Statics - TAM 210 & TAM 211

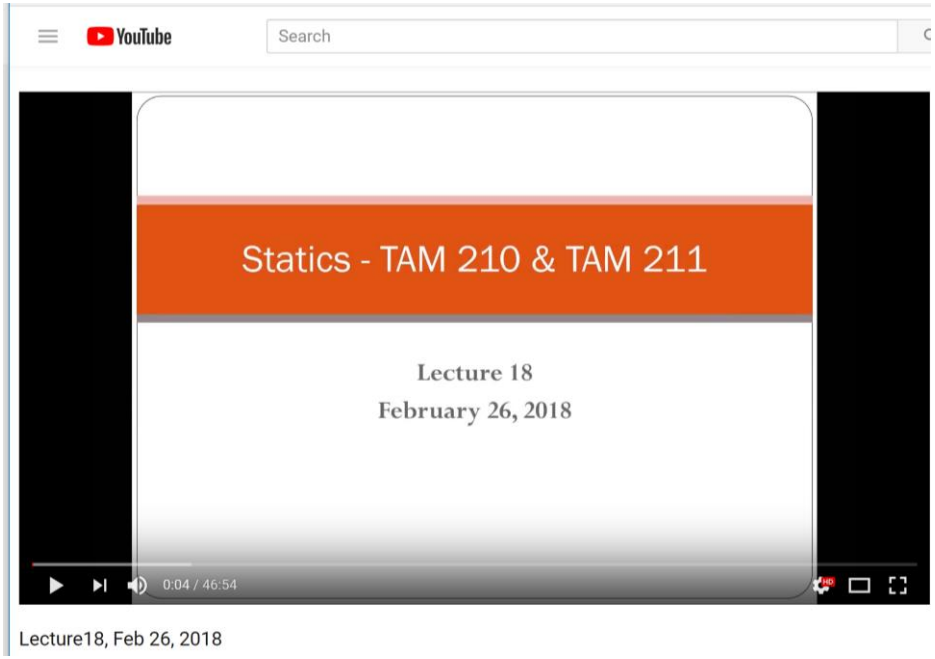
Lecture 19

February 28, 2018

Announcements

- Monday's lecture: See recorded video lecture.
- Concept Inventory: Ungraded assessment of course knowledge
  - Extra credit: Sign up at CBTF (2/26-3/1 M-Th)
- **Check your grades on Compass2g!**

- Upcoming deadlines:
  - Thursday (3/1)
    - WA 3
    - See enhanced instructions
  - Monday (3/5)
    - Mastering Engineering Tutorial 8
  - Tuesday (3/6)
    - PL HW 6



Chapter 6: Structural Analysis

Goals and Objectives

- Determine the forces in members of a truss using the method of joints
- Determine zero-force members
- Determine the forces in members of a truss using the method of sections
- Determine the forces and moments in members of a frame or machine

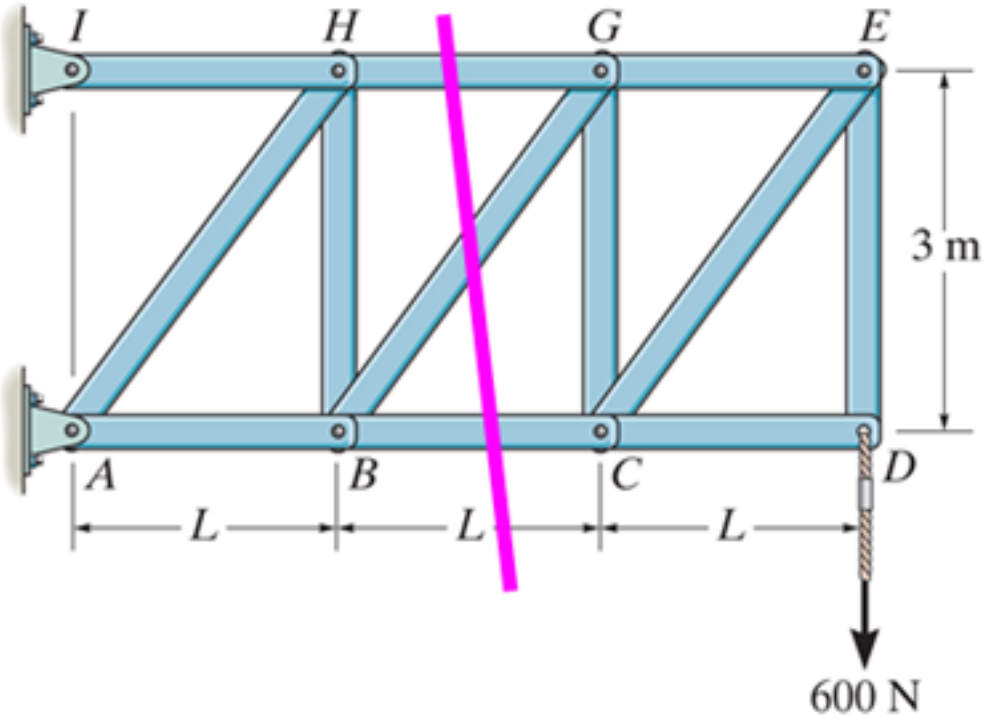
As shown, a cut is made through members GH, BG and BC to determine the forces in them. Which section will you choose for analysis and why?

✓A) Right, fewer calculations.

B) Left, fewer calculations.

C) Either right or left, same amount of work.

D) None of the above, too many unknowns.



This problem is similar to example in Lecture 18.

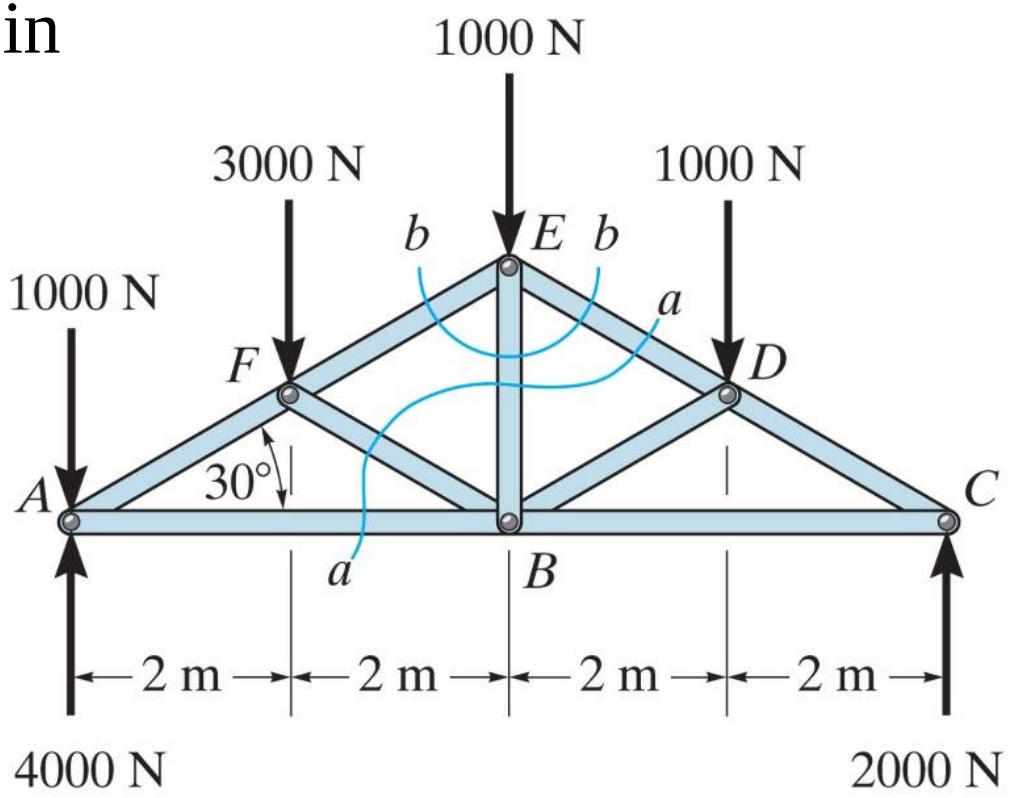
Can you determine the force in member ED by making the cut at section a-a? Explain your answer.

A) No, there are four unknowns.

B) Yes, using $\Sigma M_D = 0$.

C) Yes, using $\Sigma M_E = 0$.

D) Yes, using $\Sigma M_B = 0$.



How is this problem different from the last example in Lecture 17 which also had a section cut through 4 members?

Recap: Frames and machines

Frames and machines are two common types of structures that have at least **one multi-force member.** (Recall that trusses have **only** two-force members.) Therefore, it is not appropriate to use Method of Joints or Method of Sections for frames and machines.

Frames are generally **stationary** and used to support various external loads.

Machines contain **moving parts** and are designed to alter the effect of forces

Forces/Moment in frames and machines

The members can be truss elements, beams, pulleys, cables, and other components. The general solution method is the same:

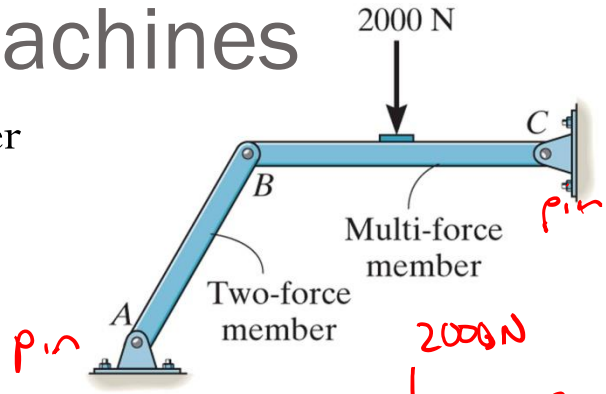
1. Identify two-force member(s) to simplify direction of unknown force(s).

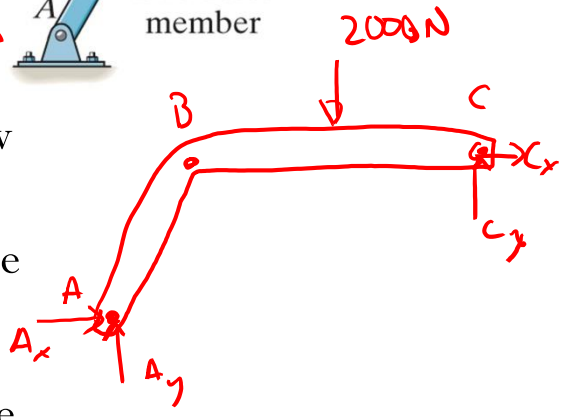
2. Identify external support reactions on entire frame or machine. (Draw FDB of entire structure. Set the structure into external equilibrium: $\sum F_x = 0, \sum F_y = 0, \sum M_{most\ efficient\ pt} = 0$. This step will generally produce more unknowns than there are relevant equations of equilibrium.)

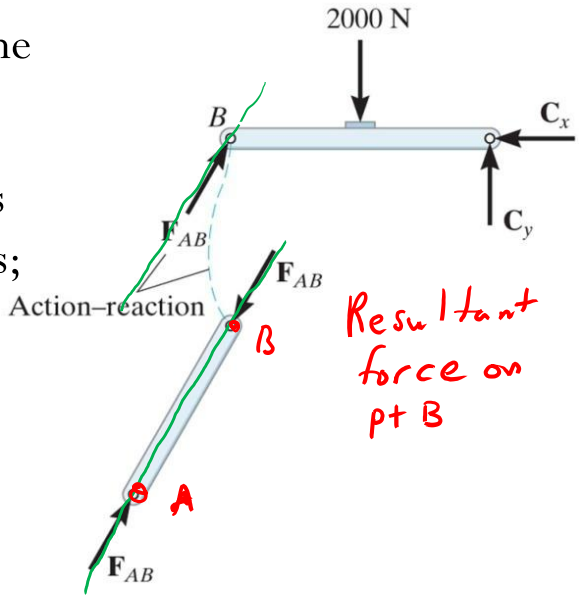
3. Draw FDBs of individual subsystems (members). (Isolate part(s) of the structure, setting each part into equilibrium $\sum F_x = 0, \sum F_y = 0,$ $\sum M_{most\ efficient\ pt} = 0$. The sought forces or couples must appear in one or more free-body diagrams.)

4. Solve for the requested unknown forces or moments. (Look for ways to solve efficiently and quickly: single equations and single unknowns; equations with least # unknowns.)

Problems are going to be **challenging** since there are usually several unknowns (and several solution steps). A lot of practice is needed to develop good strategies and ease of solving these problems.

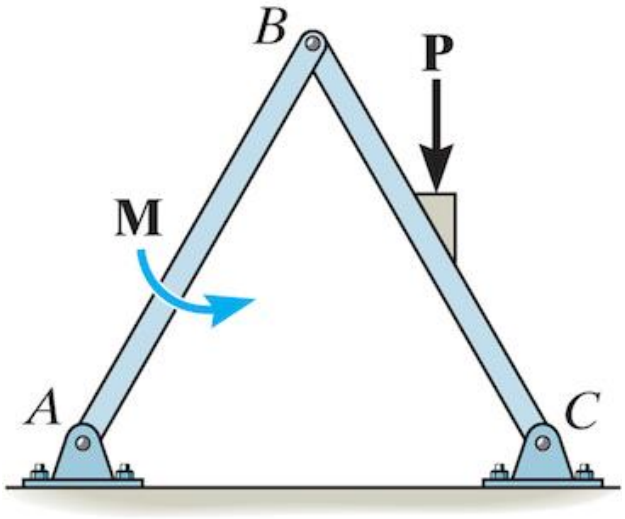


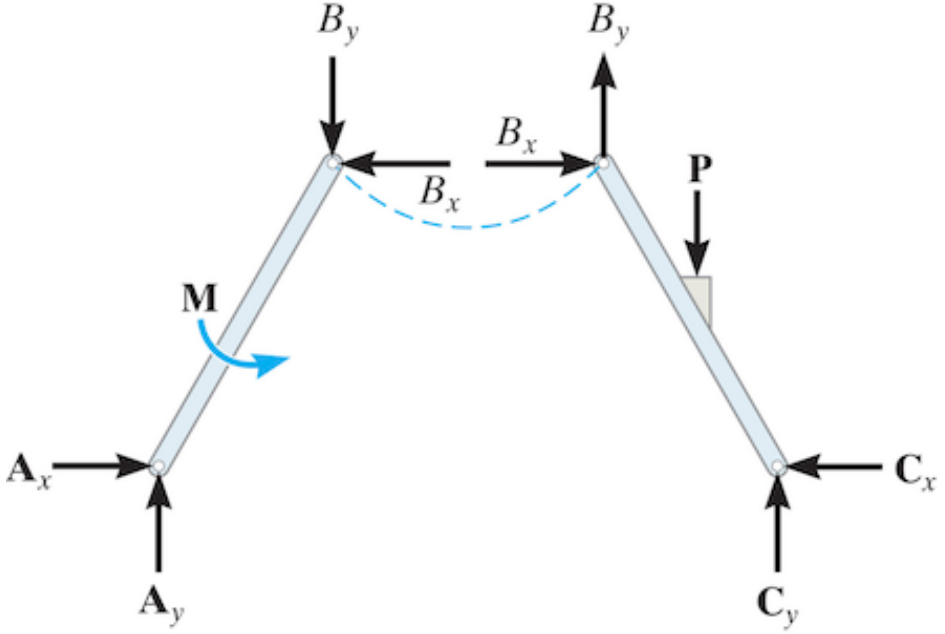


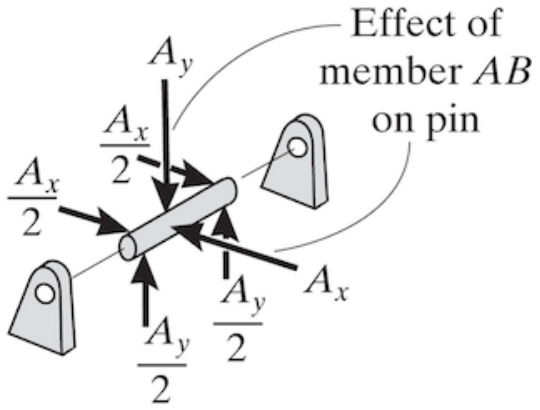


A note about why skip drawing FBD of the pin joint between members:

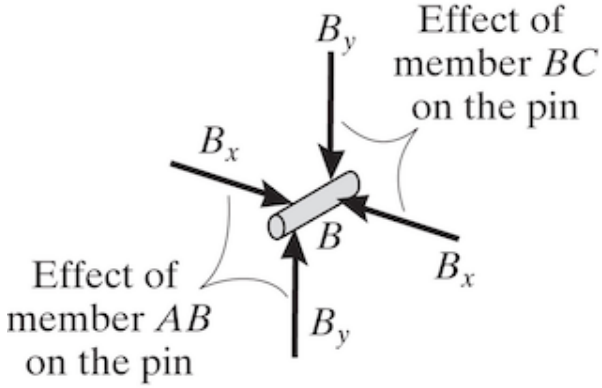
For the frames, we are interested in forces and/or moments on the rigid body members. Because this method examines individual members, we can ignore the pin that connects the members and directly consider that adjacent members experience equal and opposite forces at the joints.





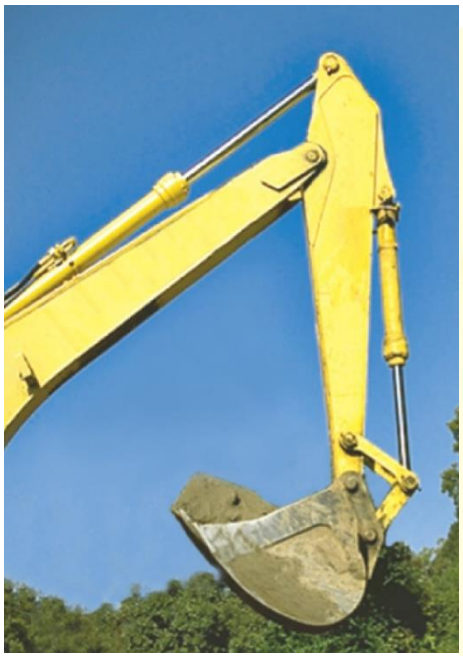


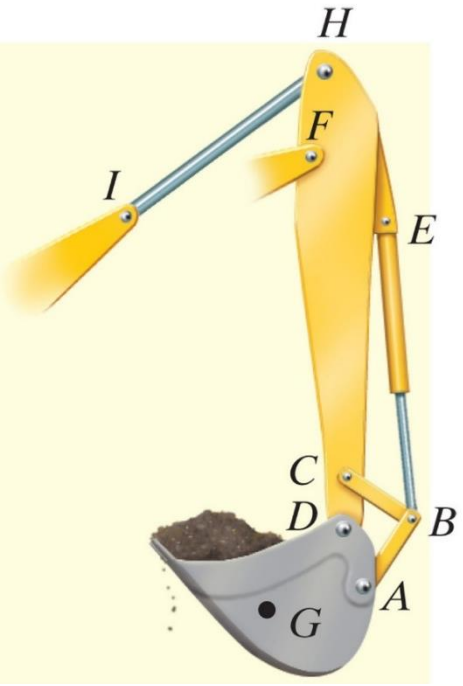
Pin A



Pin B

Draw the FBD of the members of the backhoe. The bucket and its contents have a weight *W*.





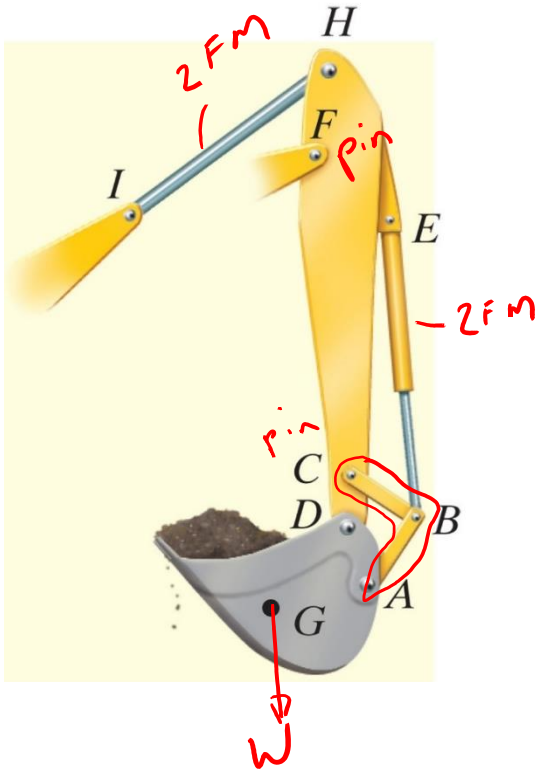
1) Label 2 force members:

Defines single resultant forces along the line of action connecting the end joints

2) ID support reactions

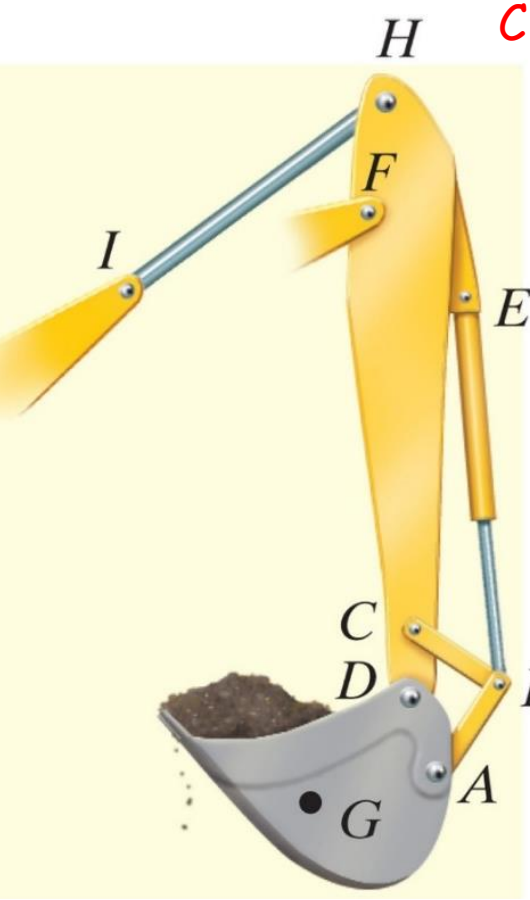
3) other joints have 2 components (x, y) for unknown forces

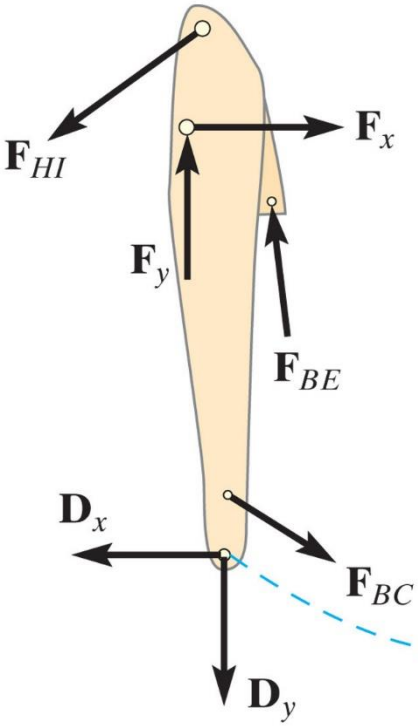
Draw the FBD of the members of the backhoe. The bucket and its contents have a weight *W*.

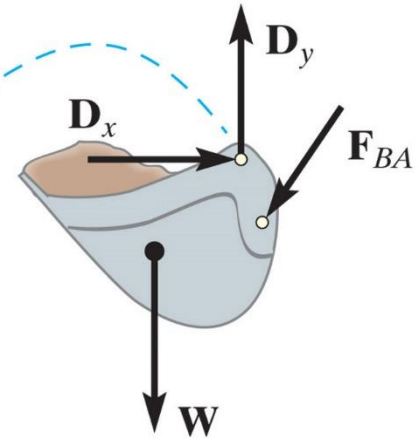


Draw the FBD of the members of the backhoe. The bucket and its contents have a weight *W*.

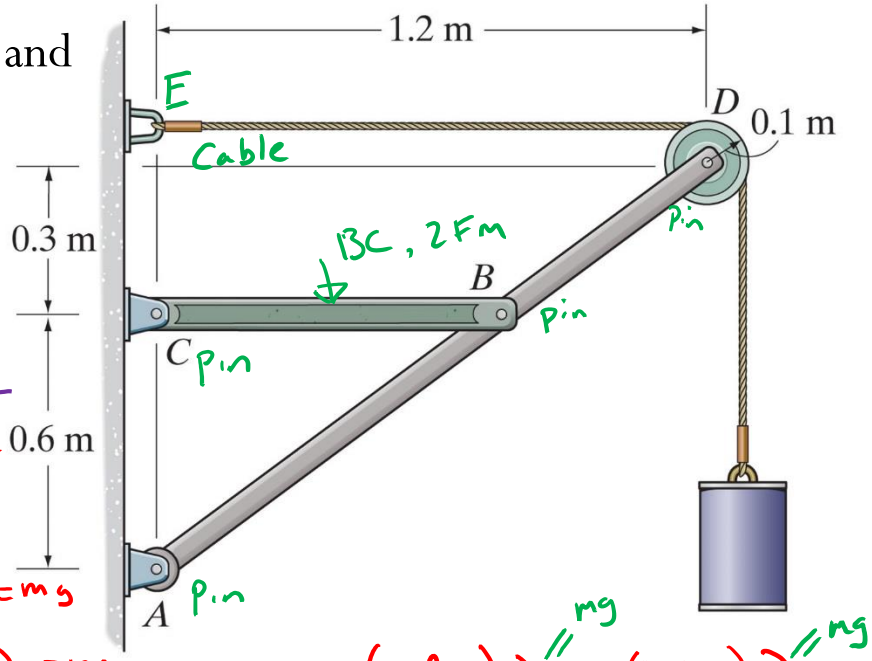
MODIFICATION for members connecting ABC. If not consider as single 3 joint link and rather as two 2-force members, note difference in unknown force vectors on joints C and A in FBDs.







The frame supports a 50kg cylinder. Determine the horizontal and vertical components of reaction at A and the force at C



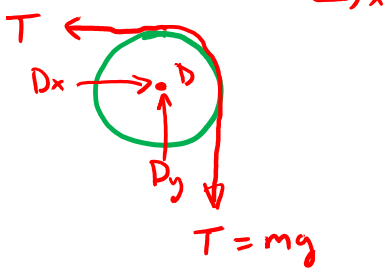
Find: A_x, A_y, F_{BC}

ID: 2FM ?

ID: supports

FBD: BC (2FM)

FBD pulley:



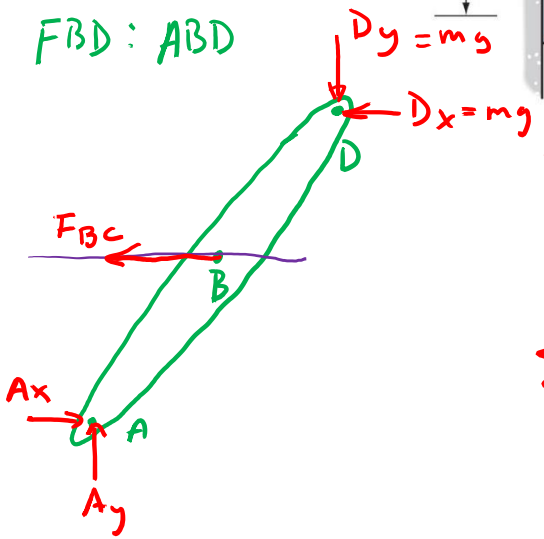
$\Sigma F_x: \quad D_x - T = 0$

$\boxed{D_x = T = mg}$

$\Sigma F_y: \quad D_y - T = 0$

$\boxed{D_y = mg}$

FBD: ABD



$+\circlearrowleft \Sigma M_A: \quad (0.9\text{m})\,D_x - (1.2\text{m})\,D_y + (0.6\text{m})\,F_{BC} = 0$

(D_x: mg, D_y: mg)

$\boxed{F_{BC} = 245\text{N}}$

$m = 50\text{kg}$

$\Sigma F_x: \quad A_x - F_{BC} - D_x = 0$

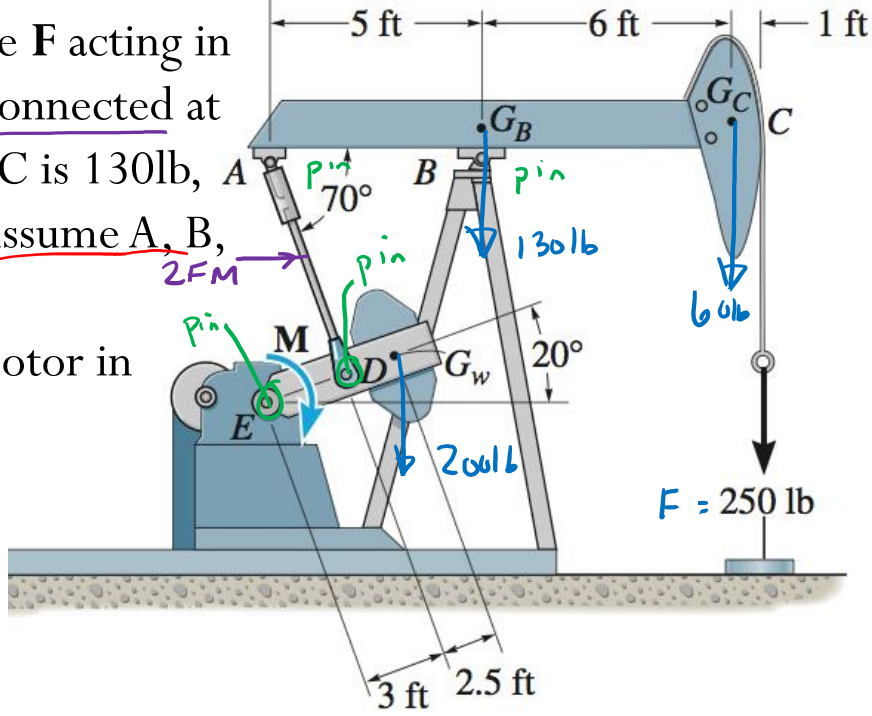
$\boxed{A_x = 736\text{N}}$

$\Sigma F_y: \quad A_y - D_y = 0$

$\boxed{A_y = 490\text{N}}$

Given: The pumping unit used to recover oil has force **F** acting in the wireline at the well head. The pitman, *AD*, is pin connected at its ends and has negligible weight. Weight of beam ABC is 130lb, horsehead at C is 60lb, counterweight at D is 200lb. Assume A, B, C, G_B and G_C are collinear.

Find: The torque **M** which must be exerted by the motor in order to overcome this load.

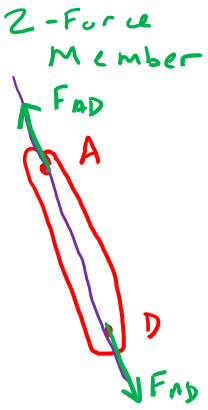


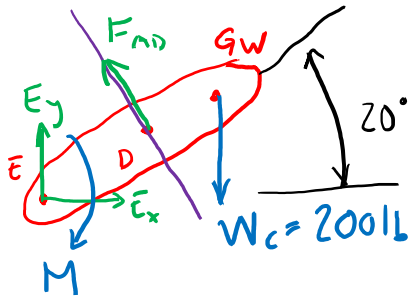
[Solved outside of class]

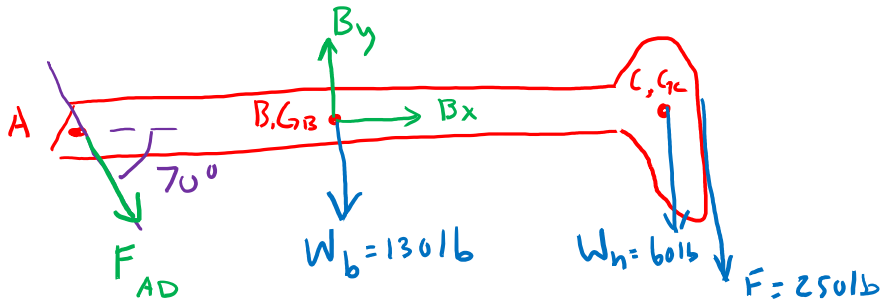
1) Identify any two-force members ⇒ AD
   Any zero force members? No

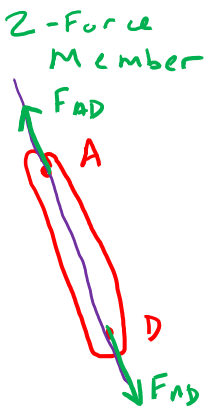
2) Identify support reaction types.
   Recall supports are ways to secure the structure to ground.
   ⇒ pin supports at B & E

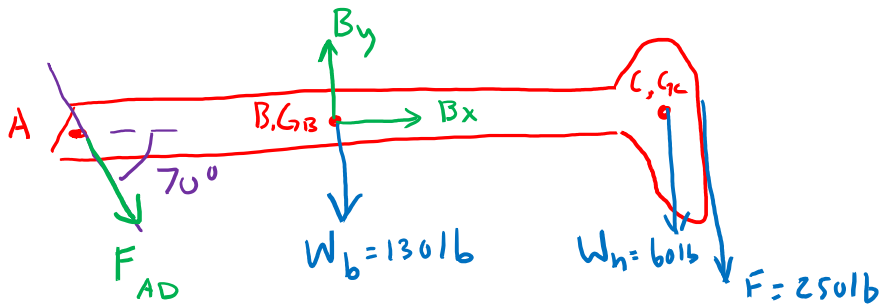
3) Draw FBDs of individual members.

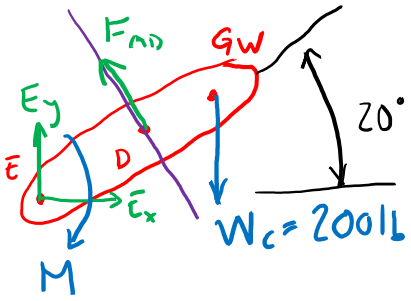












4) Solve for unknowns ⇒ Find M

+↺ $\sum M_E$: $-M + (3ft)F_{AD} - (5.5ft)W_c \cos 20° = 0$

$M = (3ft)F_{AD} - (5.5ft)(200lb)\cos 20°$

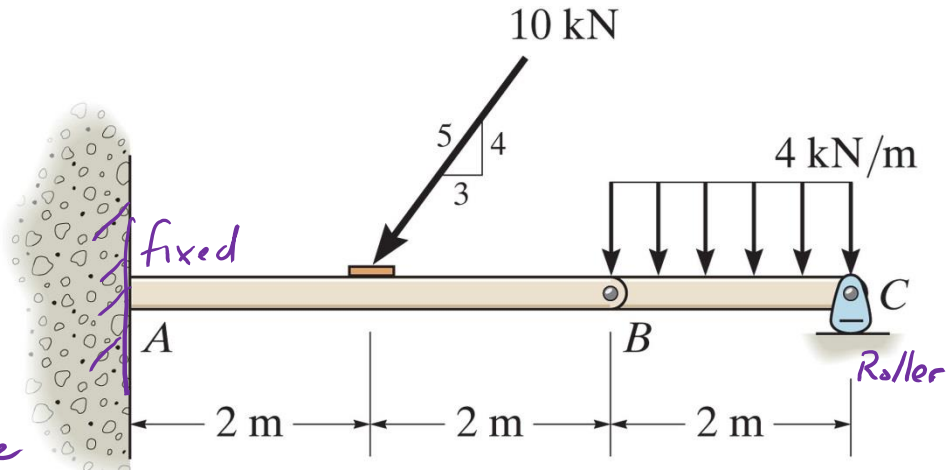
+↺ $\sum M_B$: $(5ft)F_{AD}\sin(70°) - (6ft)W_h - (7ft)F = 0$

$F_{AD} = \dfrac{(6ft)(60lb) + (7ft)(250lb)}{(5ft)\sin 70°}$ ⇒ $\boxed{F_{AD} = 449lb}$

∴ $M = (3ft)(449lb) - (5.5ft)\,200lb\cos 20°$

⇒ $\boxed{M = 314\,lb\,ft}$ ↺

The compound beam shown is pin-connected at
Determine the components of reaction at its supports. Neglect its weight and thickness.



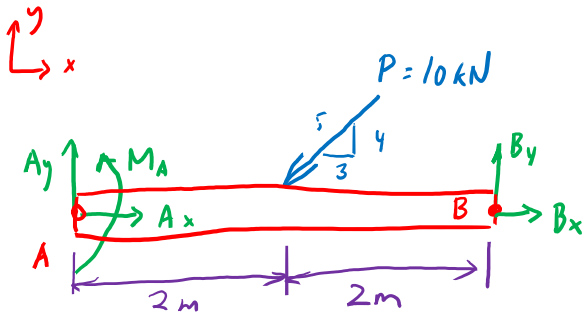
[Solved outside of class]

Find: A_x, A_y, M_A, C_y

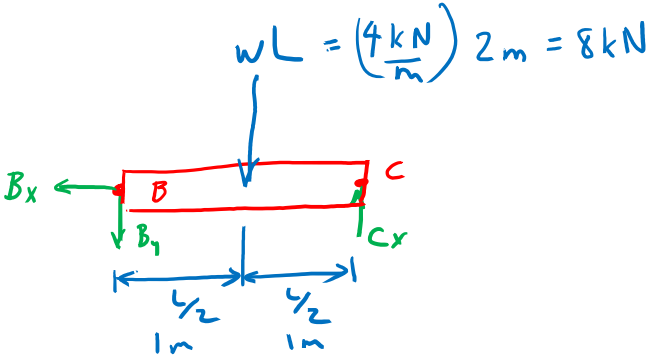
1) Identify 2 force or zero force members → None

2) Identify support reaction types ⇒ fixed@A, roller@C

3) Draw FBDs of individual members



5 unknowns



3 unknowns

4) Solve for unknowns

Start with solving for unknowns on BC:

$\Sigma F_x: \quad -B_x = 0 \quad \Rightarrow \boxed{B_x = 0}$

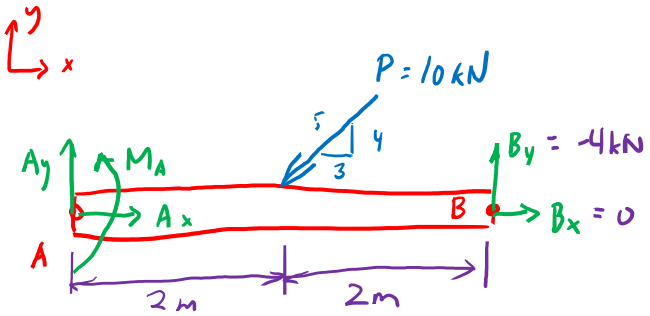
$\Sigma F_y: \quad -B_y - wL + C_y = 0$

$B_y = C_y - 8\,kN$

$+\circlearrowleft \Sigma M_B: \quad -\left(\frac{L}{2}\right) wL + L C_y = 0$

$C_y = \frac{(1m)(8kN)}{2m} \rightarrow \boxed{C_y = 4\,kN}\ \uparrow$ upward

$\therefore B_y = 4\,kN - 8\,kN = -4\,kN \rightarrow \boxed{B_y = -4\,kN}$



Now solve for remaining unknowns on left side:

$$\Sigma F_x: \quad A_x - P\left(\tfrac{3}{5}\right) + \underbrace{B_x}_{=0} = 0$$

$$A_x = P\tfrac{3}{5}$$

$$\boxed{A_x = 6\,kN} \text{ toward right}$$

$$\Sigma F_y: \quad A_y - P\left(\tfrac{4}{5}\right) + B_y = 0$$

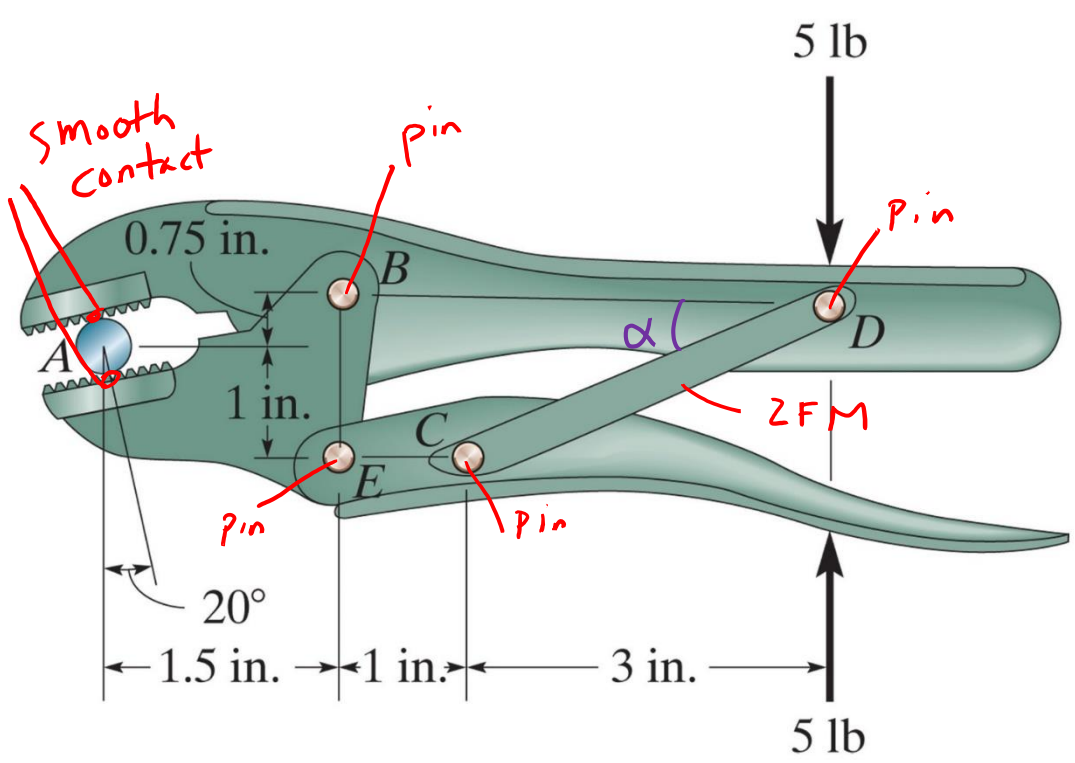
$$A_y = P\left(\tfrac{4}{5}\right) - (-4kN)$$

$$\boxed{A_y = 12kN} \text{ upward}$$

$$+\circlearrowleft \Sigma M_A: \quad M_A - (2m)\,P\left(\tfrac{4}{5}\right) + (4m)\,B_y = 0$$

$$M_A = \left(\tfrac{8}{5}m\right)(10kN) - (4m)(-4kN)$$

$$\boxed{M_A = 32\,kN\cdot m} \circlearrowleft \text{ ccw}$$



A 5 lb force is applied to the handles. Determine the compressive force developed at the smooth bolt shank A at the jaws.

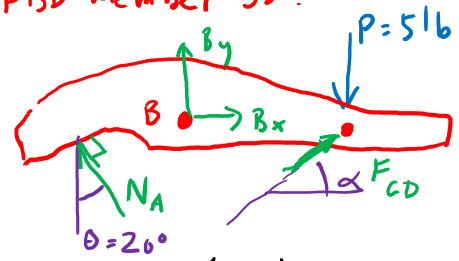
[Solved outside of class]

1) Identify 2 force or zero force members: CD = 2FM, no ΣFM

2) Identify support reaction types

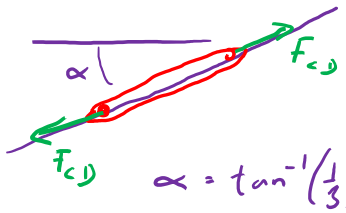
3) Draw FBDs of individual members

FBD member BD:

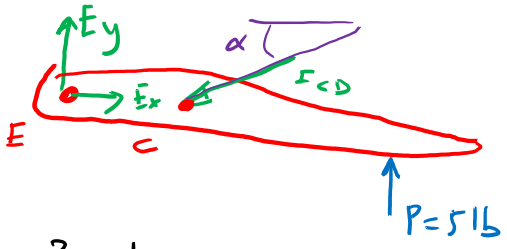


4 unknowns

ΣFM CD:

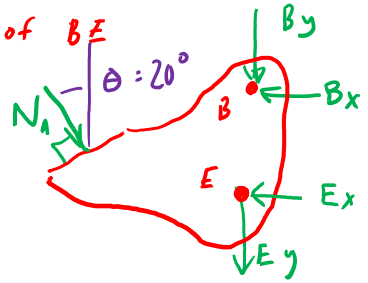


FBD of member EC



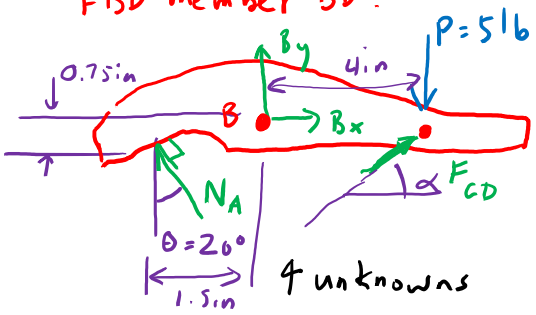
3 unknowns

FBD of BE



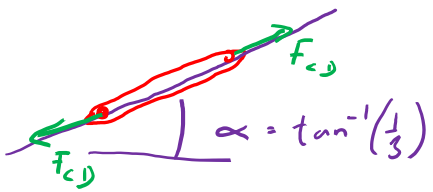
5 unknowns

FBD member BD:

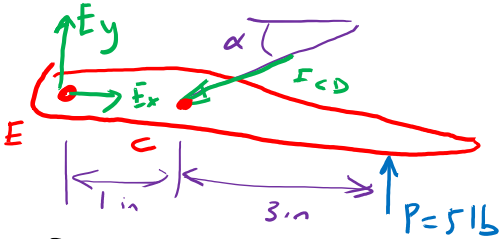


4 unknowns

2FM CD:

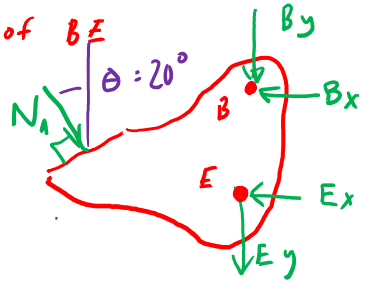


FBD of member EC



3 unknowns

FBD of BE



5 unknowns

4) Solve for unknowns: Goal: Find N_A

Start with FBD for EC since 3 unknowns

$$+\circlearrowleft \Sigma M_E: \quad (4in)\underbrace{P}_{=5lb} - (1in)F_{CD}\sin\underbrace{\alpha}_{=\tan^{-1}(\frac{1}{3})} = 0$$

$$F_{CD} = \frac{4P}{\sin\alpha} = 63.246lb$$

Solve for unknowns in BD:

$$+\circlearrowleft \Sigma M_B: \quad -(4in)P - (1.5in)N_A\cos 20° - (0.75in)N_A\sin 20° + (4in)F_{CD}\sin\alpha = 0$$

$$N_A = \frac{-(4in)(5lb) + (4in)\left(\frac{4P}{\sin\alpha}\right)\sin\alpha}{(1.5in)\cos 20° + (0.75in)\sin 20°}$$

$$\therefore \boxed{N_A = 36.0lb}$$

Note that by carefully selecting FBDs and eqns, we solved problem with only 2 eqns!