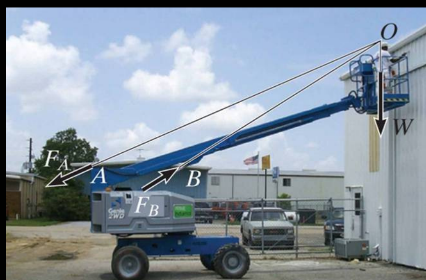
EQUATIONS OF EQUILIBRIUM & TWO- AND THREE-FORCE MEMEBERS

Today's Objectives:

Students will be able to:

a) Apply equations of equilibrium to solve for unknowns, and,

b) Recognize two-force members.



In-Class Activities:

Reading Quiz

- Applications
- Equations of Equilibrium
- Two-Force Members
- Concept Quiz
- Group Problem Solving
- Attention Quiz

READING QUIZ

1. The three scalar equations $\sum F_X = \sum F_Y = \sum M_O = 0$, are ____ equations of equilibrium in two dimensions.

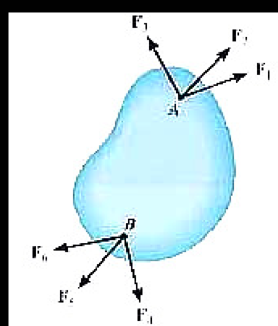
   A) Incorrect B) The only correct

   C) The most commonly used D) Not sufficient

2. A rigid body is subjected to forces as shown. This body can be considered as a ______ member.

   A) Single-force B) Two-force

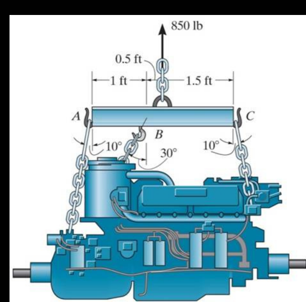
   C) Three-force D) Six-force



APPLICATIONS

The uniform truck ramp has a weight of 400 lb.
The ramp is pinned at A and held in the position by the cable.
How can we determine the forces acting at the pin A and the force in the cable ?

APPLICATIONS (continued)

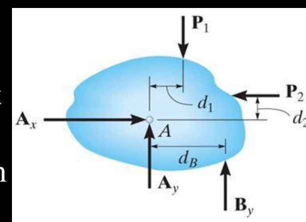


A 850 lb of engine is supported by three chains, which are attached to the spreader bar of a hoist.

You need to check to see if the breaking strength of any of the chains is going to be exceeded. How can you determine the force acting in each of the chains?

EQUATIONS OF EQUILIBRIUM
(Section 5.3)

A body is subjected to a system of forces that lie in the x-y plane. When in equilibrium, the net force and net moment acting on the body are zero (as discussed earlier in Section 5.1). This 2-D condition can be represented by the three scalar equations:



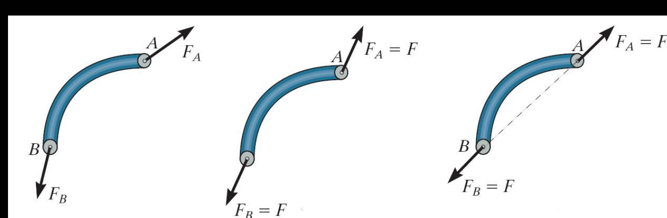
$$\sum F_x = 0 \qquad \sum F_y = 0 \qquad \sum M_O = 0$$

where point O is any arbitrary point.

Please note that these equations are the ones most commonly used for solving 2-D equilibrium problems. There are two other sets of equilibrium equations that are rarely used. For your reference, they are described in the textbook.

TWO-FORCE MEMBERS & THREE FORCE-MEMBERS
(Section 5.4)

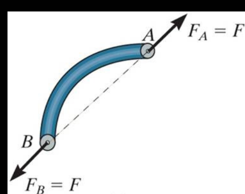
The solution to some equilibrium problems can be simplified if we recognize members that are subjected to forces at only two points (e.g., at points A and B).



If we apply the equations of equilibrium to such a member, 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.

EXAMPLE OF TWO-FORCE MEMBERS

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



This fact simplifies 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).

STEPS FOR SOLVING 2-D EQUILIBRIUM PROBLEMS

1. If not given, establish a suitable x - y coordinate system.

2. Draw a free body diagram (FBD) of the object under analysis.

3. Apply the three equations of equilibrium (E-of-E) to solve for the unknowns.

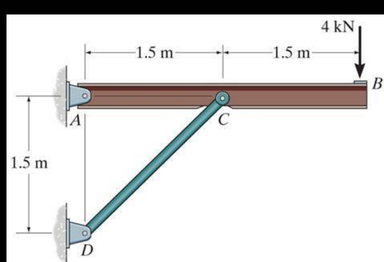
IMPORTANT NOTES

1. If there are more unknowns than the number of independent equations, then we have a statically indeterminate situation. We cannot solve these problems using just statics.

2. The order in which we apply equations may affect the simplicity of the solution. For example, if we have two unknown vertical forces and one unknown horizontal force, then solving $\sum F_X = 0$ first allows us to find the horizontal unknown quickly.

3. If the answer for an unknown comes out as negative number, then the sense (direction) of the unknown force is opposite to that assumed when starting the problem.

EXAMPLE



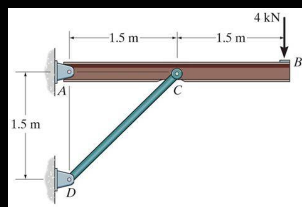
Given: The 4kN load at B of the beam is supported by pins at A and C .

Find: The support reactions at A and C.

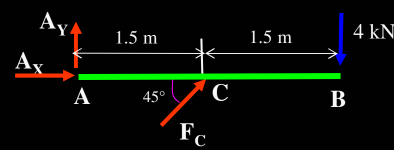
Plan:

1. Put the x and y axes in the horizontal and vertical directions, respectively.
2. Determine if there are any two-force members.
3. Draw a complete FBD of the boom.
4. Apply the E-of-E to solve for the unknowns.

EXAMPLE (Continued)



FBD of the beam:



Note: Upon recognizing CD as a two-force member, the number of unknowns at C are reduced from two to one. Now, using E-o-f E, we get,

$\circlearrowleft + \sum M_A = F_C \sin 45° * 1.5 - 4 * 3 = 0$

$F_c = 11.31$ kN or 11.3 kN

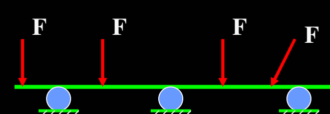
$\rightarrow + \sum F_X = A_X + 11.31 \cos 45° = 0;$ $A_X = -8.00$ kN

$\uparrow + \sum F_Y = A_Y + 11.31 \sin 45° - 4 = 0;$ $A_Y = -4.00$ kN

Note that the negative signs means that the reactions have the opposite direction to that shown on FBD.

CONCEPT QUIZ

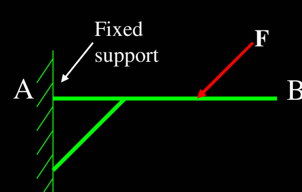
1. For this beam, how many support reactions are there and is the problem statically determinate?
   A) (2, Yes) B) (2, No)
   C) (3, Yes) D) (3, No)



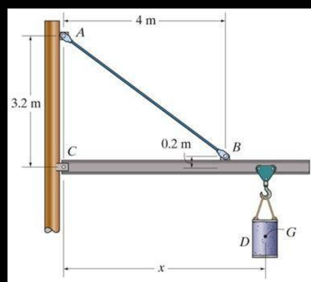
2. The beam AB is loaded and supported as shown: a) how many support reactions are there on the beam, b) is this problem statically determinate, and c) is the structure stable?

   A) (4, Yes, No) B) (4, No, Yes)

   C) (5, Yes, No) D) (5, No, Yes)



GROUP PROBLEM SOLVING



Given: The jib crane is supported by a pin at C and rod AB. The load has a mass of 2000 kg with its center of mass located at G.

Assume x = 5 m.

Find: Support reactions at B and C.

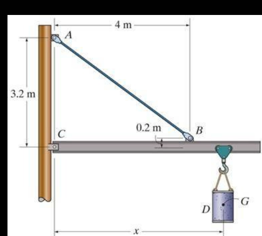
Plan:

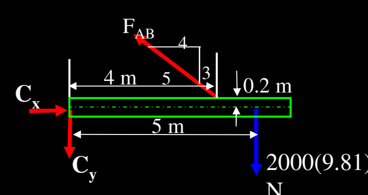
a) Establish the x – y axes.

b) Draw a complete FBD of the jib crane beam.

c) Apply the E-of-E to solve for the unknowns.

GROUP PROBLEM SOLVING (Continued)





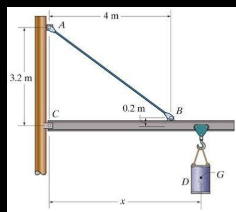
FBD of the beam

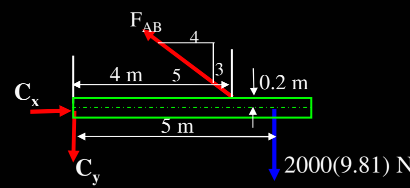
First write a moment equation about Point C. Why point C?

$$+\sum M_C = (3/5)\,F_{AB} * 4 + (4/5)\,F_{AB} * 0.2 - 2000(9.81) * 5 = 0$$

$F_{AB} = 38320 \text{ N} = 38.3 \text{ kN}$

GROUP PROBLEM SOLVING (Continued)





FBD of the beam

$F_{AB} = 38320 \text{ N} = 38.3 \text{ kN}$

Now solve the $\sum F_X$ and $\sum F_Y$ equations.

$\rightarrow + \ \sum F_X = C_x - (4/5)\, 38320 = 0$

$\uparrow + \ \sum F_Y = -C_y + (3/5)\, 38320 - 2000(9.81) = 0$

Solving these two equations, we get

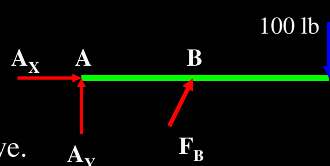
$C_x = 30656$ N or 30.7 kN and $C_y = 3372$ N or 33.7 kN

ATTENTION QUIZ

1. Which equation of equilibrium allows you to determine F_B right away?

   A) $\sum F_X = 0$ B) $\sum F_Y = 0$

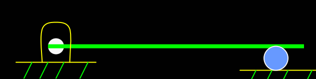
   C) $\sum M_A = 0$ D) Any one of the above.



2. A beam is supported by a pin joint and a roller. How many support reactions are there and is the structure stable for all types of loadings?

   A) (3, Yes) B) (3, No)

   C) (4, Yes) D) (4, No)



End of the Lecture

Let Learning Continue