GIVE FEEDBACK

CONTINUE >

This chapter is about frames, namely pin-jointed frames.

The analysis of frames brings together our knowledge of free body diagrams, as well as equilibrium of both concurrent and non-concurrent bodies.

Frames are structures made from individual members joined together with hinge-like joints, known as 'pin joints'. A single bolt forms a convenient pin-joint.

This definition is not as restrictive as is sounds. While many frames are likely to be rigidly bolted or even welded togther, the calculation of forces in members requires pin-joint connections to simplify analysis.

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GIVE FEEDBACK

CONTINUE >

If individual members are relatively slender, there is little difference between pin-jointed and rigid-jointed behaviour. Even when there is a difference, the rigid joint will usually improve performance, so the pin-joint assumption will err on the safe side. However, critical structures (like bridges) often deliberately include pin-type joints to avoid introducing unnecessary stresses.

Once the force at each pin joint is known, the entire frame is fully solved. This requires the use of free body diagrams as well as concurrent equilibrium (joints) and non-concurrent equilibrium (members).

< BACK GIVE FEEDBACK OK

A frame is an assembly of parts that forms some sort of structure. In this section we will limit our frames to two dimensions - planar frames. The components are joined with hinges too, called pin joints. So we are looking at "pin jointed planar frames".

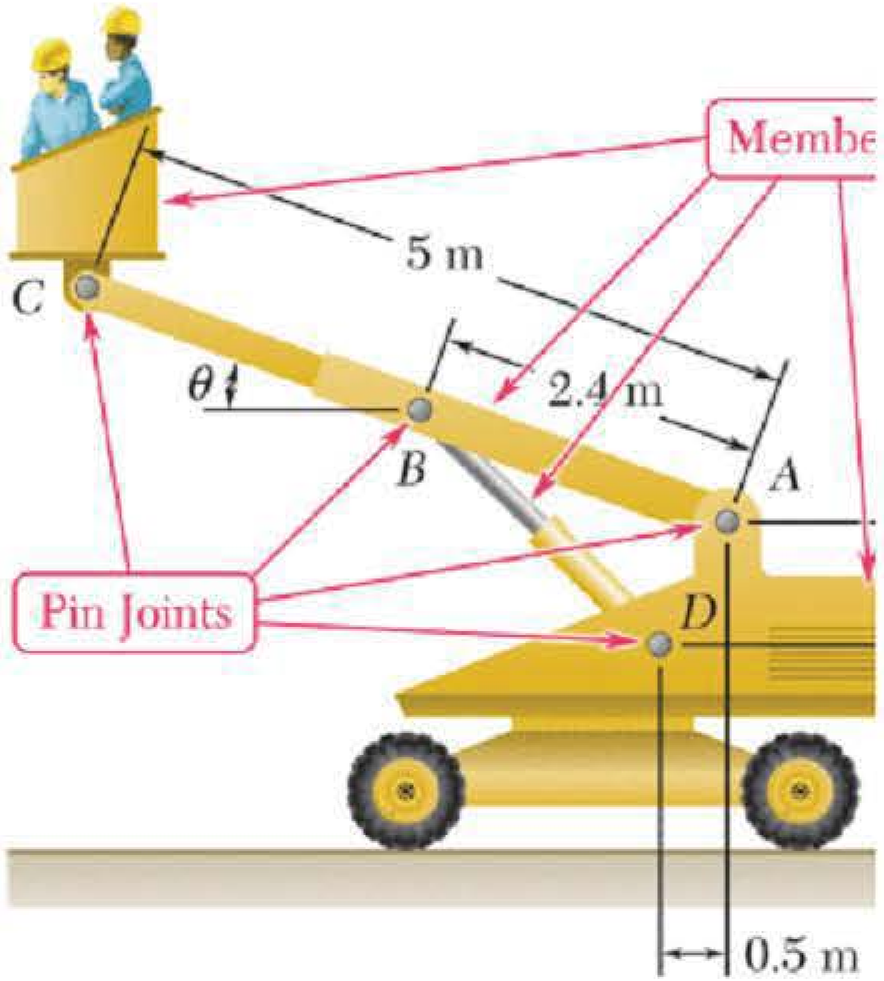
What is a frame?

A frame is an assembly of bodies. It can be a **static structure**, like a roof truss or machine structure.

If the frame is designed to move we call it a **mechanism**, but while it remains stationary it acts like a frame.

Each structural beam component is called a **member**, and they are all connected by **pin joints**. This is known as a pin-jointed structure.

In this section we will only work in two dimensions, so we are dealing with **pin-jointed planar structures**.



GIVE FEEDBACK

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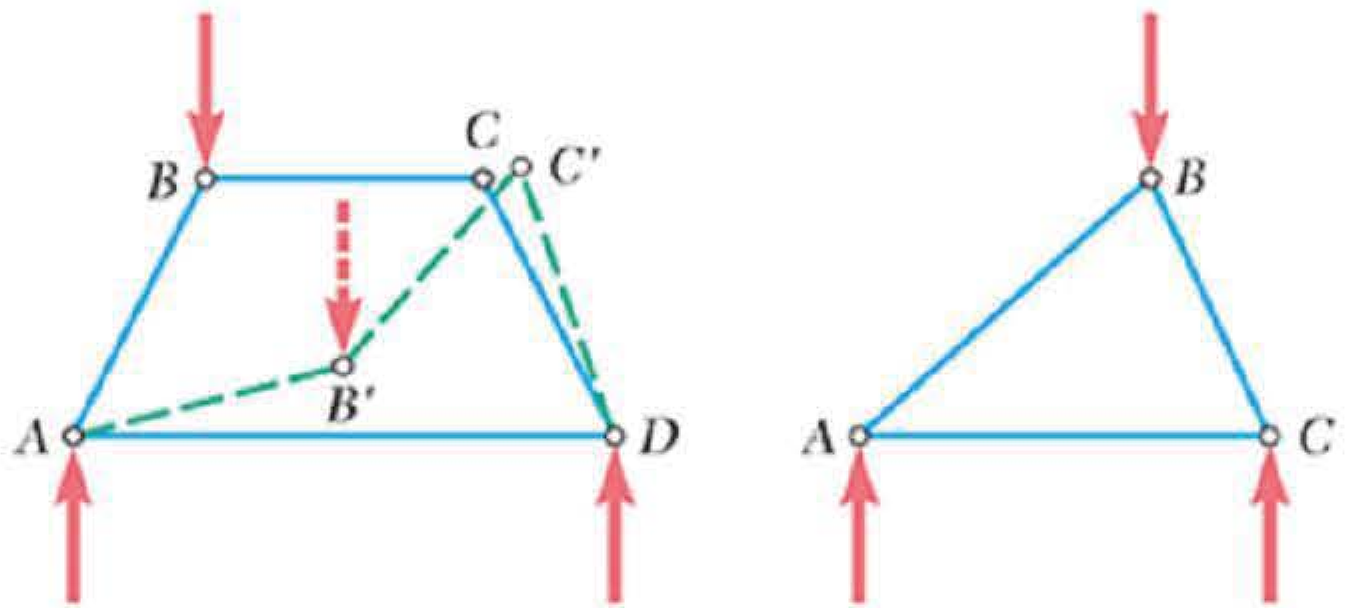


Match the following descriptions for each structure shown above.

Drag statements on the right to match the left.

Fig (a)	Frame
Fig (b)	Not in equilibrium
Fig (a)	In equilibrium
Fig (b)	Pin jointed
Both Fig (a) and Fig (b)	Mechanism

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Which of the following are true regarding a **pin-jointed planar structure?**

Check all that apply.

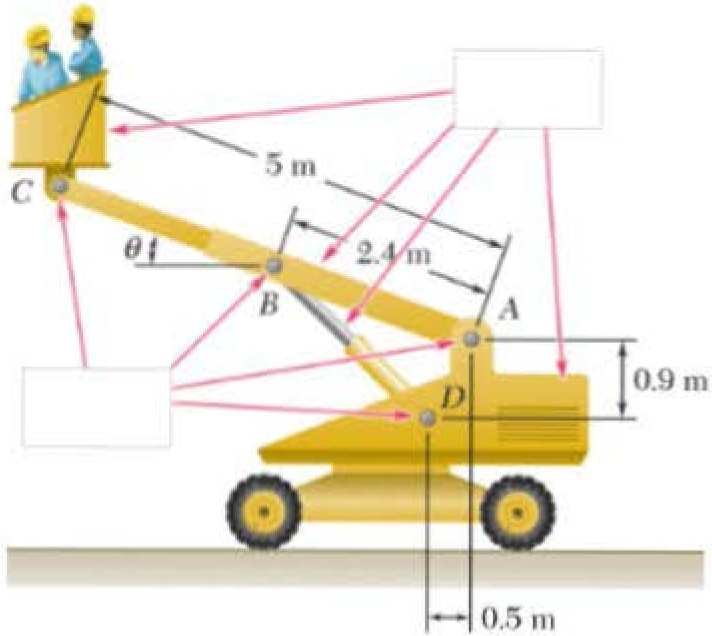
- [ ] It is connected by frictionless hinge joints
- [ ] It is stationary
- [ ] All the parts lie in the same 2D plane
- [ ] The members are all of equal length

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Label the members and joints in this free body diagram.

Joints Members



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What is a pin joint within a frame?

A pin joint in a frame allows small movement to ensure forces are transmitted, but not moments.

For a planar frame, a pin joint acts like a hinge. It will freely rotate but it cannot be pulled apart.

For a 3 dimensional frame this requires a ball joint, but in 2D we only need one axis of rotation. This can be achieved with a hinge or a single bolt.

Another joint that behaves like a pin joint is a contact point with high friction (like the foot of a ladder on a clean concrete floor).

GIVE FEEDBACK

CONTINUE >

When members are welded together or joined with multiple bolts this is regarded as a rigid joint, not a pin joint.

Rigid bolted joints

A large pin joint

< BACK GIVE FEEDBACK OK

Which of the following connections act like a pin joint in a planar frame?

Check all that apply.

- [ ] A joint between 2 members with a single bolt
- [ ] A hinge fitted between 2 members
- [ ] A welded joint between 2 members
- [ ] A joint between 3 members with a single bolt
- [ ] A joint between 2 members with multiple bolts

Do you know the answer?

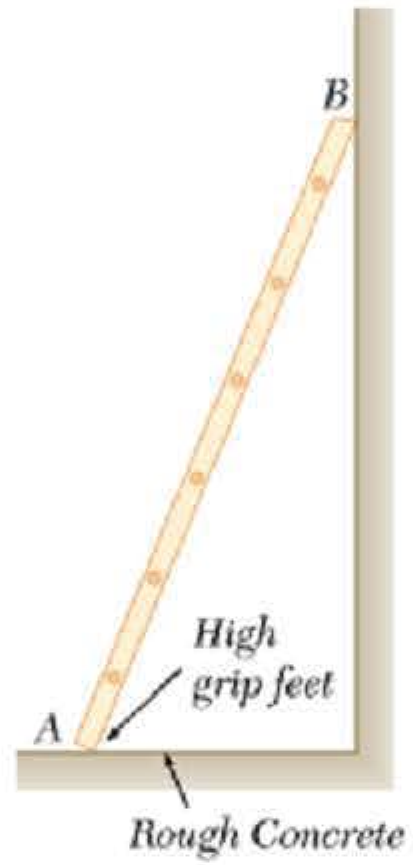
I KNOW IT | THINK SO | UNSURE | NO IDEA

The foot of a ladder rests on a concrete floor.

The floor is rough (not slippery).

The feet have high friction rubber.

This is an example of which type of joint?



Click the correct answer.

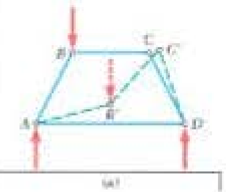
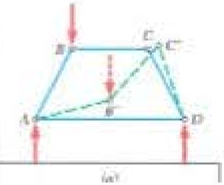
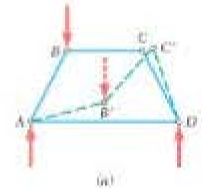
- rigid joint
- pin joint
- roller joint
- it is not regarded as a joint

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Not every frame can be solved using the equilibrium equations of statics. It cannot be over constrained or under constrained.

What is a statically determinate frame?

Under-constrained means the frame can move as soon as loads are applied at certain angles. This makes it a mechanism, not a static structure.	
Solvable frames (statically determinate) have exactly the right number of joints and members to remain rigid without being over-constrained.	
An over-constrained (or statically indeterminate) frame will be rigid even if a member or joint is removed. These are difficult to analyse because internal forces can exist if one member is shortened. Solving this type of frame requires elasticity to be accounted for.	

GIVE FEEDBACK

OK

Match the following definitions for whether a frame can be solved.

Drag statements on the right to match the left.

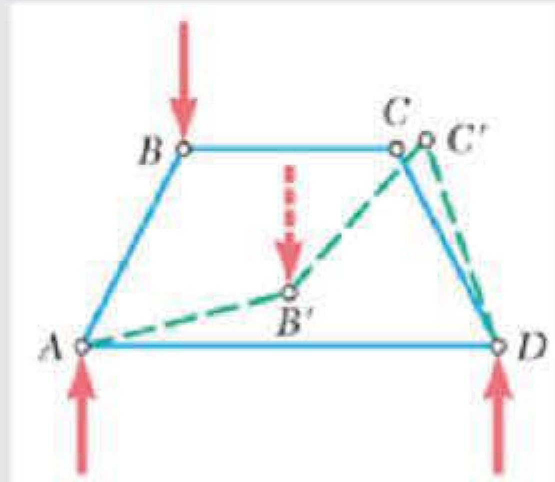
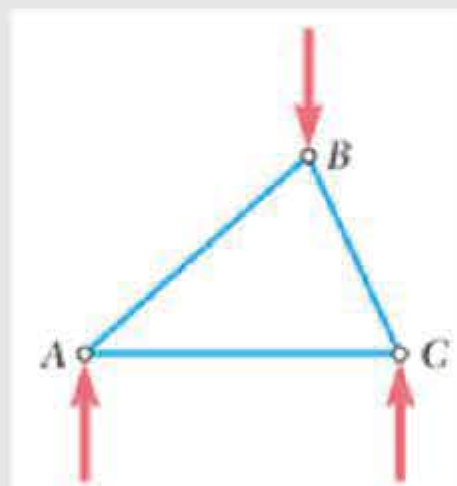
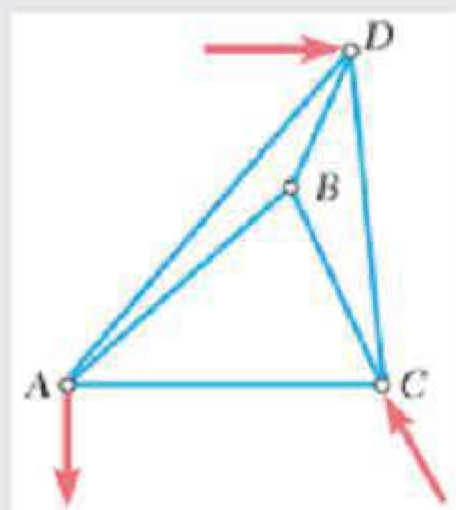
Statically Indeterminate	A frame with excess members
Statically Determinate	Simply supported frame
Statically Indeterminate	A frame with inadequate members that allow movement
Statically Determinate	An rigid framework that will move if one member is removed

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Match the following types of pin-jointed planar structures to their diagrams.

Drag statements on the right to match the left.

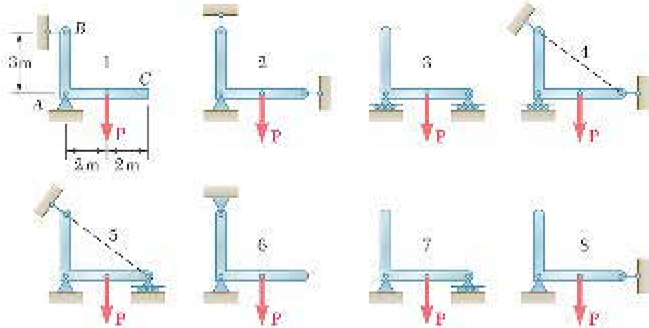
Statically indeterminate mechanism	
Statically determinate frame	
Statically indeterminate structure	

Solvable frame support arrangements

The supports of a frame also need to be correctly arranged to allow a solution. In practice a statically determinate support arrangement gives more predictable behaviour.

The frame supports must allow solution (statically determinate). In practice a statically determinate support arrangement gives more predictable behaviour, especially in allowing for changes such as thermal expansion or shrinkage.

- If motion is possible (3), even for a short range (2,8), then this is not statically determinate (i.e. cannot be solved using equilbrium equations).
- Supports that are excessive are also unsolvable because the supports can be pushing or pulling against each other. (5,6).
- A common solvable setup has one roller joint and one pin joint (simply supported) (1.,7,4)

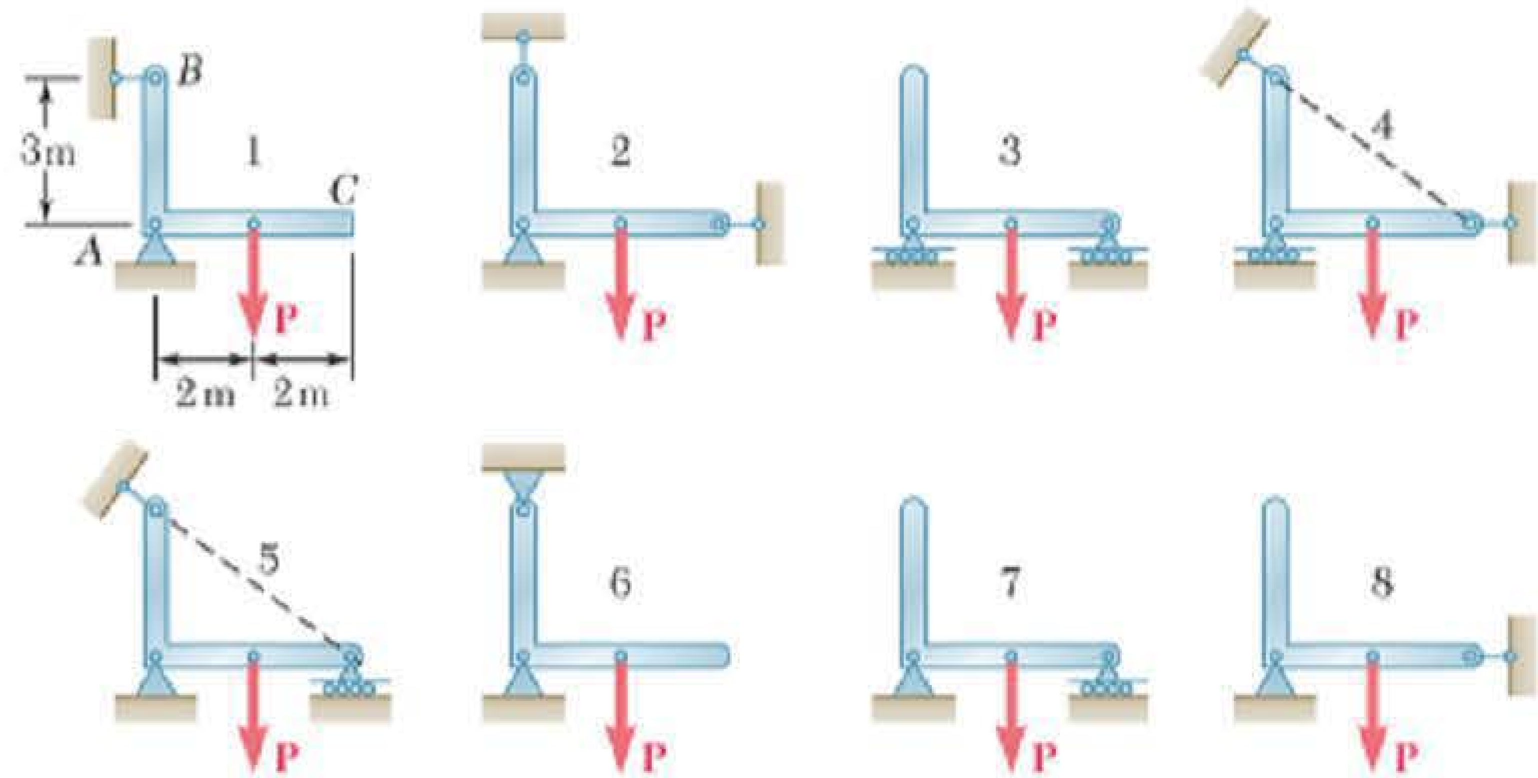


Frame Supports

GIVE FEEDBACK

OK

Match the following diagrams to their definitions of solvability.



Drag statements on the right to match the left.

Statically determinate	Diagrams 1 and 7
Statically indeterminate due to inadequate constraint	Diagrams 5 and 6
Statically indeterminate due to excess constraint	Diagrams 2,3 and 8

Do you know the answer?

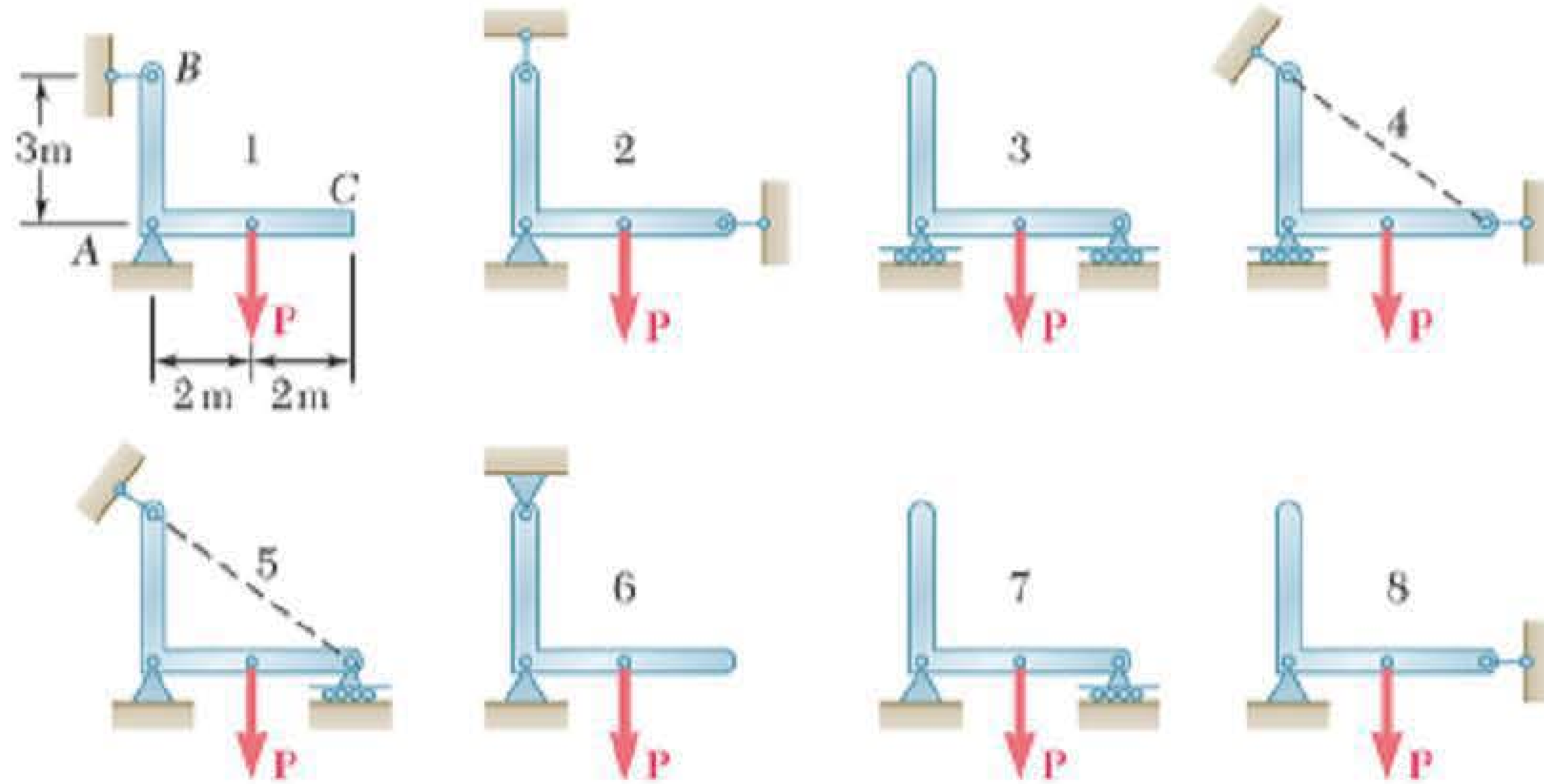
I KNOW IT

THINK SO

UNSURE

NO IDEA

Which frames are simply supported?



Check all that apply.

- [ ] Diagram 5
- [ ] Diagram 6
- [ ] Diagram 3
- [ ] Diagram 8
- [ ] Diagram 7
- [ ] Diagram 1

Designing a frame (and its supports) to be statically determinate has the advantages of being __________.

Check all that apply.

- [ ] easier to analyse
- [ ] less sensitive to thermal expansion and contraction
- [ ] more predictable under load
- [ ] cheaper to make

Do you know the answer?

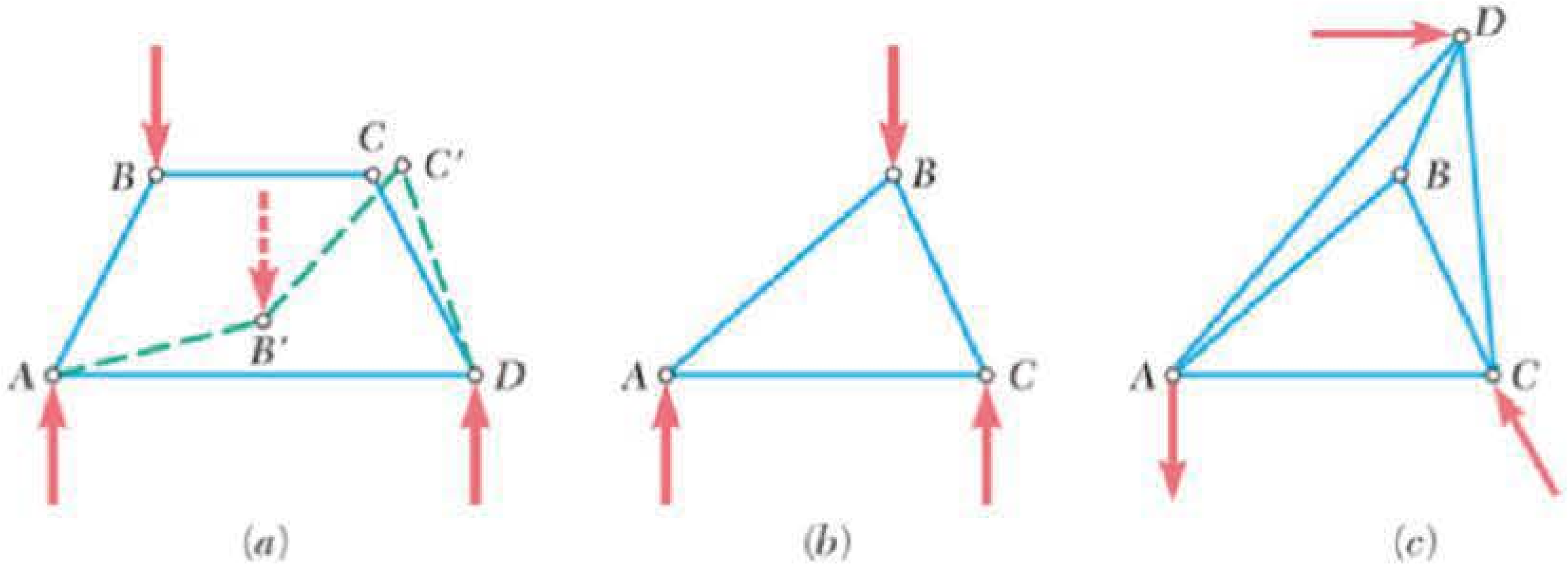
I KNOW IT | THINK SO | UNSURE | NO IDEA

These are the rules for the types of frames we can analyse using the laws of static equilibrium. Frames that disobey these rules will probably need to be analysed by computer methods.

The assumptions for a pin-jointed frame

To make calculations simpler there are a few assumptions to be made:

- The weight of each member is ignored (applied loads are relatively high).
- Each member is pin-jointed to the others (can transfer forces but not moments).
- The frame is stationary (even if it is designed as a moving mechanism – it is a stationary structure during the calculation).
- There are a correct number of joints and supports for static equilibrium, preventing either mobility or collapse as a mechanism like fig (a), or excessive bracing as a statically indeterminate structure like fig (c).



GIVE FEEDBACK

OK

One of the assumptions for the analysis of a pin-jointed planar frame is:
The weight of each member is ignored.
Which of the following situations is this most suited to?

Check all that apply.

- [ ] A small frame structure
- [ ] Large bridges and building structures
- [ ] A moving structure in high-speed machinery
- [ ] A heavily loaded frame

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

When dealing with frames, the assumptions we make are:

The weight of each member is (please select) ▼.

If there is an insufficient number of joints and supports for static equilibrium, the frame is unstable and could collapse, which is known as a (please select) ▼.

The opposite problem is when the frame has excessive bracing , which is known as a (please select) ▼.

Submit

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Each member of a frame is treated as a non-concurrent body, held together by frictionless pin joints.

The assumptions for calculation of static equilibrium of each member

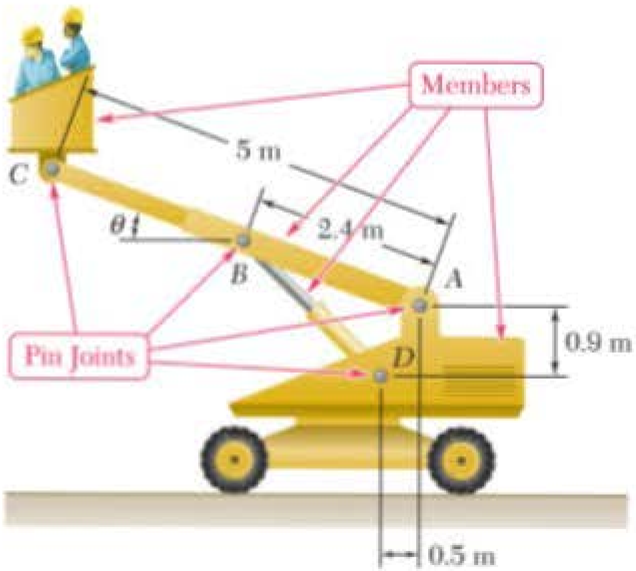
For a non-concurrent body, there are three equations of equilibrium.

$$\circlearrowright + \Sigma M_L = 0$$
$$+\uparrow \Sigma F_Y = 0$$
$$\overset{+}{\rightarrow} \Sigma F_X = 0$$

Every pin joint is assumed to have zero friction, which means it can transmit forces but not moments. This allows the assumption that the forces on each member do not produce a moment, and that a moment cannot be transmitted through any joint.

GIVE FEEDBACK

OK



For our study of frames, every pin joint between members is assumed to have zero friction. This means each joint is able to transmit [Select...] from one frame member to the other.

What each pin joint cannot transmit is [Select...].

Submit

Match the meaning of these three equations of equilibrium.

$$\circlearrowright^{+} \Sigma M_L = 0$$
$$+\uparrow \Sigma F_Y = 0$$
$$\xrightarrow{+} \Sigma F_X = 0$$

Drag statements on the right to match the left.

Taking clockwise as positive, the sum of all moments around point L is zero	$\xrightarrow{+} \Sigma F_X = 0$
Taking upwards as positive, the sum of all forces in the y direction is zero	$+\uparrow \Sigma F_Y = 0$
Taking positive as to the right, the sum of all forces in the x direction is zero	$\circlearrowright^{+} \Sigma M_L = 0$

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

For a non-concurrent body, there are three equations of equilibrium.

$$\circlearrowleft^{+} \Sigma M_{L=O}$$
$$+\uparrow \Sigma F_{Y=O}$$
$$\xrightarrow{+} \Sigma F_{X=O}$$

Why do we need the first one if a pin joint cannot transmit a moment?

Click the correct answer.

- This is used to find reaction forces for the whole frame
- It is always zero
- Some a pin joints can transmit a moment through them
- It is not used in frame analysis; it is just included for completeness

Do you know the answer?

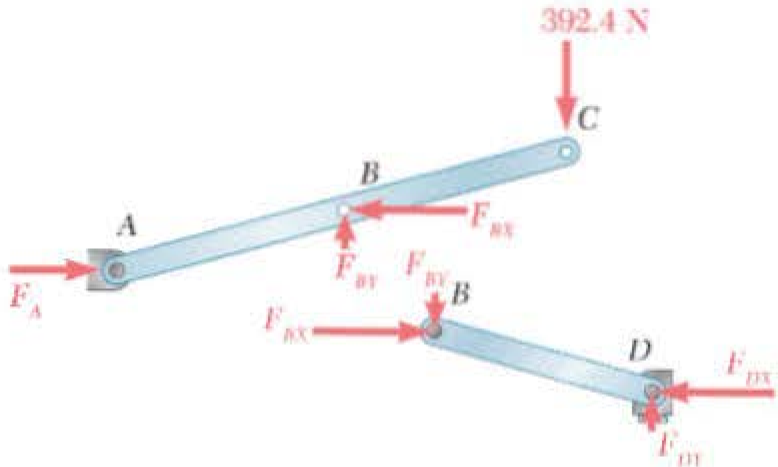
I KNOW IT | THINK SO | UNSURE | NO IDEA

The forces between members of a frame are called pin reactions.

Pin-reaction forces

In a stationary pin-jointed frame that is designed to support a load, forces produced by the load are transmitted through members to the pins at the joints, and then by the pins to other connected members.

These forces at the joints are referred to as **pin reactions**.



GIVE FEEDBACK

OK

The forces applied between connected members of a frame are called ____.

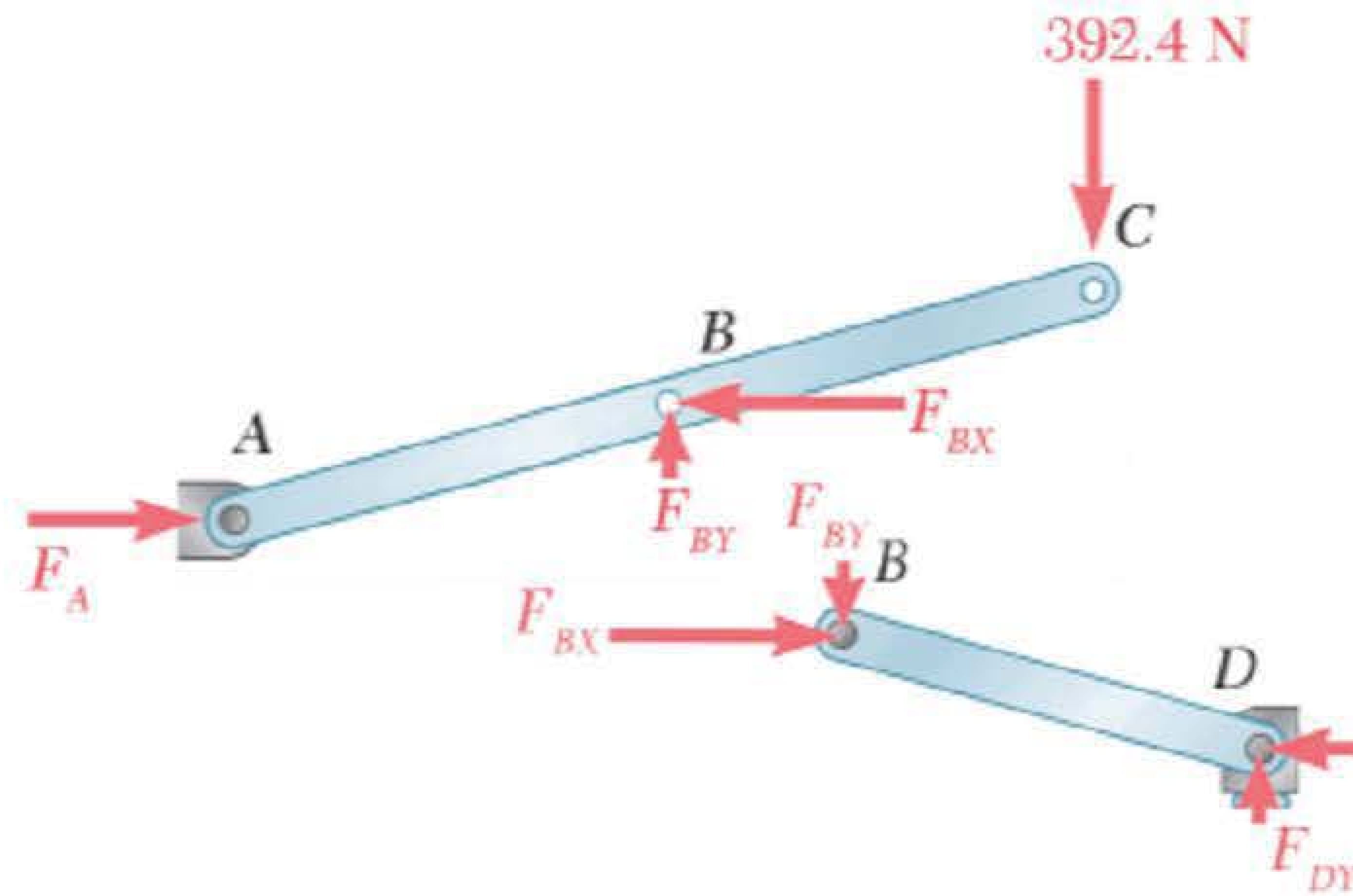
Click the correct answer.

- pin reactions
- support reactions
- roller joints
- pin joints

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Match the **pin reactions** to their forces.



Drag statements on the right to match the left.

Horizontal component of the force of member BD onto member ABC	F_{BY} @ 270°
Vertical component of the force of member ABC onto member BD	F_{BY} @ 90°
Vertical component of the force of member BD onto member ABC	F_{BX} @ 0°
Horizontal component of the force of member ABC onto member BD	F_{BX} @ 180°

Why are pin joints used in a frame?

Click the correct answer.

- To transmit forces but not moments
- To transmit moments but not forces
- To transmit forces and moments
- To transmit no forces or moments

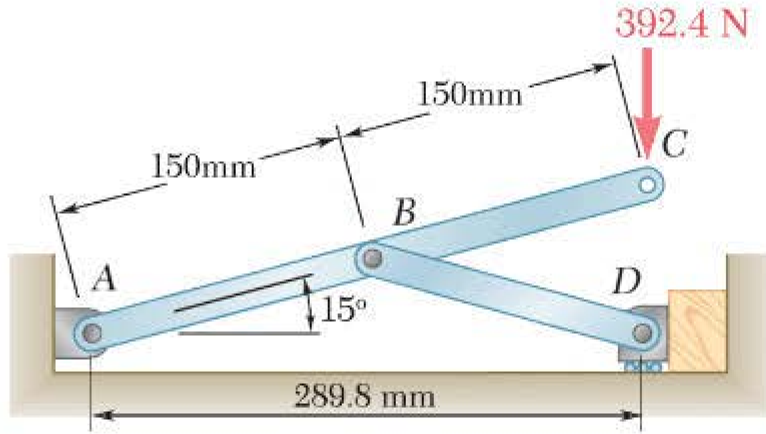
Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Overview of solving equilibrium for different parts of a simple frame

A frame is shown in blue.

There are a number of ways to analyse this frame using the FBD (free body diagram) technique.



The problem	FBD of whole frame	FBD of link BD	FBD for body ABC

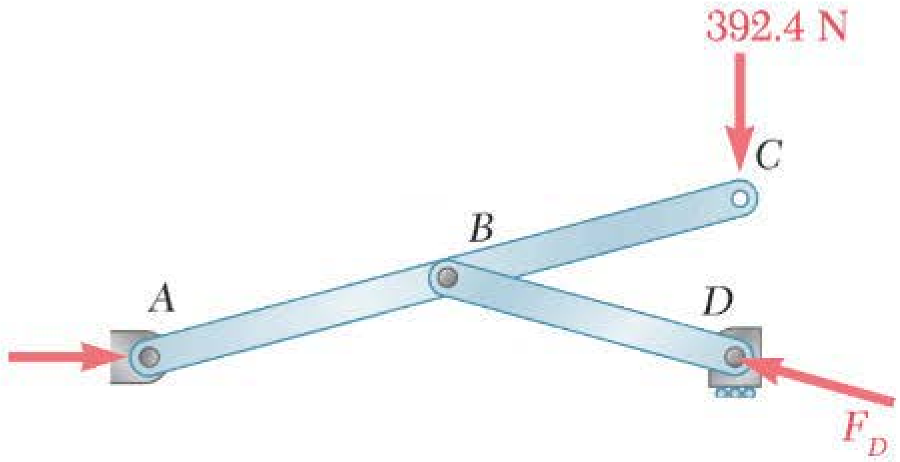
GIVE FEEDBACK

OK

Overview of solving equilibrium for different parts of a simple frame

This is the FBD of the whole frame.

We can use this to solve the reaction forces at supports A and D.



The problem	FBD of whole frame	FBD of link BD	FBD for body ABC

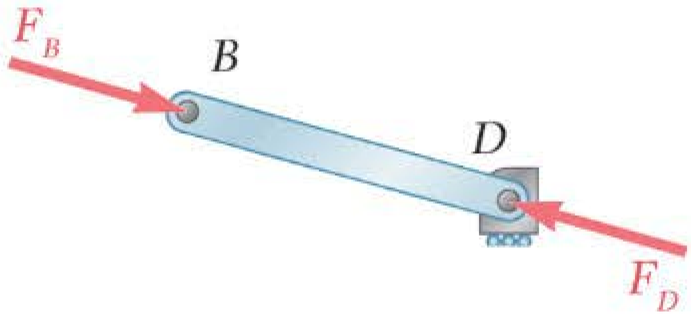
GIVE FEEDBACK

OK

Overview of solving equilibrium for different parts of a simple frame

This is a FBD of link BD.

This is in equilibrium, which means $F_B = F_D$



The problem	FBD of whole frame	FBD of link BD	FBD for body ABC

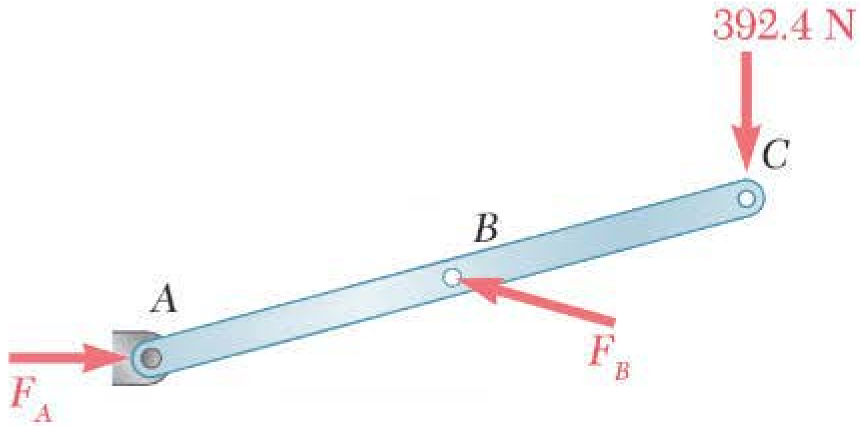
GIVE FEEDBACK

OK

Overview of solving equilibrium for different parts of a simple frame

There are three forces on body ABC, and they are in equilibrium:

$$\circlearrowleft + \Sigma M_L = 0$$
$$+\uparrow \Sigma F_Y = 0$$
$$\xrightarrow{+} \Sigma F_X = 0$$



The problem

FBD of whole frame

FBD of link BD

FBD for body ABC

GIVE FEEDBACK

OK

In solving a pin-jointed frame, sort the following steps into order.

↑↓ Place these in the proper order.

- Free body diagram of whole frame
- Find 2-force members
- Solve equilibrium for the first frame member
- Keep solving equilibrium for adjacent frame member
- Check equilibrium at selected joints

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Label the members and joints in this free body diagram.

Joint A

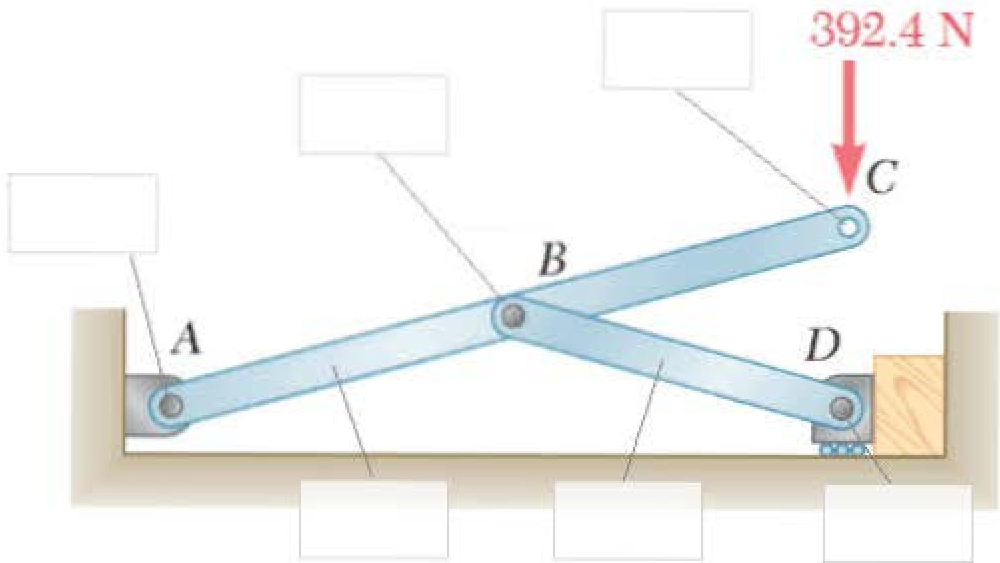
Joint B

Joint C

Joint D

Member ABC

Member BD



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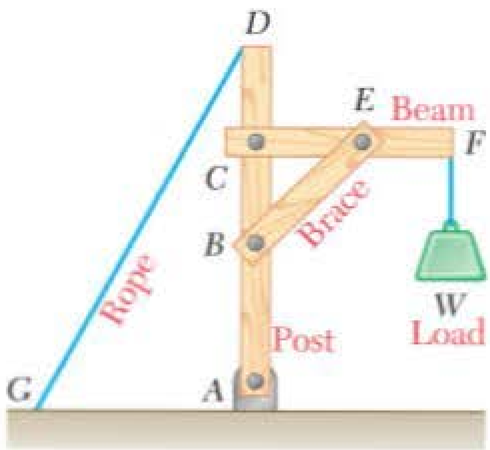
Which members are in equilibrium?



Check all that apply.

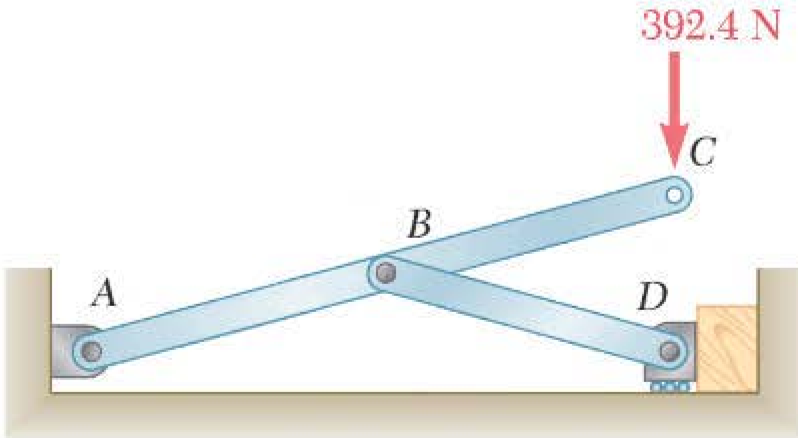
- [ ] The beam (member CEF)
- [ ] The brace (member BE)
- [ ] The post (member ABCD)
- [ ] The rope (member GD)
- [ ] None of the members are in equilibrium because a rope is used

Use equilibrium to solve a simple frame

A frame is shown in blue.

The frame will be solved using the equations of static equilibrium.

$$\circlearrowleft+ \Sigma M_A = 0$$
$$+\uparrow \Sigma F_Y = 0$$
$$\xrightarrow{+} \Sigma F_X = 0$$



The problem	Geometry	FBD of whole frame	Use X, Y components to solve	FBD for member BD	Components for member BD	FBD for member ABC	FBD for body ABC

GIVE FEEDBACK

OK

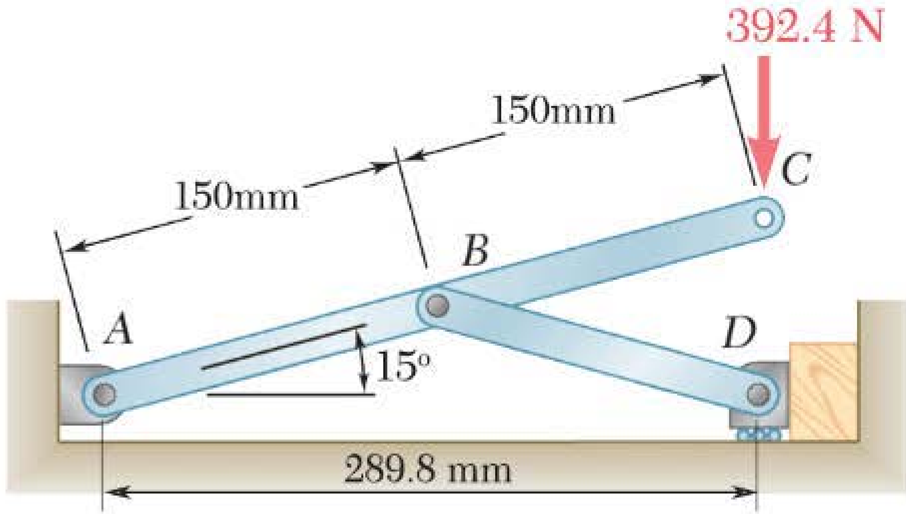
Use equilibrium to solve a simple frame

Use geometry to determine necessary dimensions.

$AB_X = 150 \cdot \cos 15 = 144.9 \text{ mm}$

$AB_Y = 150 \cdot \sin 15 = 38.82 \text{ mm}$

$AD_X = 2 \cdot AB_X = 289.8 \text{ mm}$



The problem	Geometry	FBD of whole frame	Use X, Y components to solve	FBD for member BD	Components for member BD	FBD for member ABC	FBD for body ABC

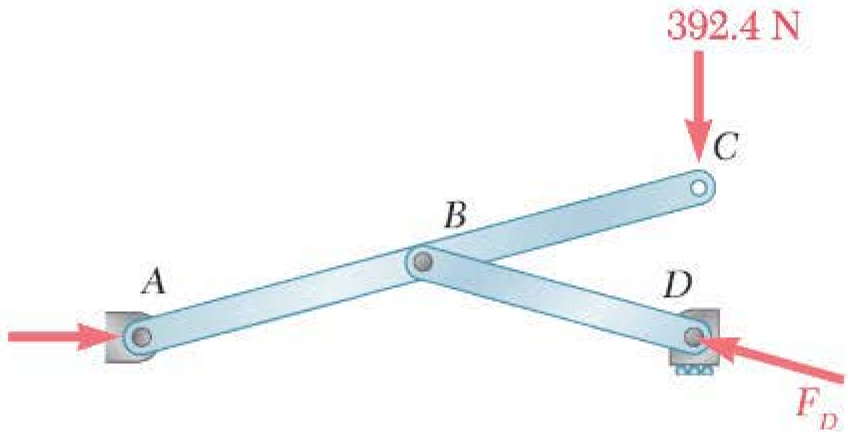
GIVE FEEDBACK

OK

Use equilibrium to solve a simple frame

This is the FBD of the whole frame. We are treating member ABC and member BD as a single entity (free body).

We can use this to solve the reactions forces at supports A and D.



The problem	Geometry	FBD of whole frame	Use X, Y components to solve	FBD for member BD	Components for member BD	FBD for member ABC	FBD for body ABC

GIVE FEEDBACK

OK

Use equilibrium to solve a simple frame

Use X and Y components for the FBD of the frame.

Solving equilibrium of moments at A;

$$\circlearrowleft \Sigma M_A = O$$

$$\uparrow \Sigma F_Y = O$$

$$\Sigma M = (392.4 \cdot 289.8) - (F_{DY} \cdot 289.8)$$

$$\rightarrow \Sigma F_X = O$$

$$\therefore F_{DY} = 392.4 \text{ N}$$

Solving horizontal equilibrium;

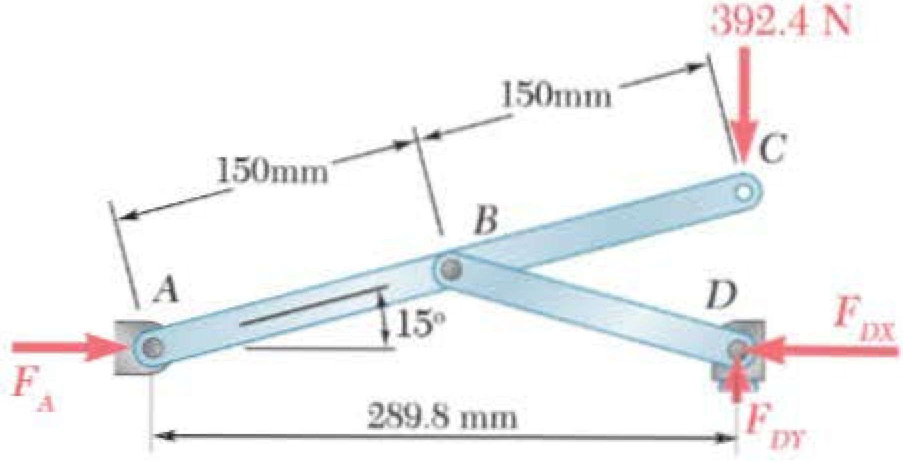
$$\circlearrowleft \Sigma M_A = O$$

$$\uparrow \Sigma F_Y = O$$

$$\Sigma F = F_{DX}$$

$$\rightarrow \Sigma F_X = O$$

We don't know F_{DX} yet, but there is a simple way to work it out...



The problem	Geometry	FBD of whole frame	Use X, Y components to solve	FBD for member BD	Components for member BD	FBD for member ABC	FBD for body ABC

GIVE FEEDBACK

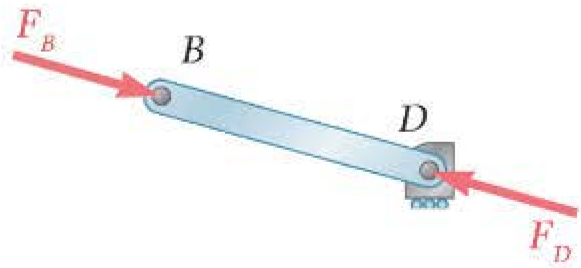
OK

Use equilibrium to solve a simple frame

Member BD is a 2-force body. The only way to keep this in equilibrium is by ensuring the two forces are equal and opposite.

This means force F_D must be in line with the link, which is at 15 degrees.

Using the 360° format, the angle of F_D is 165° and the angle of F_B is 345°



The problem	Geometry	FBD of whole frame	Use X, Y components to solve	FBD for member BD	Components for member BD	FBD for member ABC	FBD for body ABC

GIVE FEEDBACK

OK

Use equilibrium to solve a simple frame

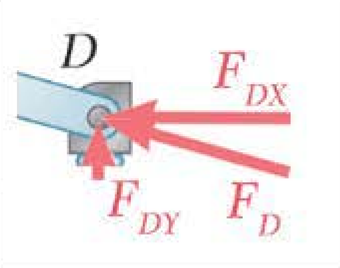
Resolving these forces into X and Y components:

From trigonometry:

$$F_{DX} = \frac{F_{DY}}{\tan 15}$$

but $F_{DY} = 392.4\ \text{N}$, so;

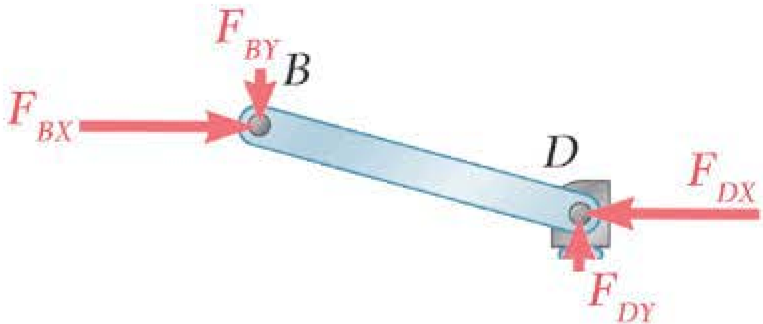
$$F_{DX} = \frac{392.4}{\tan 15} = 1{,}464\ \text{N}$$



By equilibrium of the 2-force member BD;

$F_{BX} = F_{DX} = 1{,}464\ \text{N}$

$F_{BY} = F_{DY} = 392.4\ \text{N}$



The problem	Geometry	FBD of whole frame	Use X, Y components to solve	FBD for member BD	Components for member BD	FBD for member ABC	FBD for body ABC

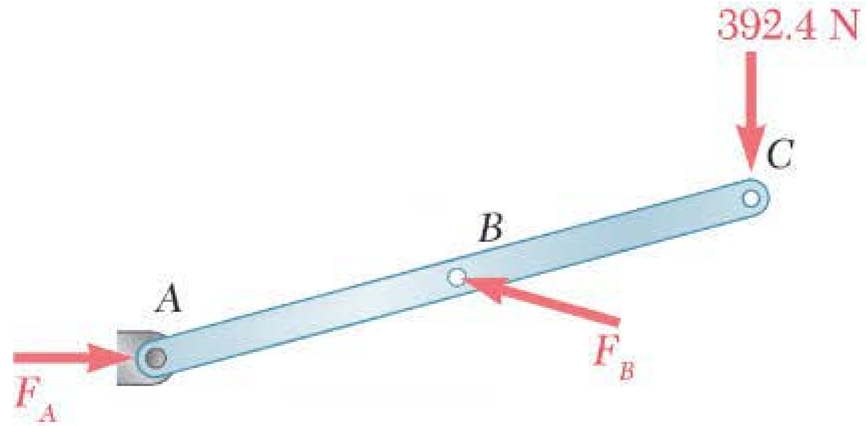
GIVE FEEDBACK

OK

Use equilibrium to solve a simple frame

There are three forces on body ABC, and they are in equilibrium:

$$\circlearrowleft^{+} \Sigma M_{L} = 0$$
$$+\uparrow \Sigma F_{Y} = 0$$
$$\overset{+}{\rightarrow} \Sigma F_{X} = 0$$



The problem	Geometry	FBD of whole frame	Use X, Y components to solve	FBD for member BD	Components for member BD	FBD for member ABC	FBD for body ABC

GIVE FEEDBACK

OK

Use equilibrium to solve a simple frame

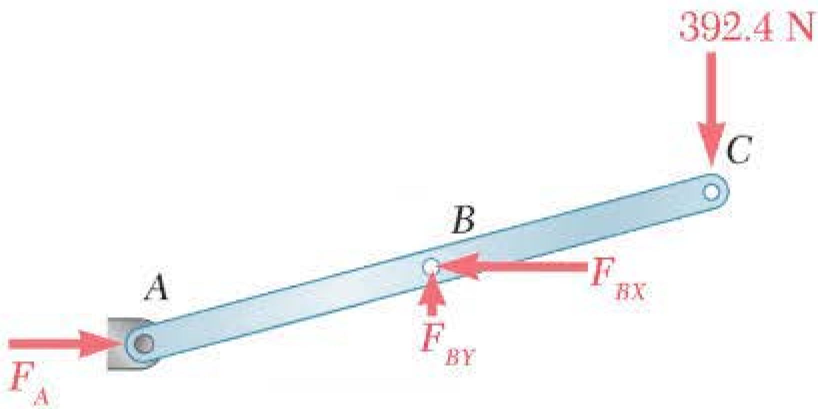
When we solved BD we showed the forces applied at B by link ABC. This time we have the exact opposite, forces applied by BD *to* ABC.

$F_{BX} = 1{,}464 \text{ N}$
$F_{BY} = 392.4 \text{ N}$

By equilibrium in X direction:

$\Sigma F_X = F_A - F_{BX} = F_A - 1{,}464 = 0$
$\therefore F_A = 1{,}464 \text{ N}$

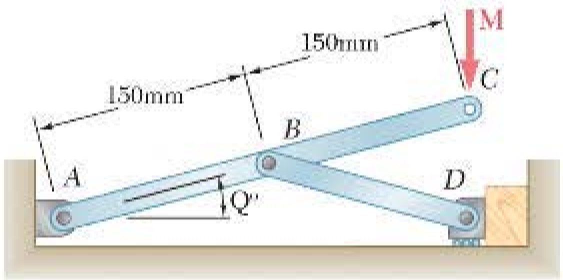
We have now solved all forces in this frame.



The problem	Geometry	FBD of whole frame	Use X, Y components to solve	FBD for member BD	Components for member BD	FBD for member ABC	FBD for body ABC

GIVE FEEDBACK

OK



Load M = 70 kg and angle Q = 20 degrees. Calculate the horizontal support reaction at point D. ("+" = to the right, "-" = to the left)

(Minimum 0 decimal places. Include units)

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE

SUBMIT

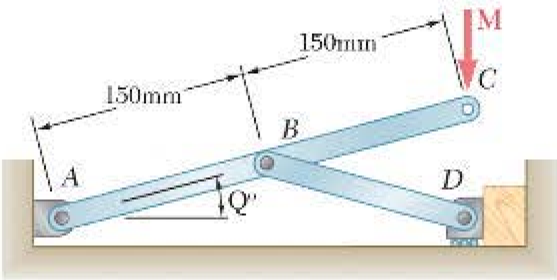
SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question



Load M = 70 kg and angle Q = 20 degrees. Calculate the vertical support reaction at point D. ("+" = upwards, "-"= downwards)

(Minimum 1 decimal place. Type symbol for Newtons)

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

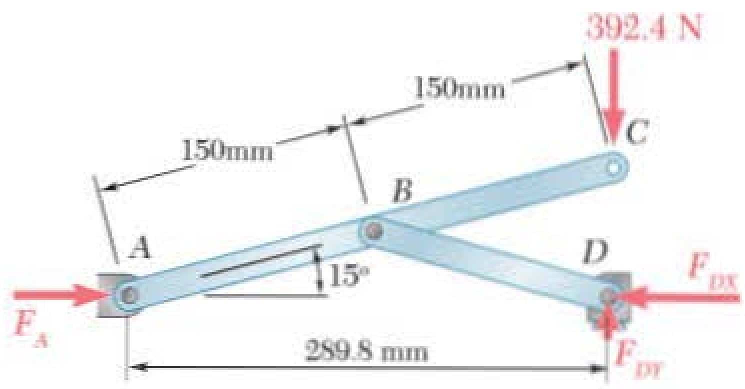
- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

During the solution of this frame problem, a FBD is constructed as shown.

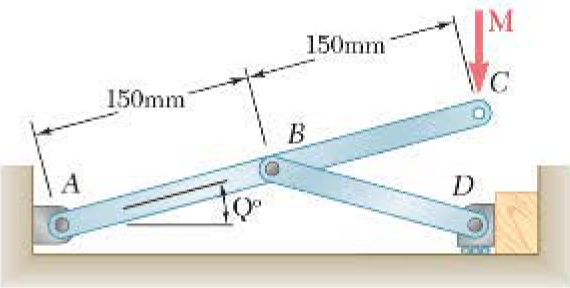
The purpose of this FBD is ______________.



Click the correct answer.

- to find reaction forces at A and D
- to find pin reactions at joint B
- to find the angle between member ABC and member BD
- to work out the length of member BD

Do you know the answer?



Load M = 70 kg and angle Q = 20 degrees. Calculate the **magnitude** of the total reaction force at point D.

(Minimum 0 decimal places. Type symbol for Newtons)

Clear
Clear line
?
Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

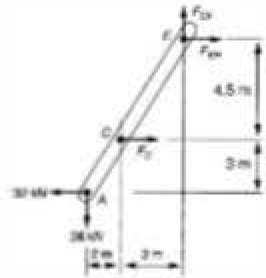
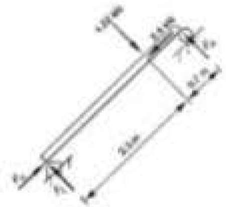
- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

Solving a frame by components is best done by setting all components to the X and Y axes.

Two ways to set up a coordinate systems on each member

Two ways to set up a coordinate system on a frame member.	
Global coordinate system. (X/Y) Set up coordinates parallel to the X axis and Y axis. In this case, all components in the X direction will be horizontal regardless of the inclination of the member. *We will use this method most often.*	
Local coordinate system. (Axial/Transverse) Set up coordinates parallel to the axis of the member. In this case, there is an axial coordinate axis and a transverse coordinate axis. *This can be quicker for a simple frame.*	

GIVE FEEDBACK

OK

Match the following coordinate systems used for frame analysis.

Drag statements on the right to match the left.

Every force throughout the frame has X and Y components	Global
Each member has axial and transverse components	Local

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

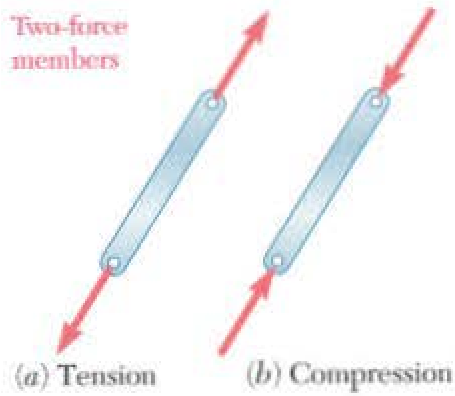
Two force members are special. They can only be in pure tension or compression. This assumes they have negligible weight - which would be a third force.

Properties of a two-force member within a frame

Every member in a frame must have two or more forces applied.

Members with exactly two forces have special properties:

- They can only be in tension or compression.
- The two forces have exactly opposite directions.
- The two forces are in line with each other.
- The is no bending occuring in the member.



GIVE FEEDBACK

OK

Which of the following are true for a strong, lightweight member with only two pin joints?

Check all that apply.

- [ ] It can only undergo tension or compression
- [ ] It cannot be in equilibrium
- [ ] It must have all forces in the same line of action
- [ ] It must have forces in opposite directions
- [ ] It is the only type of member in a pin-jointed frame
- [ ] It must have two forces

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

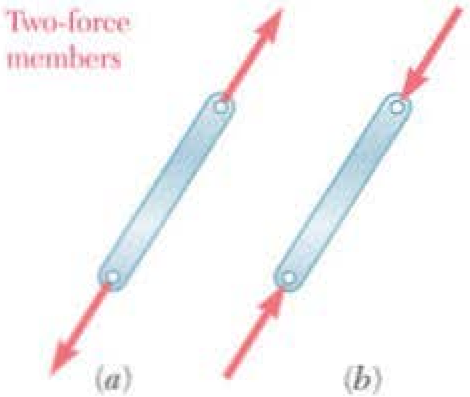
The direction of forces can be determined from the geometry of which types of joints and members?

Check all that apply.

- [ ] Two-force member
- [ ] Three-force member
- [ ] Roller joint
- [ ] Pin Joint

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA



Which two-force member is in tension, and which is in compression?

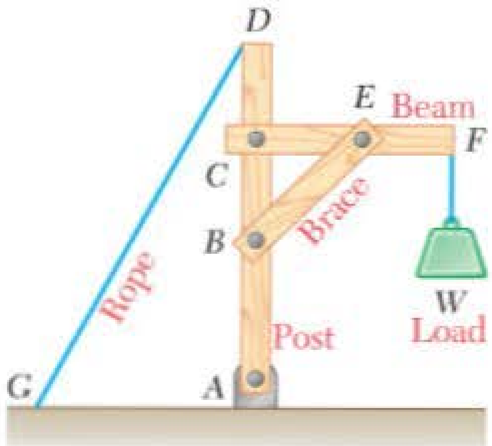
Drag statements on the right to match the left.

This member is in tension	Fig (a)
This member is in compression	Fig (b)

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Which type of frame member is a lightweight cable?



Click the correct answer.

- Two-force member
- Three-force member
- It cannot be a frame member
- It depends on the angle

Do you know the answer?

Here is a procedure for solving any frame. The procedure is called the method of members.

The mathematical method used for determining pin reactions in a frame

The mathematical method for determining pin reactions in a frame is sometimes called the method of members, since it consists of examining the conditions of static equilibrium of each member individually.

1. Analyse the whole frame as one body to find support reactions in X and Y components.
2. Identify two-force members in the frame, with both forces in line and opposed.
3. Draw a FBD for each frame member.
4. Select a solvable member, with maximum of three unknowns plus at least one known force.
5. Solve an adjacent member
6. Repeat steps 4 and 5 until all members have been determined.
7. Check equilibrium of pin-reaction forces at selected joints.

GIVE FEEDBACK

OK

Procedure for solving a frame

Step 1: Analyse the whole frame as one body to find support reactions in X and Y components.

Step 2: Identify two-force members in the frame, with both forces in line and opposed.

Step 3: Draw a FBD for each frame member.

Step 4: Select a solvable member, with maximum of three unknowns plus at least one known force.

Step 5: Solve an adjacent member

Step 6: Repeat steps 4 and 5 until all members have been determined.

Step 7: Check equilibrium of pin-reaction forces at selected joints.

Match the summary of this procedure:

Drag statements on the right to match the left.

Step 1	Solve the frame supports
Steps 2 and 3	Rough the FBD for every member
Steps 4, 5 and 6	Solve each member
Step 7	Check results

Do you know the answer?

Procedure for solving forces in every member of a pin-jointed frame:
Sort the steps into order.

↑↓ Place these in the proper order.

- Analyse the whole frame as one body to find support reactions in X and Y components
- Identify two-force members in the frame, with both forces in line and opposed
- Draw a FBD for each frame member
- Select a solvable member, with maximum of three unknowns plus at least one known force
- Solve adjacent members until all members have been determined
- Check equilibrium of pin-reaction forces at selected joints

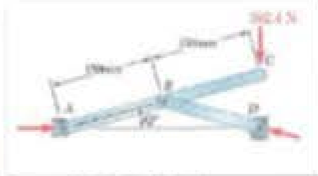
Do you know the answer?

Here is a step-by-step illustration of solving a frame problem. There are 9 steps here because 2 extra steps are needed at the beginning - for setting up the Free Body Diagram.

Summarise solution procedure for solving a frame

Solving a simple frame with two members uses the same technique as solving a frame with many members.

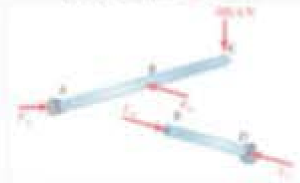
Define Frame



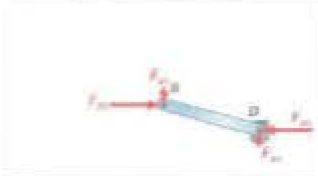
FBD whole frame

FBD frame X&Y

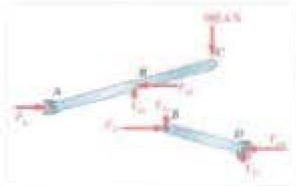
Look for 2 force members



Rough FBD all

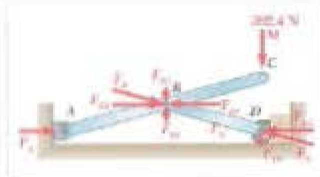


Solve first member



Transfer to next member

Solve next member



Check joint equilibrium

GIVE FEEDBACK

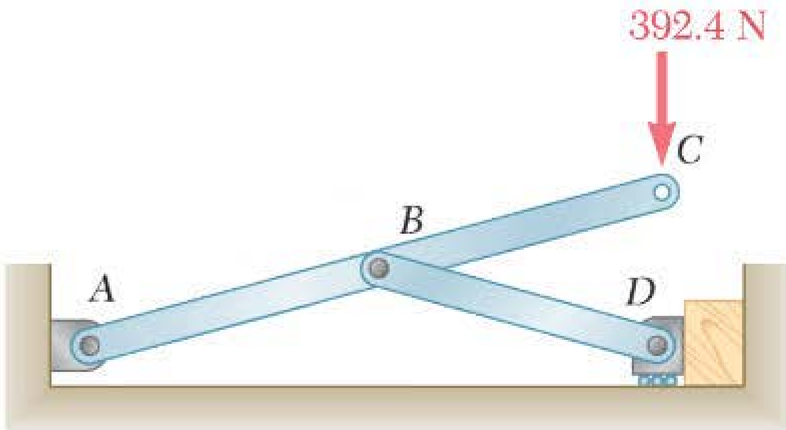
OK

The procedure for solving any frame

This is a series of seven steps that can be used to solve **any** frame problem.

Using this procedure according to the order given will solve every force throughout the whole frame structure.

Of course, the first thing is to identify the frame–blue in this case.



Solving frames	Step 1: FBD of whole frame	Step 2: Find two-force members	Step 3: Member FBDs	Step 4: Solve appropriate member	Step 5: Go to next member	Step 6: Repeat steps 4 and 5	Step 7: Check equilibrium

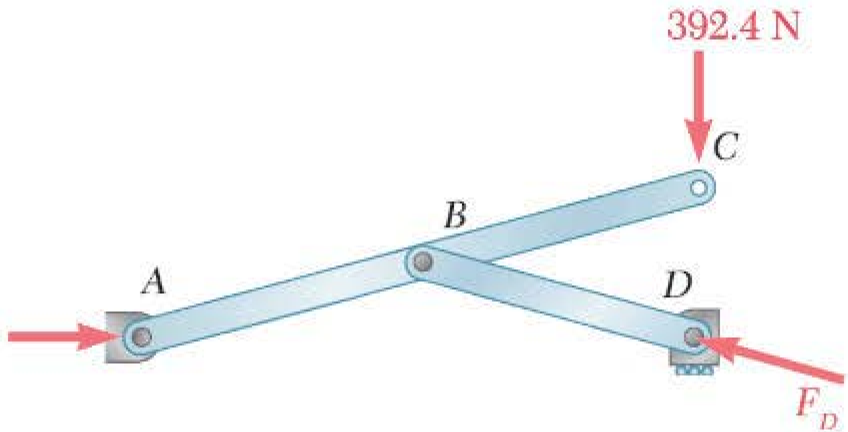
GIVE FEEDBACK

OK

The procedure for solving any frame

This is the FBD of the whole frame. We are treating member ABC and member BD as a single entity (free body).

We can use this to solve the reaction forces at supports A and D.



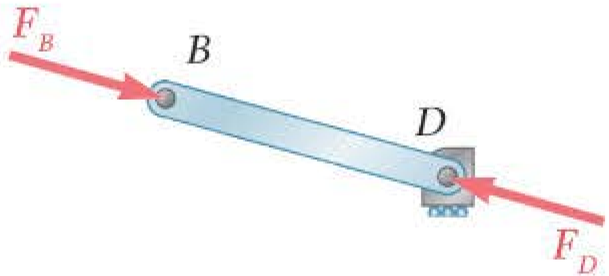
Solving frames	Step 1: FBD of whole frame	Step 2: Find two-force members	Step 3: Member FBDs	Step 4: Solve appropriate member	Step 5: Go to next member	Step 6: Repeat steps 4 and 5	Step 7: Check equilibrium

GIVE FEEDBACK

OK

The procedure for solving any frame

Identify any two-force members in the frame. It is important to recognise these as having two equal and opposite forces applied through the pins and acting along the axis of such members. This helps to recognise the lines of action of forces acting on other connected members.



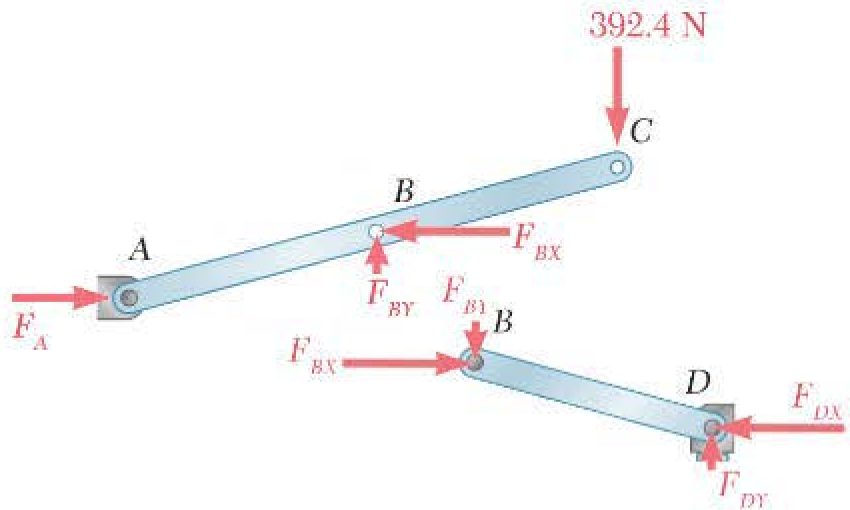
Solving frames	Step 1: FBD of whole frame	Step 2: Find two-force members	Step 3: Member FBDs	Step 4: Solve appropriate member	Step 5: Go to next member	Step 6: Repeat steps 4 and 5	Step 7: Check equilibrium

GIVE FEEDBACK

OK

The procedure for solving any frame

Isolate each separate member of the frame and draw it as a free body, showing all known and unknown forces acting on the member. As usual, the sense of an unknown force may be assumed, and then revised in the light of subsequent calculations.



Solving frames	Step 1: FBD of whole frame	Step 2: Find two-force members	Step 3: Member FBDs	Step 4: Solve appropriate member	Step 5: Go to next member	Step 6: Repeat steps 4 and 5	Step 7: Check equilibrium

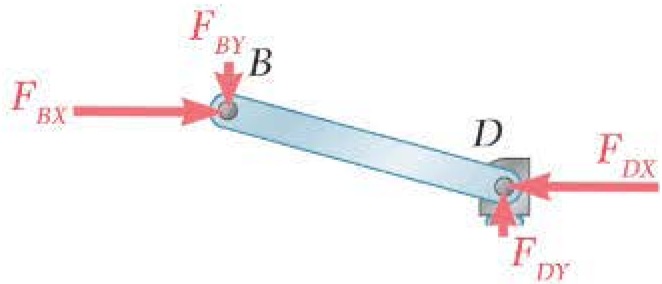
GIVE FEEDBACK

OK

The procedure for solving any frame

Select a member, with at least one known force, which contains no more than three unknowns. Use the three equations of statics to calculate the unknown pin-reaction forces acting on the member.

3 unknowns: Moment equation
2 unknowns: $(\Sigma F_X, \Sigma F_Y)$ or force polygon



Solving frames	Step 1: FBD of whole frame	Step 2: Find two-force members	Step 3: Member FBDs	Step 4: Solve appropriate member	Step 5: Go to next member	Step 6: Repeat steps 4 and 5	Step 7: Check equilibrium

GIVE FEEDBACK

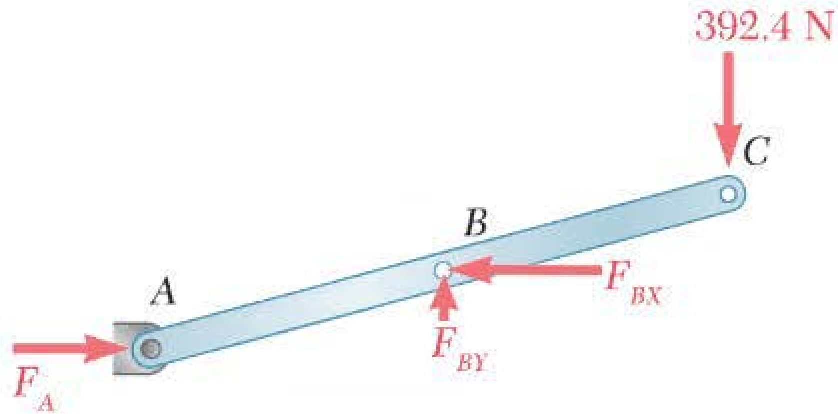
OK

The procedure for solving any frame

With the knowledge gained from the previous step, select another member and solve for more unknowns.

Remember that a reaction force acting on any given member at a joint IS the pulling or pushing action from another member transmitted through the joint.

Between any two members connected through a pin: action and reaction forces are always equal and opposite.



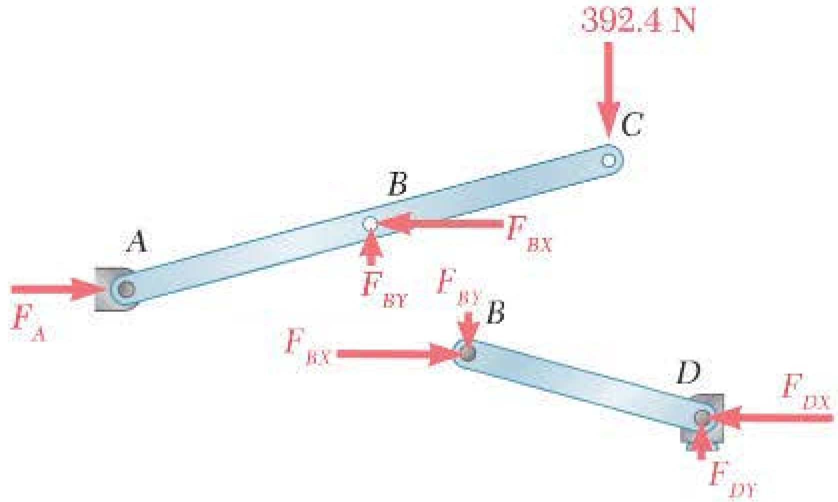
Solving frames	Step 1: FBD of whole frame	Step 2: Find two-force members	Step 3: Member FBDs	Step 4: Solve appropriate member	Step 5: Go to next member	Step 6: Repeat steps 4 and 5	Step 7: Check equilibrium

GIVE FEEDBACK

OK

The procedure for solving any frame

Repeat steps 4 and 5 until all components of pin-reaction forces have been determined.



Solving frames	Step 1: FBD of whole frame	Step 2: Find two-force members	Step 3: Member FBDs	Step 4: Solve appropriate member	Step 5: Go to next member	Step 6: Repeat steps 4 and 5	Step 7: Check equilibrium

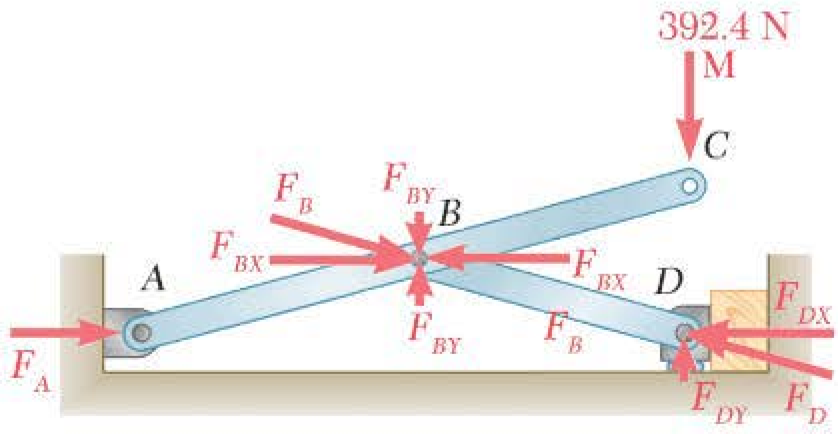
GIVE FEEDBACK

OK

The procedure for solving any frame

As a final step: if desired, combine horizontal and vertical components of pin-reaction forces at each (or any) joint into their resultant in order to determine the total magnitude of the reaction force at the joint.

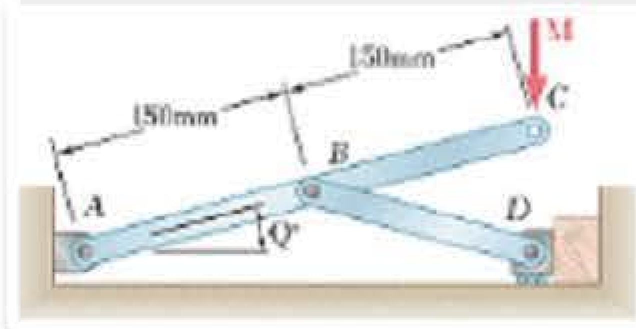
At every joint, the forces should add up to zero, of course.



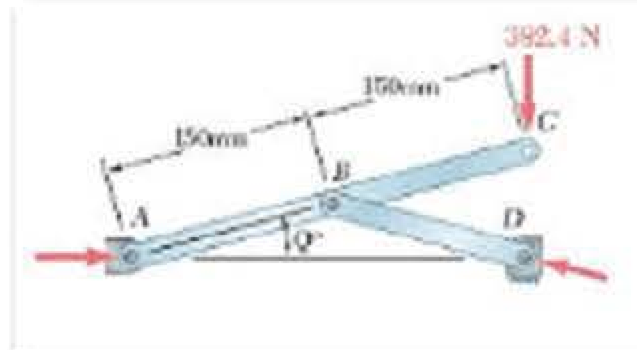
Solving frames	Step 1: FBD of whole frame	Step 2: Find two-force members	Step 3: Member FBDs	Step 4: Solve appropriate member	Step 5: Go to next member	Step 6: Repeat steps 4 and 5	Step 7: Check equilibrium

GIVE FEEDBACK

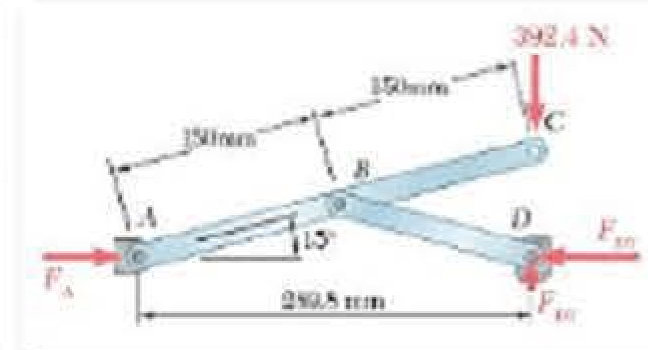
OK



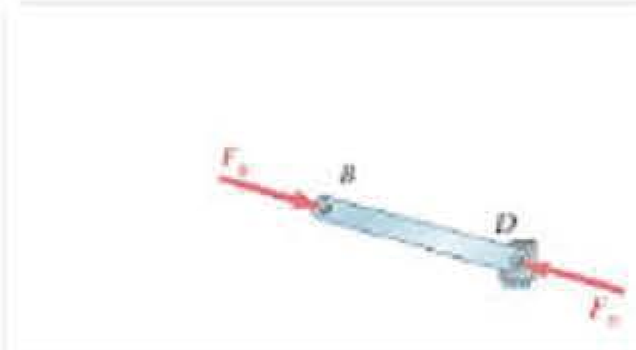
Define Frame



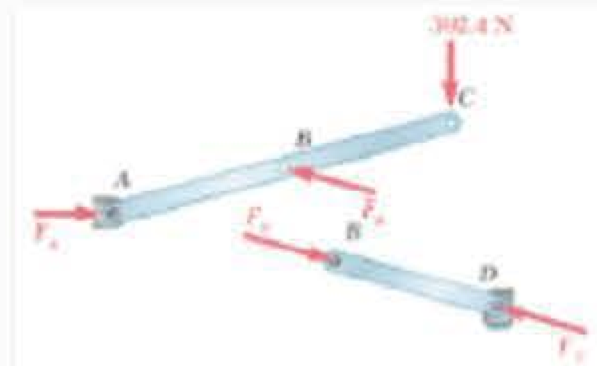
FBD whole frame



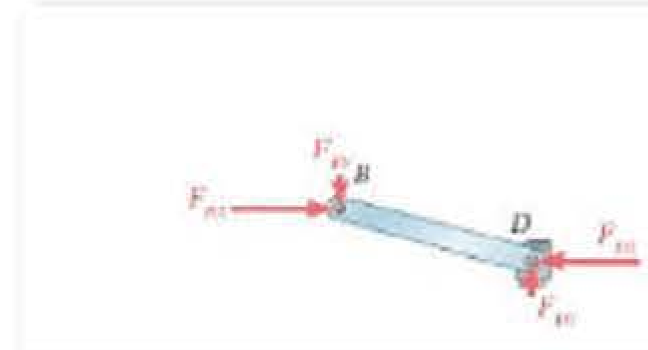
FBD frame X&Y



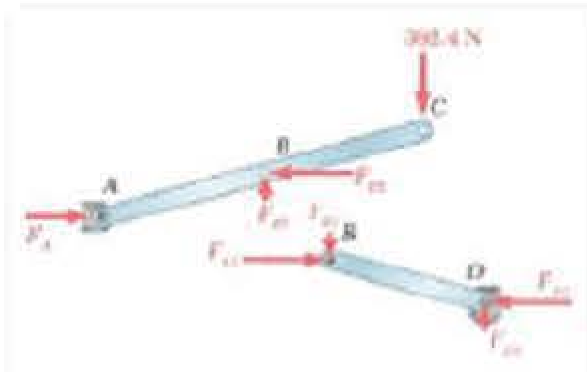
Look for 2 force members



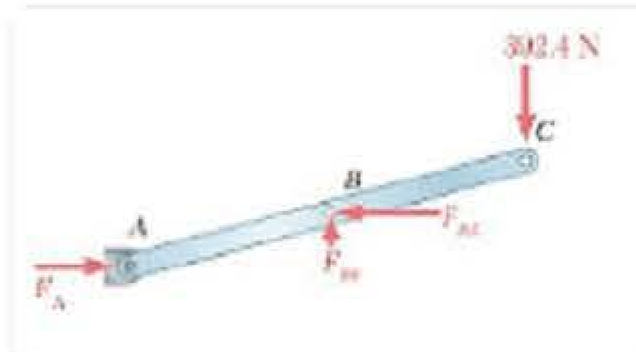
Rough FBD all



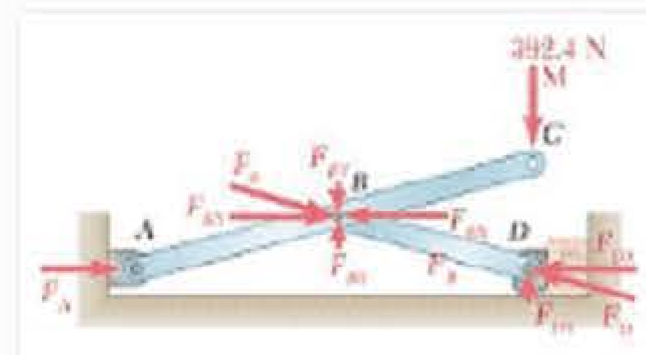
Solve first member



Transfer to next member



Solve next member



Check joint equilibrium

Select the correct statements about some of these steps.

Check all that apply.

- [ ] The rules for '**Solve first member**' are exactly the same as the rules for '**Solve next member**'
- [ ] '**Look for 2-force members**' provides the direction of those forces in the '**Rough FBD all**'
- [ ] '**Solve first member**' is always a two-force member
- [ ] '**Check joint equilibrium**' can be done at any time after a joint is solved

Procedure for solving the ***first member*** in a simple frame.
Sort the steps into order.

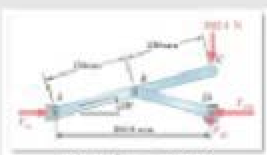
Place these in the proper order.


FBD whole frame


Rough FBD all


Solve first member


Define Frame

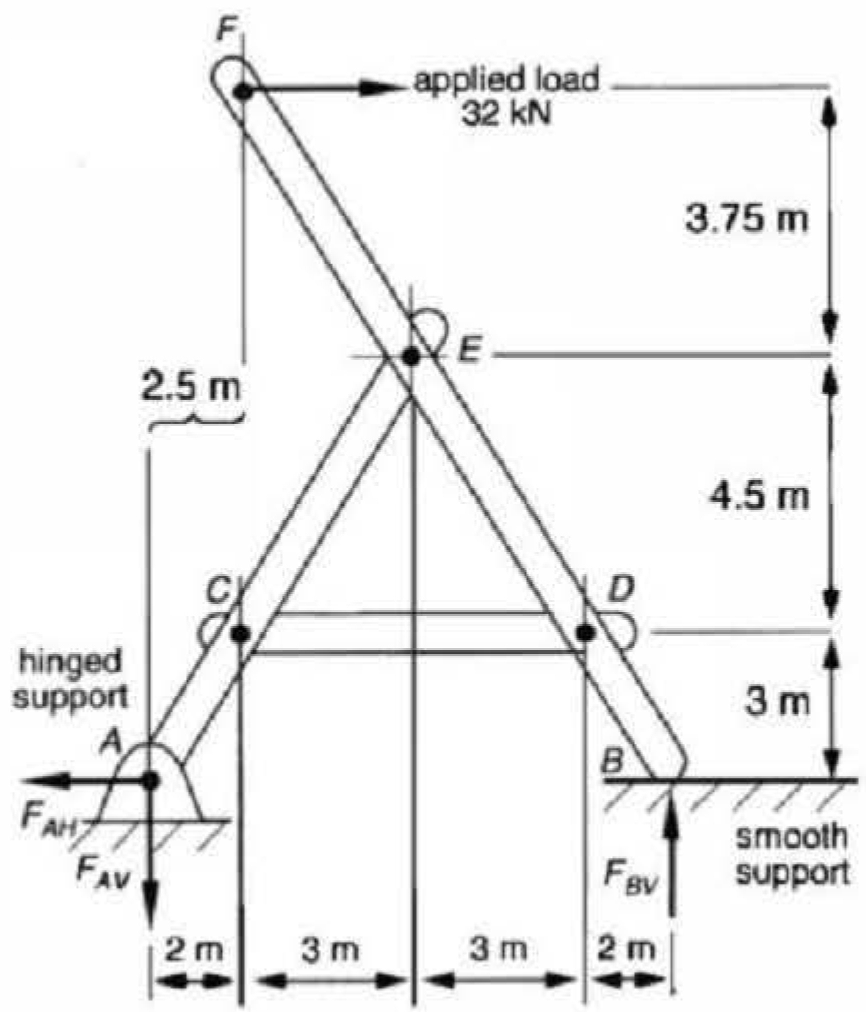

FBD frame X&Y


Look for 2 force members

Step 1 of the procedure for solving any frame: Find the support reactions.

Determine the support reactions for a whole frame.

There is a pin support with reactions F_{AH} and F_{AV}, and a roller support F_{BV}.



Taking moments about the hinged support A:

$$\Sigma M = 32\,\text{kN} \times 11.25\,\text{m} - F_{BV} \times 10\,\text{m}$$

$$\therefore F_{BV} = 36\,\text{kN}$$

Hence reaction at B is 36 kN upwards.

Summation of forces:

$$\Sigma F_H = 32\,\text{kN} - F_{AH}$$

$$\therefore F_{AH} = 32\,\text{kN}\ \text{to the left}$$

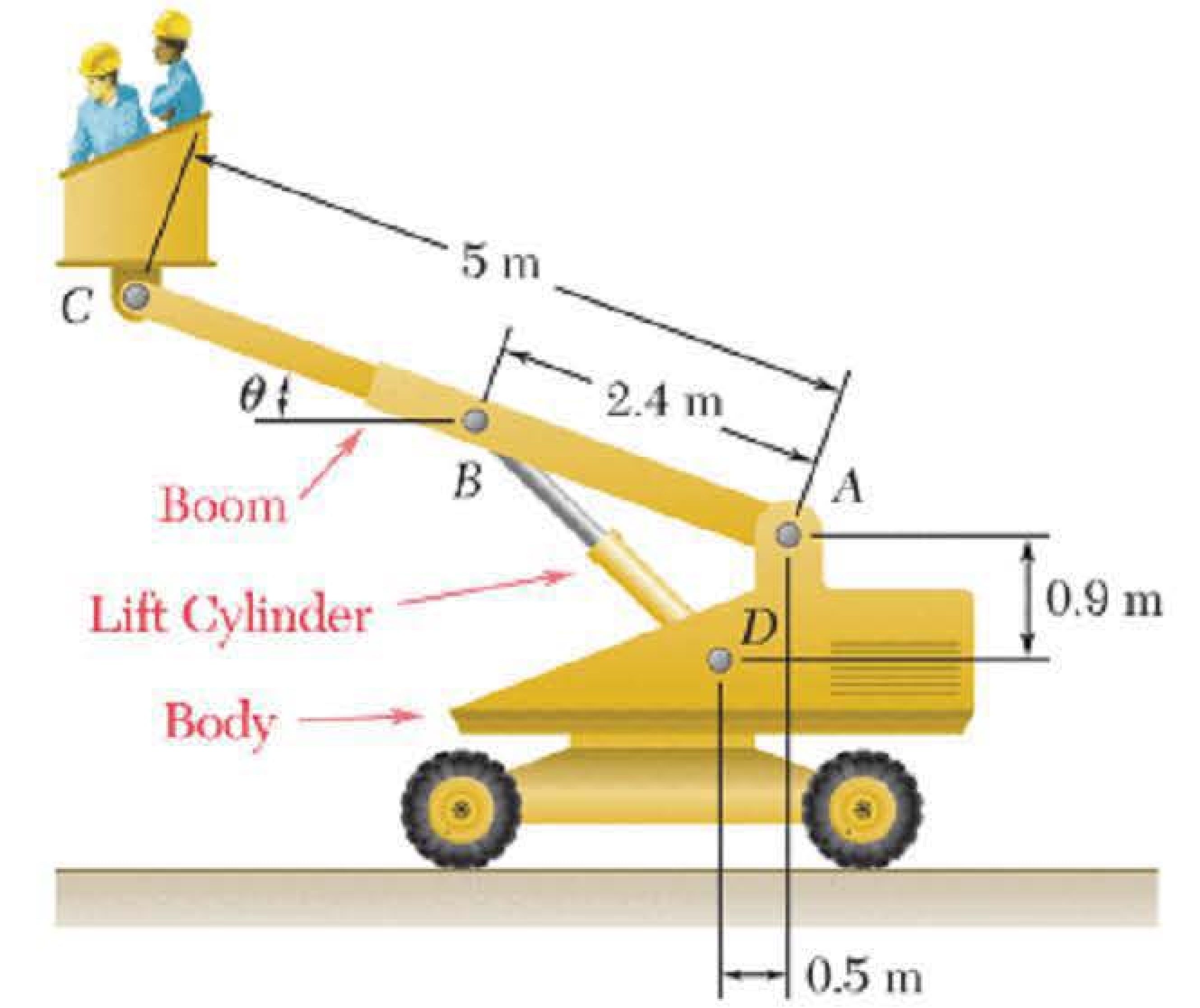
$$\Sigma F_V = F_{BV} - F_{AV}$$

$$= 32\,\text{kN} - F_{AV}$$

$$\therefore F_{AV} = 36\,\text{kN}\ \text{downwards}$$

In the process of solving a FBD for the **Boom**, match the appropriate pins for each of the four steps below.

***Note:** Here we must assume the platform stays vertical somehow. In reality, this is accomplished by another link or cable that maintains the vertical orientation of the bucket)*



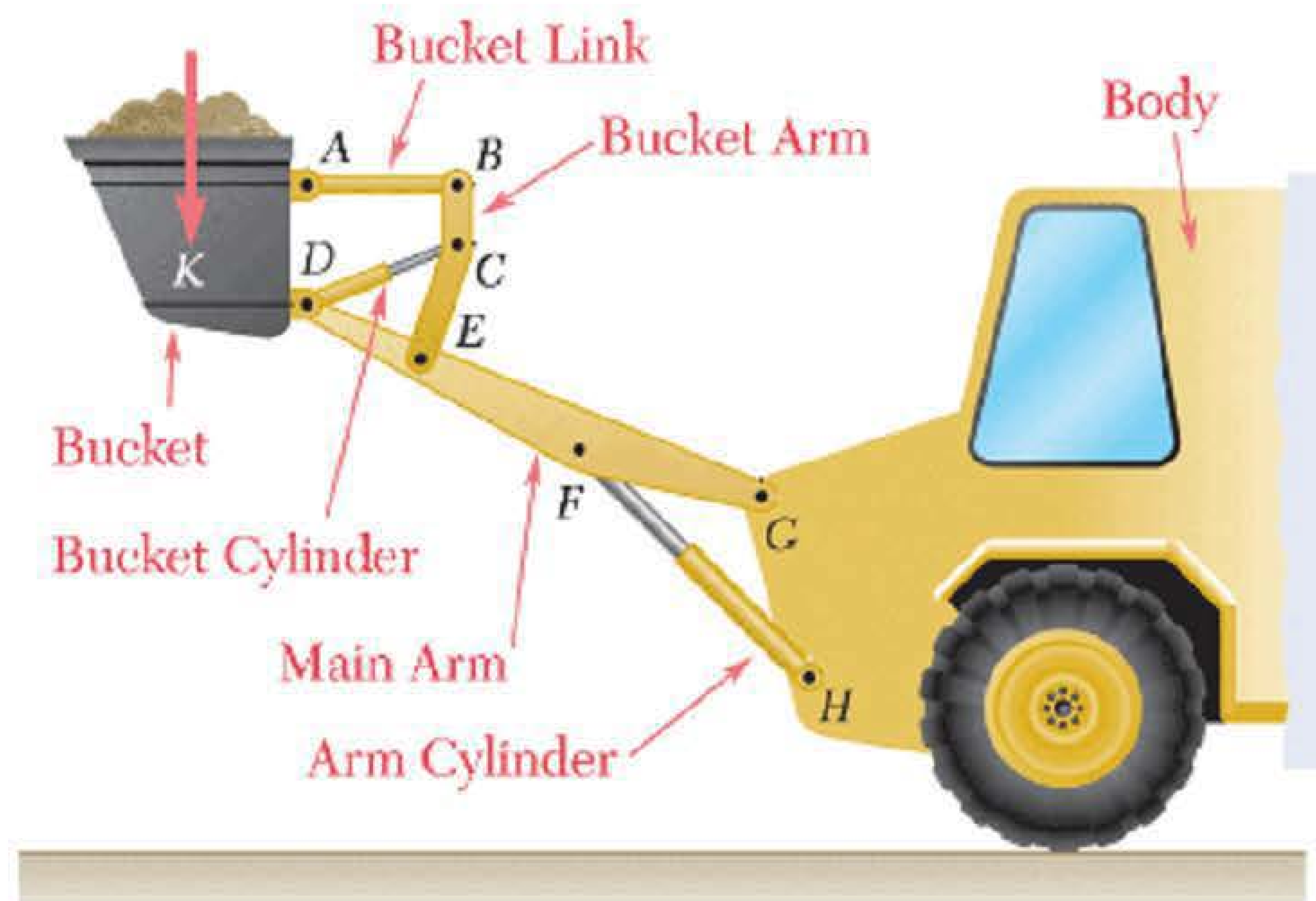
Drag statements on the right to match the left.

The weight force is applied at ...	pin C.
Take moments around ...	pin A.
Use moments to find the force at ...	pin B.
Ignore forces at places like ...	pin D.

Assume the tractor body as the ground.

Take the **frame** as the hydraulic arm assembly, which is everything that is supported on pins G and H, except the load itself (soil in the bucket).

In the process of solving the support forces for the frame, match the following steps with the appropriate pins.

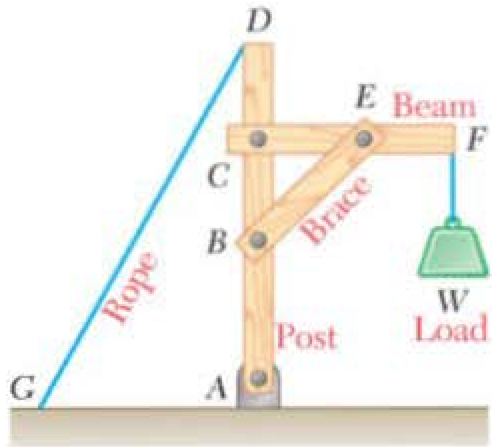


Drag statements on the right to match the left.

The weight force is applied at...	pin K.
Take moments around ...	pin F
Use moments to find the force at ...	pin B
Ignore forces at places like ...	pin G.

Assume the frame is the wooden structure only.

In setting up a FBD for the **frame** (wooden structure), match each of the following steps with the appropriate joint involved.



Drag statements on the right to match the left.

The weight force is applied at ...	pin F.
Take moments around pin ...	pin A.
Use moments to find the force at ...	pin D.
Ignore forces at places like pin...	pin B.

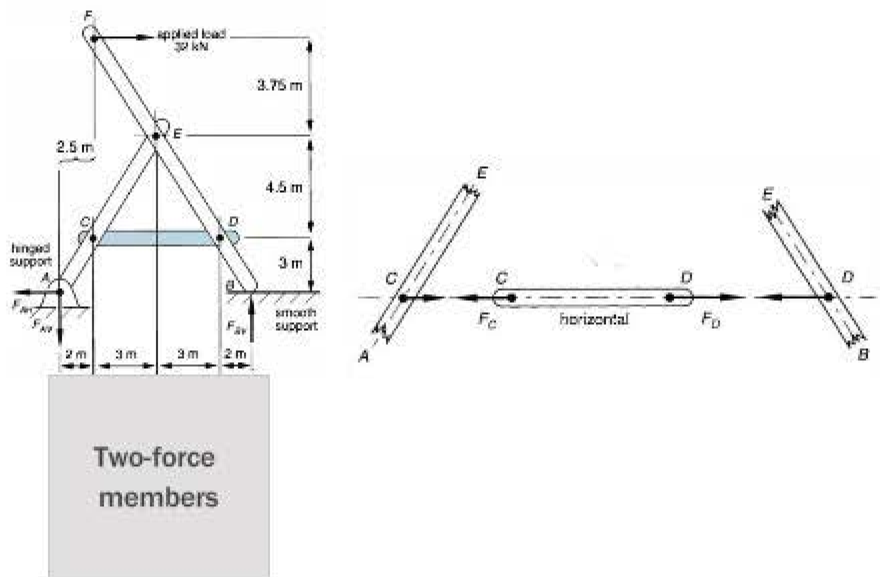
Identify two-force members within a frame

Step 2 of the procedure for solving any frame: Identify any two-force members

Step 2

Look for any members with only two forces (or two joints). These can only be in pure tension or compression, but without bending. The X and Y components of a force are counted as one force.

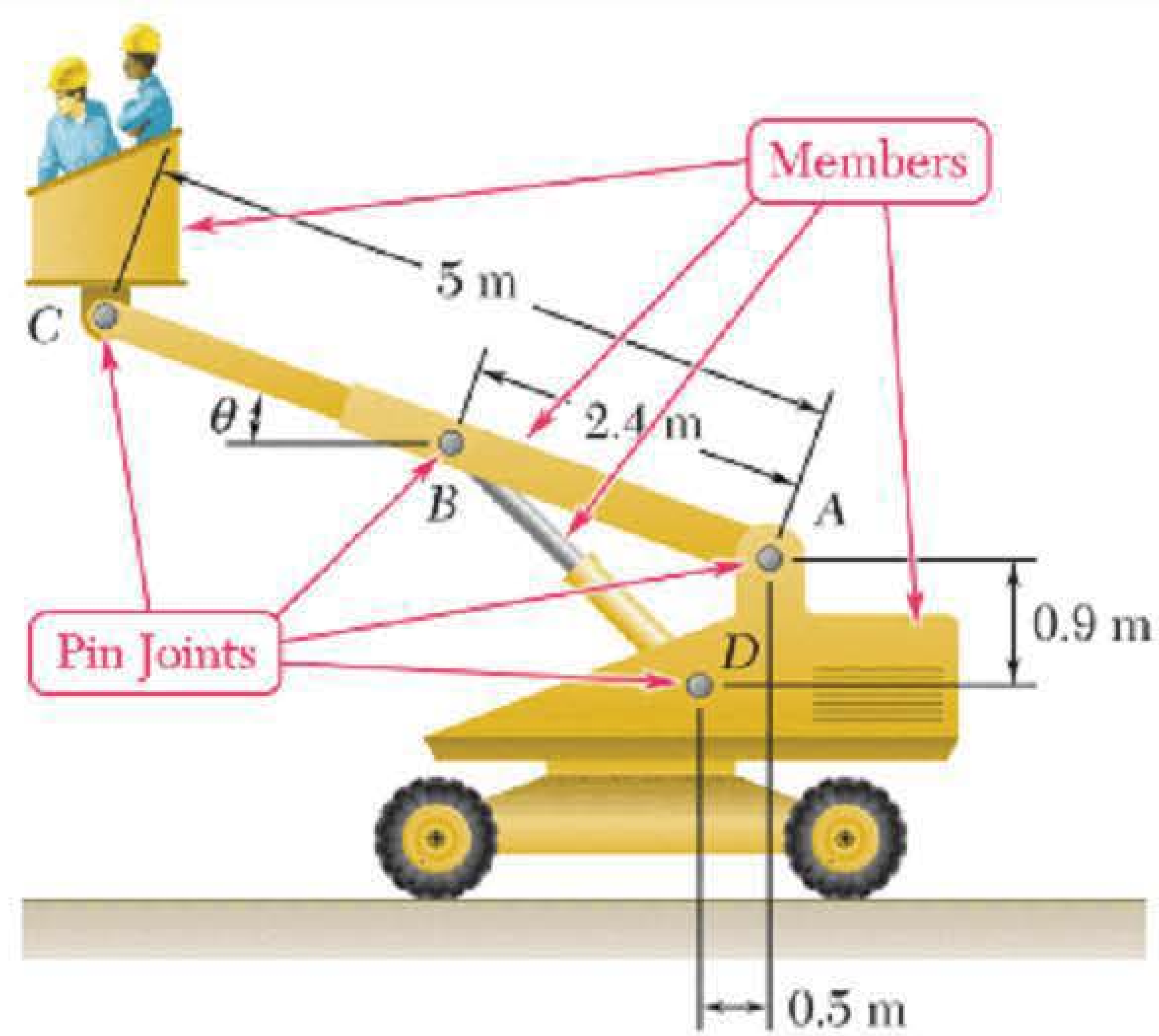
Here, we identify member CD as a two-force member in the frame, so it must have equal and opposite forces applied through the pins and acting along the axis CD. Therefore, these forces acting through joints C and D, and their interaction with members ACE and $BDEF$, must all be horizontal. The directional sense of these forces is just a guess for now, but calculations will soon tell us exactly.



GIVE FEEDBACK

OK

Identify two-force members.



Click the correct answer.

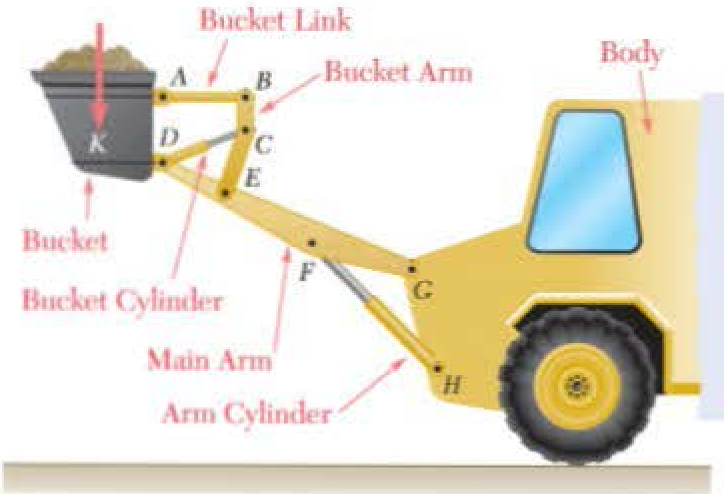
Member BD

Member AC

Member AD

Member C

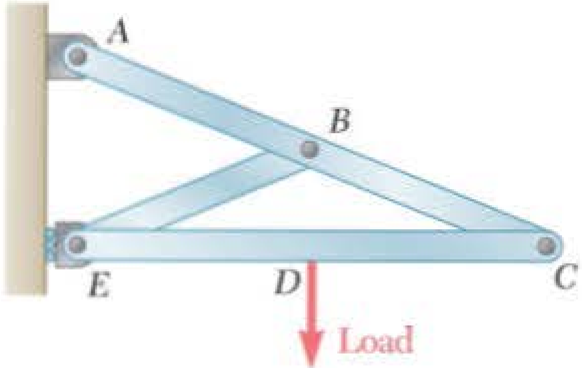
Identify two-force members:



Check all that apply.

- [ ] Bucket
- [ ] Bucket link
- [ ] Bucket arm
- [ ] Bucket cylinder

Identify two-force members.



Click the correct answer.

ABC

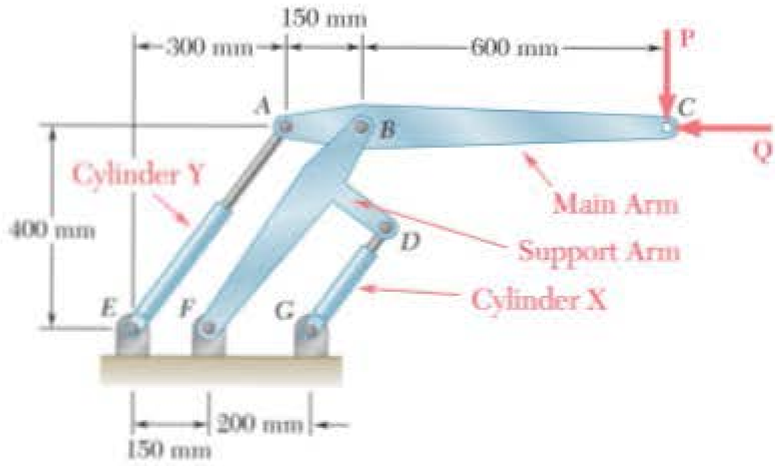
EB

EC

AE

Do you know the answer?

Identify two-force members.

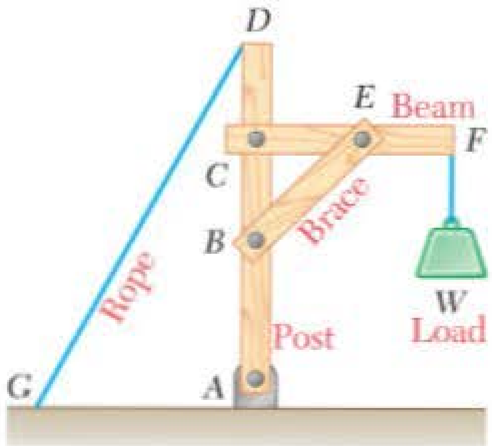


Check all that apply.

- [ ] Main arm
- [ ] Support arm
- [ ] Cylinder X
- [ ] Cylinder Y

Do you know the answer?

Identify two-force members.



Check all that apply.

- [ ] Beam
- [ ] Brace
- [ ] Post
- [ ] Rope
- [ ] Load

Draw a FBD for all members of a frame

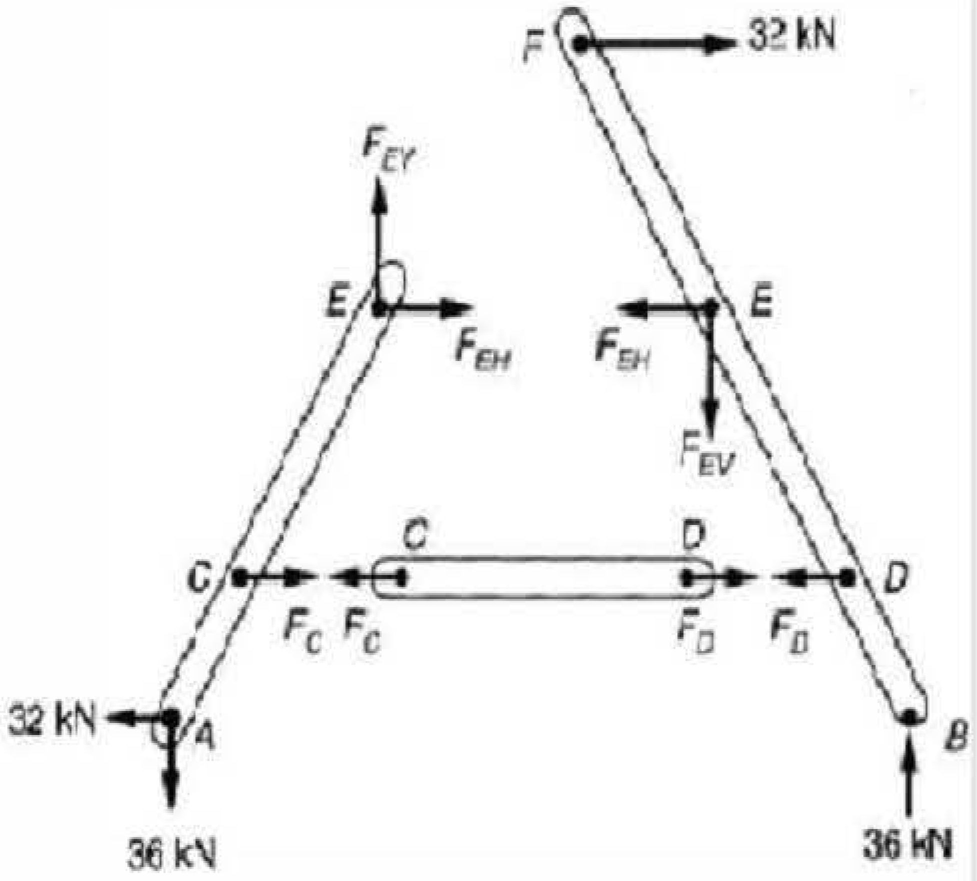
Step 3: Draw a Free Body Diagram for each member as an exploded view of the frame.

Step 3

Isolate each separate member of the frame and draw it as a free body, showing all known and unknown forces acting on the member

We guess the directional sense of the unknown forces, subject to revision in subsequent calculations.

With each pair of action-and-reaction forces interacting at the same joint, the arrowheads will always oppose each other in the two images of each 'separated' joint. This can be seen in joint C, joint D and especially joint E.



GIVE FEEDBACK

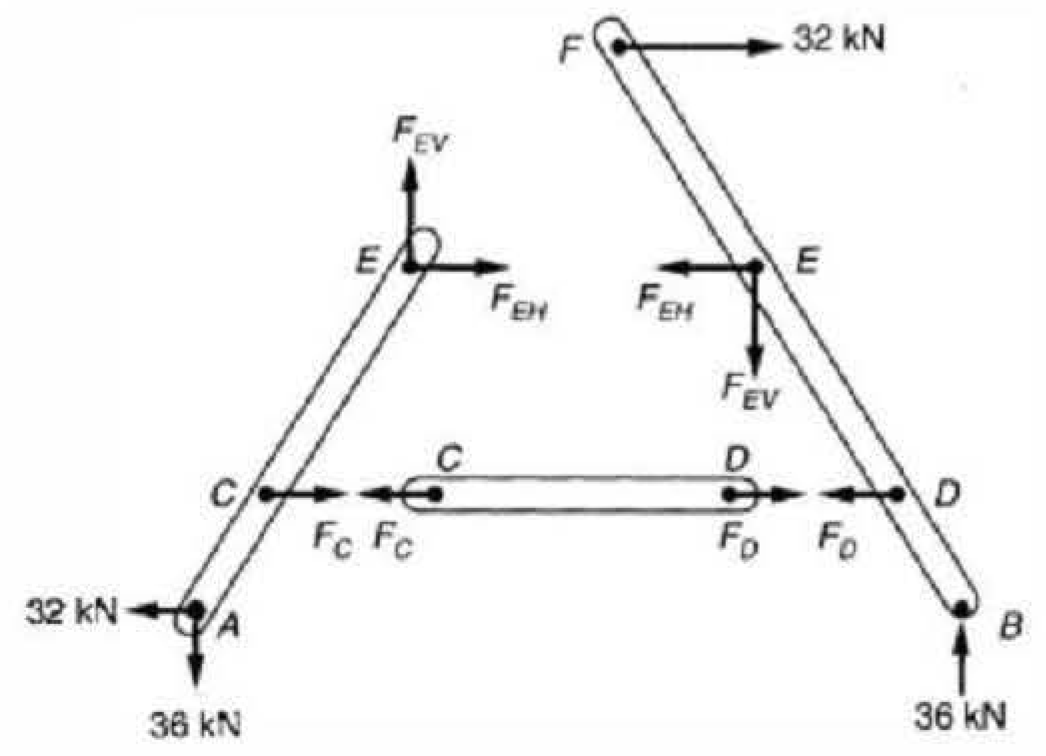
OK

'*Step 3 of solving a frame.*

Isolate each separate member of the frame and draw it as a free body, showing all known and unknown forces acting on every member.

We take a guess at the directional sense of the unknown forces... '.

Why is guessing allowed here?



Click the correct answer.

- The line of action is known, but the tension/compression of each pin reaction does not matter. It has no effect on the rest of the frame
- Every joint has an equal and opposite force, so both pulling or pushing forces can be safely applied to both members
- The line of action is known, but the tension/compression of each pin reaction will be found by equilibrium at the joint
- The joints cannot be solved, but guessing is good enough for most engineering problems

Constructing the approximate FBD for every member of a frame

Isolate each separate member of the frame and draw it as a free body, showing [Select... ▼] acting on the member.

We [Select... ▼] the directional sense of the unknown forces, subject to revision in subsequent calculations.

With each pair of action-and-reaction forces interacting at the same joint, the arrowheads from each member will always [Select... ▼].

Submit

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Step 4 of the process for solving any frame: Solve a member within a frame.

Select and solve a member within a frame

Step 4

Look for a member, with at least one known force, which contains no more than three unknowns. We could choose members ACE or $BDEF$. Solving equilibrium for ACE:

Taking moments about point E: $\Sigma M_E = 0$

$$\Sigma M_E = +(32\text{ kN} \times 7.5\text{ m}) - (36\text{ kN} \times 5\text{ m}) - (F_{CH} \times 4.5\text{ m})$$

$$\therefore F_{CH} = 13.3\text{ kN}$$

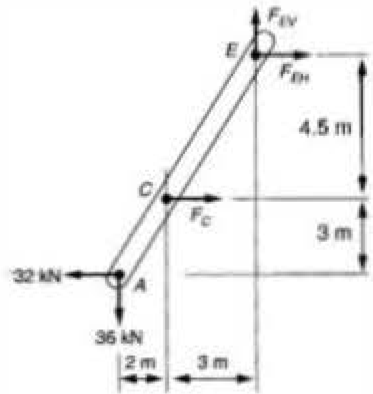
Summation of forces:

$$\Sigma F_H = F_{EH} + 13.33\text{ kN} - 32\text{ kN} = 0$$

$\therefore F_{EH} = 18.67\text{ kN}$ to the right

$$\Sigma F_V = F_{EV} - 36\text{ kN} = 0$$

$\therefore F_{EV} = 36\text{ kN}$ upwards



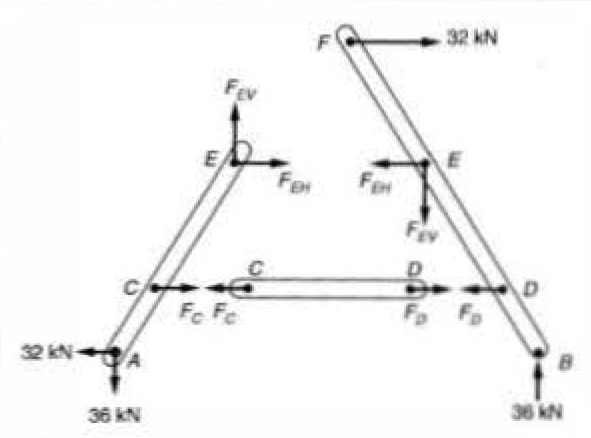
GIVE FEEDBACK

OK

Solving any member in this frame:

Which of the following statements are true?

- *Assume the reaction forces are given as shown*
- *Assume all dimensions are known*



Check all that apply.

- [ ] We can solve member ACE by taking moments at E
- [ ] We can solve member FEDB by taking moments at E
- [ ] We can solve member CD by taking moments at C
- [ ] We can solve member ACE by taking moments at C
- [ ] We can solve member FEDB by taking moments at C

Do you know the answer?

To solve the first member in a frame, which of the following conditions must be met?

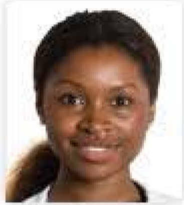
Check all that apply.

- [ ] The member has at least one known force
- [ ] The member has no more than three unknowns
- [ ] The member has at least two knowns
- [ ] The member has no more than four unknowns

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Solve a frame member using data from an adjacent member



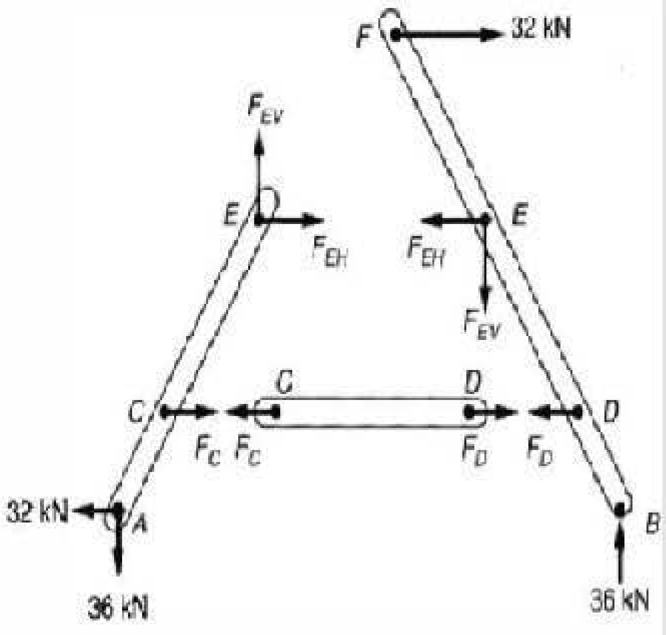
Step 5 of the process for solving any frame:
Solve an adjacent member

Step 5
Once a member has been solved (e.g. ACE), an adjacent member (CD) can be analysed through the action/reaction of connecting joint (C).

If we already know from ACE that $F_C = 13.3\,\mathrm{kN}$, it is easy to see that force F_D must be equal and opposite to F_C.

$\therefore F_{DH} = 13.3\,\mathrm{kN}$

This completes another member and we can move on to the next one.



GIVE FEEDBACK

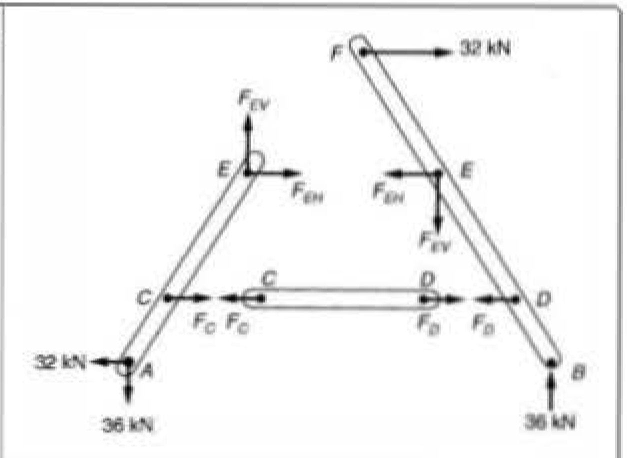
OK

We have just solved member ACE and know all the forces applied to it.

Which member/s can we do next?

Remember, the rules for a solvable member are:

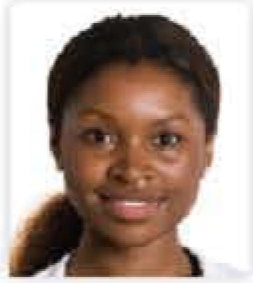
- *Maximum three unknowns (forces or angles)*
- *At least one known forces*



Check all that apply.

- [ ] Member CD
- [ ] Member FEDB
- [ ] Member ACE
- [ ] We need more information to continue

Do you know the answer?

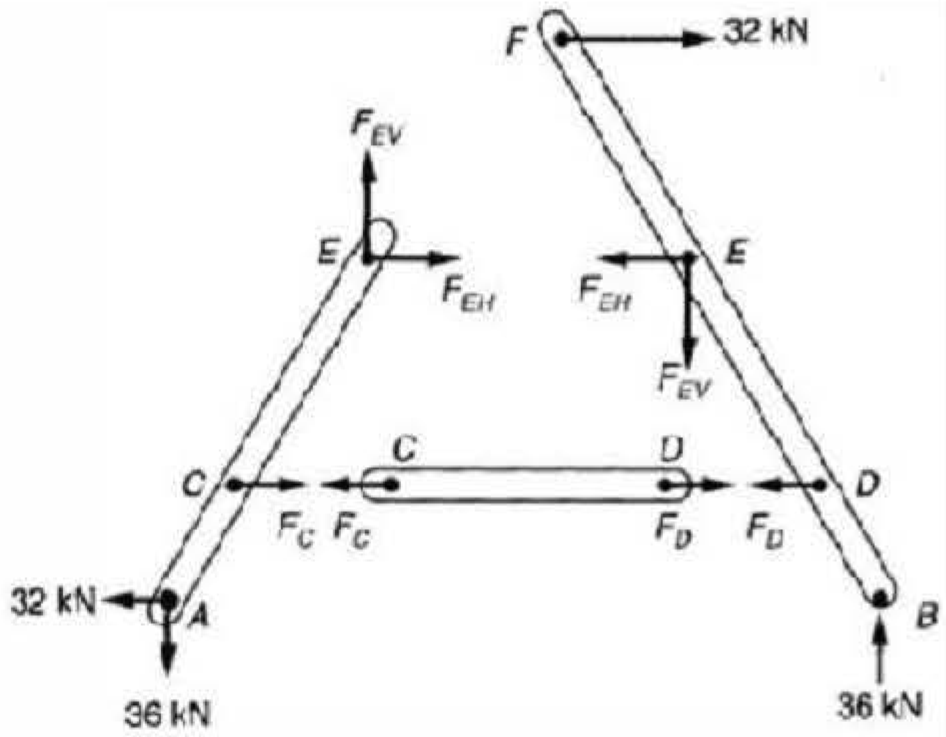


Step 6 of the process to solve any frame: Keep working on the next available member until all are solved

Solve a frame member using data from an adjacent member

Step 6

After solving of members ACE and CD, we can now move on to solve member BDEF.



Looking at forces at joint E on member ACE:

$F_{EH} = 18.67\,\mathrm{kN}$ to the right, and

$F_{EV} = 36\,\mathrm{kN}$ upwards.

This is reversed onto BDEF:

$F_{EH} = 18.67\,\mathrm{kN}$ to the left, and

$F_{EV} = 36\,\mathrm{kN}$ downwards.

This completes member BDEF and all forces are now known for the entire frame.

GIVE FEEDBACK

OK

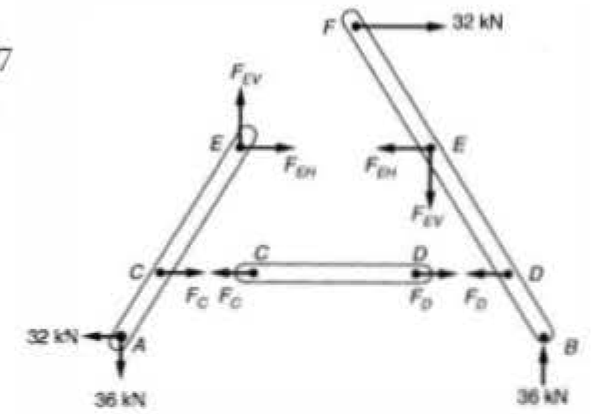
Assuming we have just solved member ACE,

$F_C = 13.3\ \text{kN} @ 0^0$, $F_{EV} = 36\ \text{kN} @ 90^0$, $F_{EH} = 18.67$

and member CD

$F_D = 13.3\ \text{kN} @ 0^0$

Match the three unknown forces on member FEDB.



Drag statements on the right to match the left.

F_{EH}	$18.67\ \text{kN} @ 180^0$
F_{EV}	$36\ \text{kN} @ 270^0$
F_D	$13.3\ \text{kN} @ 180^0$

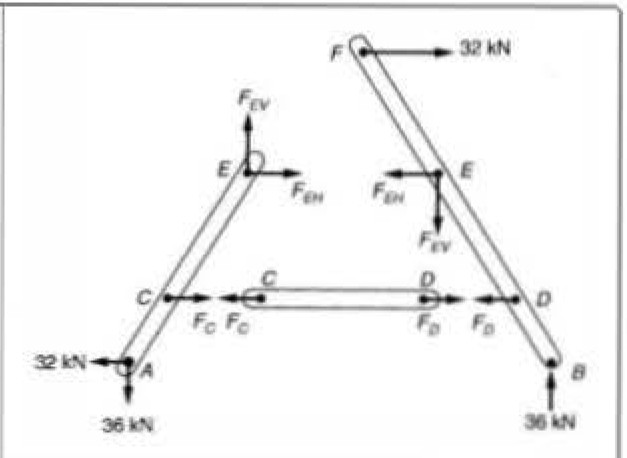
Do you know the answer?

We have just solved member ACE and know all the forces applied to it.

Which member/s can we do next?

Remember, the rules for a solvable member are:

- *Maximum three unknown forces*
- *At least one known forces*



Check all that apply.

- [ ] Member CD
- [ ] Member FEDB
- [ ] Member ACE
- [ ] We need more information to continue

Do you know the answer?

Check equilibrium of joints inside a solved frame

Step 7 of the process for solving any frame: Check equilibrium of any joint, member or assembly to see if equilibrium is correct.

Step 7

As a final step, we can combine horizontal and vertical components of the pin-reaction force at joint E in order to determine its total magnitude.

$$F_E = \sqrt{F_{EH}^2 + F_{EV}^2} = \sqrt{18.67^2 + 36^2} = 40.6\,\mathrm{kN}$$

Similarly, the total magnitude of reaction force at A is:

$$F_A = \sqrt{F_{AH}^2 + F_{AV}^2} = \sqrt{32^2 + 36^2} = 48.2\,\mathrm{kN}$$

Summarising the answers for the total pin-reaction force at each joint:

Joint A: Pin reaction 48.2 kN ($F_{AH} = 32\,\mathrm{kN}, F_{AV} = 36\,\mathrm{kN}$)

Joint C: Pin reaction 13.3 kN ($F_{CH} = 13.3\,\mathrm{kN}, F_{CV} = 0$)

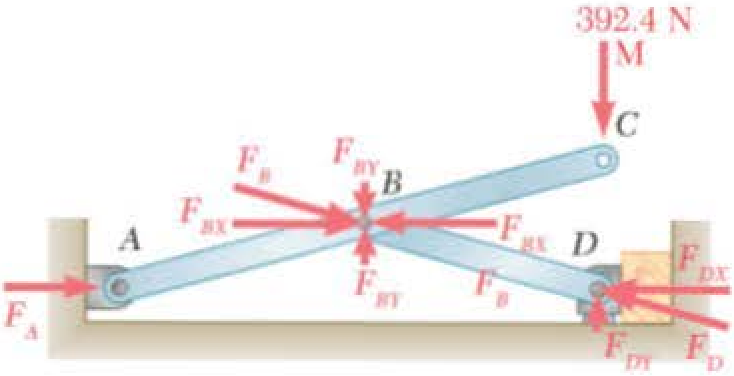
Joint D: Pin reaction 13.3 kN ($F_{DH} = 13.3\,\mathrm{kN}, F_{DV} = 0$)

Joint E: Pin reaction 40.6 kN ($F_{EH} = 18.67\,\mathrm{kN}, F_{EV} = 36\,\mathrm{kN}$)

GIVE FEEDBACK

OK

After completing the frame analysis, we can check if forces are correct by ___________.



Check all that apply.

- [ ] adding up all forces at any joint
- [ ] checking that opposing members have equal and opposite forces
- [ ] adding up all forces on any member
- [ ] understaing that no forces should be higher than the applied load

Do you know the answer?