Statics - TAM 210 & TAM 211

Lecture 18

February 26, 2018

Announcements

- Today's lecture: physical lecture is cancelled. See recorded video lecture.
- Concept Inventory: Ungraded assessment of course knowledge
  - Extra credit: Complete #1 or #2 for 0.5 out of 100 pt of final grade each, or both for 1.5 out of 100 pt of final grade
  - #1: Sign up at CBTF (2/26-3/1 M-Th)
- **Check your grades on Compass2g!**

- Upcoming deadlines:
- Tuesday (2/27)
  - PL HW 6
- Thursday (3/1)
  - WA 3
  - See enhanced instructions
- Monday (3/5)
  - Mastering Engineering Tutorial 8

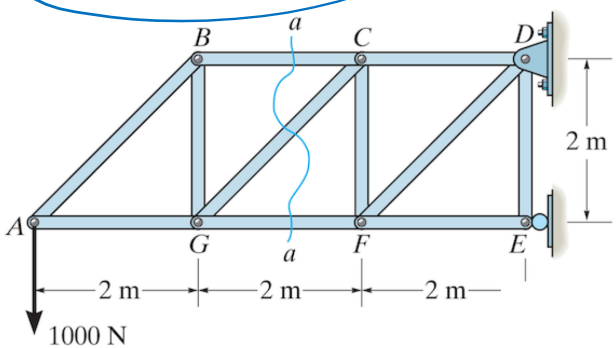
Chapter 6: Structural Analysis

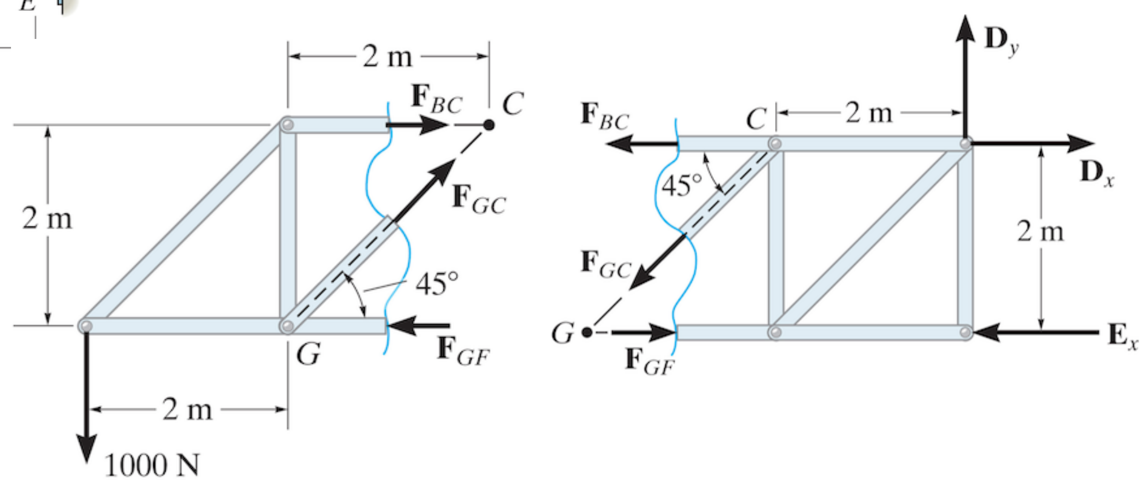
Goals and Objectives

- 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

Recap: Method of sections

- Determine external support reactions
- "Cut" the structure at a section of interest into two separate pieces and set either part into force and moment equilibrium (your cut should be such that you have **no more than** three unknowns)

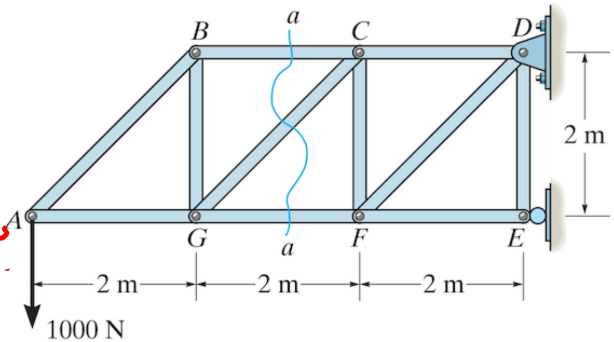


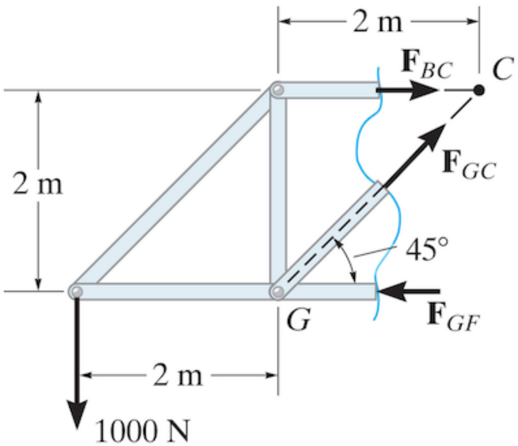


- Determine equilibrium equations (e.g., moment around point of intersection of two lines)
- Assume all internal loads are tensile.

Method of sections

- Determine equilibrium equations (e.g., moment around point of intersection of two lines) ⇐ Reduces # unknowns in eqn. Solve faster.
- Assume all internal loads are tensile.

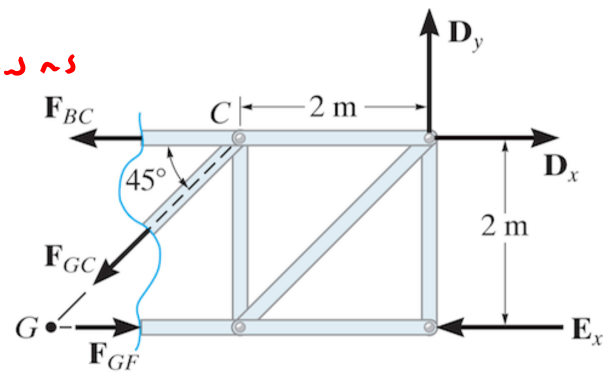




Left section : 3 unknowns

Right section : 6 unkns

⇒ solve left section first!



$+\circlearrowleft \sum M_C : -2m(F_{GF}) + 4m(1000N) = 0$

$\sum F_x$

$\sum F_y$ ⇒ F_{BC}, F_{GC}

$+\circlearrowleft \sum M_G :$

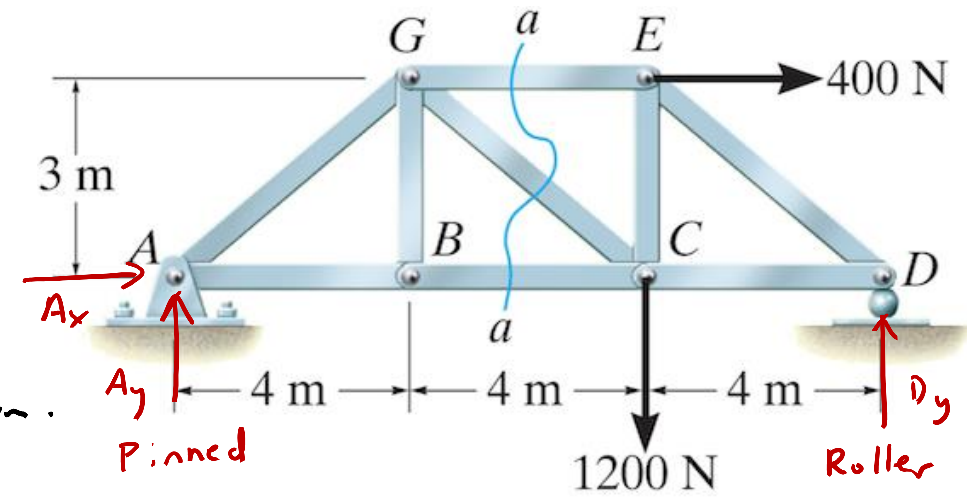
$2m(F_{BC}) - 2m(D_x) + 2m(D_y) = 0$

E_x passes thru G, so no effect on moment.

$\sum F_x$

$\sum F_y$ ⇒ D_x, D_y, E_x

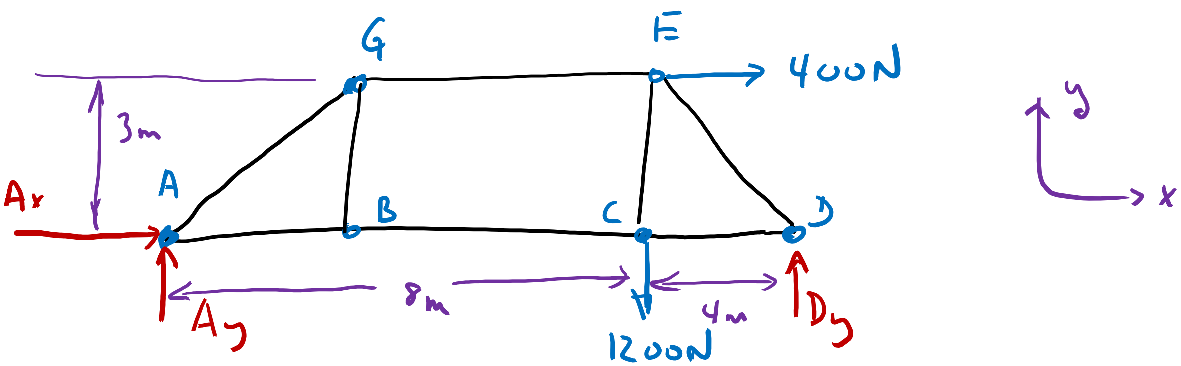
Determine the force in member BC of the truss and state if the member is in tension or compression.



[Problem solved outside of class.]

① Solve for reaction forces @ A & D.

Draw FBD. Solve Eqns of Equilibrium.



$\Sigma F_x: \; A_x + 400\,N = 0 \;\Rightarrow\; \boxed{A_x = -400\,N\,\hat{i} \;\; (\leftarrow)}$

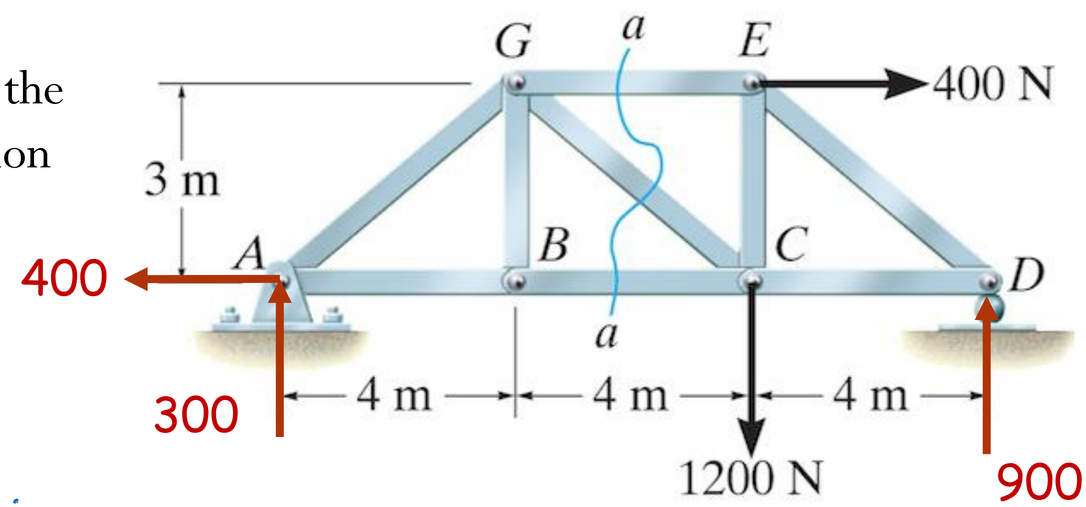
$\Sigma F_y: \; A_y - 1200\,N + D_y = 0 \;\Rightarrow\; A_y = 1200\,N - D_y$

$\circlearrowleft + \Sigma M_A$: pick A since want eqn w/ least # unknowns (solve faster)

$-(3m)\,400\,N - (8m)\,1200\,N + (12\,m)\,D_y = 0$

$\therefore \; \boxed{D_y = 900\,N\,\hat{j} \;(\uparrow), \quad A_y = 300\,N\,\hat{j} \;(\uparrow)}$

Determine the force in member BC of the truss and state if the member is in tension or compression.



(2) Use method of Sections to solve for force in BC (F_{BC})

- Extend two lines at cut to find point of intersection.
- Draw unknown truss forces in cut members.
- Solve Eq of Eq around created point (pt C in this case):

$$+\circlearrowleft \sum M_c: \; -(3m)F_{EG} - (8m)\,300\,N = 0$$

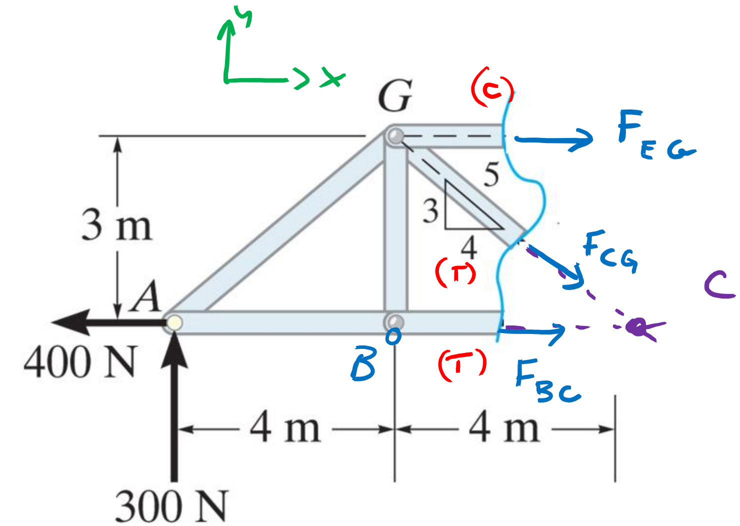
$$\Rightarrow F_{EG} = -800N$$

$$\sum F_x: \; -400N + F_{EG} + F_{BC} + F_{CG}\left(\tfrac{4}{5}\right) = 0$$

$$\sum F_y: \; 300N - F_{CG}\left(\tfrac{3}{5}\right) = 0 \;\Rightarrow F_{CG} = 500N$$

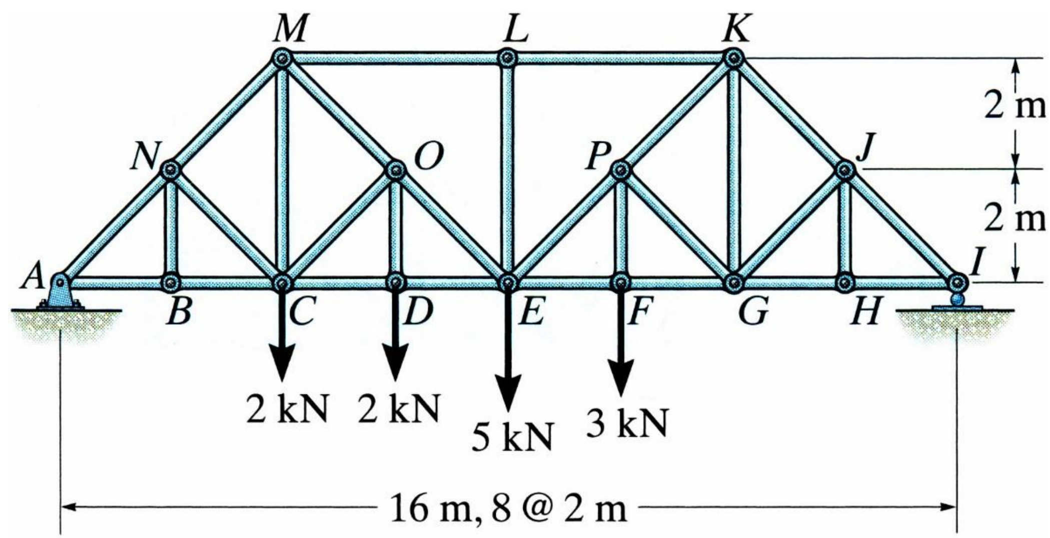
$$\therefore F_{BC} = 400N - 500\left(\tfrac{4}{5}\right) - (-800N)$$

$$\Rightarrow \boxed{F_{BC} = 800N\,\hat{i} \;\; (\rightarrow)}$$



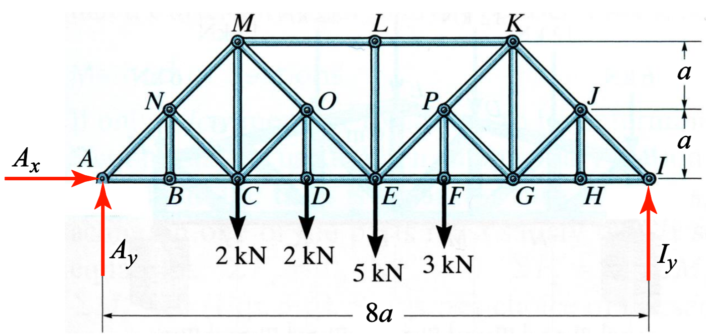
Since F_{BC}, F_{CG} are positive, FBD is correct, so BC & CG are in tension. F_{EG} is negative therefore F_{EG} is drawn incorrectly in the original FBD, so it should point in the opposite direction.
∴ member EG is in compression

Determine the force in members OE, LE, LK of the Baltimore truss and state if the member is in tension or compression.



Solution:

Use method of sections, since cutting LK, LE, OE, and DE will separate the truss into two pieces. Note that LE is a zero-force member. Draw free-body diagram of entire structure, and set into external equilibrium:

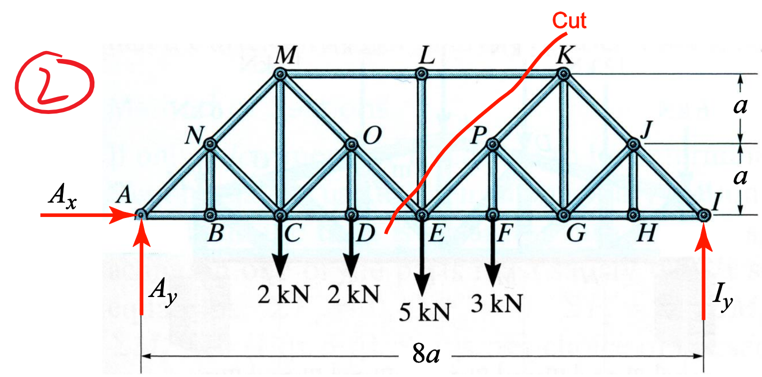


$$\Sigma F_x = 0: \qquad A_x = 0,$$

$$\Sigma F_y = 0: \qquad A_y + I_y - 2 - 2 - 5 - 3 = 0,$$

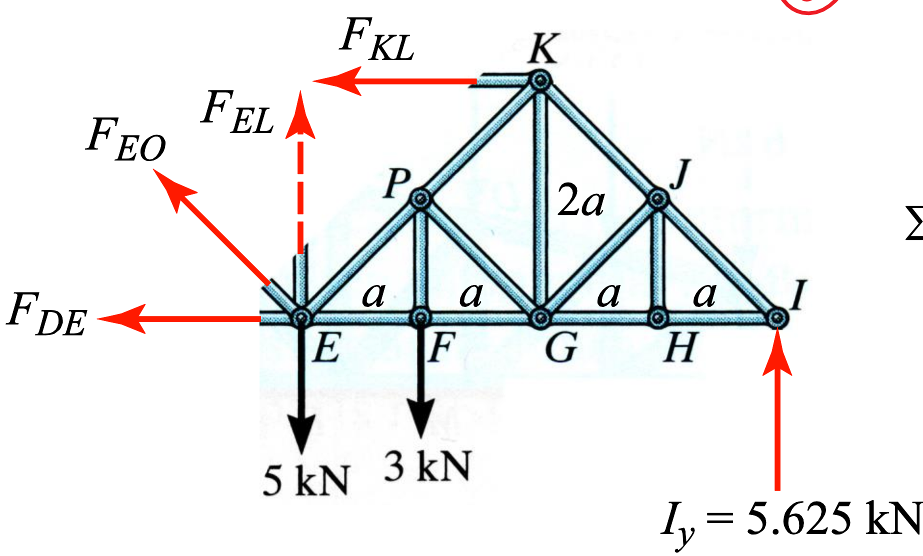
$$\Sigma M_A = 0: \quad -2a(2) - 3a(2) - 4a(5) - 5a(3) + 8aI_y = 0.$$

$$\boxed{A_x = 0, \quad A_y = 6.375\text{ kN}, \quad I_y = 5.625\text{ kN}.}$$



Normally, introducing four unknowns would make the problem intractable. However, *LE* is a *zero-force* member. Set *either* remaining section into equilibrium. Here, there is no real preference, but the right half will be fine

③



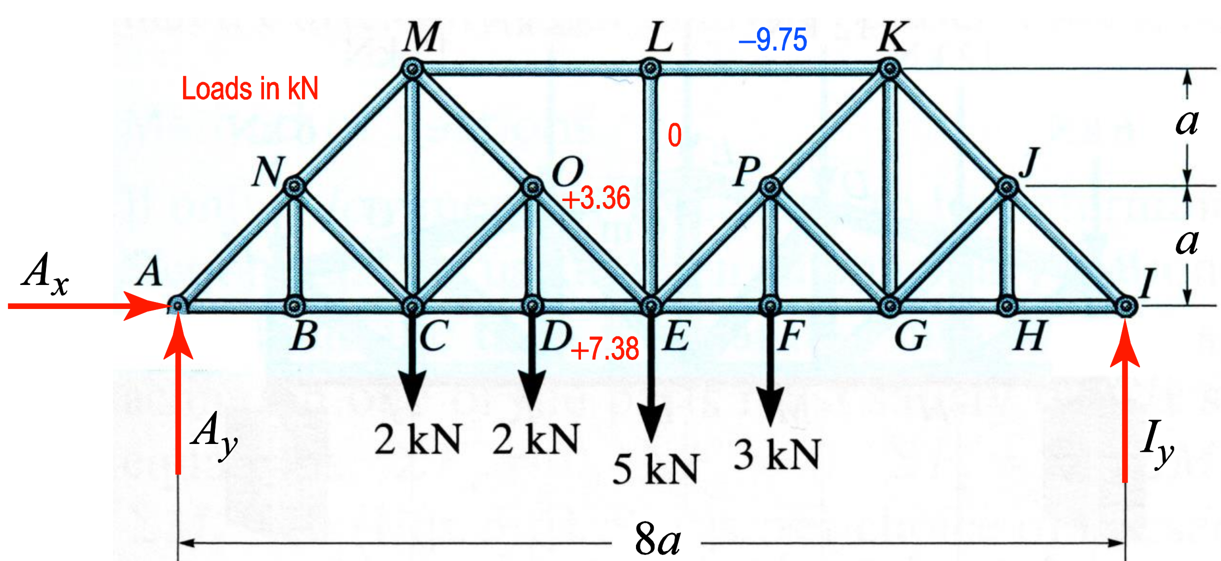
$$\Sigma F_x = 0: \quad -F_{DE} - \frac{1}{\sqrt{2}} F_{EO} - F_{KL} = 0,$$

$$\Sigma F_y = 0: \quad \frac{1}{\sqrt{2}} F_{EO} + 0 - 5 - 3 + I_y = 0,$$

$$\Sigma M_E = 0: \quad 0(5) + a(-3) + 4aI_y + 2aF_{KL} = 0.$$

$F_{DE} = +7.38$ kN (T), $F_{EL} = 0$ (zero-force),
$F_{EO} = +3.36$ kN (T), $F_{KL} = -9.75$ kN (C).

④ Final Result :



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.

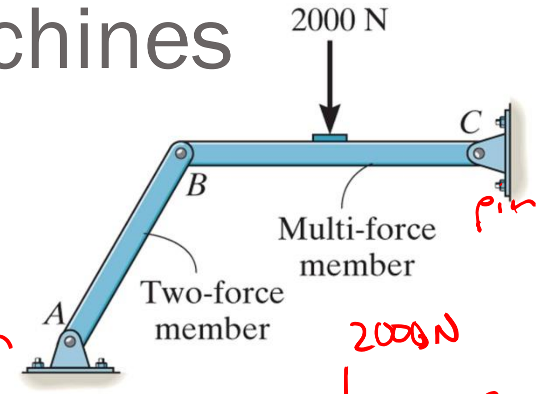
Frames are generally **stationary** and used to support various external loads.

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.

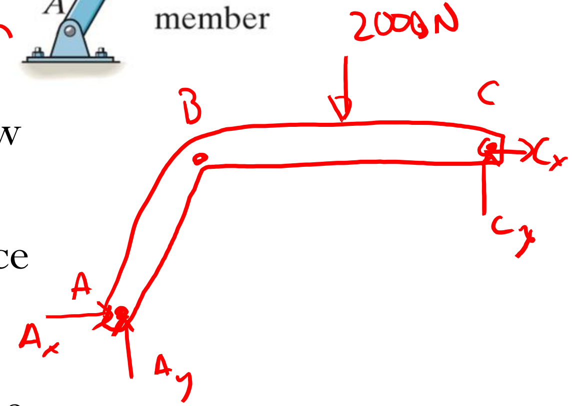
Machines contain **moving parts** and are designed to alter the effect of forces.

Forces/Moment in frames and machines



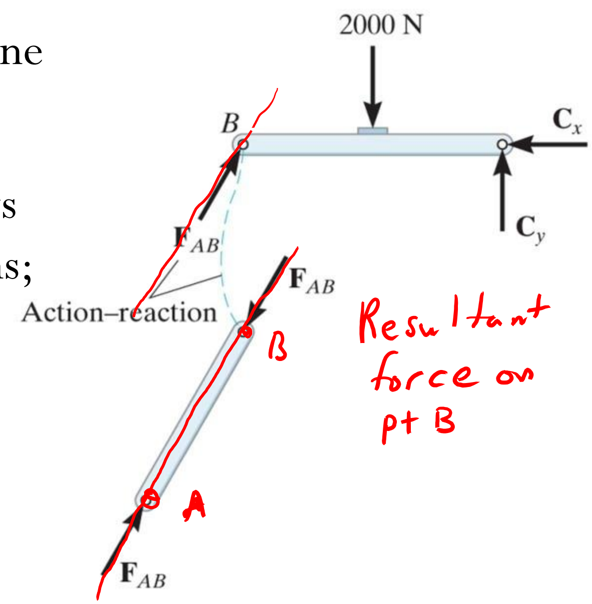
The members can be truss elements, beams, pulleys, cables, and other components. The general solution method is the same:

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.)

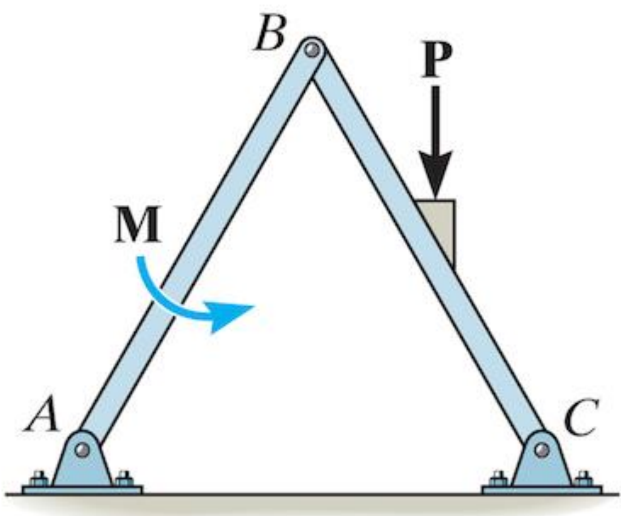


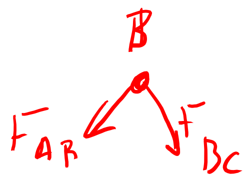
4. Solve for the requested unknown forces or moments. (Look for ways to solve efficiently and quickly: single equations and single unknowns; equations with least # unknowns.)

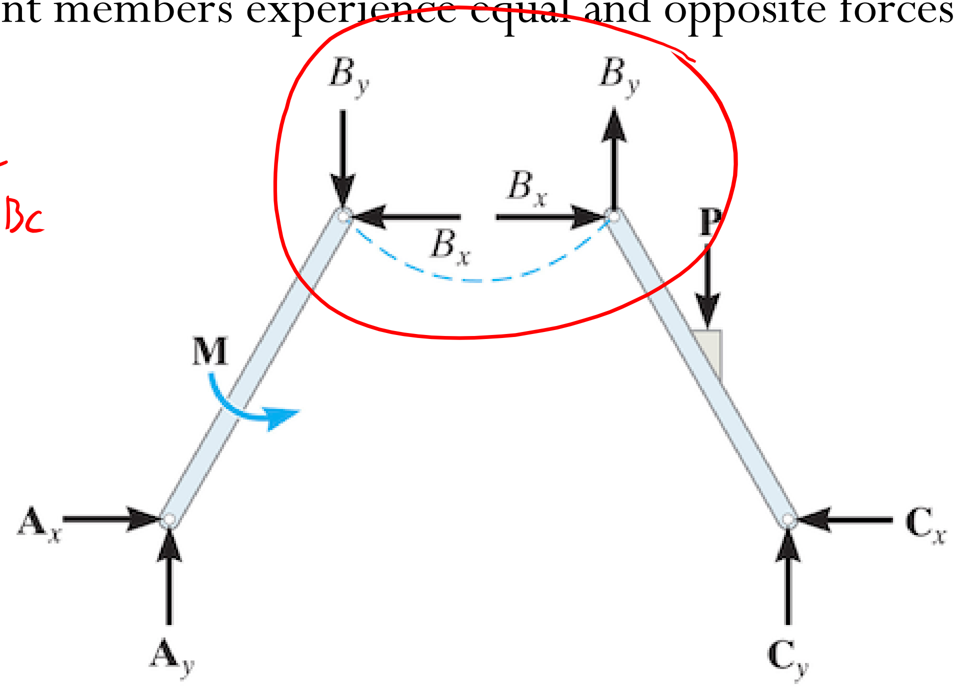
Problems are going to be **challenging** since there are usually several unknowns (and several solution steps). A lot of practice is needed to develop good strategies and ease of solving these problems.

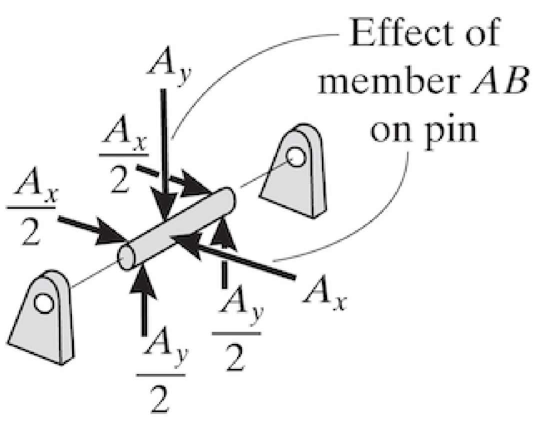
A note about why skip drawing FBD of the pin joint between members:

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.

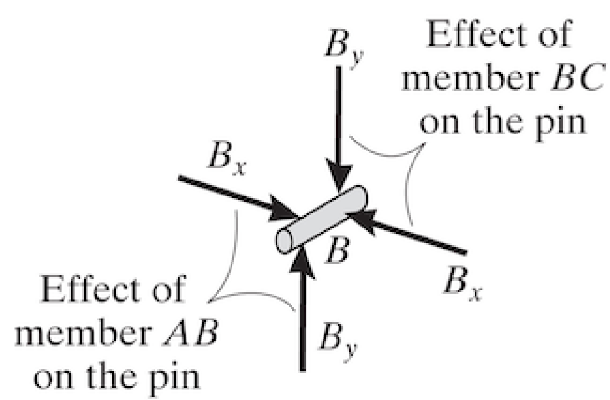








Pin A



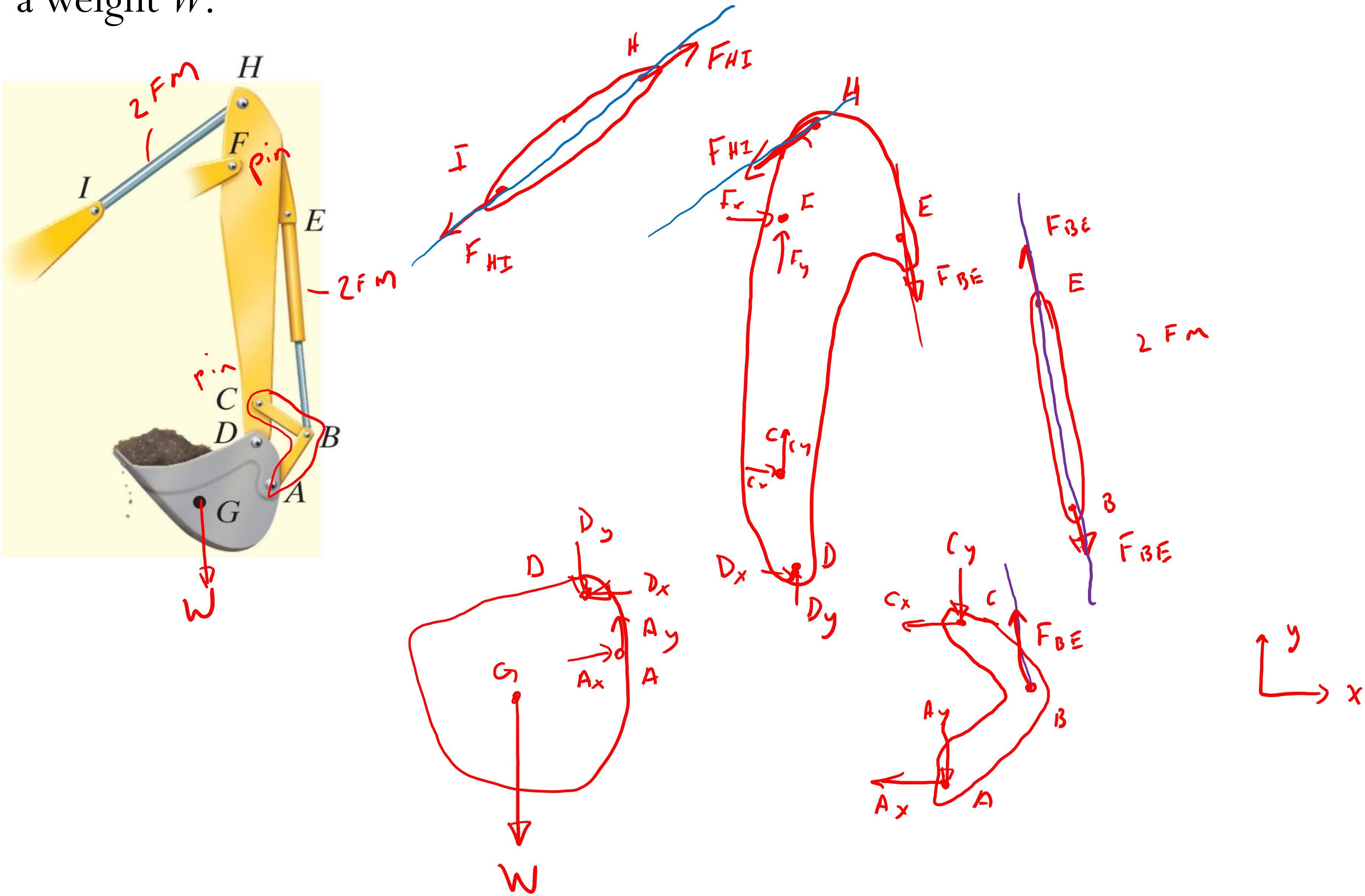
Pin B

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

1) Label 2 force members
2) ID support reactions
3) other joints have 2 components (x, y) for unknown forces

force single resultant force along the line of action connecting the end joints

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



A 500 kg elevator car is being hoisted by a motor using a pulley system. If the car travels at a constant speed, determine the force developed in the cables. Neglect the cable and pulley masses.

We'll label the tension in the rightmost cable T_1, and tension in the leftmost cable T_2. Which is an equation for equilibrium of pulley C?

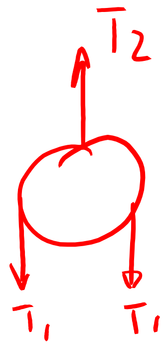
A. $T_1+2T_2 = 0$

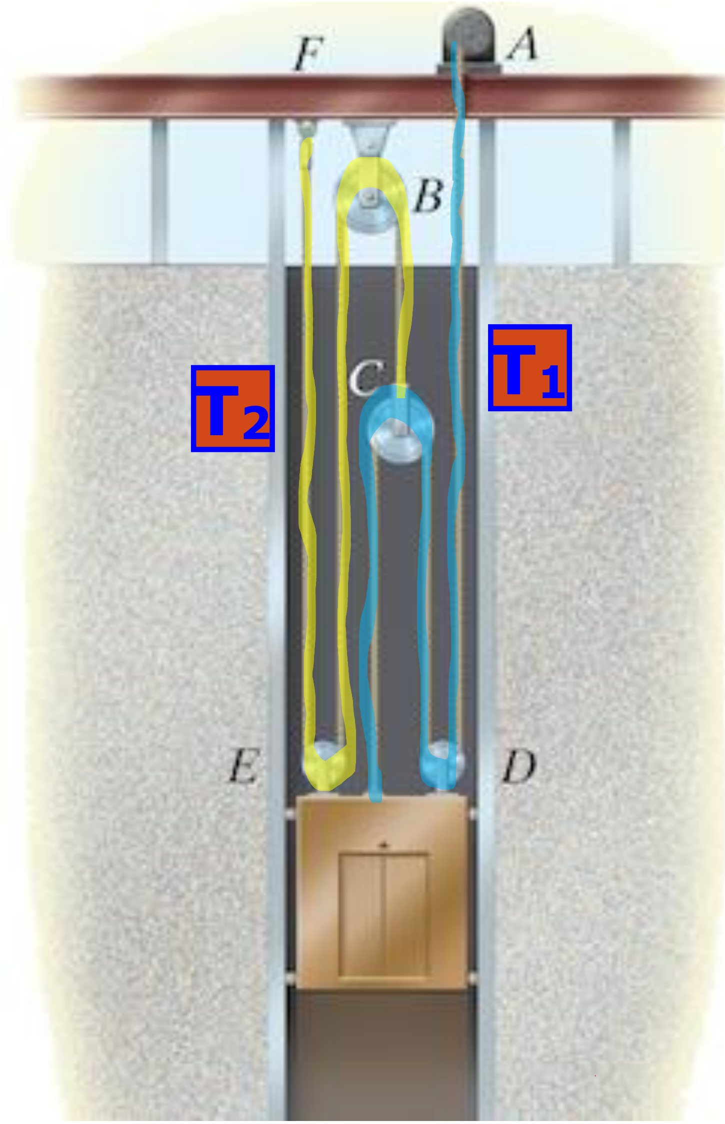
B. $2T_1+T_2 = 0$

C. $T_1-T_2 = 0$

D. $2T_1-T_2 = 0$

E. $T_1-2T_2 = 0$





A 500 kg elevator car is being hoisted by a motor using a pulley system. If the car travels at a constant speed, determine the force developed in the cables. Neglect the cable and pulley masses.

We'll label the tension in the rightmost cable T_1, and tension in the leftmost cable T_2. Which is an equation for equilibrium of the car?

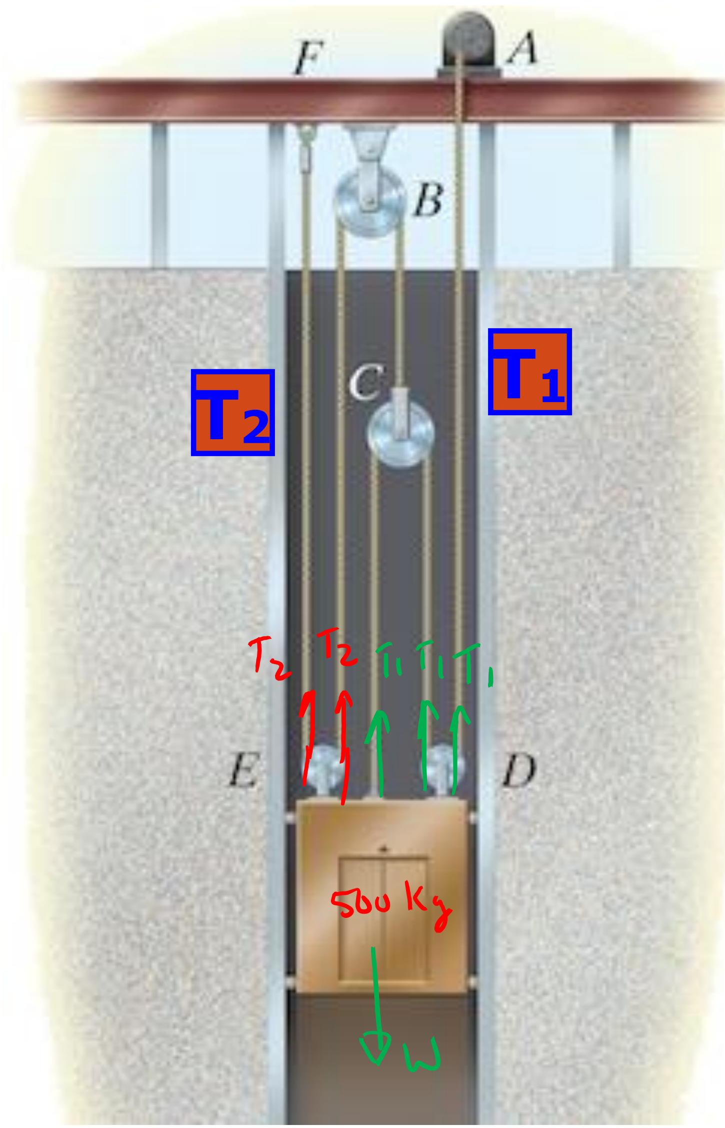
A. $3T_1 + 2T_2 + 500(9.81)\text{ N} = 0$

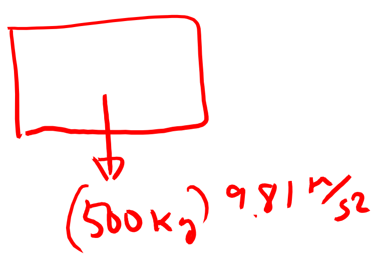
B. $3T_1 - 4T_2 + 500(9.81)\text{ N} = 0$

C. $3T_1 + 2T_2 - 500(9.81)\text{ N} = 0$

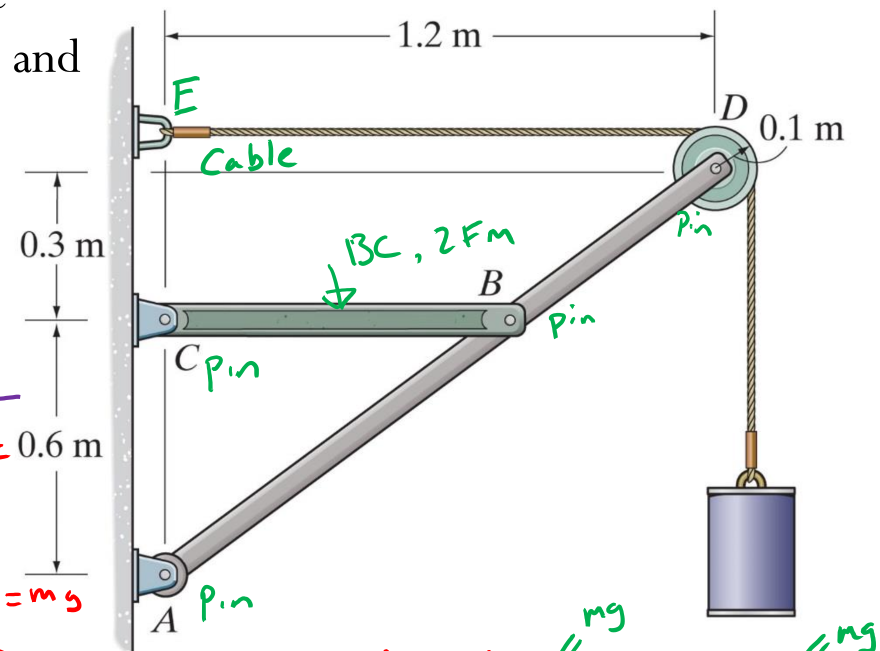
D. $3T_1 - 2T_2 - 500(9.81)\text{ N} = 0$

E. None of the above





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



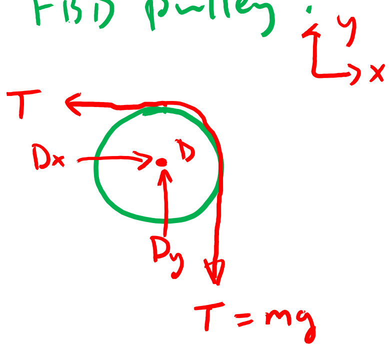
Find: A_x, A_y, F_{BC}

ID: 2FM ?

ID: supports

FBD: BC (2FM)

FBD pulley:



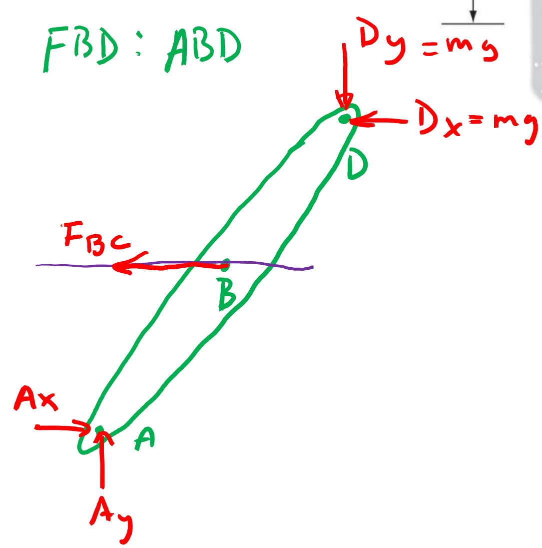
$\Sigma F_x: D_x - T = 0$

$D_x = T = mg$

$\Sigma F_y: D_y - T = 0$

$D_y = mg$

FBD: ABD



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

$F_{BC} = 245\,N$

$m = 50\,kg$

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

$A_x = 736\,N$

$\Sigma F_y: A_y - D_y = 0$

$A_y = 490\,N$