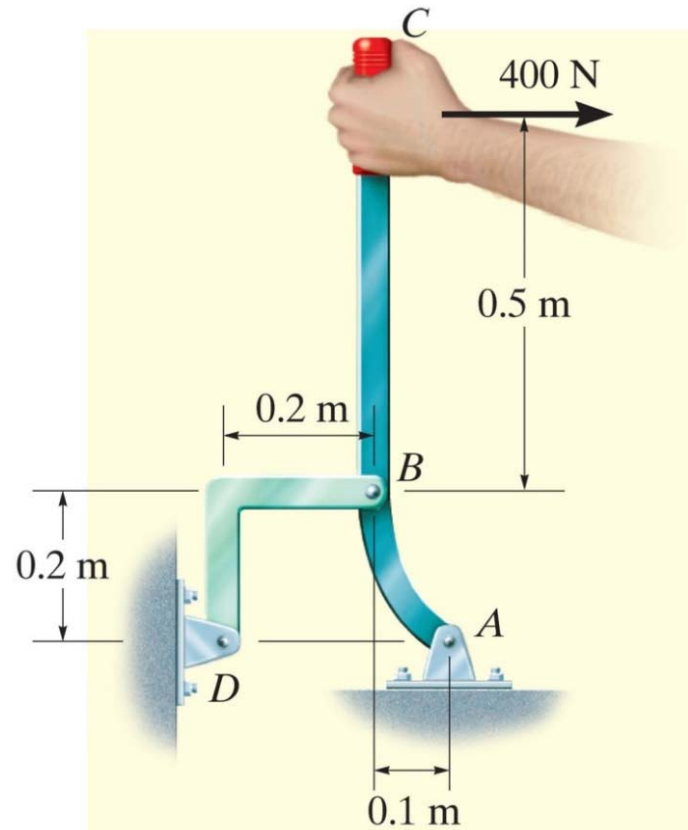
Two-force and three-force members

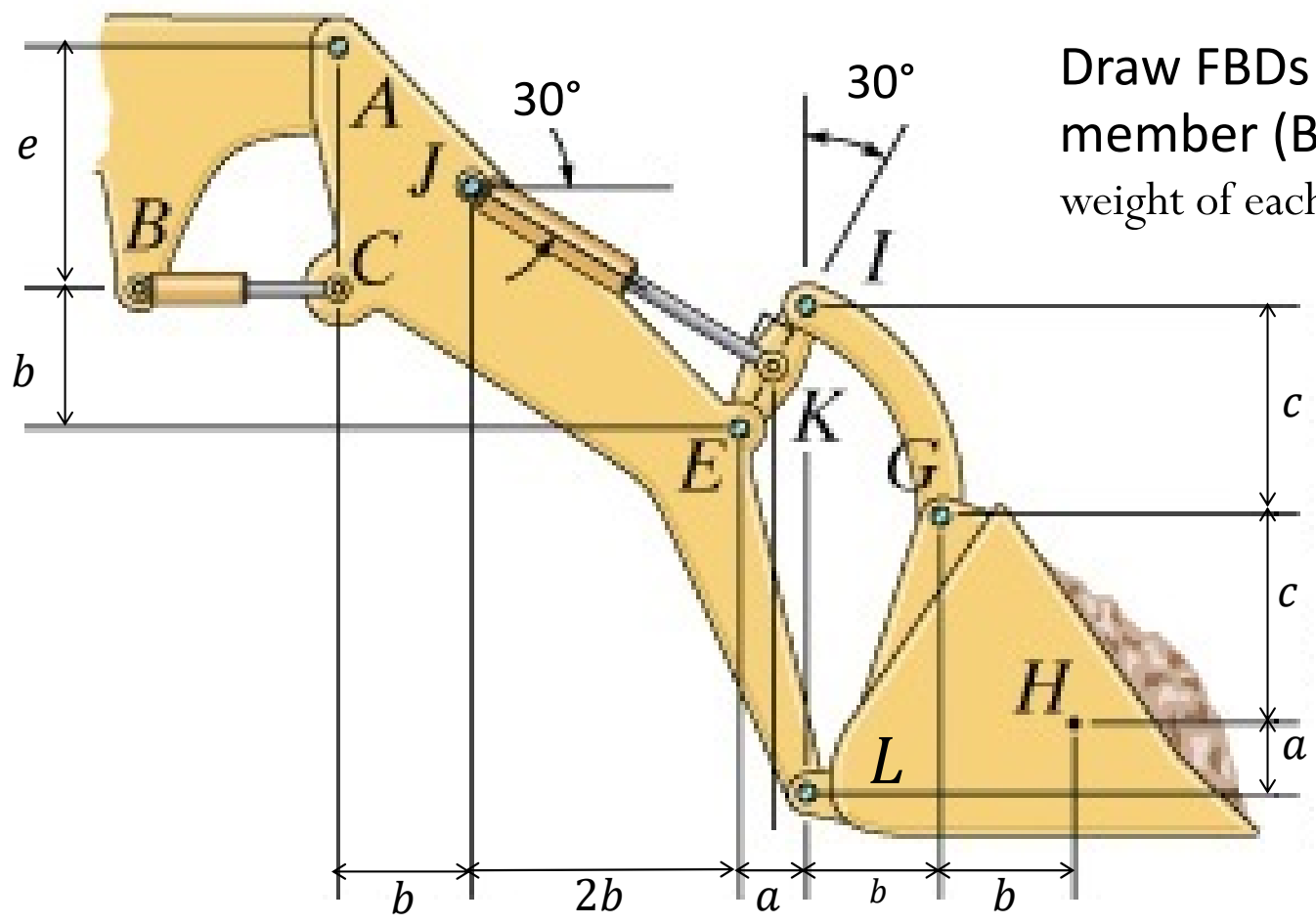
One can use these concepts to quickly identify the direction of an unknown force.

Two-force member:
the two forces at ends are equal, opposite, collinear

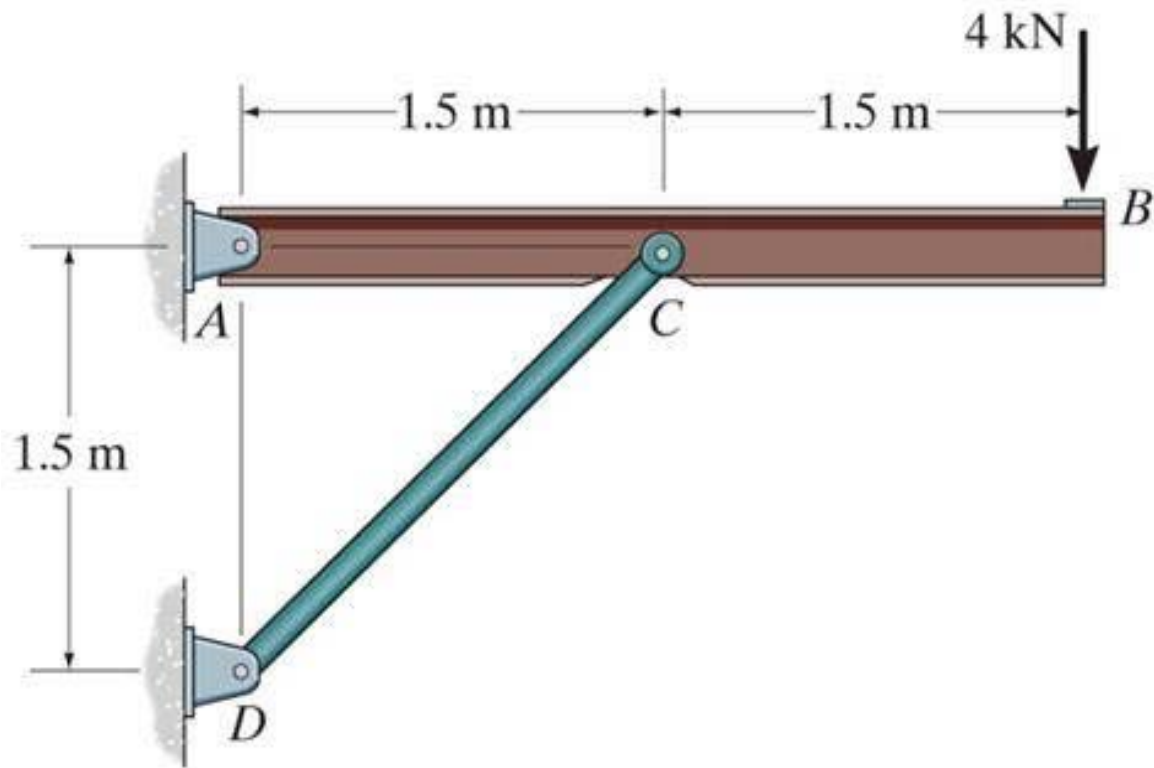
Three-force member: a force system where the three forces

1. meet at the same point (point O), or
2. are parallel

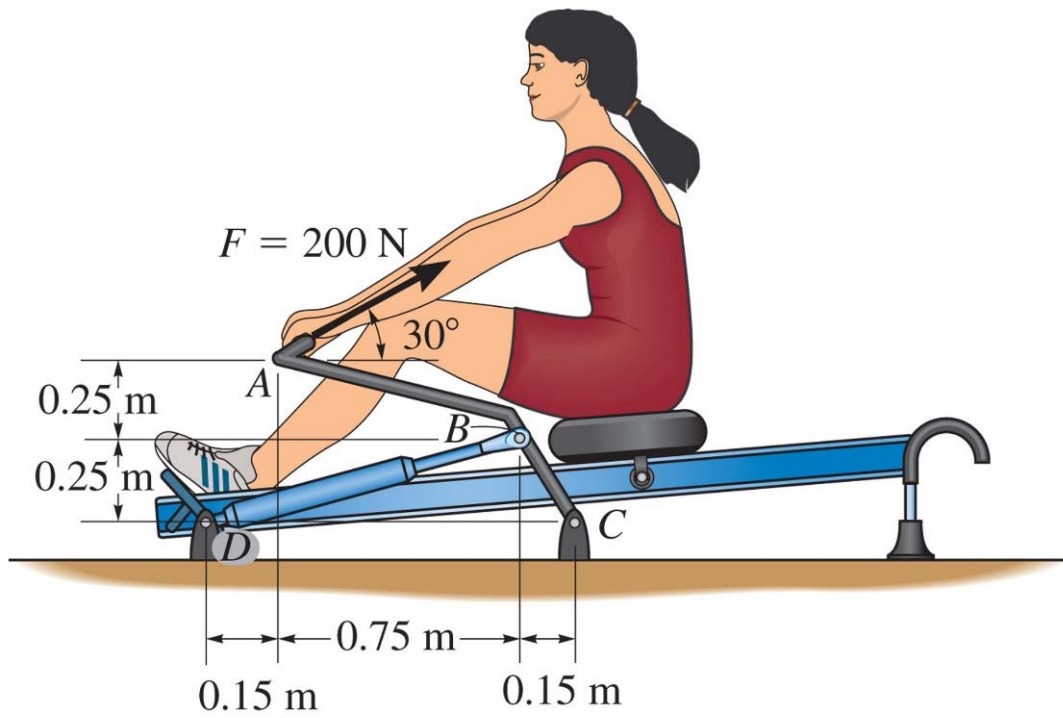




Draw FBDs for each two or three force member (BC, JK, IE, I,G, Bucket). Ignore weight of each link. Include dirt weight in bucket.

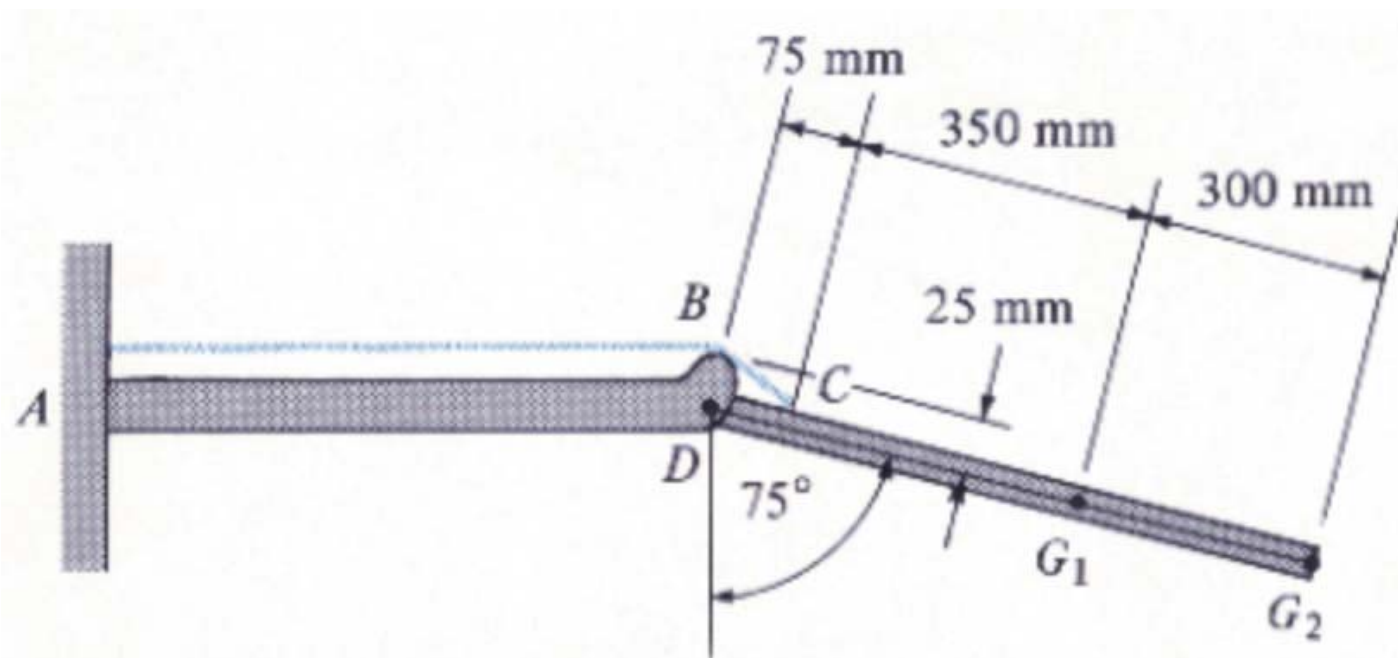
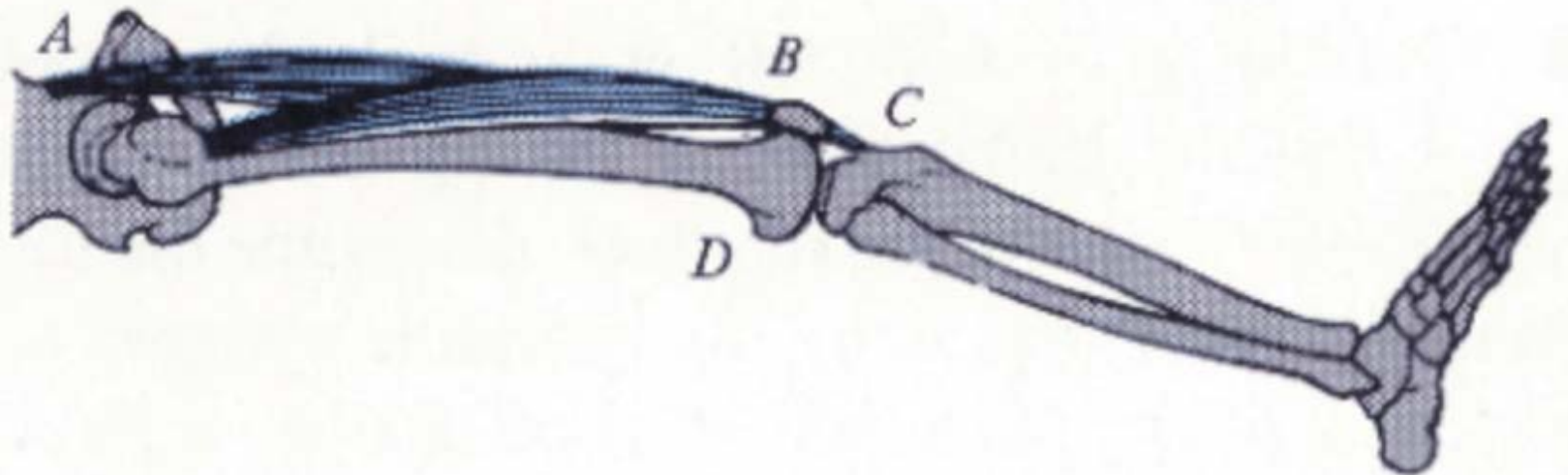


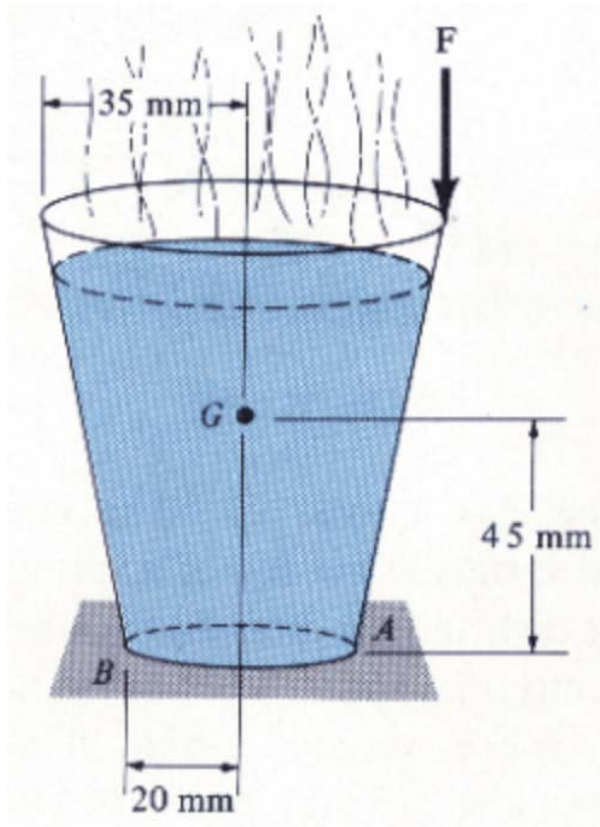
Given the 4kN load at B of the beam is supported by pins at A and C. Find the support reactions at A and C.



The woman exercises on the rowing machine. If she exerts a holding force of $F = 200\text{ N}$ on the handle ABC, determine the reaction force at pin C and the force developed along the hydraulic cylinder BD on the handle.

A skeletal diagram of the lower leg is shown. Model the lower leg and determine the tension T in the quadriceps and the magnitude of the resultant force at the femur (pin) at D in order to hold the lower leg in the position shown. The lower leg has a mass of 3.2 kg and the foot has a mass of 1.6 kg.



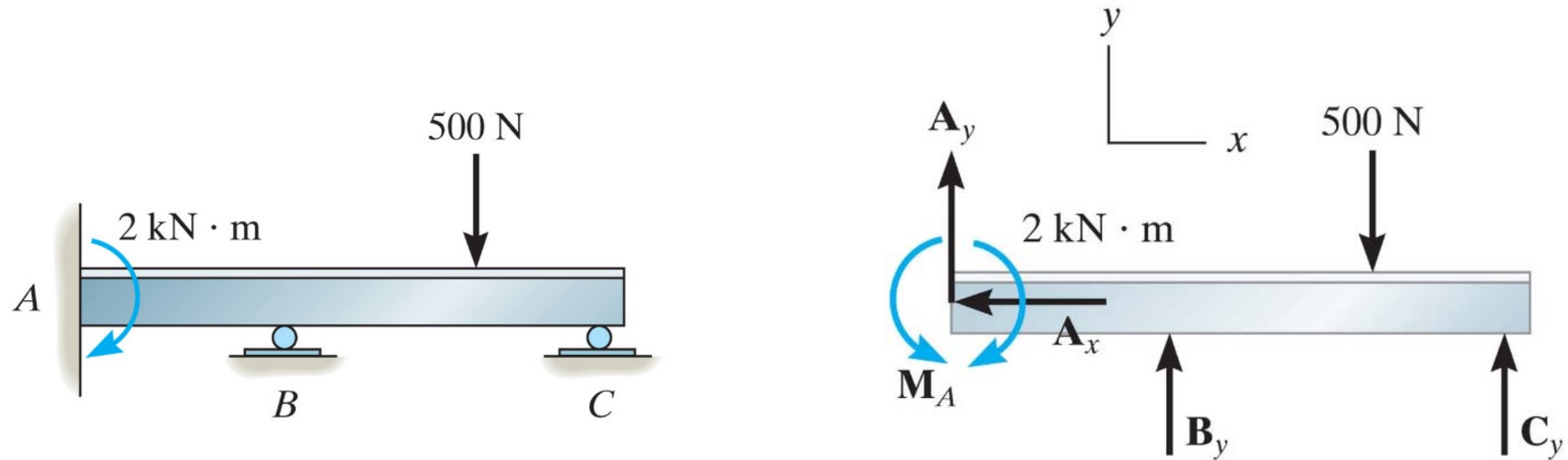


The cup is filled with 125 g of liquid. The mass center is located at G. If a vertical force F is applied to the rim of the cup, determine its magnitude so the cup is on the verge of tipping over.

Constraints

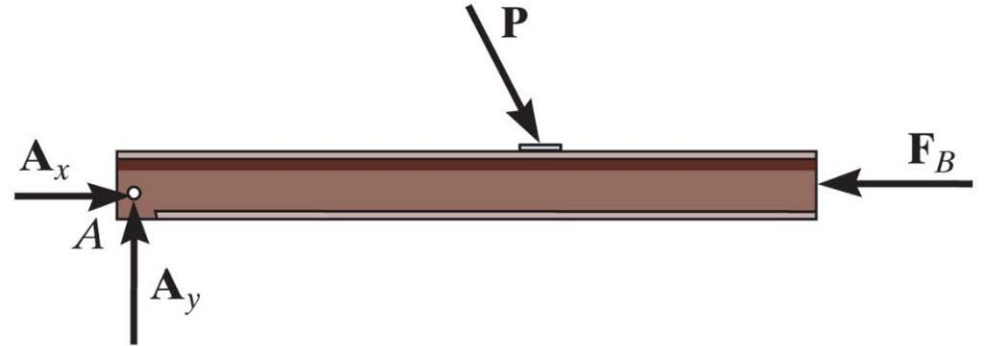
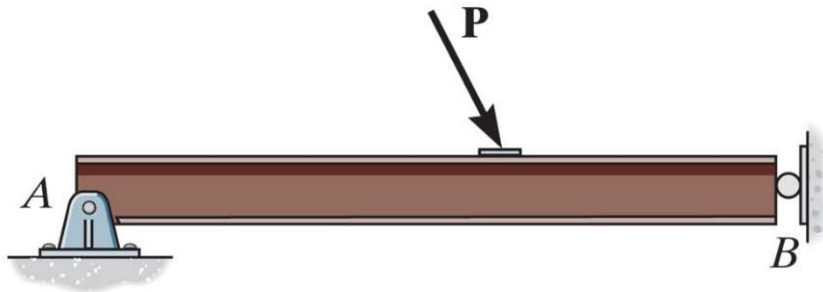
To ensure equilibrium of a rigid body, it is not only necessary to satisfy equations of equilibrium, but the body must also be properly constrained by its supports

- **Redundant constraints:** the body has more supports than necessary to hold it in equilibrium; the problem is **STATICALLY INDETERMINATE** and cannot be solved with statics alone. **Too many unknowns, not enough equations**

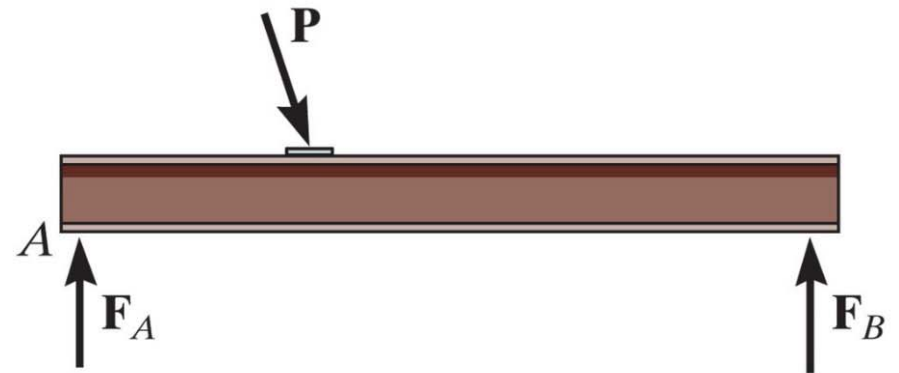
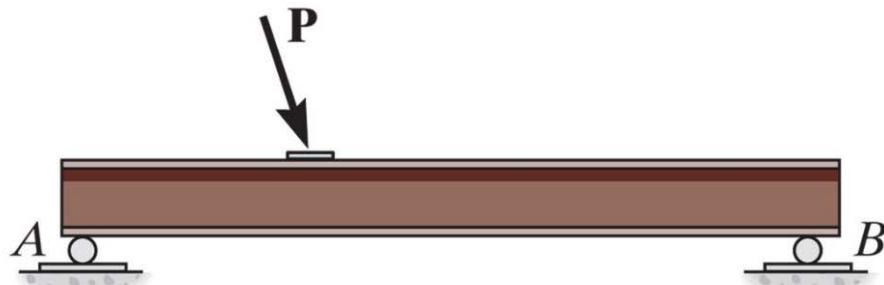


Constraints

- **Improper constraints:** In some cases, there may be as many unknown reactions as there are equations of equilibrium (statically determinate). However, if the supports are not properly constrained, the body may become unstable for some loading cases.
 - BAD: Reactive forces are concurrent at same point (point A) or line of action



- BAD: Reactive forces are parallel



Stable body: lines of action of reactive forces do not intersect at common axis, and are not parallel