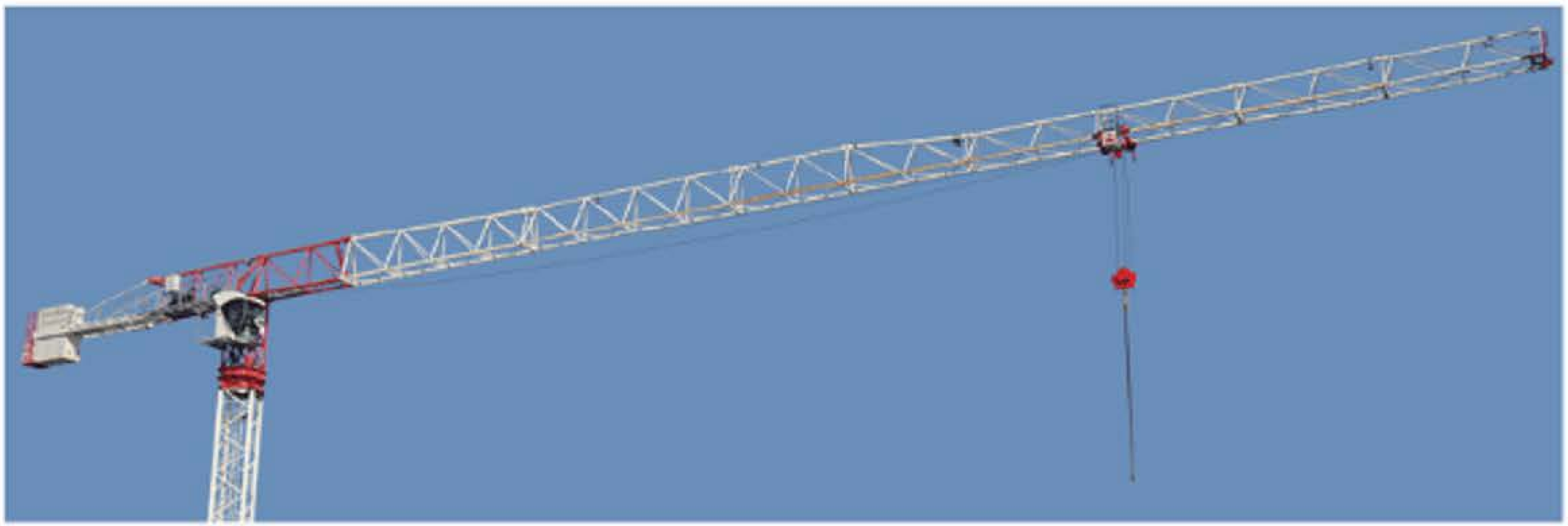
GIVE FEEDBACK

CONTINUE >

Trusses are a special type of frame and can be solved in exactly the same way. What makes something a truss is whether it can be simplified to where each member has only two forces. This is a good approximation where the members in a structure are lightweight and slender, which is typical for a truss. It also allows for rapid calculation of complex frameworks.

In this chapter we look at two of these truss analysis methods:

- **Method of joints,** which solves from one joint to the next
- **Method of sections,** which can jump to the centre of a truss to determine member forces



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This chapter is about trusses. They are essentially the same as frames but we will focus on specialised methods for solving a large number of members.

The need for truss analysis

A **truss** is a lightweight structure with many engineering applications, commonly as steel frameworks.

In this chapter we use the methods of **static equilibrium** to solve the internal forces in truss members. The methods are similar to **frame analysis** but are quicker to solve and can be much more convenient for complex trusses having a large number of members.

Although they may do the same job, trusses are distinguished from **beams** (which are one piece) and **frames** (which contain bending members).

Tower crane. Photo by Tim Lovett 2015

GIVE FEEDBACK

OK

Frame analysis versus truss analysis

The methods used in frame analysis will (please select) for trusses.

Compared to the frame analysis methods, truss analysis techniques are (please select).

Truss methods are more suitable for (please select).

Submit

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Before we get into the technicalities, keep in mind that the principles behind a truss also apply to many designs. A truss-like structure is often used to save weight and stiffen an object.

Applications of truss principles

Trusses are not confined to roofs and bridges.

Video object isn't supported in c++ version

Truss-like elements can be found in many designs, like the internal ribs in this plastic injection-moulded component (video).

Truss-like zig-zag webbing is a common technique to stiffen an object. These internal diagonal members are called webs.

Even a bicycle frame is a truss-like structure.

Trusses are a lightweight solution for beams in bending and 3D shapes in torsion.

GIVE FEEDBACK

OK

Select the correct statements about trusses.

Check all that apply.

- [ ] A truss can be made lighter than a comparable beam
- [ ] A truss will usually have less height than a comparable beam
- [ ] Many trusses have pin joints but calculations assume rigid joints
- [ ] A 3D truss can also resist torsion

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

A truss is made up of members joined together by pin joints.

The assumptions that define a truss

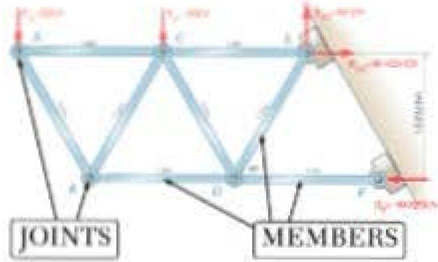
Members

- All members are slender and cannot support side loads anywhere along their length
- Loads are applied only at the joints
- Each member of a truss has only two forces, so can only be stretched or compressed, no bent
- The weight of each member is ignored
- All members lie in the same plane (planar or two-dimensional truss).

There are only two forces per member but any number of forces at a joint.

Joints

- Every connection is a frictionless pin joint, with only one pin per joint, making all forces at that joint concurrent
- No moments are applied at any joint



GIVE FEEDBACK

OK

When dealing with trusses, 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

One of the assumptions for the analysis of a pin-jointed planar frame is that 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

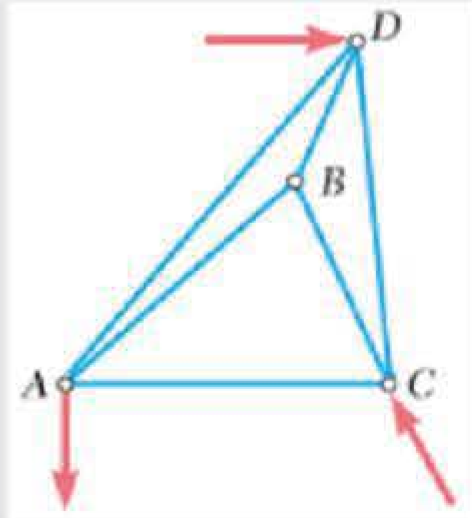
Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

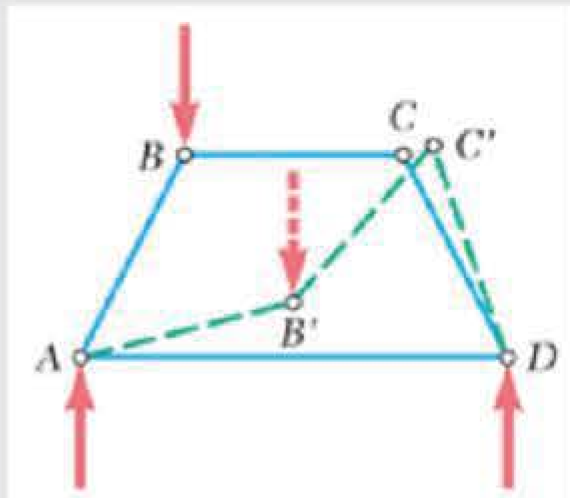
Match the following types of pin-jointed planar structures to their diagrams.

Drag statements on the right to match the left.

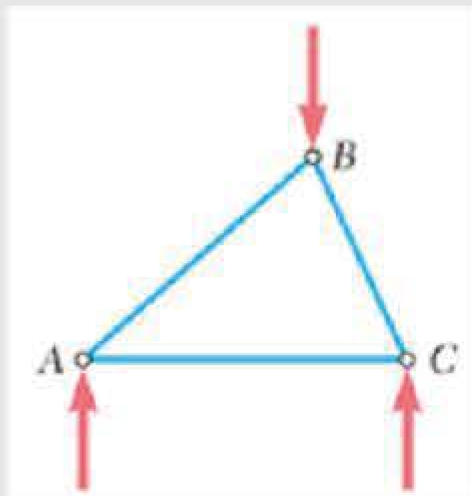
Statically indeterminate mechanism



Statically determinate frame



Statically indeterminate structure



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

Check all that apply.

- [ ] It is connected by frictionless hinge joints
- [ ] The weight of each member must be equal
- [ ] All the parts lie in the same two-dimensional plane
- [ ] The members are all of equal length
- [ ] Members cannot have more than two forces applied

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

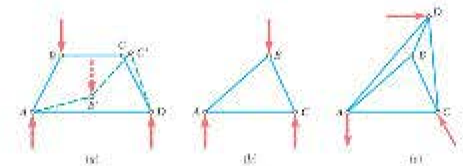
These are the rules for the types of trusses we can analyse using the laws of static equilibrium.

They must be: lightweight, pin-jointed, stationary structures that are not over-constrained. Trusses that do not obey these rules will probably need to be analysed by computer methods.

Compare the assumptions for a pin-jointed truss and a pin-jointed frame

To make calculations simpler, these are the assumptions of a **pin-jointed frame:**

- 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 Figure (a), or excessive bracing as a statically indeterminate structure like Figure (c) opposite.	

In addition, we make one more assumption to define a **pin-jointed truss:**

- Every member has only **two forces** (pure tension or compression only, no bending loads)

GIVE FEEDBACK

OK

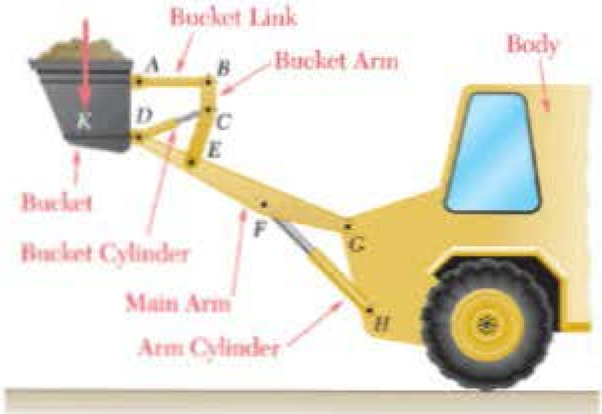
The forces applied between connected members of a frame are called:

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



Which of the above members are two-force members (ignore the weight of each member)?

Check all that apply.

- [ ] Bucket link
- [ ] Bucket cylinder
- [ ] Arm cylinder
- [ ] Main arm
- [ ] Bucket arm

Why are pin joints used in a truss from one member to another?

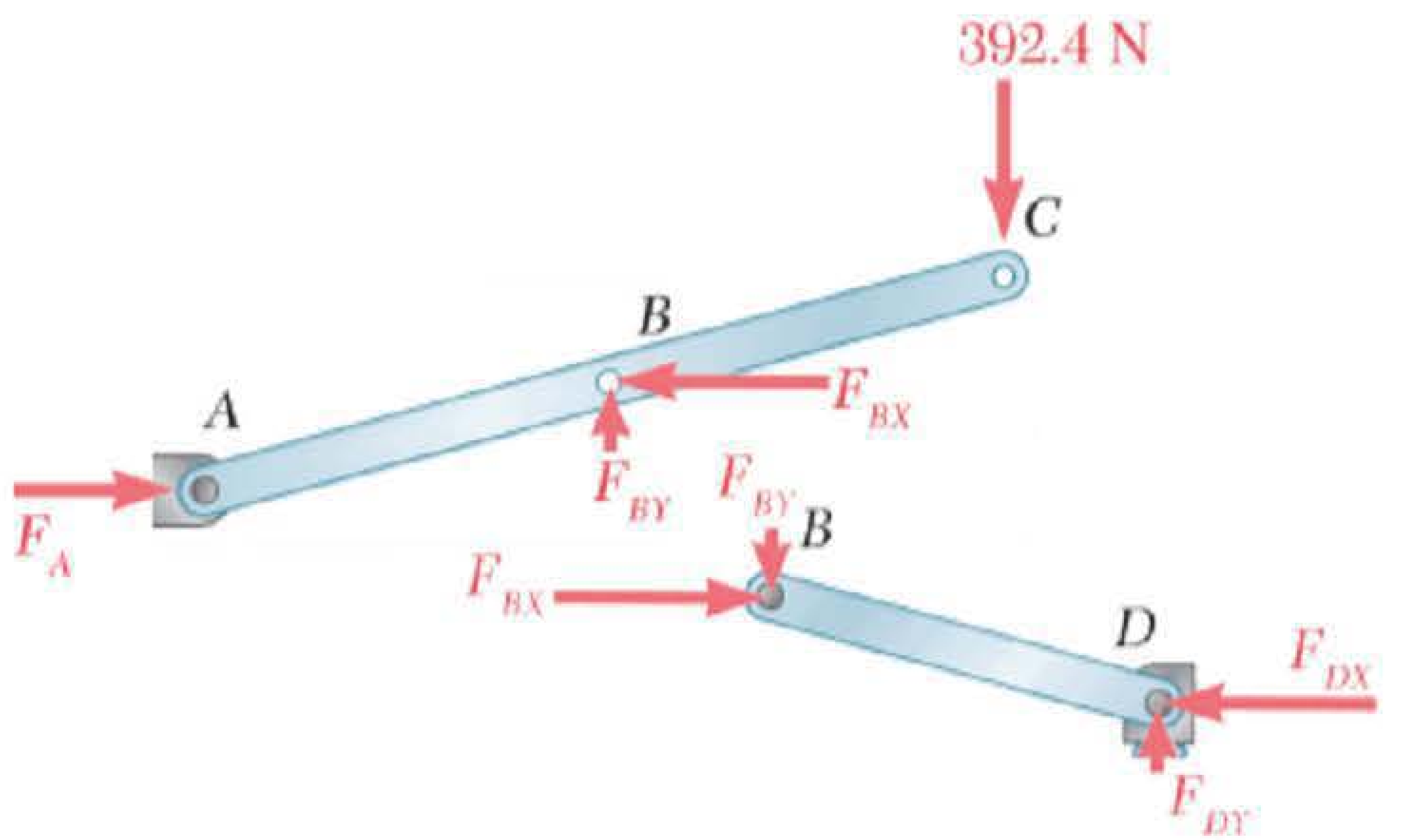
Click the correct answer.

- To transmit forces but not moments
- To transmit moments but not forces
- To transmit forces and moments
- To transmit neither forces nor moments

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Match the components to their forces.

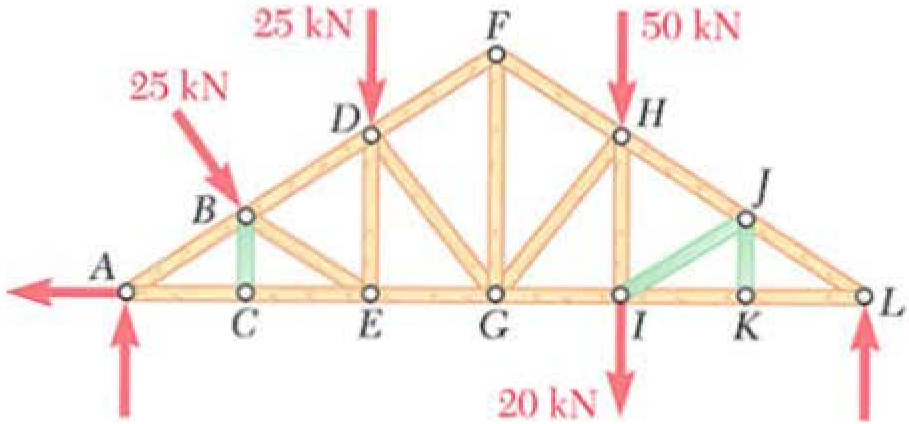


Drag statements on the right to match the left.

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} @ 180°
Horizontal component of the force of member *ABC* onto member *BD*	F_{BX} @ 0°

Some trusses contain members that carry no load at all, until the loading is changed of course.

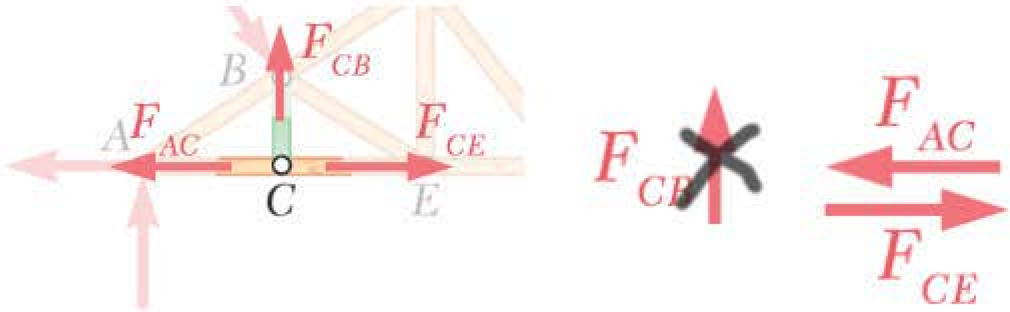
Zero-force members are members that do nothing, even when the loads are increased. These members cannot carry any load under the given loading arrangement. It saves time to identify these first. They occur whenever there is a T-joint without external force, where the leg of the T-joint carries no force. For example, in the truss below, member *BC* cannot have any force.



GIVE FEEDBACK

CONTINUE >

To explain how this occurs, we can look at the force polygon for Joint C. Here, Force F_{AC} must be equal and opposite to F_{CE}, which means Force F_{CB} does nothing.



The same occurs at Joint K, where member JK must be zero in exactly the same way as occured at Joint C. Now that JK is zero we are left with a T-type joint at J, so member IJ must also be zero.

According to the above loading, these three members could be removed with no effect on the truss. However, additional loads at these points would put loads into these members.

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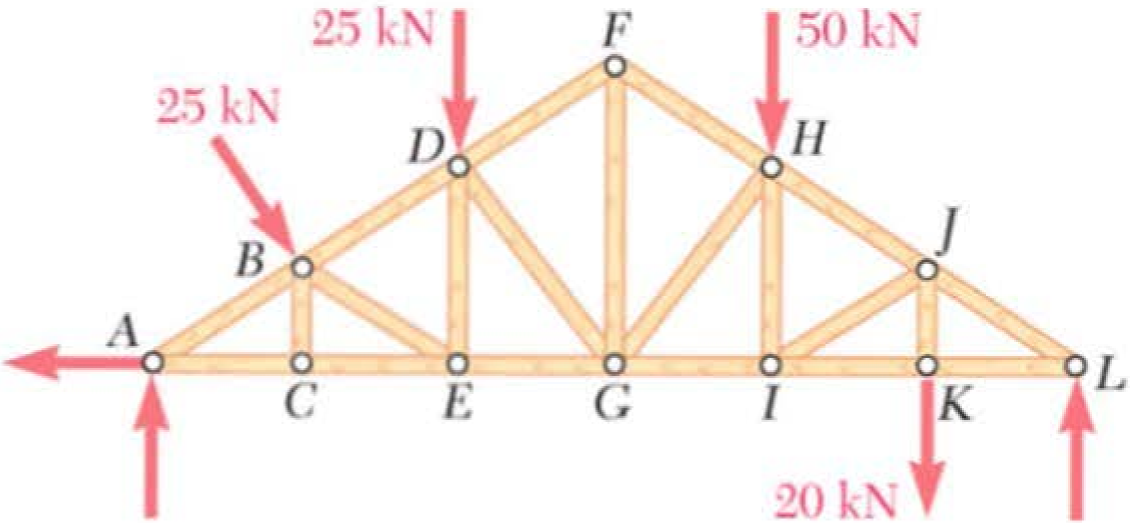
Click on the members of this truss that are carrying no load (zero-force members).

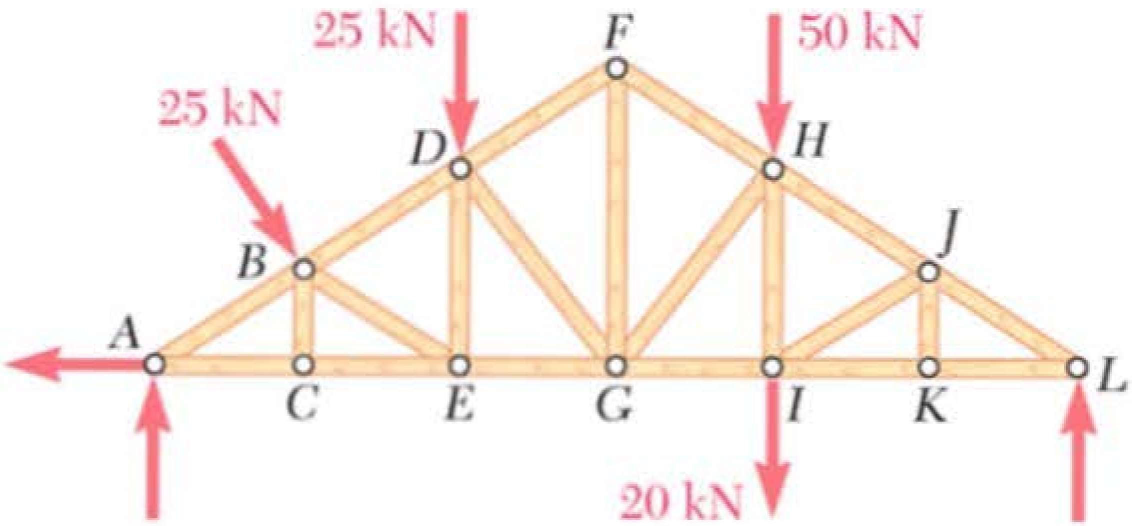


Submit

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Click on the members of this truss that are carrying no load (zero-force members).



Submit

Do you know the answer?

I KNOW IT

THINK SO

UNSURE

NO IDEA

The members of a truss can only be in tension or compression. This is what a tension member looks like--arrows show the member is pulling on the joints on each end.

Tensile force in any member

Forces directed away from the joint are **tensile.**

This makes better sense when we appreciate that this diagram is showing the free body diagrams as the **joints**. The key consideration is what the member *AB* does to joints *A* and *B*.

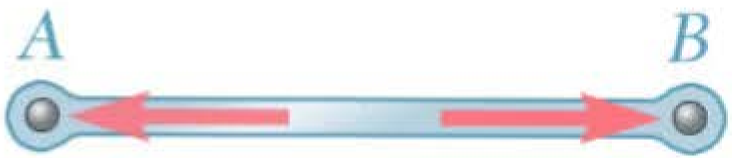
If the member is in tension, it is pulling Joint *A* to the right and Joint *B* to the left. Being in tension there is no risk of buckling under load, so these members can be very slender or even replaced with a cable of sufficient strength.

In the method of joints, forces are shown within the truss using the free body diagrams of each **joint**.

GIVE FEEDBACK

OK

This member is in tension:



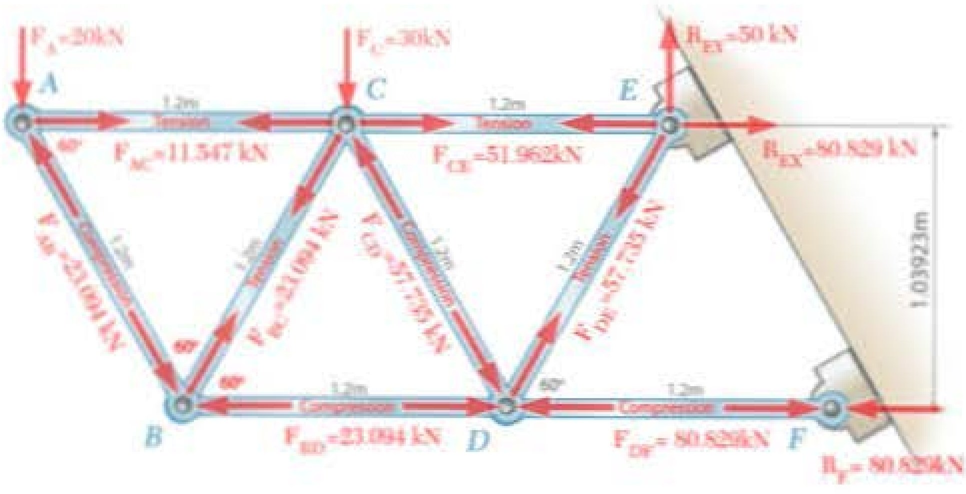
This free body diagram shows the body as:

Click the correct answer.

- Joints *A* and *B*
- Joint *A*
- Joint *B*
- Member *AB*
- Joint *A*, Joint *B* and Member *AB*

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA



During the method of joints, the truss diagram shows forces acting on:

Click the correct answer.

- Joints
- Members
- Supports
- Both the joints and the members

If the free body diagrams are the joints, what state of loading is this member in?

Click the correct answer.

- Tension
- Compression
- There is no loading—the forces cancel each other out
- Bending

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

This member is in tension:

The free body diagram has the body defined as:

Click the correct answer.

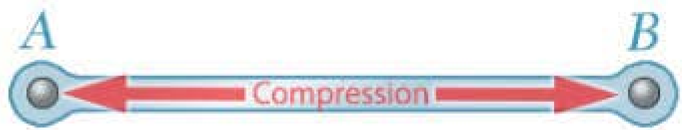
- Joint *A* and joint *B*
- Joint *A*
- Joint *B*
- Member *AB*
- Joint *A*, Joint *B* and Member *AB*

Do you know the answer?

This is what a compression member looks like—arrows show the member is pushing on the joints on each end.

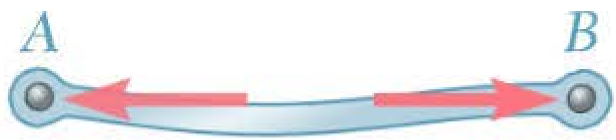
Compressive force in any member

Since forces are based on joint free body diagrams, any forces directed towards the joint describe **compressive** member loads.



The consideration is what the member *AB* does to joints *A* and *B*.

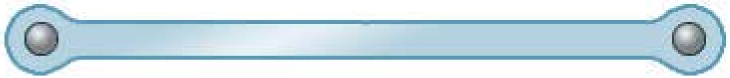
If the member is in compression, it is pushing Joint *A* to the left and Joint *B* to the right. Compression members are at risk of buckling under heavy loads, so these need to be thick enough to resist the bending caused by buckling.



GIVE FEEDBACK

OK

A truss member is assumed to handle which types of loading?



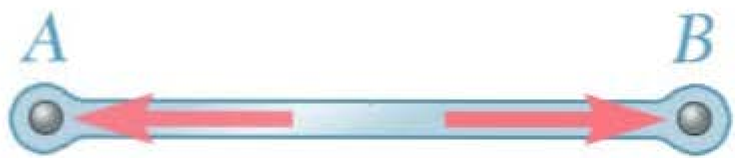
Check all that apply.

- [ ] Tensile
- [ ] Compressive
- [ ] Bending
- [ ] Torsion

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

If the free body diagrams are the joints, what state of loading is this member in?



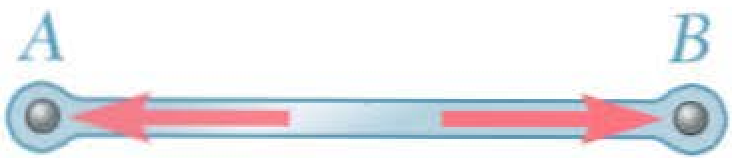
Click the correct answer.

- Tension
- Compression
- There is no loading—the forces cancel each other out.
- Bending

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

This member is in compression:



The free body diagram is:

Click the correct answer.

- Joints *A* and *B*
- Joint *A*
- Joint *B*
- Member *AB*
- Joint *A*, Joint *B* and Member *AB*

Do you know the answer?

This member is in compression:

The free body diagram is:

Click the correct answer.

- Joints *A* and *B*
- Joint *A*
- Joint *B*
- Member *AB*
- Joint *A*, Joint *B* and Member *AB*

Do you know the answer?

To solve forces on the body we will assume the body is in equilibrium.

Definitions of equilibrium

Equilibrium of planar forces can be defined many ways, e.g.:

- The sum of all forces is zero
- The net force is zero
- The body is at rest (static equilibrium)
- The body is not accelerating (Newton's second law, $\Sigma F = m\,a$, where $a = 0$)
- The forces are balanced
- $\Sigma M = 0$ and $\Sigma F_x = 0$ and $\Sigma F_y = 0$
- A force polygon can be constructed
- The resultant = 0
- The equilibrant is applied
- Constant velocity (Newton's first law of motion)

GIVE FEEDBACK

OK

For two-dimensional (planar) concurrent forces, constructing a force polygon is the same as solving:

Click the correct answer.

- $\Sigma F_x = 0$ and $\Sigma F_y = 0$
- $\Sigma M_A = 0$
- $F \cos \theta = F \sin \theta$
- $F \sin \theta = 0$

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Which of the following bodies are in equilibrium?

Check all that apply.

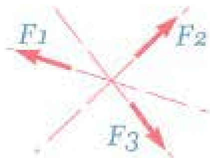
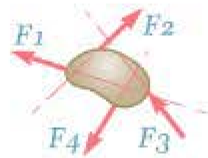
- [ ] Body at rest
- [ ] Body moving at constant velocity
- [ ] Body accelerating
- [ ] Body where sum of all forces is zero
- [ ] Body with negligible weight

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Classes of equilibrium

Equilibrium is ensured by setting unknown forces to make resultant zero:

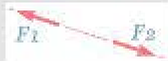
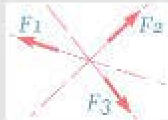
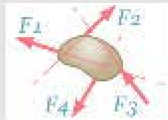
Forces	Free body diagram	Force polygon	Description	Unknowns (mag = magnitude(s))
2			Equal and opposite: $F_1 = -F_2$	• 1 force
3 or more			$\circlearrowleft + \Sigma \mathbf{M}_A = \mathbf{0}$ $\xrightarrow{+} \Sigma F_x = \mathbf{0}$ $+\uparrow \Sigma F_y = \mathbf{0}$	• 2 mag • 2 angles (rare) • 1 mag, 1 angle
4 or more			$\circlearrowleft + \Sigma \mathbf{M}_A = \mathbf{0}$ $\xrightarrow{+} \Sigma F_x = \mathbf{0}$ $+\uparrow \Sigma F_y = \mathbf{0}$	• 3 mag (reactions) • 2 mag, 1 angle • 1 mag, 2 angles • 3 angles (rare)

GIVE FEEDBACK

OK

Match the equilibrium conditions for each set of forces acting on a body:

Drag statements on the right to match the left.

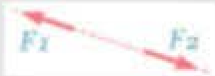
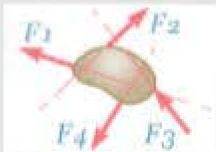
$F_1 = -F_2$	
$\circlearrowleft + \Sigma \mathbf{M}_A = 0$ $\xrightarrow{+} \Sigma F_x = 0$ $+\uparrow \Sigma F_y = 0$	
$\circlearrowleft + \Sigma \mathbf{M}_A = 0$ $\xrightarrow{+} \Sigma F_x = 0$ $+\uparrow \Sigma F_y = 0$	

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Match the following classifications of forces acting on a body:

Drag statements on the right to match the left.

Co-linear	
Concurrent	
Non-concurrent	

Do you know the answer?

A typical graphical solution by method of joints

The method of joints solves equilibrium at each joint, starting from the first solvable joint, then moves to adjacent joints until the truss is completed. It works like this:

Notice how the force polygon is solved for Joint *A* , which gives information for adjacent joints *B* and *C*.

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Then Joint *B* is chosen, equilibrium is solved and then we move on to the next, and so on.

This is an overview, so we will go through this in more detail in later slides.

GIVE FEEDBACK

OK

Which type of truss analysis is demonstrated here?

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Click the correct answer.

- Method of joints (graphical)
- Method of sections
- Non-concurrent forces
- Method of joints (mathematical)

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The method of joints is a simple procedure of three steps. This procedure is repeated from one joint to the next until the truss is completed.

Procedure of method of joints for any truss (graphically)

Doing method of joints (graphically) involves:

1. Choosing a solvable joint (maximum two unknowns) and drawing a free body diagram of that joint*
2. Solving equilibrium of that joint and finding unknown forces (by a force polygon)
3. Transferring these forces to adjacent joints with balancing forces on each member**
4. Repeating these steps until all joints are solved

Notes:

* Forces in two-joint members are in-line with the members, but where tension/compression is a mystery, we can simply guess tension (pulling on joint). The correct sense will be obtained in the force polygon.

** Once a force is known on one end of the member, the same force is then opposite on the other end (rotated by 180 degrees). This is equilibrium applied to these members (compression = pushing both ends; tension = pulling both ends).

GIVE FEEDBACK

OK

For the overall procedure of the method of joints, match the task within the truss to the class of equilibrium analysis.

Drag statements on the right to match the left.

Solve that joint and find unknown forces using a force polygon	Equilibrium of concurrent forces
Transfer these forces to adjacent joints with balancing forces on each member	Equilibrium of co-linear forces
Solve reactions at the truss supports	Equilibrium of non-concurrent forces

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

For the overall procedure of the method of joints, match the type of equilibrium analysis to its description of solution.

Drag statements on the right to match the left.

Equilibrium of concurrent forces	Ensure $\Sigma F_x = 0$ and $\Sigma F_y = 0$
Equilibrium of co-linear forces	Forces are equal and opposite
Equilibrium of non-concurrent forces	Solve by $\Sigma M = 0$ and $\Sigma F_x = 0$ and $\Sigma F_y = 0$
Equilibrium of concurrent forces	Construct a force polygon

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Sort the steps into order for the procedure for method of joints (graphical).

↑↓ Place these in the proper order.

- Choose a solvable joint with a maximum of two unknowns, then draw a free body diagram of that joint
- Solve that joint and find unknown forces using a force polygon (equilibrium of concurrent forces at the joint)
- Transfer these forces to adjacent joints with balancing forces on each member (equilibrium of co-linear forces in the member)
- Repeat this process from the first step until the truss is completed

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Overview a simple truss by method of joints (graphically)

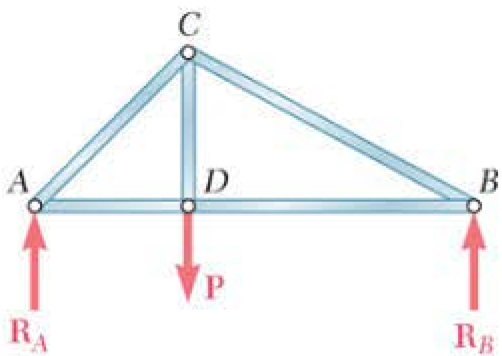


Fig (a) FBD of whole Truss

The following overview shows how the method of joints would apply to a simple truss with five members and four joints (Figure (a)). The reaction forces at the supports must first be solved before truss analysis can begin. So far we know three forces: the applied load P, and reactions R_A and R_B.

Reactions completed	Member and joint free body diagrams	Joint *A*	Joint *D*	Joint *C*	Joint *B*

GIVE FEEDBACK

OK

Overview a simple truss by method of joints (graphically)

The truss can be broken into component parts and a free body diagram constructed for each joint and member as shown in Figure (b).

The method of joints starts from the first solvable joint, which can have no more than two unknowns.

Since the geometry of a truss is usually provided, the angles will be known (or easily determined). So it is the force magnitudes that are the unknowns.

Currently we have four joints, where the known and unknown forces are:

	Knowns	Unknowns	Solvable?
Joint *A*	R_A	*AC*, *AD*	Yes
Joint *B*	R_B	*CB*, *DB*	Yes
Joint *C*		*AC*, *CD*, *CB*	No
Joint *D*	P	*AD*, *DB*, *CD*	No

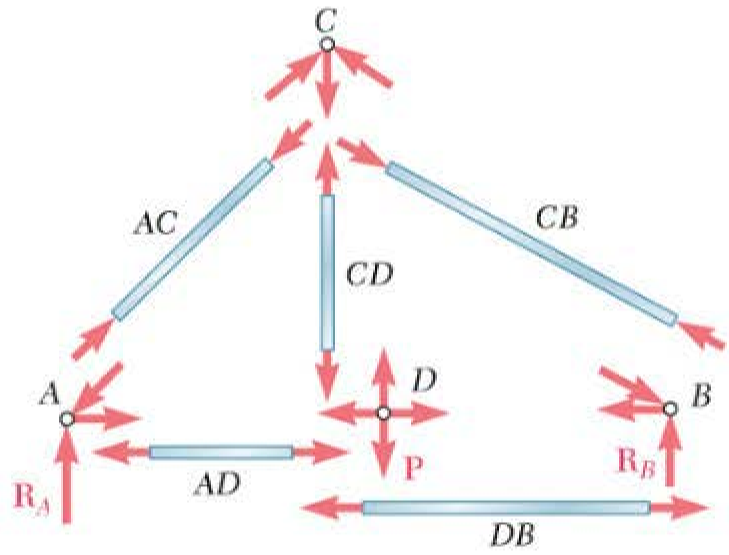


Fig (b) FBD of Members and Joints

Reactions completed	Member and joint free body diagrams	Joint *A*	Joint *D*	Joint *C*	Joint *B*

GIVE FEEDBACK

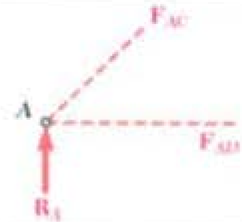
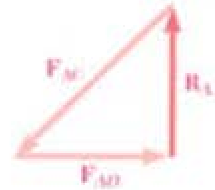
OK

Overview a simple truss by method of joints (graphically)

In this case we will start with Joint *A*, where there are two unknowns, F_{AC} and F_{AD}. Completing a force triangle for Joint *A* gives these unknown member forces.

From this triangle, we can see that F_{AC} is pushing Joint *A*, therefore member *AC* is in compression; and that F_{AD} is pulling Joint *A*, therefore member *AD* is in tension.

A member in tension will pull on both of its joints and a member in compression will push on both ends. So member *AC* pulls on Joint *C* and member *AD* pushes on Joint *D*. We can transfer this information to adjacent joints *C* and *D*.

	Free Body Diagram	Force Polygon
Joint *A*		

	Knowns	Unknowns	Solvable?
Joint *A*	R_A, *AC*, *AD*		Complete
Joint *B*	R_B	*CB*, *DB*	Yes
Joint *C*	*AC*	*CD*, *CB*	Yes
Joint *D*	P, *AD*	*DB*, *CD*	Yes

Reactions completed	Member and joint free body diagrams	Joint *A*	Joint *D*	Joint *C*	Joint *B*

GIVE FEEDBACK

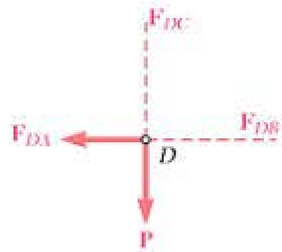
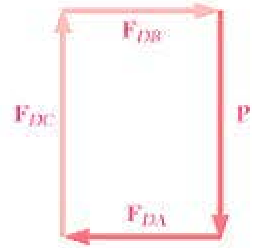
OK

Overview a simple truss by method of joints (graphically)

In this case we could move to Joint *C* or *D*, where there are two unknowns. We choose *D*, where unknowns are F_{DB} and F_{DC}.

Completing a force polygon for Joint *D* gives these unknown member forces. From this polygon, we can see that both F_{DB} and F_{DC} are pulling Joint *D*, therefore both are in tension.

A member in tension will pull on both of its joints, so Member *DC* pulls on Joint *C* and Member *DB* pulls on Joint *B*. We can transfer this information to adjacent joints *C* and *B*.

	Free Body Diagram	Force Polygon
Joint *D*		

	Knowns	Unknowns	Solvable?
Joint *A*	R_A, *AC*, *AD*		Complete
Joint *B*	R_B	*CB*, *DB*	Yes
Joint *C*	AC, *CD*	*CB*	Yes
Joint *D*	P, *AD*, *DB*, *CD*		Complete

Reactions completed	Member and joint free body diagrams	Joint *A*	Joint *D*	Joint *C*	Joint *B*

GIVE FEEDBACK

OK

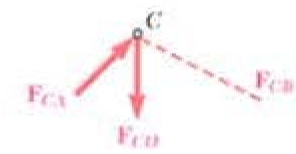
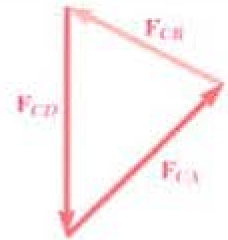
Overview a simple truss by method of joints (graphically)

In this case we could move to Joint *C* or *B*. We choose *C*, where there is only one unknown F_{CB}.

Completing a force polygon for Joint *C* gives this unknown member force.

From this polygon, we can see that F_{CB} is pushing on Joint *C*, so this member is in compression. Therefore it also pushes with the same force on Joint *B*.

We can transfer this information to adjacent Joint *B*.

	Free Body Diagram	Force Polygon
Joint *C*		

	Knowns	Unknowns	Solvable?
Joint *A*	R_A, *AC*, *AD*		Complete
Joint *B*	R_B, *CB*	*DB*	Yes
Joint *C*	*AC*, *CD*, *CB*		Complete
Joint *D*	P, *AD*, *DB*, *CD*		Complete

Reactions completed	Member and joint free body diagrams	Joint *A*	Joint *D*	Joint *C*	Joint *B*

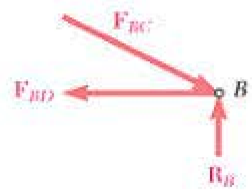
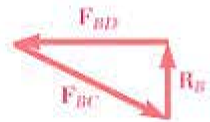
GIVE FEEDBACK

OK

Overview a simple truss by method of joints (graphically)

Joint *B* is fully solved since all forces are known.

If these forces form a correct free body diagram, we know that our truss analysis has been correct.

	Free Body Diagram	Force Polygon
Joint *B*		

	Knowns	Unknowns	Solvable?
Joint *A*	R_A, *AC*, *AD*		Complete
Joint *B*	R_B, *CB*, *DB*		Complete
Joint *C*	*AC*, *CD*, *CB*		Complete
Joint *D*	P, *AD*, *DB*, *CD*		Complete

Reactions completed	Member and joint free body diagrams	Joint *A*	Joint *D*	Joint *C*	Joint *B*

GIVE FEEDBACK

OK

Match the number of unknowns for each joint.

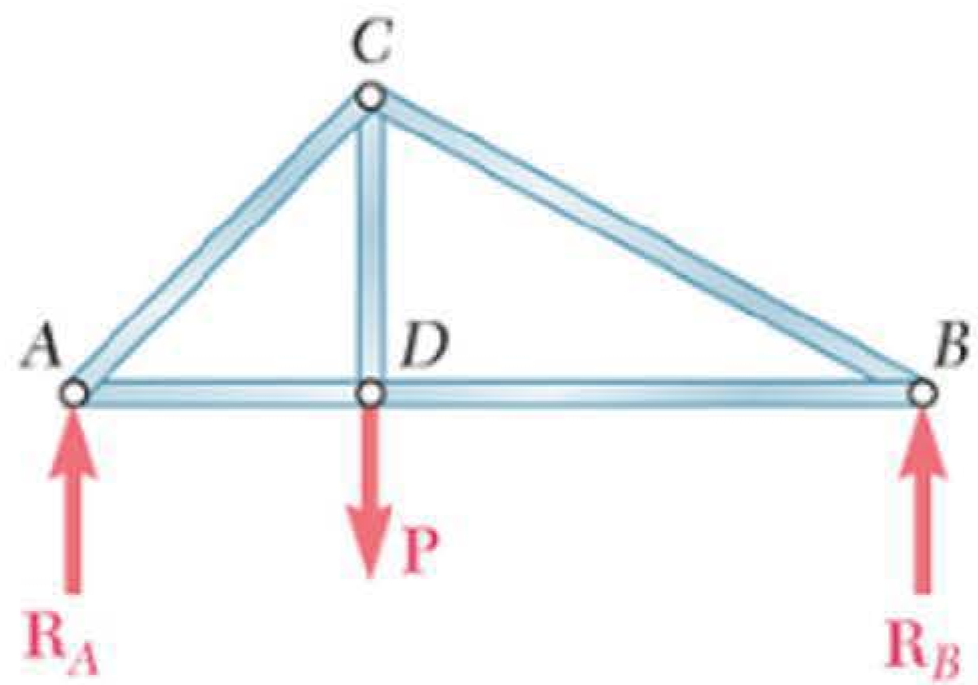
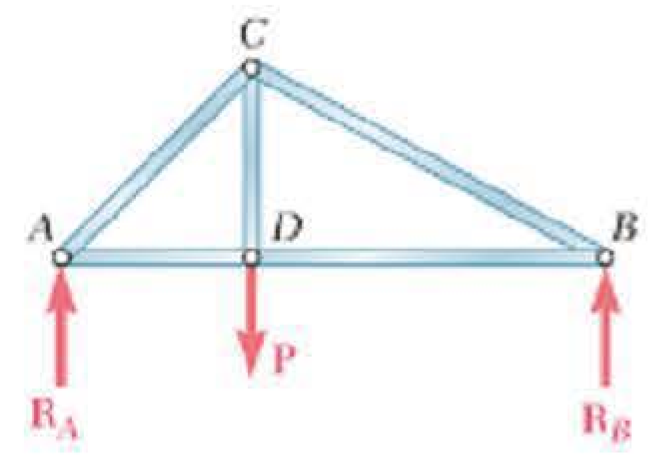


Fig (a) FBD of whole Truss

Drag each item into appropriate category.
Click on an item to send it to the back of the stack.

Joint *B*

Two unknowns	Three unknowns

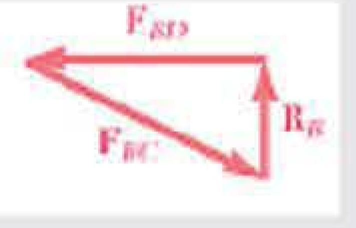


This truss has a load P applied at Joint *D*.
The reactions at supports *A* and *B* have been calculated.

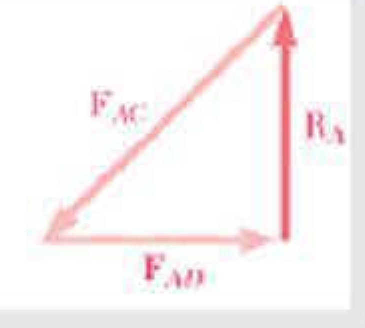
Match the force polygons for the joints *A*, *B*, *C* and *D*.

Drag statements on the right to match the left.

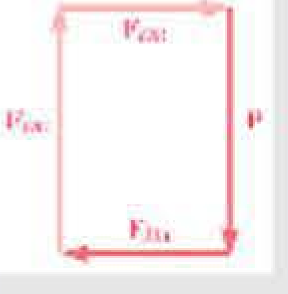
A



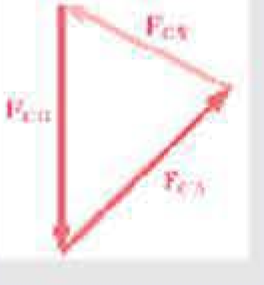
B

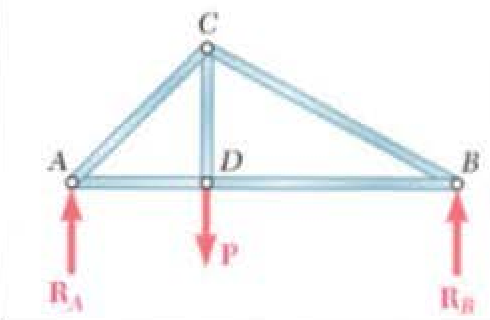


C



D





This truss has a load P applied at Joint *D*.
The reactions at supports *A* and *B* have been calculated.

If the method of joints is used, which of the following are a valid sequence for the solving of all joints in this truss?

Check all that apply.

- [ ] *A*, *C*, *D*, *B*
- [ ] *B*, *C*, *D*, *A*
- [ ] *C*, *A*, *D*, *B*
- [ ] *D*, *A*, *B*, *C*

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Which joints can be solved immediately by method joints (i.e. not requiring another joint to be solved first)?

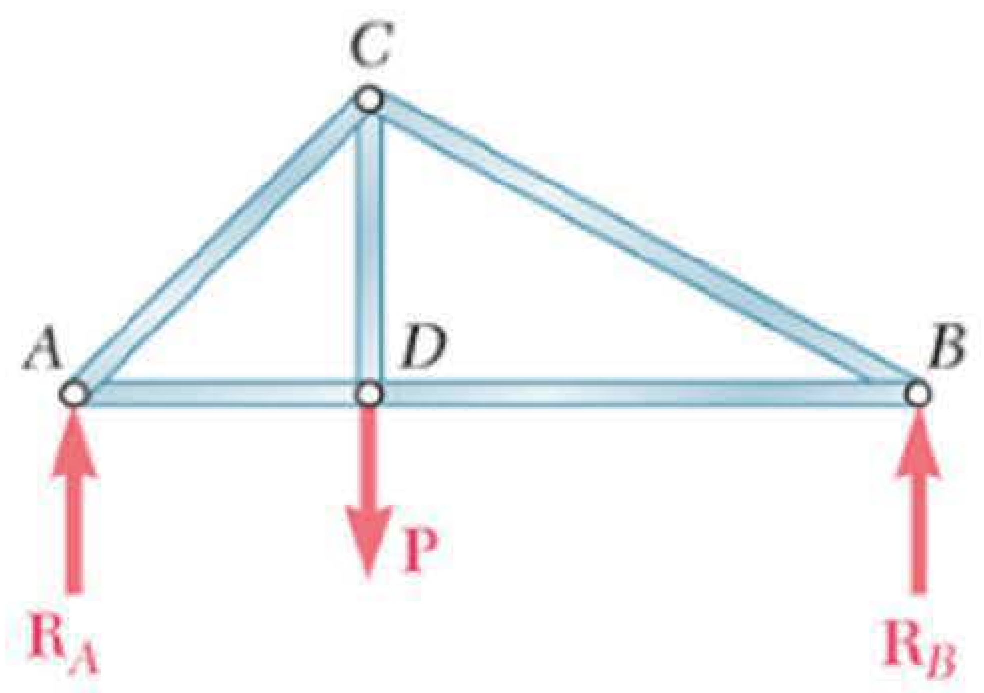


Fig (a) FBD of whole Truss

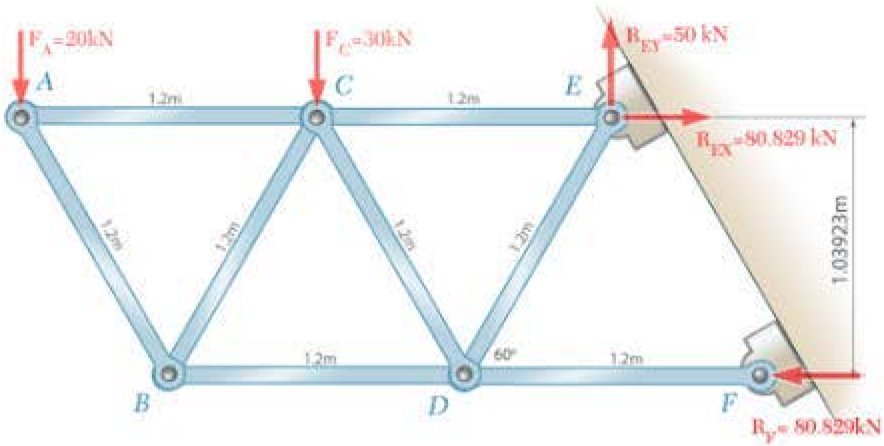
Check all that apply.

- [ ] Joint *A*
- [ ] Joint *D*
- [ ] Joint *B*
- [ ] Joint *C*

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Solve for first two joints in a truss by method of joints (graphically)



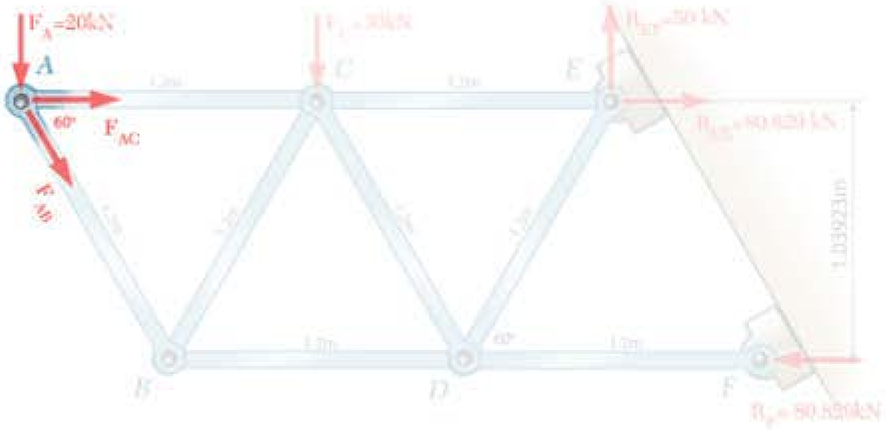
Truss analysis begins once the reactions are known. These reaction forces can be used to double-check the solution at the end by testing equilibrium at joints E and F.

Begin with known reactions	Step 1 (A): Find a solvable joint and draw free body diagram	Step 2 (A): Equilibrium for Joint *A*	Step 3 (A): Equilibrium for members AC, AB	Step 1 (B): Find a solvable joint and draw free body diagram	Step 2 (B): Equilibrium for Joint *B*	Step 3 (B): Equilibrium for members BD, BC

GIVE FEEDBACK

OK

Solve for first two joints in a truss by method of joints (graphically)



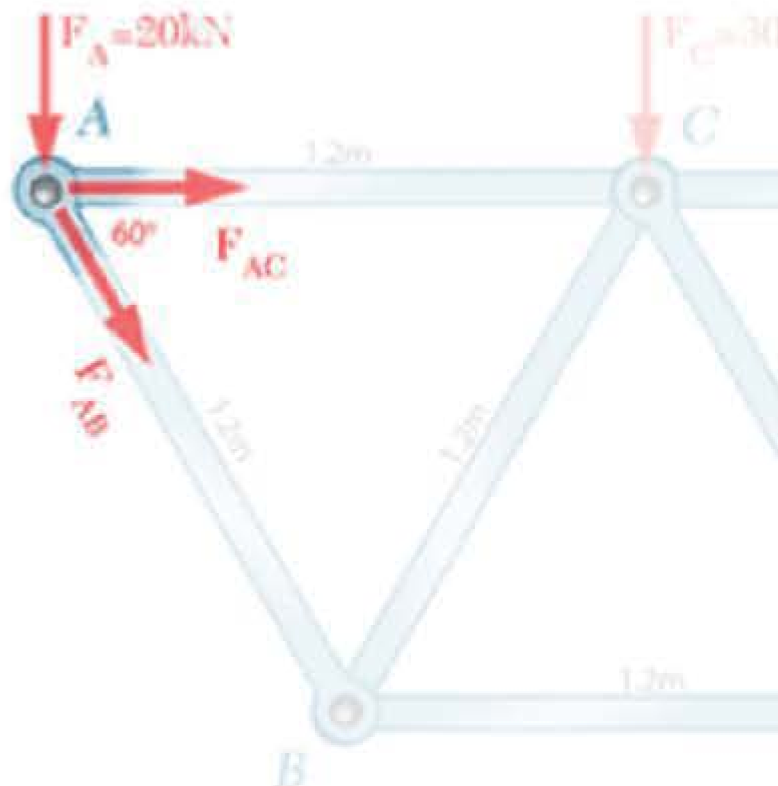
Step 1: Look for a joint with a maximum of two unknowns. Draw a free body diagram of Joint *A*. Note: We might have chosen joints *A* or *E*. We chose *A* to work from left to right.

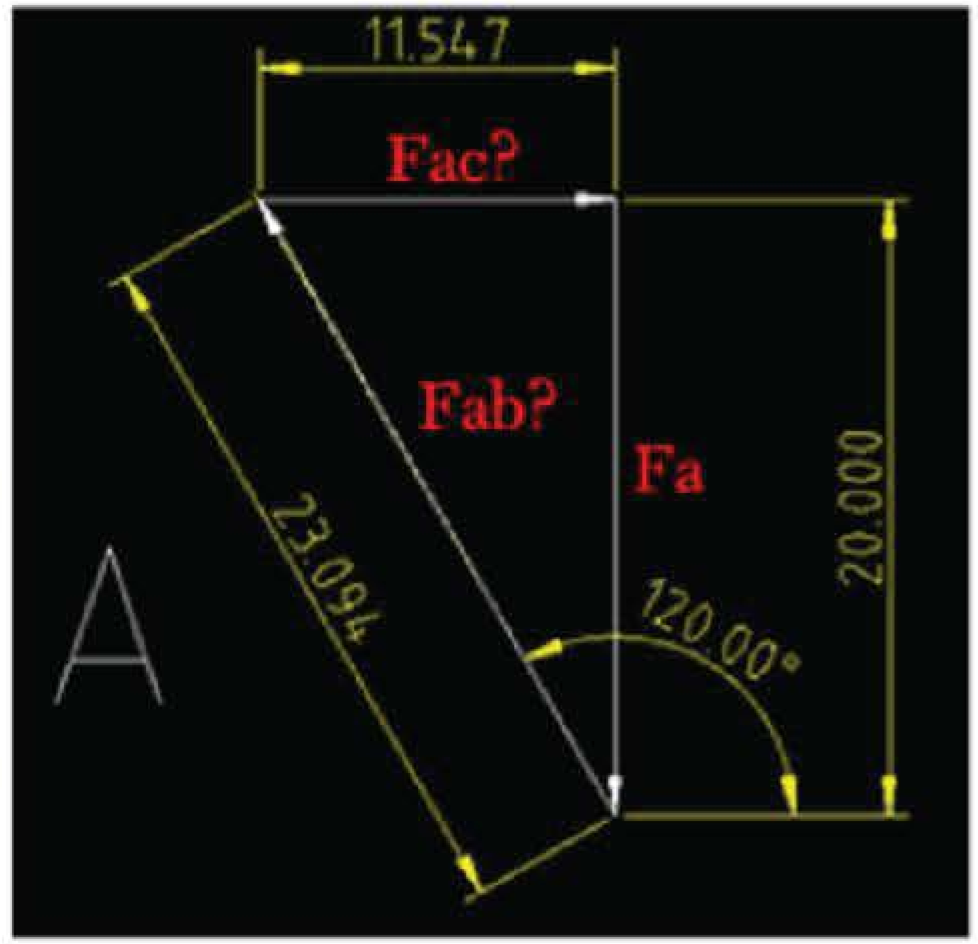
Begin with known reactions	Step 1 (A): Find a solvable joint and draw free body diagram	Step 2 (A): Equilibrium for Joint *A*	Step 3 (A): Equilibrium for members AC, AB	Step 1 (B): Find a solvable joint and draw free body diagram	Step 2 (B): Equilibrium for Joint *B*	Step 3 (B): Equilibrium for members BD, BC

GIVE FEEDBACK

OK

Solve for first two joints in a truss by method of joints (graphically)





Step 2: Solve equilibrium for Joint *A*. There are two unknowns $-F_{AC}$ and F_{AB}, which are solvable in a force triangle since all angles are known.

We must interpret the force triangle as showing the forces acting to the joint, which is Joint *A:*

$F_{AC} = 11.547\,\text{kN}\,@\,0^\circ$ Pulling the joint, Member AC in tension

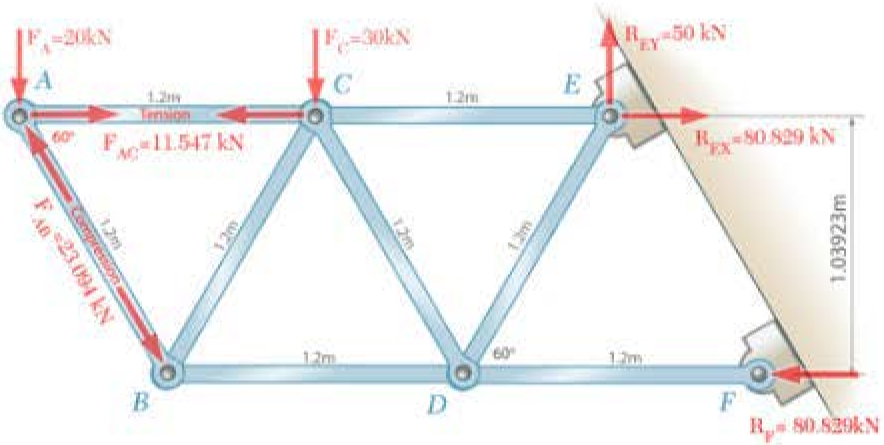
$F_{AB} = 23.094\,\text{kN}\,@\,120^\circ$ Pushing, AB in compression, direction reversed

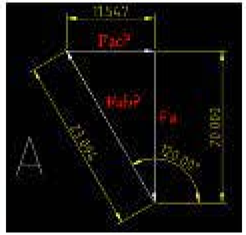
Begin with known reactions	Step 1 (A): Find a solvable joint and draw free body diagram	Step 2 (A): Equilibrium for Joint *A*	Step 3 (A): Equilibrium for members AC, AB	Step 1 (B): Find a solvable joint and draw free body diagram	Step 2 (B): Equilibrium for Joint *B*	Step 3 (B): Equilibrium for members BD, BC

GIVE FEEDBACK

OK

Solve for first two joints in a truss by method of joints (graphically)





Step 3: Transfer these forces from Joint *A* to adjacent joints B and C. (This is really equilibrium of members AC and AB). Members in compression *push* both joints while members in tension *pull* both joints.

$F_{AC} = 11.547\ \text{kN} @ 0°$ (Tension); Joint C becomes: $F_{AC} = 11.547\ \text{kN} @ 180°$

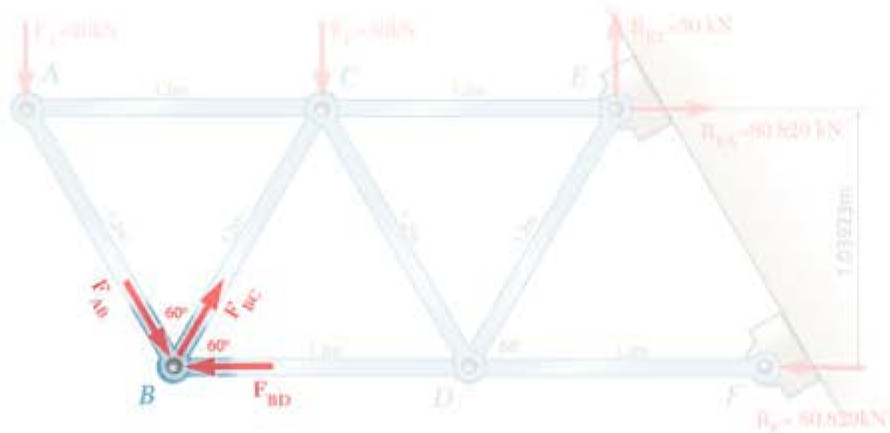
$F_{AB} = 23.094\ \text{kN} @ 120°$ (Compression); Joint B becomes: $F_{AB} = 11.547\ \text{kN} @ 300°$

Begin with known reactions	Step 1 (A): Find a solvable joint and draw free body diagram	Step 2 (A): Equilibrium for Joint *A*	Step 3 (A): Equilibrium for members AC, AB	Step 1 (B): Find a solvable joint and draw free body diagram	Step 2 (B): Equilibrium for Joint *B*	Step 3 (B): Equilibrium for members BD, BC

GIVE FEEDBACK

OK

Solve for first two joints in a truss by method of joints (graphically)



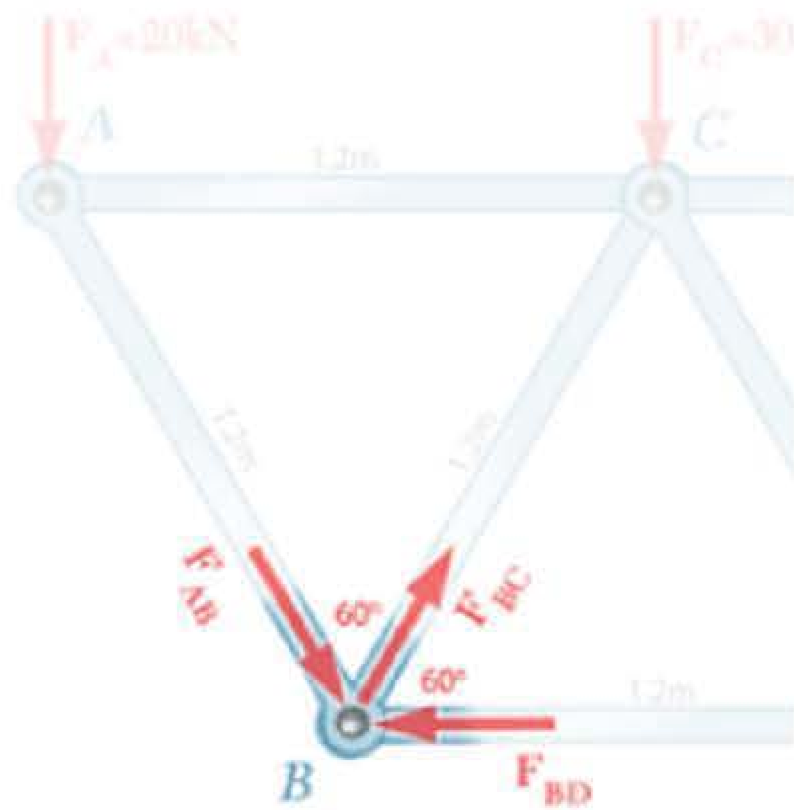
Step 1: Back to Step 1 again. Looking for a joint with a maximum of two unknowns, we choose Joint *B*. Draw a free body diagram of Joint *B*. (We cannot choose Joint *C* because it has three unknowns.)

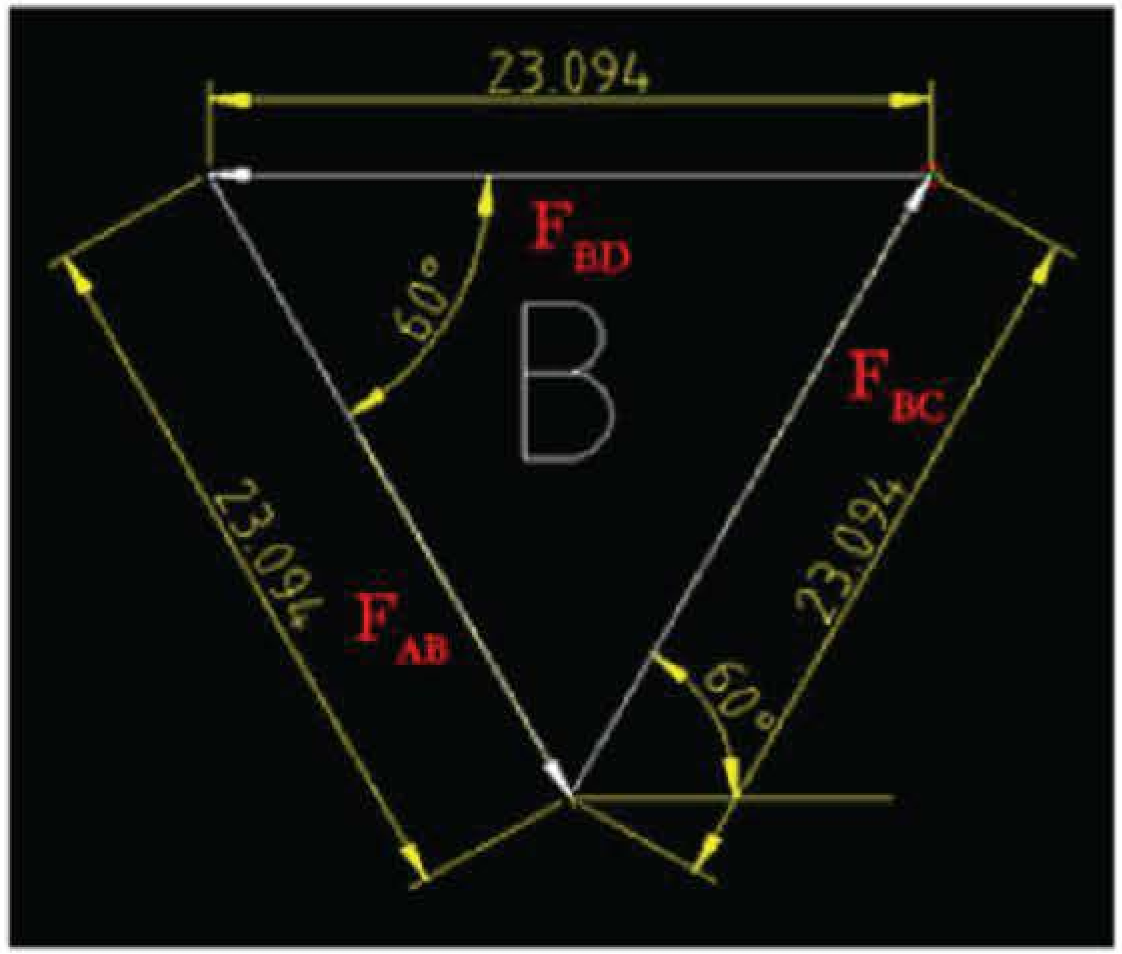
Begin with known reactions	Step 1 (A): Find a solvable joint and draw free body diagram	Step 2 (A): Equilibrium for Joint *A*	Step 3 (A): Equilibrium for members AC, AB	Step 1 (B): Find a solvable joint and draw free body diagram	Step 2 (B): Equilibrium for Joint *B*	Step 3 (B): Equilibrium for members BD, BC

GIVE FEEDBACK

OK

Solve for first two joints in a truss by method of joints (graphically)





Step 2: Solve equilibrium for Joint *B*. There are two unknowns, $-F_{BC}$ and F_{BD}, which are solvable in a force triangle since all angles are known.

We must interpret the force triangle as showing the forces acting to the joint, which is Joint *B*:

$F_{BD} = 23.094\ \mathrm{kN} @ 180°$ Pushing the joint, Member BD in compression

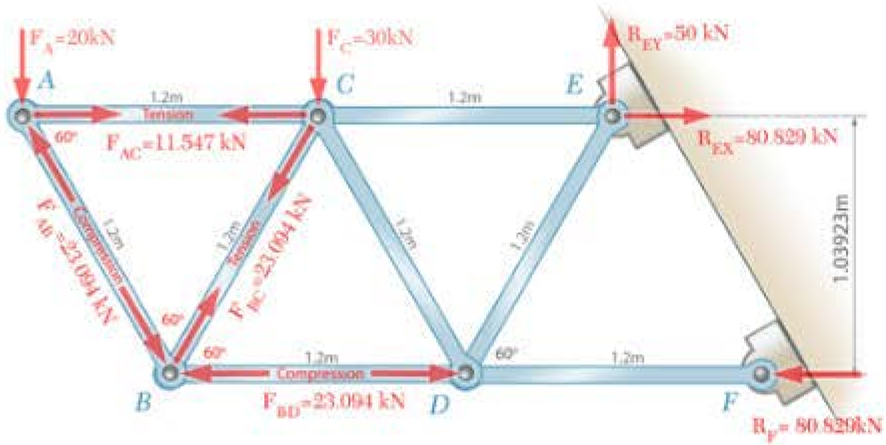
$F_{BC} = 23.094\ \mathrm{kN} @ 60°$ Pulling the joint, Member BC in tension

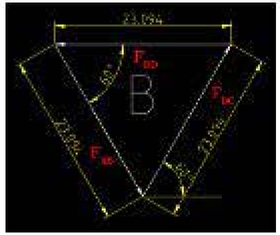
Begin with known reactions	Step 1 (A): Find a solvable joint and draw free body diagram	Step 2 (A): Equilibrium for Joint *A*	Step 3 (A): Equilibrium for members AC, AB	Step 1 (B): Find a solvable joint and draw free body diagram	Step 2 (B): Equilibrium for Joint *B*	Step 3 (B): Equilibrium for members BD, BC

GIVE FEEDBACK

OK

Solve for first two joints in a truss by method of joints (graphically)





Step 3: Transfer these forces from Joint *B* to adjacent joints *C* and *D*. (This is really equilibrium of members BC and BD). Members in compression *push* both joints while members in tension *pull* both joints.

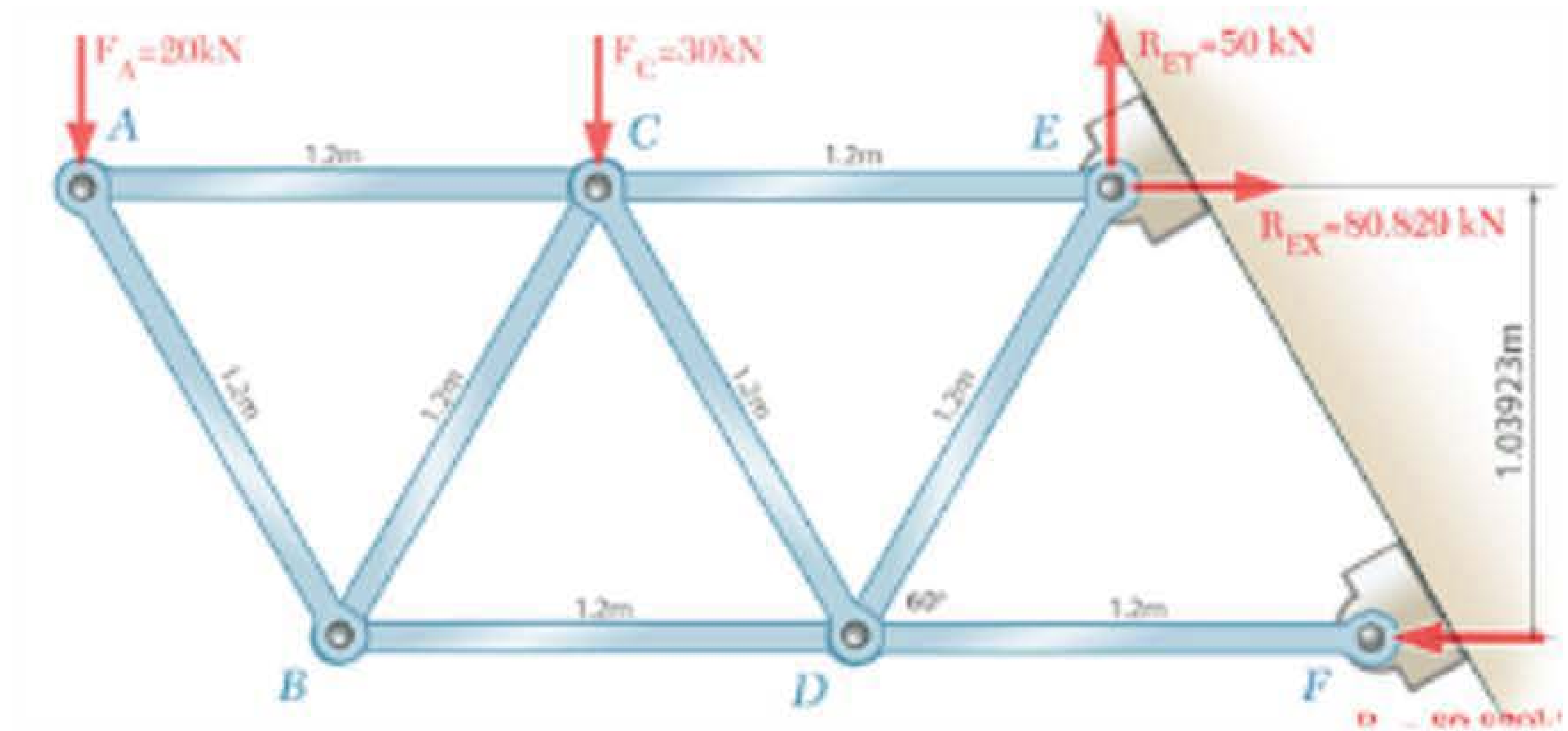
$F_{BD} = 23.094\ \text{kN}@0°$ (Compression); Joint D becomes: $F_{BD} = 23.094\ \text{kN}@0°$

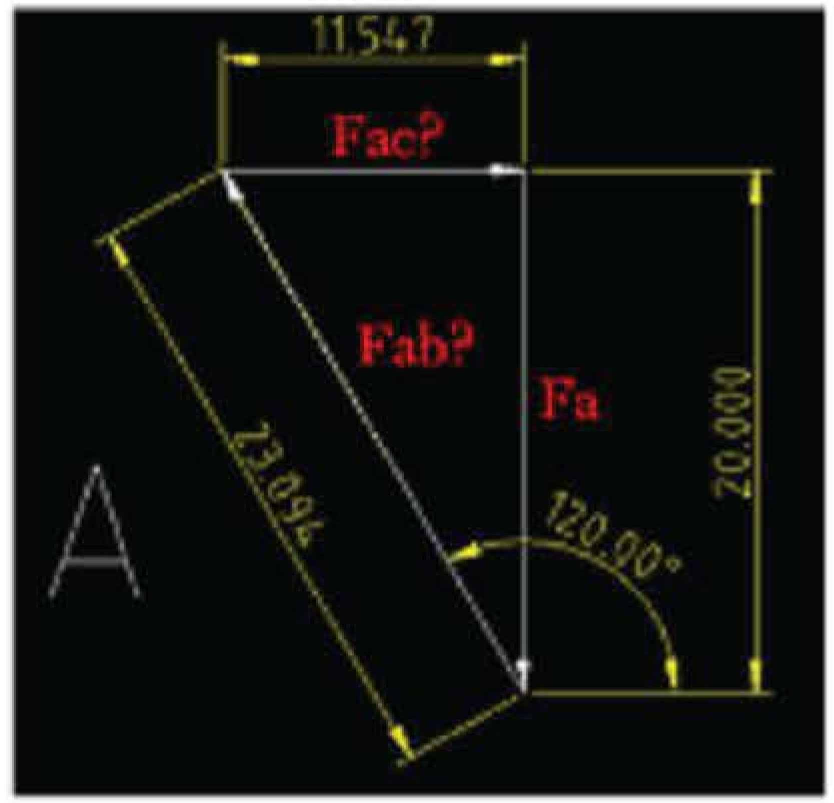
$F_{BC} = 23.094\ \text{kN}@60°$ (Tension); Joint B becomes: $F_{BC} = 11.547\ \text{kN}@240°$

Begin with known reactions	Step 1 (A): Find a solvable joint and draw free body diagram	Step 2 (A): Equilibrium for Joint *A*	Step 3 (A): Equilibrium for members AC, AB	Step 1 (B): Find a solvable joint and draw free body diagram	Step 2 (B): Equilibrium for Joint *B*	Step 3 (B): Equilibrium for members BD, BC

GIVE FEEDBACK

OK





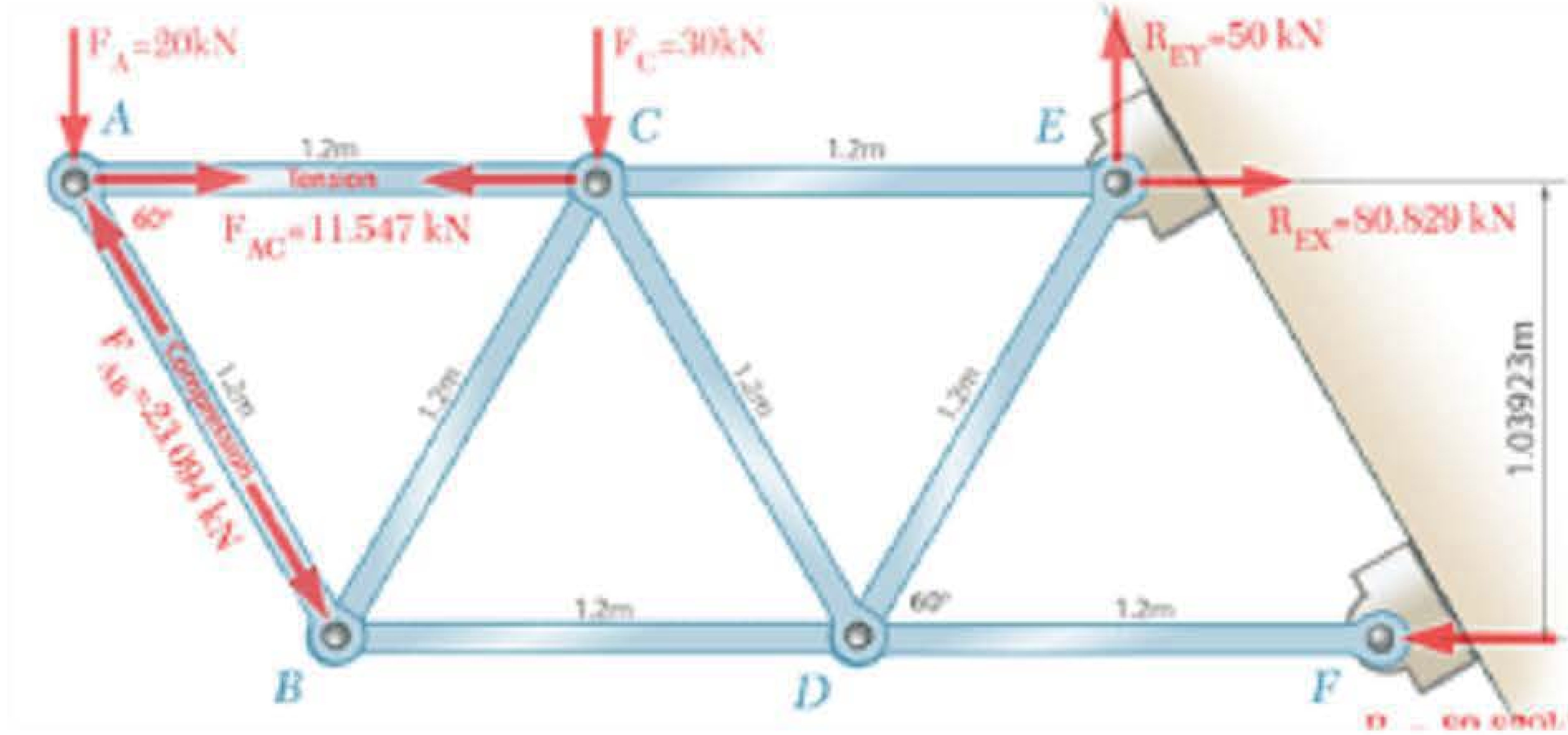
Interpreting from the force polygon for Joint *A*:

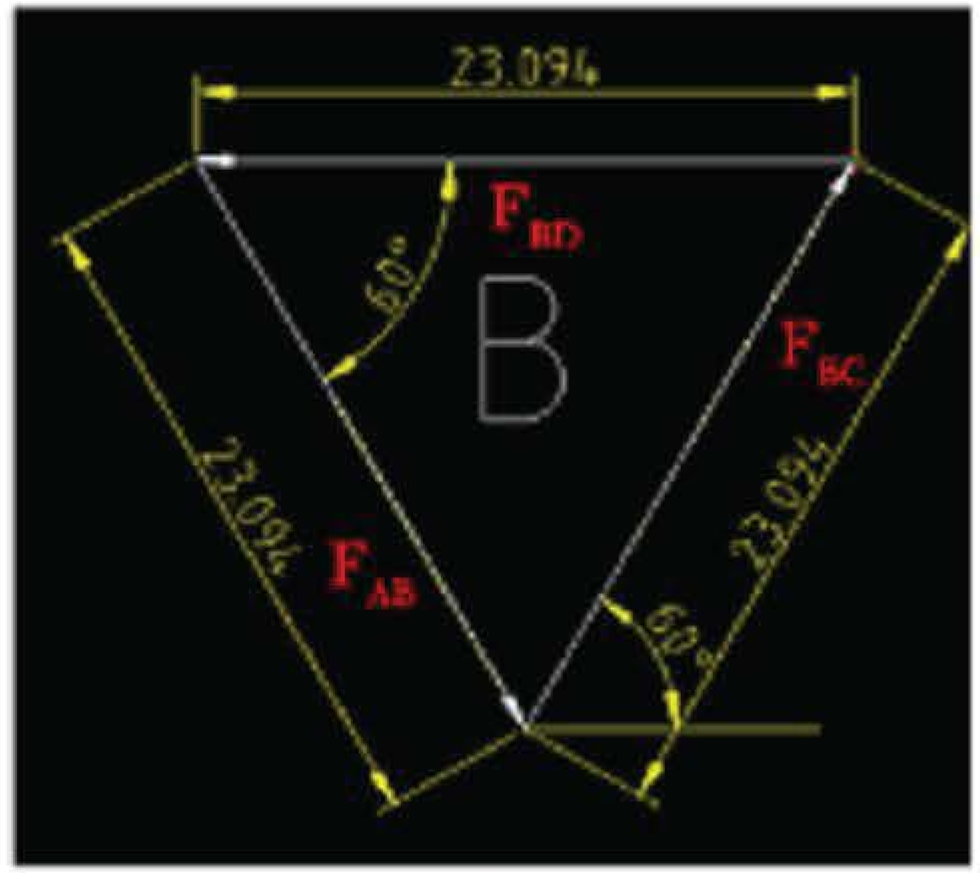
Member AB is in (please select) ▼ and Member AC is in (please select) ▼.

Submit

Do you know the answer?

I KNOW IT **THINK SO** **UNSURE** **NO IDEA**





Interpreting the force polygon for Joint *B*:

Member BD is in (please select) ▼ and Member BC is in (please select) ▼.

Submit

Do you know the answer?

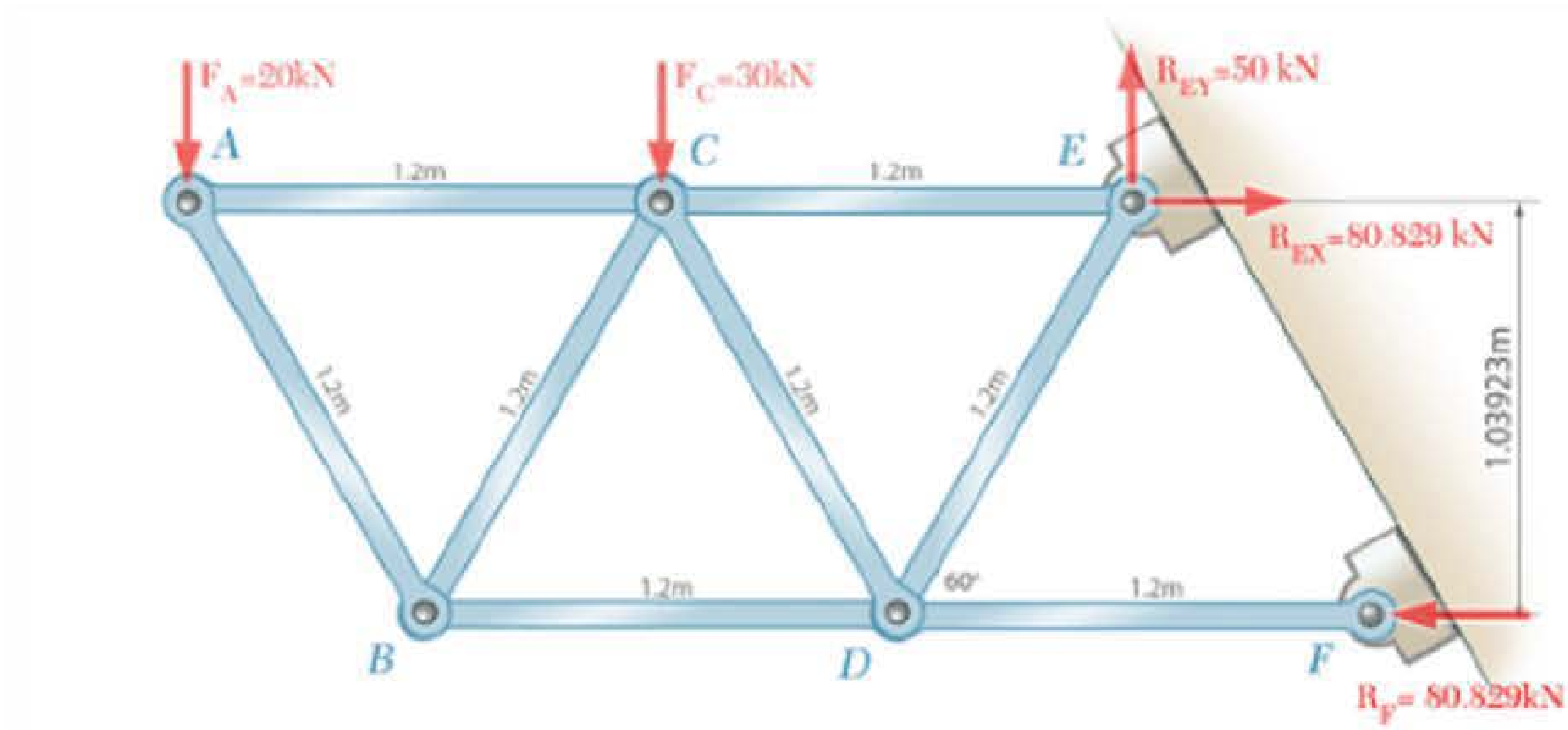
I KNOW IT

THINK SO

UNSURE

NO IDEA

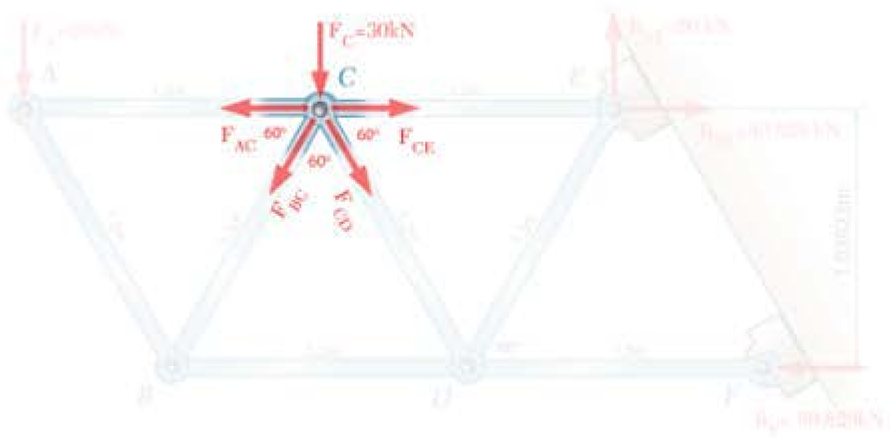
Select all joints that can be solved immediately by method of joints (i.e. not requiring another joint to be solved first):



Check all that apply.

- [ ] Joint *C*
- [ ] Joint *A*
- [ ] Joint *E*
- [ ] Joint *D*
- [ ] Joint *B*
- [ ] Joint *F*

Complete the last few joints in a truss by method of joints (graphically)



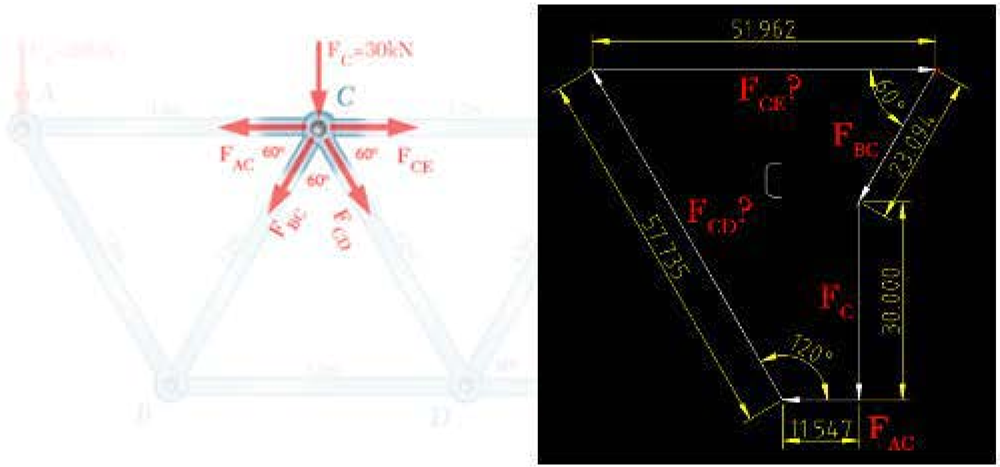
Step 1: Looking for a joint with a maximum of two unknowns, we choose Joint *C*. Draw a free body diagram of Joint *C*. (We cannot choose Joint *D* because it has three unknowns.)

Step 1 (C): Find a solvable joint and draw free body diagram	Step 2 (C): Equilibrium for Joint *C*	Step 3 (C): Equilibrium for members CD, CE	Step 1 (D): Find a solvable joint and draw free body diagram	Step 2 (D): Equilibrium for Joint *D*	Step 3 (D): Equilibrium for members DE, DF	Check Joint *E*

GIVE FEEDBACK

OK

Complete the last few joints in a truss by method of joints (graphically)



Step 2: Solve equilibrium for Joint *C*. There are two unknowns, $-F_{CD}$ and F_{CE}, which are solvable in a five-sided force polygon where all angles are known.

We must interpret the force polygon as showing the forces acting to the joint, which is Joint *C*:

$F_{CD} = 57.735\ \mathrm{kN} @ 120°$ Pushing the joint, Member CD in compression

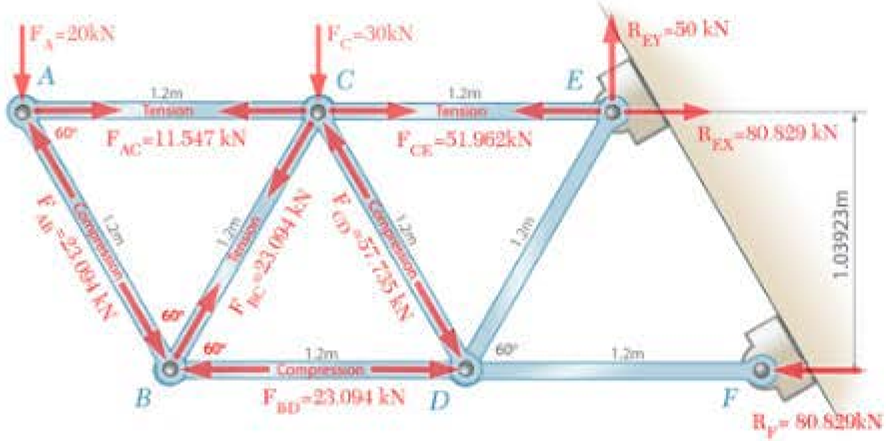
$F_{CE} = 51.962\ \mathrm{kN} @ 0°$ Pulling the joint, Member CE in tension

Step 1 (C): Find a solvable joint and draw free body diagram	Step 2 (C): Equilibrium for Joint *C*	Step 3 (C): Equilibrium for members CD, CE	Step 1 (D): Find a solvable joint and draw free body diagram	Step 2 (D): Equilibrium for Joint *D*	Step 3 (D): Equilibrium for members DE, DF	Check Joint *E*

GIVE FEEDBACK

OK

Complete the last few joints in a truss by method of joints (graphically)



Step 3: Transfer these forces from Joint *C* to adjacent joints *D* and *E*. (This is really equilibrium of members CD and CE). Members in compression *push* both joints while members in tension *pull* both joints.

F_{CD} = 57.735 kN @ 120° (Compression); Joint D becomes: F_{CD} = 57.735 kN @ 300°

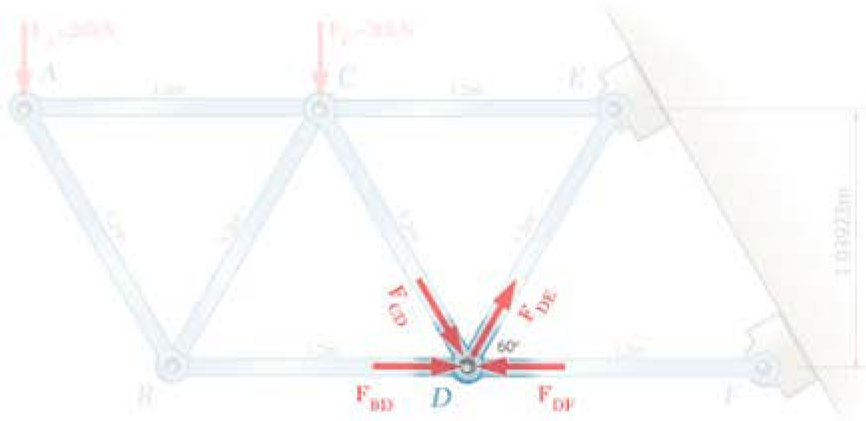
F_{CE} = 51.962 kN @ 0° (Tension); Joint E becomes: F_{CE} = 51.962 kN @ 180°

Step 1 (C): Find a solvable joint and draw free body diagram	Step 2 (C): Equilibrium for Joint *C*	Step 3 (C): Equilibrium for members CD, CE	Step 1 (D): Find a solvable joint and draw free body diagram	Step 2 (D): Equilibrium for Joint *D*	Step 3 (D): Equilibrium for members DE, DF	Check Joint *E*

GIVE FEEDBACK

OK

Complete the last few joints in a truss by method of joints (graphically)



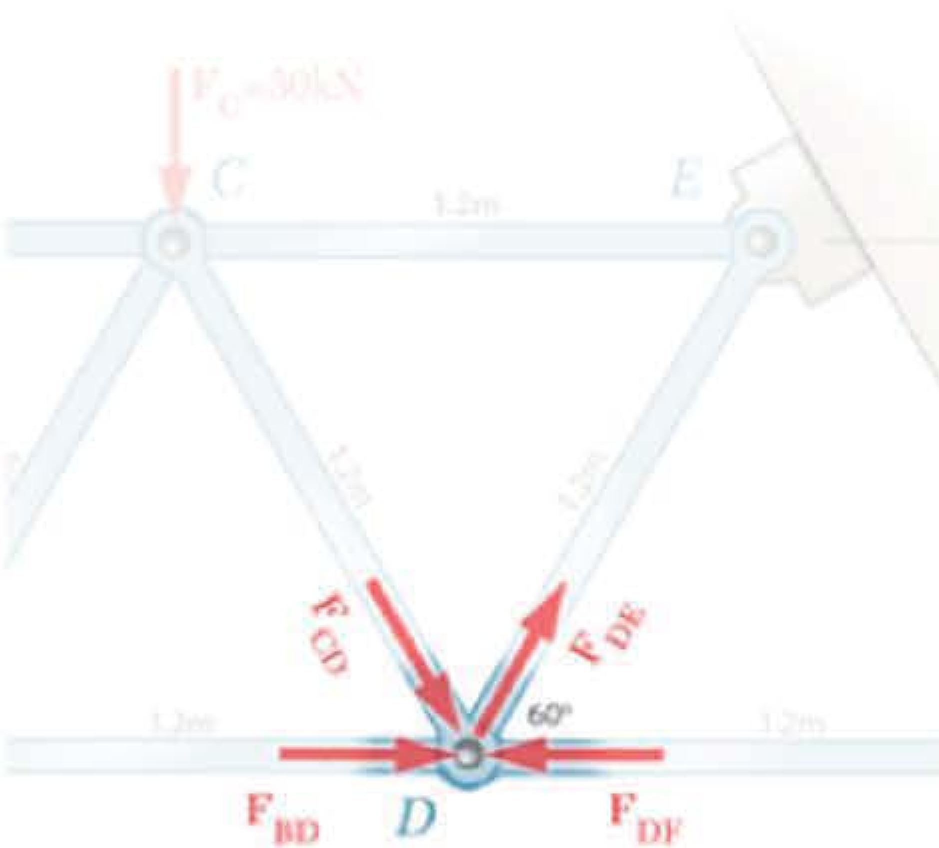
Step 1: Looking for a joint with a maximum of two unknowns, we choose Joint *D*. Draw a free body diagram of Joint *D*. (We can also choose Joint *E*, with two unknowns.)

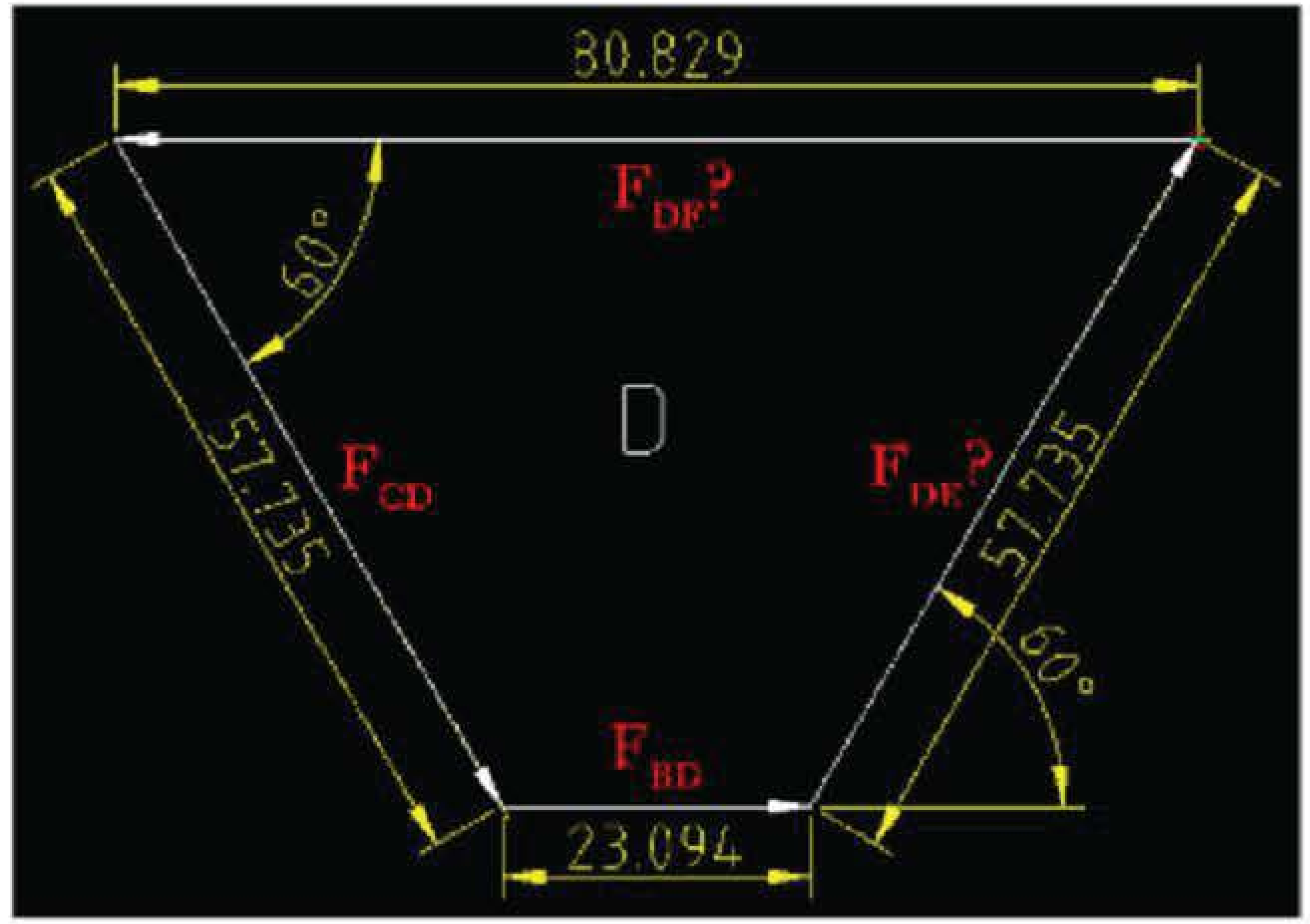
Step 1 (C): Find a solvable joint and draw free body diagram	Step 2 (C): Equilibrium for Joint *C*	Step 3 (C): Equilibrium for members CD, CE	Step 1 (D): Find a solvable joint and draw free body diagram	Step 2 (D): Equilibrium for Joint *D*	Step 3 (D): Equilibrium for members DE, DF	Check Joint *E*

GIVE FEEDBACK

OK

Complete the last few joints in a truss by method of joints (graphically)





Step 2: Solve equilibrium for Joint *D*. There are two unknowns, F_{DE} and F_{DF}, which are solvable in this force polygon since all angles are known.

We must interpret the polygon as showing the forces acting to the joint, which is Joint *D*:

$F_{DF} = 80.829\,\text{kN} @ 180°$ Pushing the joint, Member DF in compression

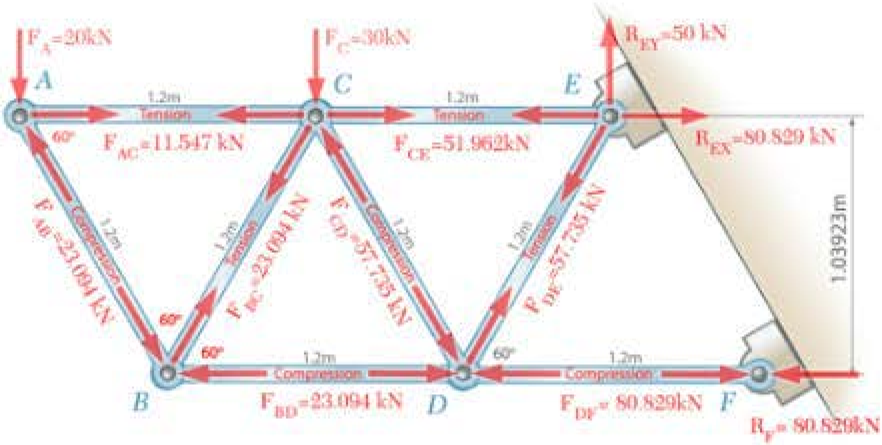
$F_{DE} = 57.735\,\text{kN} @ 60°$ Pulling the joint, Member DE in tension

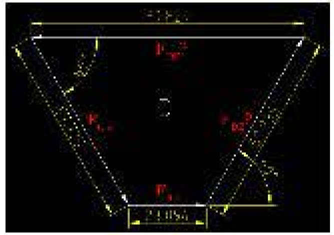
Step 1 (C): Find a solvable joint and draw free body diagram	Step 2 (C): Equilibrium for Joint *C*	Step 3 (C): Equilibrium for members CD, CE	Step 1 (D): Find a solvable joint and draw free body diagram	Step 2 (D): Equilibrium for Joint *D*	Step 3 (D): Equilibrium for members DE, DF	Check Joint *E*

GIVE FEEDBACK

OK

Complete the last few joints in a truss by method of joints (graphically)





Step 3: Transfer these forces from Joint *D* to adjacent joints *E* and *F*. (This is really equilibrium of members DE and DF.) Members in compression *push* both joints while members in tension *pull* both joints.

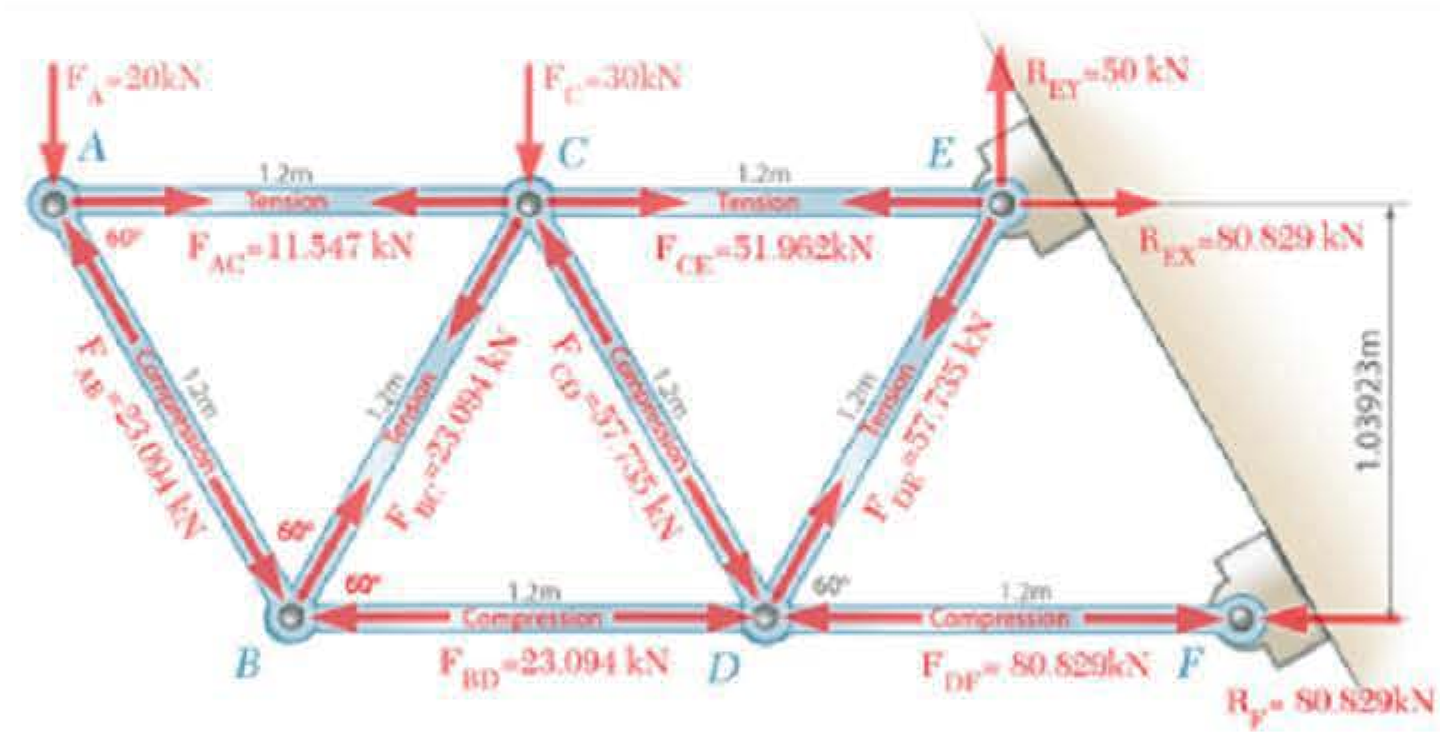
$F_{DF} = 80.829\ \text{kN} @ 180°$ (Compression); Joint F becomes: $F_{DF} = 80.829\ \text{kN} @ 0°$
$F_{DE} = 57.735\ \text{kN} @ 60°$ (Tension); Joint E becomes: $F_{DE} = 57.735\ \text{kN} @ 240°$

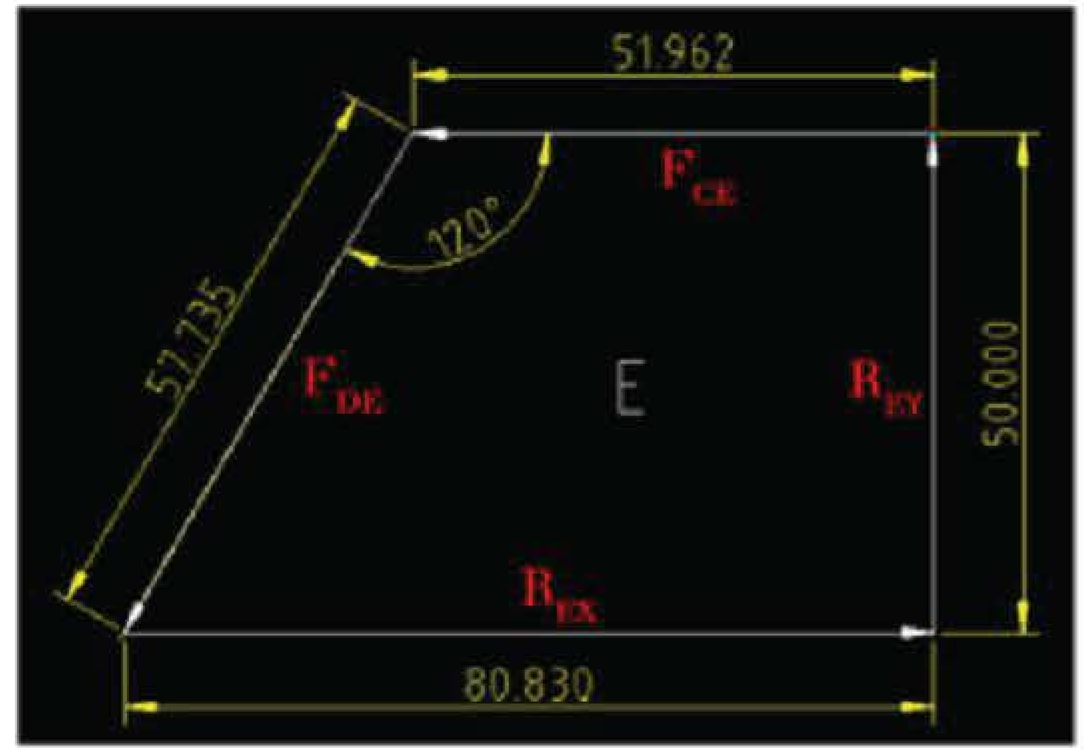
Step 1 (C): Find a solvable joint and draw free body diagram	Step 2 (C): Equilibrium for Joint *C*	Step 3 (C): Equilibrium for members CD, CE	Step 1 (D): Find a solvable joint and draw free body diagram	Step 2 (D): Equilibrium for Joint *D*	Step 3 (D): Equilibrium for members DE, DF	Check Joint *E*

GIVE FEEDBACK

OK

Complete the last few joints in a truss by method of joints (graphically)





We have completed the truss. Joint *F* is obviously correct. We can also check equilibrium at Joint *E* since all forces are known. The force polygon is correct.

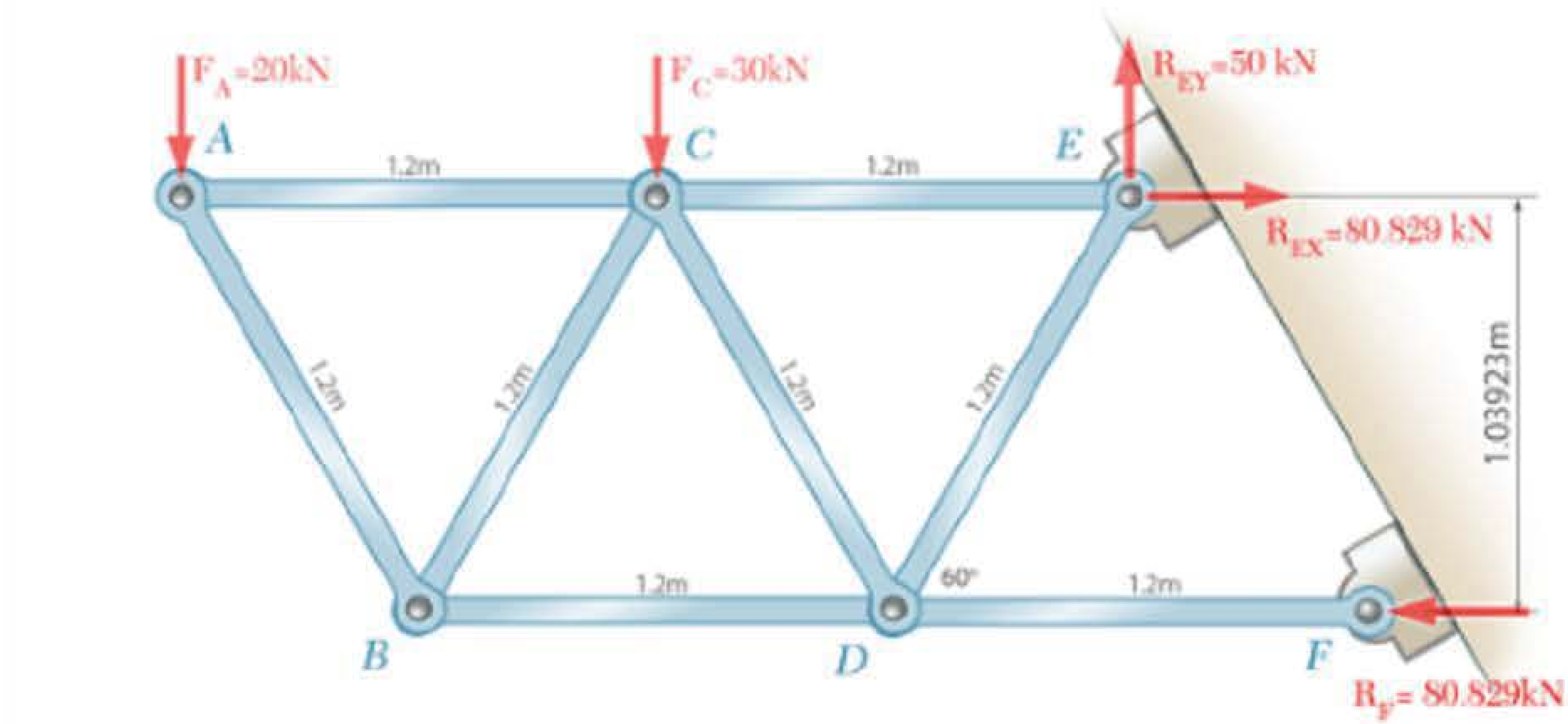
Note the small discrepency with R_{EX}. According to the reaction calculations we should have 80.829 kN, but according to this force polygon we get 80.830 kN. This is a rounding off error accumulated through the process. Always use a few extra significant figures during calculations and drop them in the final answer. Our answer is correct to four significant figures (i.e. 80.30 kN).

Step 1 (C): Find a solvable joint and draw free body diagram	Step 2 (C): Equilibrium for Joint *C*	Step 3 (C): Equilibrium for members CD, CE	Step 1 (D): Find a solvable joint and draw free body diagram	Step 2 (D): Equilibrium for Joint *D*	Step 3 (D): Equilibrium for members DE, DF	Check Joint *E*

GIVE FEEDBACK

OK

Beginning from the support Joint *E*, sort the alternative order of solving joints by the method of joints:



↑↓ **Place these in the proper order.**

Joint *C*

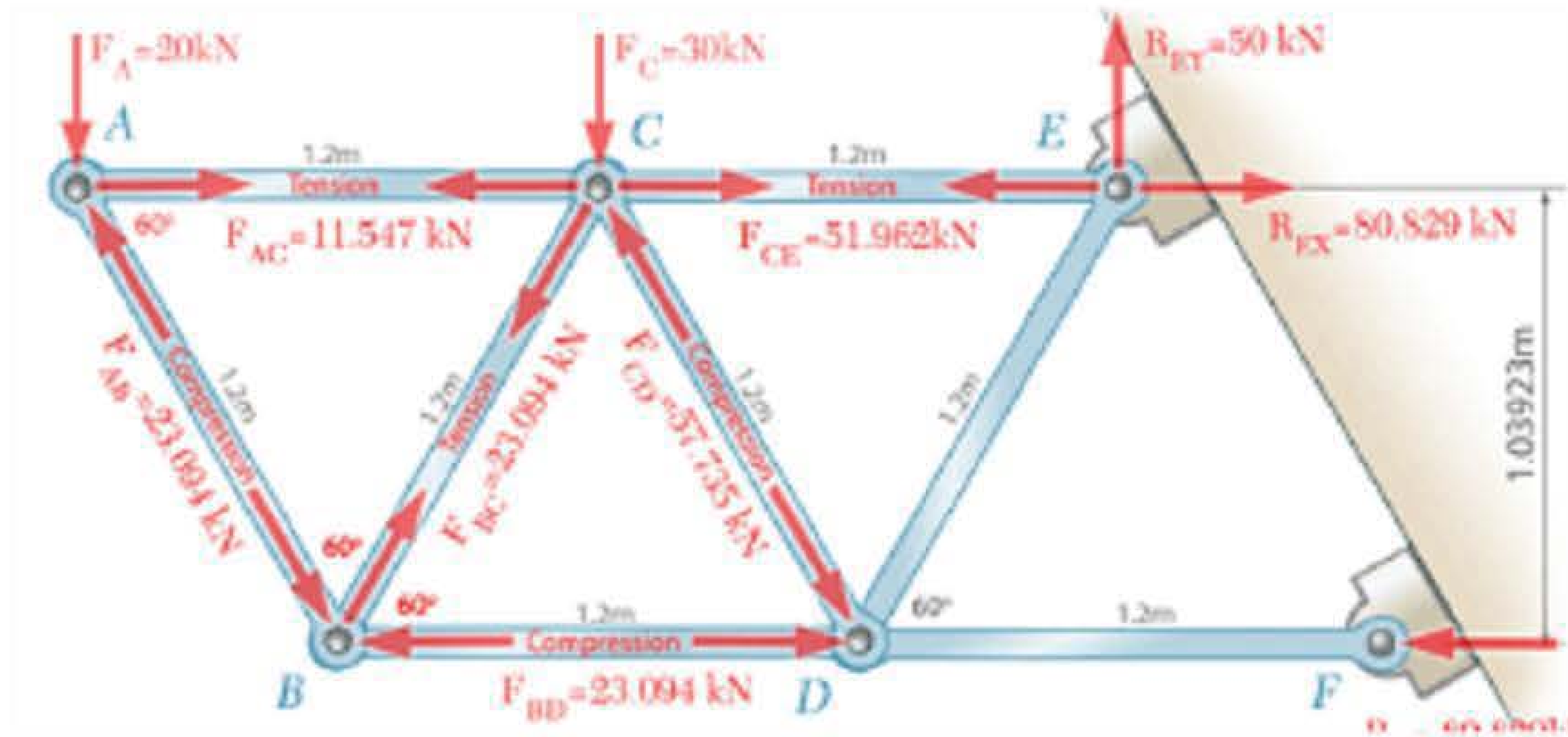
Joint *D*

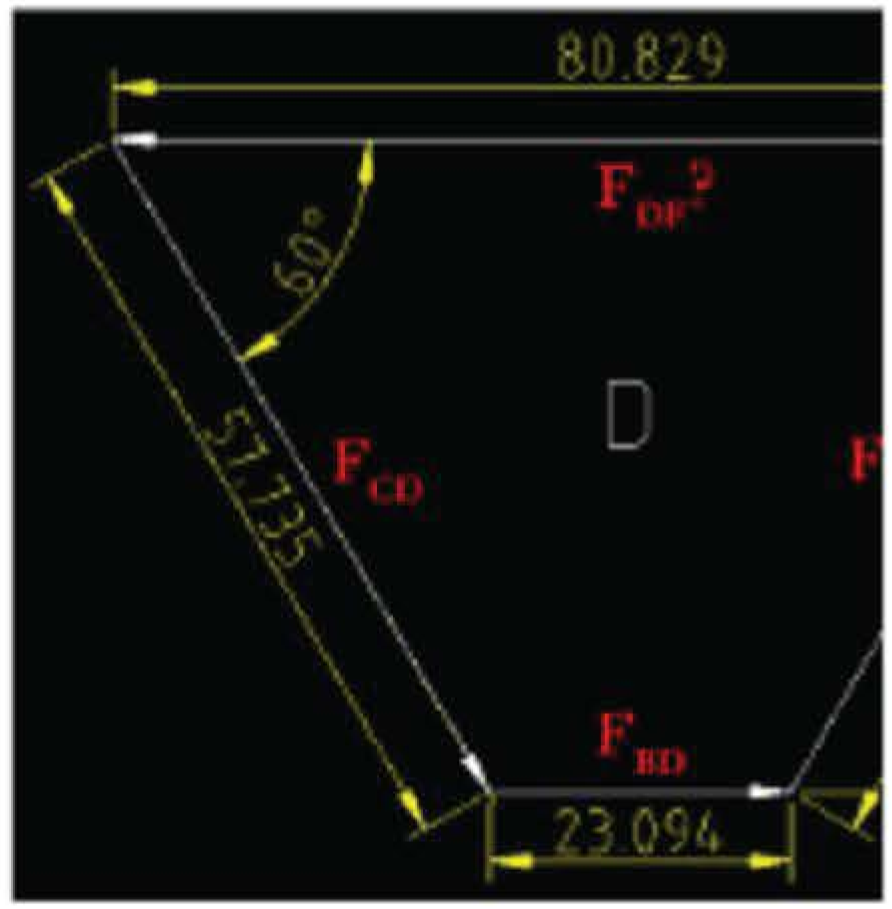
Joint *E*

Joint *A*

Joint *B*

Joint *F*





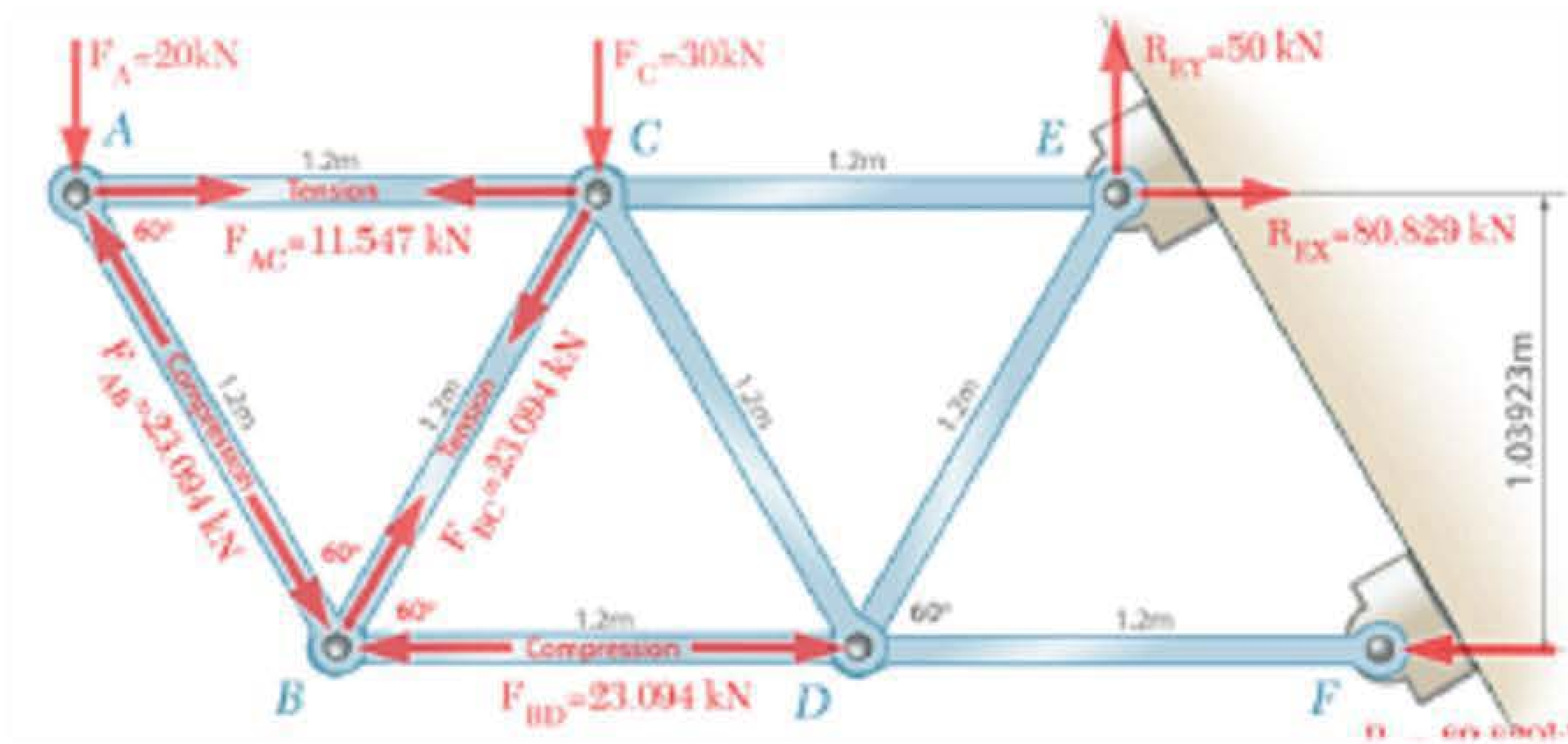
Interpreting the force polygon for Joint *D*:

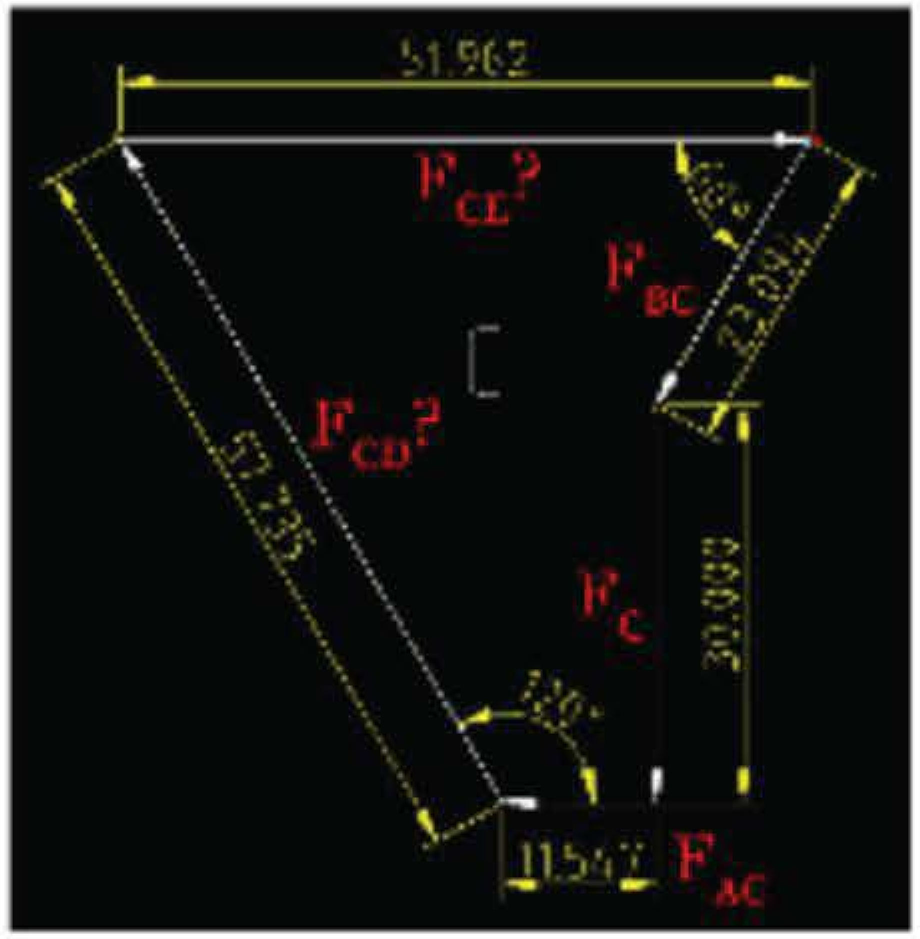
Member DE is in (please select) ▼ and Member DF is in (please select) ▼.

Submit

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA





Interpreting the force polygon for Joint *C*:

Member CE is in (please select) ▼ and Member CD is in (please select) ▼.

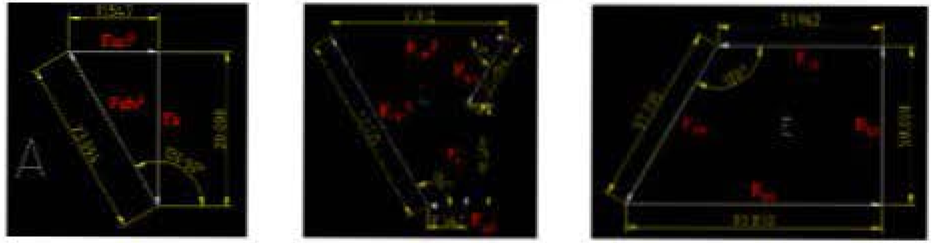
Submit

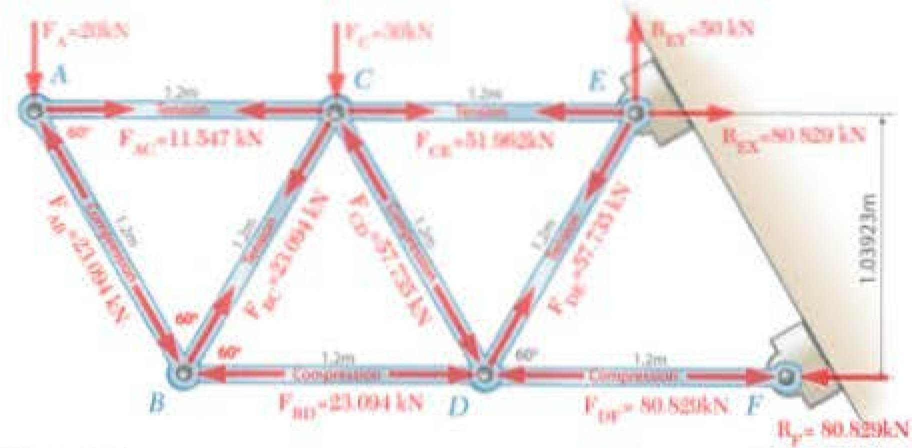
Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

This overview shows the force polygons for each joint in the truss.

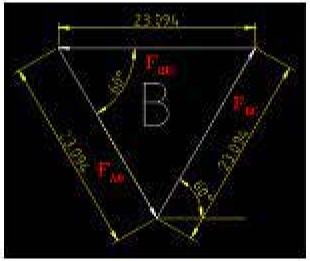
Six force polygons for all joints in the truss are used to solve every member.

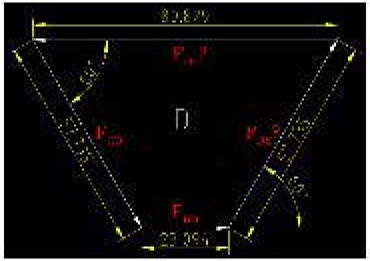




GIVE FEEDBACK

CONTINUE >

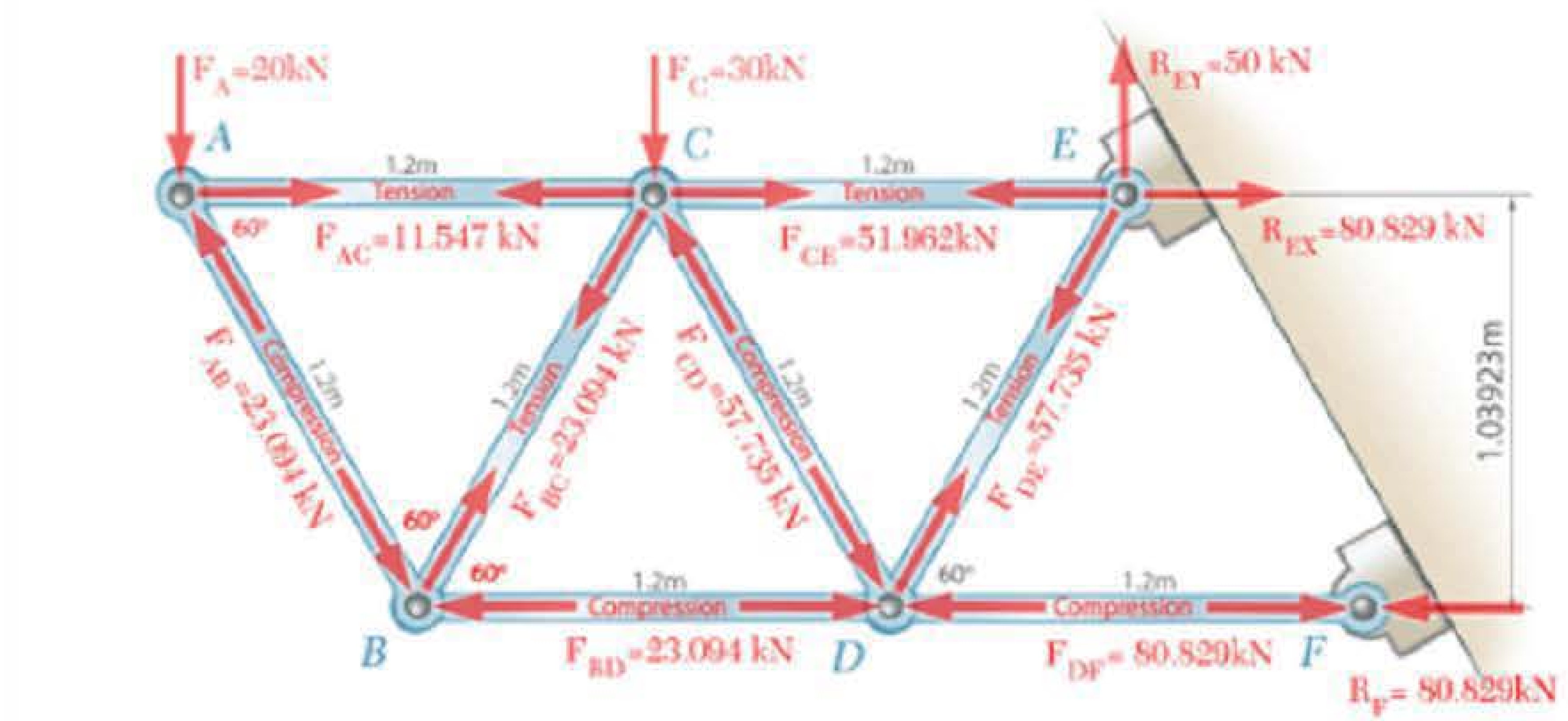




Member	Force	Type
AB	23.094 kN	Compression
AC	11.547 kN	Tension
BC	23.094 kN	Tension
BD	23.094 kN	Compression
CD	57.735 kN	Compression
CE	51.962 kN	Tension
DE	57.735 kN	Tension
DF	80.829 kN	Compression

< BACK GIVE FEEDBACK OK

Select all correct statements about the truss shown below.



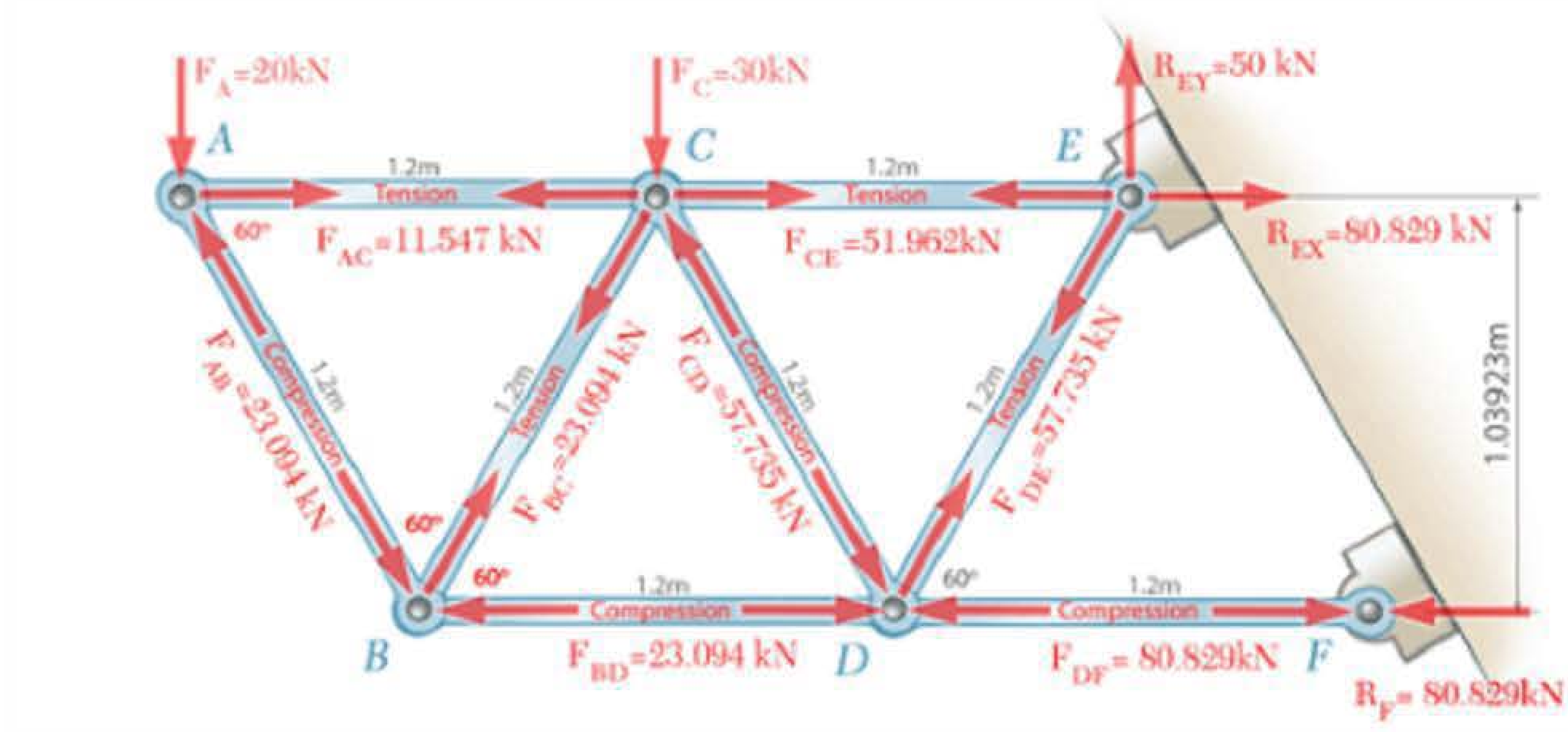
Check all that apply.

- [ ] The top chords (AC, CE) are in tension, the bottom chords (BD, DF) in compression, and the webs (AB, BC, CD, DE) have a mixture of tension and compression
- [ ] The forces in members increase nearer the supports
- [ ] Every joint is in equilibrium except Joint *F*
- [ ] Members AC, CE, BC and DE could be replaced with cables rated to handle 60 kN with safety factor

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

If every member is the same, and the loads keep increasing, which internal member (web) will fail first?



Click the correct answer.

- Web members do not normally fail. It is usually the upper or lower chords.
- Member BC
- Member CD
- Member DE

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

As an alternative to the graphical technique, the method of joints can also be carried out using the mathematical technique.

Compare the mathematical and graphical techniques for the method of joints

The alternative to drawing force polygons is to consider each free body diagram and solve for the unknown forces mathematically, in terms of their horizontal and vertical components.

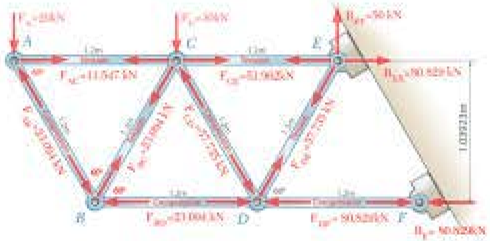
Those who are mathematically minded may prefer this alternative, which lends itself more readily to computer-assisted methods of analysis and design.

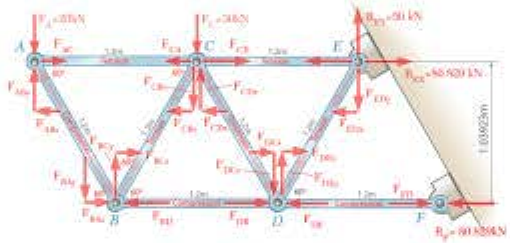
Others will probably choose the graphical method, which gives a better visual representation of the actual relationship between forces.

Of course with computer-aided design you get the best of both worlds: the precision of mathematical method and the ease of the graphical method.

GIVE FEEDBACK

OK





Solving a truss by the using the horizontal and vertical components of each force is called the (please select) ▼ method.

A better visual representation of the actual relationship between forces is usually achieved using the (please select) ▼ method.

Submit

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The mathematical method uses summation of X and Y components to analyse a truss. Compared to the graphical method, the mathematical components method has the following advantages:

Check all that apply.

- [ ] More readily adapted to computer programming
- [ ] Does not require accurate manual drafting or a computer-aided design program
- [ ] Is easier to do by hand
- [ ] Is more intuitive and easier to follow for beginners

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Outline the mathematical definition of equilibrium at any joint

The mathematical technique solves equilibrium through the use of force components.

For a general two-dimensional body there are three equilibrium equations (ΣM , ΣF_X , ΣF_Y). This is the case for non-concurrent forces on a body, such as when finding reactions.

However, when investigating the joints within a truss, there is no moment applied to any joint, and all forces at any joint are concurrent. So equilibrium can be established at any joint by summation of forces only. The sum of all forces at any joint must be zero.

The mathematical method utilises force components to determine equilibrium. The sum of all component forces at any joint must be zero, in both X (horizontal) and Y (vertical) directions.

Equilibrium

$$\overset{+}{\rightarrow} \Sigma F_x = 0$$

$$+\uparrow \Sigma F_y = 0$$

GIVE FEEDBACK

OK

When solving a planar truss by the method of joints, the majority of joints are of which type?

Click the correct answer.

- Concurrent
- Non-concurrent
- Co-linear
- Non-coplanar

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Here's a quick revision on components of a force, essential to the mathematical technique.

Outline the technique of taking components of a force

Forces are vectors. They are added graphically because they have both magnitude and angle. We can only add forces numerically (like numbers) it they are parallel. So by converting each force to components in the X and Y direction, we can add each axis numerically.

If the angle is in 360° format then we will get correct components for any force by:

$F_X = F\cos\theta, F_Y = F\sin\theta$

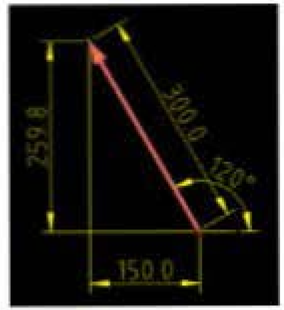
Example

A force is defined by 300 N @ 120°. Convert this force to X and Y components:

$F_X = 300\cos 120° = -150\text{ N}$

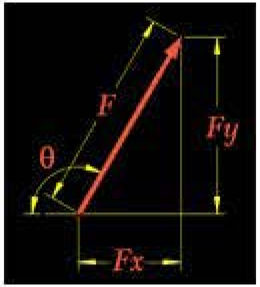
$F_Y = 300\sin 120° = 259.8\text{ N}$

Note that the X component is automatically negative using 360° angle format—the cosine of an angle in the second quadrant.



GIVE FEEDBACK

OK



Force Fx is 48 kN and Fy is 65 kN; find F in kN.

(Include units, use at least two decimal places.)

Clear

Clear line

?

Undo

Click and type your answer here

CHALLENGE

SUBMIT

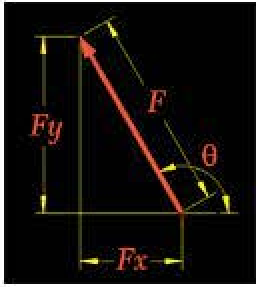
SHOW ANSWER

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



Force *F* is 73 kN at angle θ of 60 degrees. Find *Fx* in kN.

(Include units, use at least two decimal places.)

Clear

Clear line

?

Undo

Click and type your answer here

CHALLENGE

SUBMIT

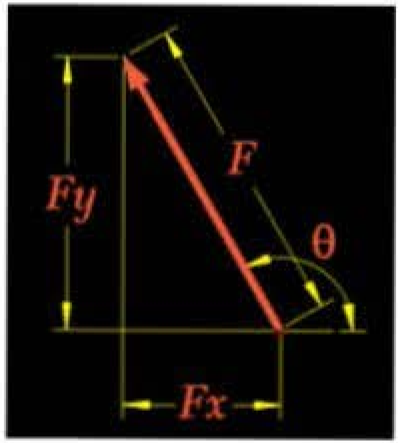
SHOW ANSWER

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



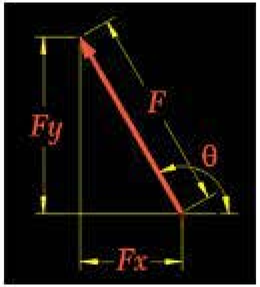
The X component of Force *F* is (please select).

The Y component of Force *F* is (please select).

Submit

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA



Force F is 73 kN at angle θ of 135 degrees. Find Fy in kN.

(Include units, use at least two decimal places.)

± ▾ kN ≤ ▾ π sin ▾

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

The mathematical technique turns out to be almost exactly the same as the graphical method. The only difference is in the second step: solving equilibrium. The graphical method uses a force polygon; the mathematical method uses summation of components.

Summarise the procedure of method of joints for any truss (mathematically)

The method of joints (mathematically) is exactly the same as the graphical method, except we use components in place of the force polygon.

These three steps get repeated until all joints are solved:

1. Choose a solvable joint (maximum two unknowns) and draw a free body diagram of that joint (we can guess the sense of the unknown forces to be finalised by equilibrium)
2. Solve equilibrium in X and Y directions ($\Sigma F x = 0, \Sigma F x = 0$) of that joint and find unknown forces (by components where $F_x = F \cos\theta$ and $F_y = F \sin\theta$)
3. Mirror these forces to adjacent joints with balancing forces on each member (once a force component is known on one end of the member, the same force is then opposite on the other end, rotated by 180 degrees)

GIVE FEEDBACK

OK

For method of joints (mathematically), sort these steps into order for the solution of each joint:

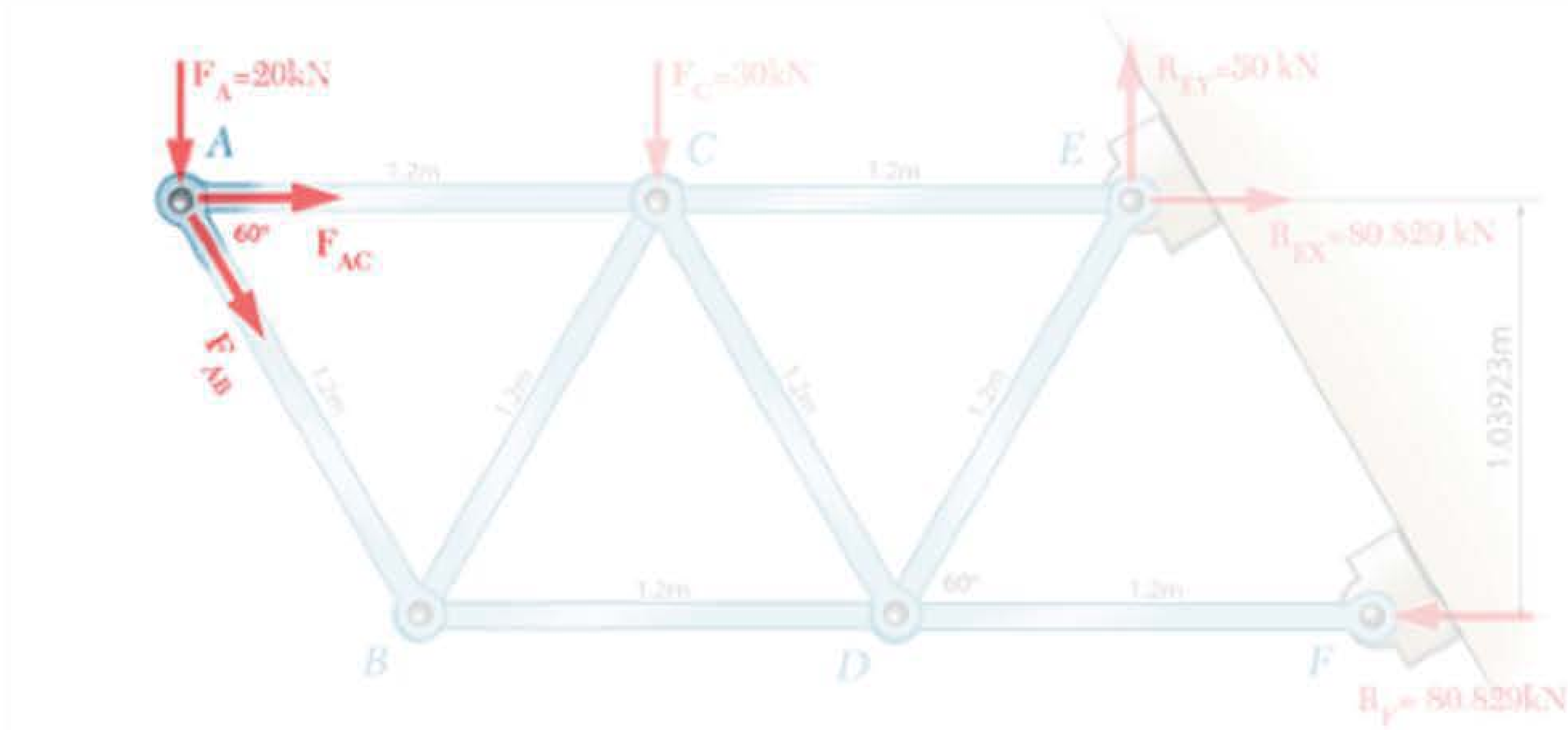
↑↓ Place these in the proper order.

- Choose a solvable joint with a maximum of two unknowns, then draw a free body diagram of that joint
- Solve equilibrium in X and Y directions ($\Sigma F\,x = 0, \Sigma F\,x = 0$) of that joint and find unknown forces (by components where $F_x = F \cos\theta$ and $F_y = F \sin\theta$)
- Mirror these forces to adjacent joints as balancing forces on each member
- Repeat this process from the first step until the truss is completed

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

What happens if we guess the wrong direction for an unknown force (such as F_{AB} or F_{AC}) applied to a joint?



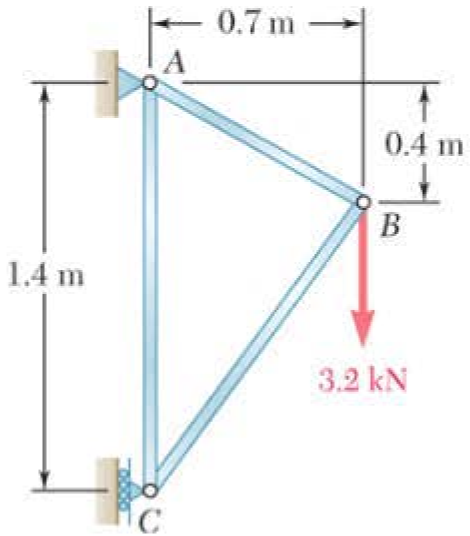
Check **all** that apply.

- [ ] The line of action is still correct and the sense is found from the force polygon
- [ ] The force polygon cannot add up to zero unless one unknown force is reversed (or both are reversed)
- [ ] The force polygon is solved but we will find out later that this joint was wrong
- [ ] The member will end up in tension instead of compression (and vice versa)

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Solve a simple truss by method of joints (mathematically)



Left figure: This simple structure is a truss because every member has two forces. We will use the mathematical method of joints (components).

Right figure: We normally calculate reactions first, then start truss analysis. To begin solving reactions, take moments at Pin joint *A*:

$$\Sigma M_A = (3.2\ \text{kN} \times 0.7) - (R_C \cdot 1.4) = 0$$

$$\therefore R_C = \frac{(3.2 \times 0.7)}{1.4} = 1.6\ \text{kN (to the right)}$$

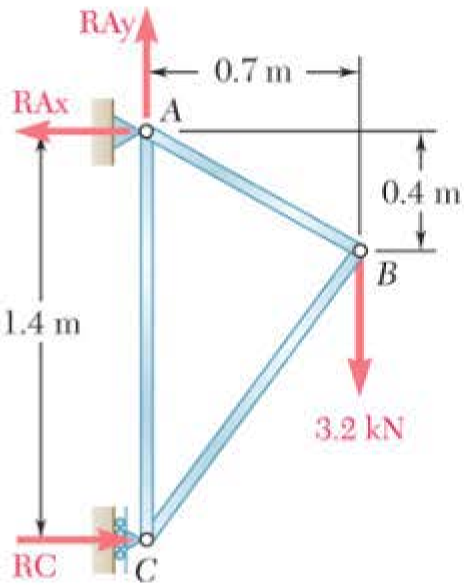
Now equilibrium of forces:

$$\Sigma F_X = R_C + R_{AX} = 1.6 + R_{AX} = 0$$

$$\therefore R_{AX} = -1.6\ \text{kN (to the left)}$$

$$\Sigma F_Y = 3.2 + R_{AY} = 0$$

$$\therefore R_A\ y = 3.2\ \text{kN (upwards)}$$

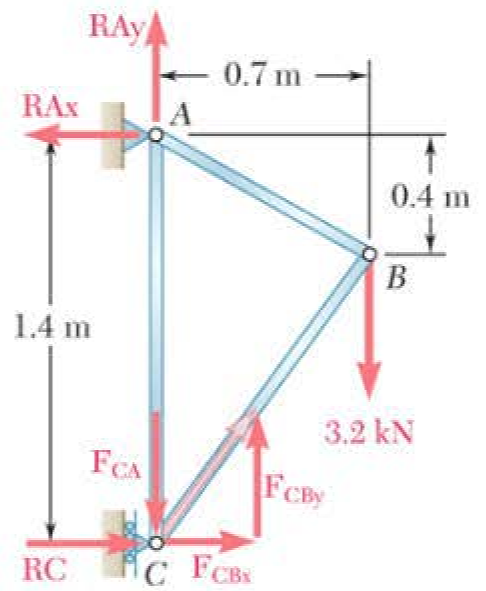


Find reactions | Solve Joint *C* | Solve Joint *A* | Completed truss | Difficult joints

GIVE FEEDBACK

OK

Solve a simple truss by method of joints (mathematically)



Left: According to equilibrium, we can solve any joint with a maximum of two unknowns. In this truss we can solve any joint *A*, *B* or *C* (all have two unknown forces).

This is where it is wise to pick the easiest way forward, Joint *C*. Equilibrium of X and Y component forces at Joint C:

$\Sigma F_X = R_C + R_{CBX} = 1.6 + R_{CBX} = 0$

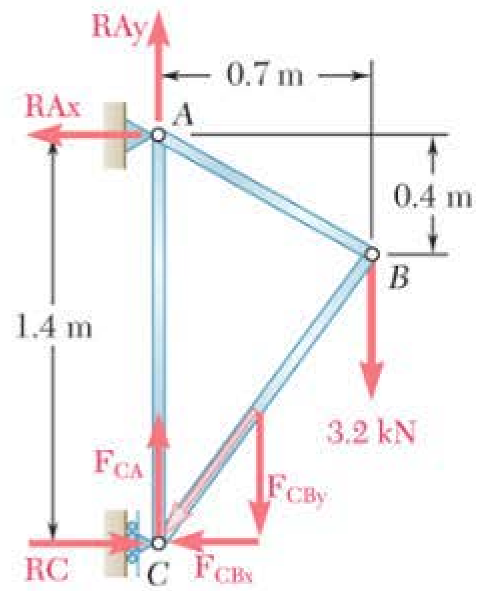
$\therefore R_{CBX} = -1.6$ kN (to the left)

Whoops, we guessed the wrong direction (see figure at right)—we know Member CB has rise of 1 over 0.7 run:

$F_{CBY} = F_{CBX} \cdot \dfrac{1}{0.7} = \dfrac{1.6}{0.7} = -2.286$ kN (to left)

$\Sigma F_Y = F_{CA} + F_{CBX} = F_{CA} - 2.286 = 0$

$\therefore F_{CA} = 2.286$ kN (upwards)

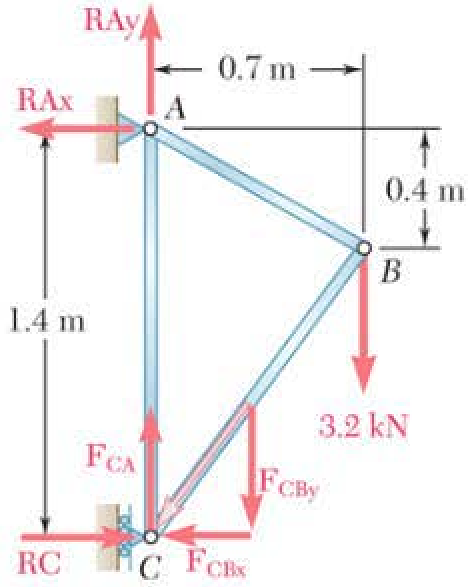


Find reactions	Solve Joint *C*	Solve Joint *A*	Completed truss	Difficult joints

GIVE FEEDBACK

OK

Solve a simple truss by method of joints (mathematically)



Left: From the last joint, solve Joint *A* (because the unknown forces are simpler than *B* (on right).

Equilibrium of X components at Joint *A*:

$\Sigma F_X = R_{AX} + F_{ABX} = 0$

$\therefore F_{ABX} = 1.6$ kN (to the right)

Equilibrium of Y components at Joint *A*

by equilibrium of Member AC:

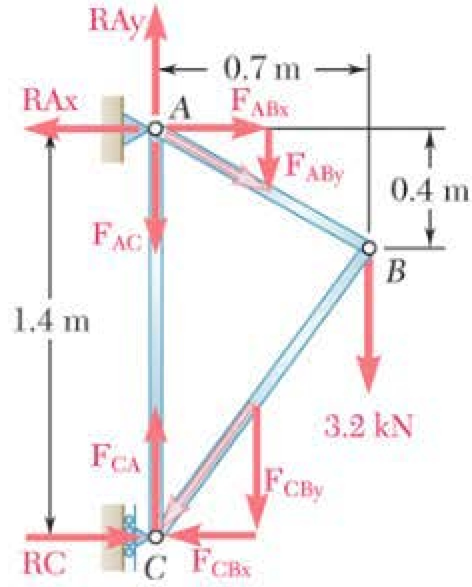
$F_{AC} = -F_{CA} = -2.286$ kN (downwards)

Solve Y:

$\Sigma F_Y = R_{AY} + F_{AC} + F_{ABY} = 0$

So $3.2 - 2.286 + F_{ABY} = 0$

$\therefore F_{ABY} = -0.914$ kN (downwards)



Find reactions | Solve Joint *C* | Solve Joint *A* | Completed truss | Difficult joints

GIVE FEEDBACK

OK

Solve a simple truss by method of joints (mathematically)

Joint *B* is instantly solved. We simply mirror the forces on members AB and CB. Checking Joint *B*:

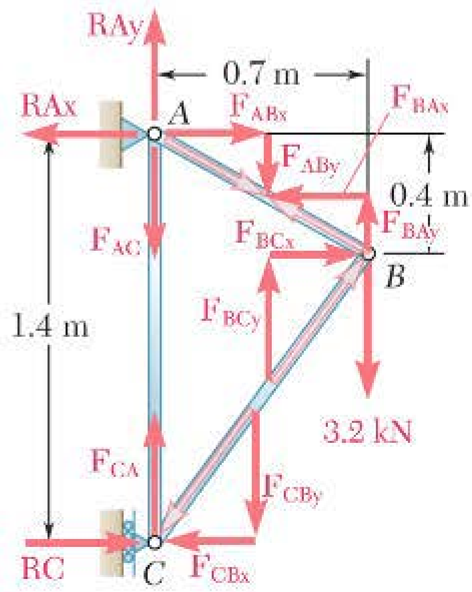
$\Sigma F_X = F_{BAX} + F_{BCX} = -1.6 + 1.6 = 0$ (correct)

$\Sigma F_Y = F_{BAY} + F_{BCY} = 0.9143 - 0.9143 = 0$ (correct)

Finally, to obtain the total compressive and tensile loadings, get resultants of X and Y, e.g. resultant for Member AB:

$$F_{AB} = \sqrt{F_{ABX}^2 + F_{ABY}^2} = \sqrt{1.6^2 + 0.9143^2} = 1.843 \text{ kN}$$

Member	X Component	Y Component	Resultant	Loading
Member AB	1.6 kN	0.9143 kN	1.843 kN	Tension
Member BC	1.6 kN	2.2857 kN	2.790 kN	Compression
Member AC	0	2.2857 kN	2.2857 kN	Tension



Find reactions | Solve Joint *C* | Solve Joint *A* | Completed truss | Difficult joints

GIVE FEEDBACK

OK

Solve a simple truss by method of joints (mathematically)

It would have been more difficult to start this analysis at Joint *B*. This gives two equilibrium equations (X and Y) but with four unknowns:

$$F_{BAX} - F_{BCX} = 0$$
$$F_{BAY} + F_{BCY} - 3.2 = 0$$

To solve this we need to use the angle information to reduce to two unknowns:

$$F_{BAY} = \frac{0.4}{0.7} \cdot F_{BAX} = 0.5714 \cdot F_{BAX}$$
$$F_{BCY} = \frac{1}{0.7} \cdot F_{BCX} = 1.4286 \cdot F_{BCX}$$

So re-writing the equilibrium equations:

$$F_{BAX} - F_{BCX} = 0 \qquad (1)$$
$$0.5714 \cdot F_{BAX} + 1.4286 \cdot F_{BCX} = 3.2 \qquad (2)$$

Solve these simultaneous equations

From (1): $F_{BCX} = F_{BAX}$

So (2) becomes:

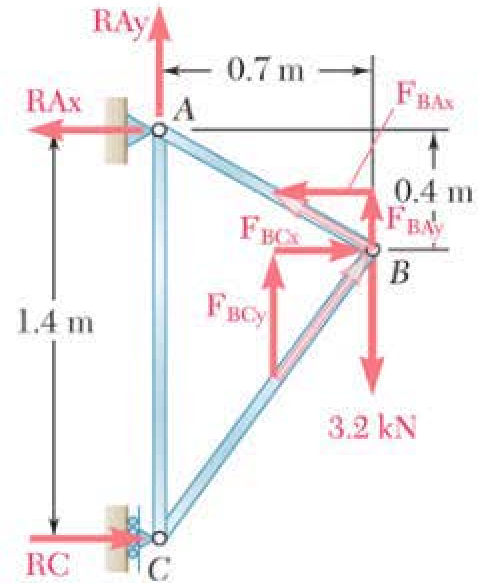
$$0.5714 \cdot F_{BAX} + 1.4286 \cdot F_{BAX} = -3.2$$
$$(0.5714 + 1.4286) \cdot F_{BAX} = -3.2$$
$$2 \cdot F_{BAX} = -3.2$$
$$\therefore F_{BAX} = -1.6 \text{ kN}$$

Substitute back into (1):

$$F_{BAY} = 0.5714 F_{BAX} = 0.5714 \cdot 1.6 = 0.9143 \text{ kN}$$

And the last component, F_{BCY}:

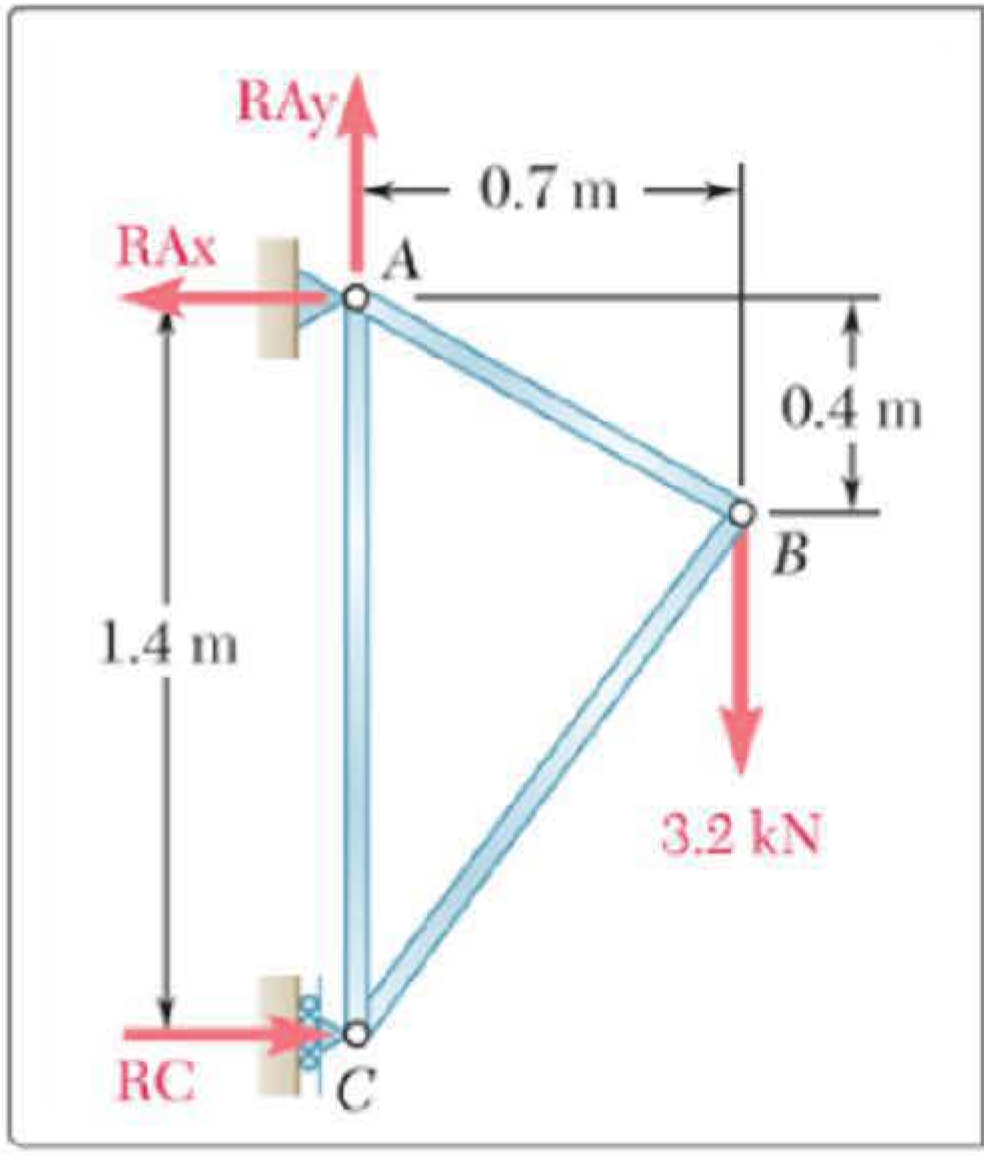
$$F_{BAY} + F_{BCY} = 3.2$$
$$\therefore F_{BCY} = 3.2 - 0.9153$$
$$= 2.2857 \text{ kN}$$



Find reactions | Solve Joint *C* | Solve Joint *A* | Completed truss | Difficult joints

GIVE FEEDBACK

OK



Choosing the first joint to analyse
using the method of joints
by components (mathematical):

Match the statements about the suitability
of the joints *A*, *B* and *C* as the first joint to solve.

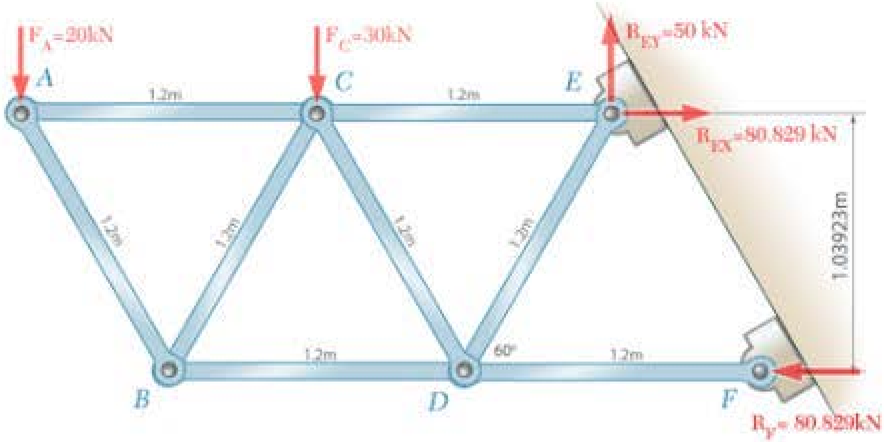
Drag statements on the right to match the left.

Joint *A*	This is the simplest because there are only three forces and one of them is vertical (it has no X component)
Joint *B*	Although there are four forces, this is fairly straightforward because three of them are horizontal or vertical
Joint *C*	This is the most difficult because we must solve this either using the sine rule or with simultaneous equations

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Solve for first two joints in a truss by method of joints (mathematically)



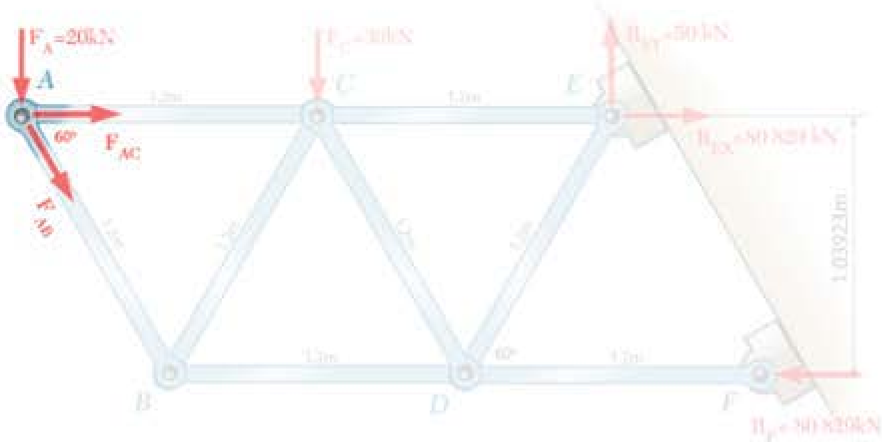
Truss analysis begins once the reactions are known. These reaction forces can be used to double-check the solution at the end by testing equilibrium at joints *E* and *F*.

Begin with known reactions	Step 1 (A): Find a solvable joint and draw free body diagram	Step 2 (A): Equilibrium for Joint *A*	Step 3 (A): Equilibrium for members AC, AB	Step 1 (B): Find a solvable joint and draw free body diagram	Step 2 (B): Equilibrium for Joint *B*	Step 3 (B): Equilibrium for members BD, BC

GIVE FEEDBACK

OK

Solve for first two joints in a truss by method of joints (mathematically)



Step 1: Look for a joint with a maximum of two unknowns. Draw a free body diagram of Joint *A*.

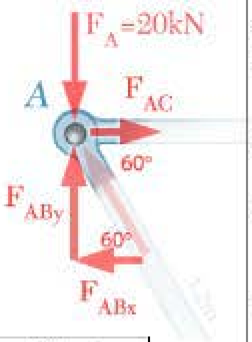
Note: We might have chosen joints *A* or *E*. We chose *A* to work from left to right.

Begin with known reactions	Step 1 (A): Find a solvable joint and draw free body diagram	Step 2 (A): Equilibrium for Joint *A*	Step 3 (A): Equilibrium for members AC, AB	Step 1 (B): Find a solvable joint and draw free body diagram	Step 2 (B): Equilibrium for Joint *B*	Step 3 (B): Equilibrium for members BD, BC

GIVE FEEDBACK

OK

Solve for first two joints in a truss by method of joints (mathematically)



Equilibrium

$\xrightarrow{+} \Sigma F_x = 0$

$+\uparrow \Sigma F_y = 0$

Step 2:

Solve equilibrium for Joint *A* using X and Y components. Consider Y axis (up is positive):

$\Sigma F_y = 0 = F_{AB\,y} - 20 \qquad \therefore F_{AB\,y} = 20$

Consider X axis (right is positive). We know that Member AC is at 60 degrees, so:

$$F_{AB\,x} = \frac{F_{AB\,y}}{\tan 60} = \frac{20}{1.73205} = 11.547 \text{ kN}$$

But since this is going to the *left*, $F_{AB\,x} = -11.547 \text{ kN}$

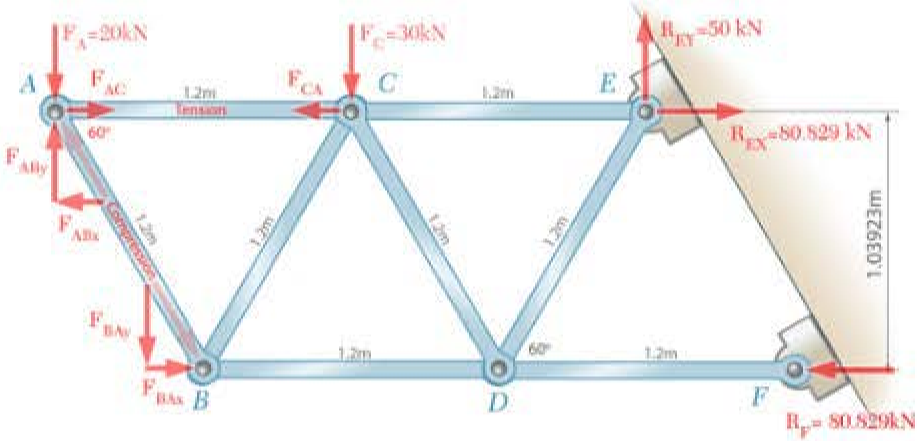
$\Sigma F_x = 0 = F_{AC} - 11.547 \text{ kN} \qquad \therefore F_{AC} = 11.547 \text{ kN}$

Begin with known reactions	Step 1 (A): Find a solvable joint and draw free body diagram	Step 2 (A): Equilibrium for Joint *A*	Step 3 (A): Equilibrium for members AC, AB	Step 1 (B): Find a solvable joint and draw free body diagram	Step 2 (B): Equilibrium for Joint *B*	Step 3 (B): Equilibrium for members BD, BC

GIVE FEEDBACK

OK

Solve for first two joints in a truss by method of joints (mathematically)



Step 3: Transfer these forces from Joint *A* to adjacent joints *B* and *C* (all component forces must balance):

$F_{AC} = 11.547$ kN so Joint C becomes: $F_{CA} = -11.547$ kN

$F_{AB\ x} = -11.547$ kN so Joint B becomes: $F_{BA\ x} = 11.547$ kN

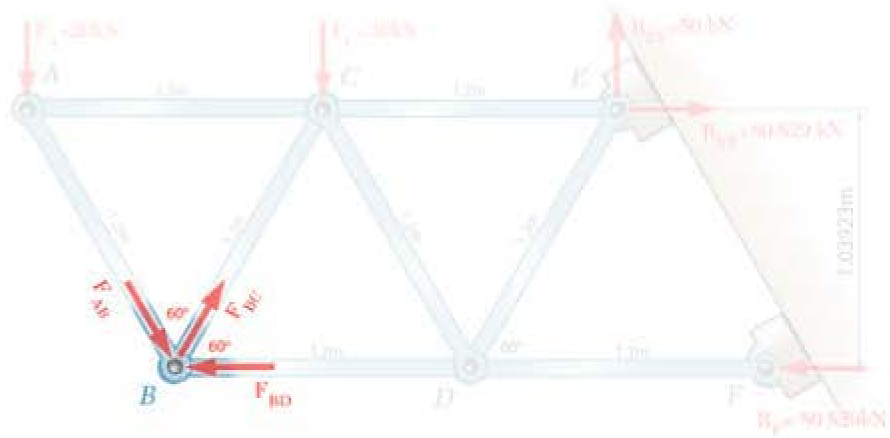
$F_{AB\ y} = 20$ kN so Joint B becomes: $F_{BA\ y} = -20$ kN

Begin with known reactions	Step 1 (A): Find a solvable joint and draw free body diagram	Step 2 (A): Equilibrium for Joint *A*	Step 3 (A): Equilibrium for members AC, AB	Step 1 (B): Find a solvable joint and draw free body diagram	Step 2 (B): Equilibrium for Joint *B*	Step 3 (B): Equilibrium for members BD, BC

GIVE FEEDBACK

OK

Solve for first two joints in a truss by method of joints (mathematically)



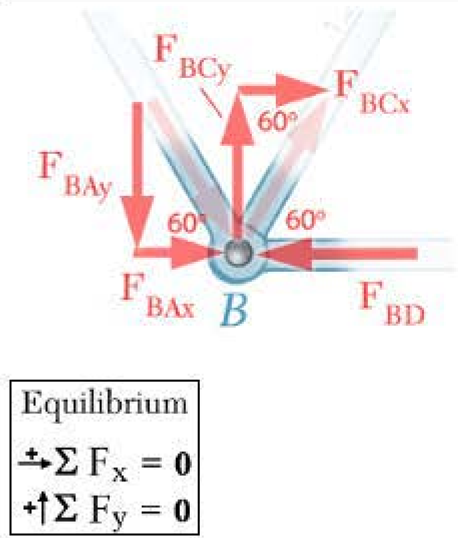
Step 1: Back to Step 1 again, looking for a joint with a maximum of two unknowns, we choose Joint *B*. Draw a free body diagram of Joint *B* (we cannot choose Joint *C* because it has three unknowns).

Begin with known reactions	Step 1 (A): Find a solvable joint and draw free body diagram	Step 2 (A): Equilibrium for Joint *A*	Step 3 (A): Equilibrium for members AC, AB	Step 1 (B): Find a solvable joint and draw free body diagram	Step 2 (B): Equilibrium for Joint *B*	Step 3 (B): Equilibrium for members BD, BC

GIVE FEEDBACK

OK

Solve for first two joints in a truss by method of joints (mathematically)



Step 2:

Solve equilibrium for Joint *B* by components.

Y axis (up is positive):

$\Sigma F_y = 0 = F_{BC\,y} + F_{BA\,y} = F_{BC\,y} - 20$

$\therefore F_{BC\,y} = 20 \text{ kN}$

X axis (right is positive)—we know that member BC is at 60°, so:

$F_{BC\,x} = \dfrac{F_{BC\,y}}{\tan 60} = \dfrac{20}{1.73205} = 11.547 \text{ kN}$

$\Sigma F_x = 0 = F_{BA\,x} + F_{BC\,x} + F_{BD}$

$\Sigma F_x = 0 = 11.547 \text{ kN} + 11.547 \text{ kN} + F_{BD}$

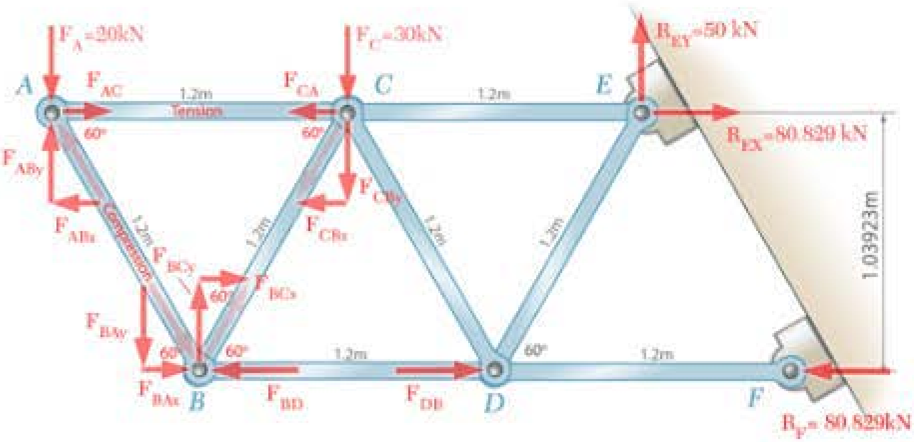
$\therefore F_{BD} = -23.094 \text{ kN}$

Begin with known reactions	Step 1 (A): Find a solvable joint and draw free body diagram	Step 2 (A): Equilibrium for Joint *A*	Step 3 (A): Equilibrium for members AC, AB	Step 1 (B): Find a solvable joint and draw free body diagram	Step 2 (B): Equilibrium for Joint *B*	Step 3 (B): Equilibrium for members BD, BC

GIVE FEEDBACK

OK

Solve for first two joints in a truss by method of joints (mathematically)



Step 3: Transfer these forces from Joint *B* to adjacent joints *C* and *D* (component forces on members BC and BD must balance):

$F_{BD} = -23.094\ \text{kN}$ so Joint D becomes: $F_{DB} = 23.094\ \text{kN}$

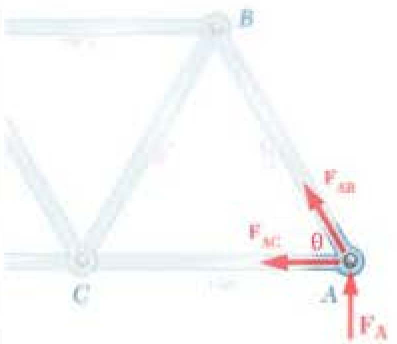
$F_{BC\,x} = 11.547\ \text{kN}$ so Joint B becomes: $F_{CB\,x} = -11.547\ \text{kN}$

$F_{BC\,y} = 20\ \text{kN}$ so Joint B becomes: $F_{CB\,y} = -20\ \text{kN}$

Begin with known reactions	Step 1 (A): Find a solvable joint and draw free body diagram	Step 2 (A): Equilibrium for Joint *A*	Step 3 (A): Equilibrium for members AC, AB	Step 1 (B): Find a solvable joint and draw free body diagram	Step 2 (B): Equilibrium for Joint *B*	Step 3 (B): Equilibrium for members BD, BC

GIVE FEEDBACK

OK



Force F_A = 73 kN and angle θ= 60 degrees.

What is the angle of force F_{AB} in 360 degree format? (This is the force applied by Member AB to the Joint A.)

WARNING! You must solve equilibrium for this joint to check the correct direction of force F_{AB}.

(Do not type units, use at least one decimal place.)

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

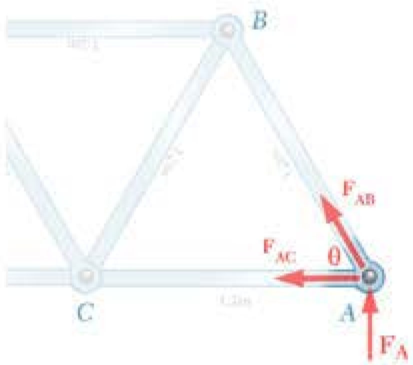
Each hint will reduce the credit received for this question

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



Force F_A = 73 kN and angle θ= 60 degrees.

Calculate the tension in Member AB (include a minus sign if the member is in compression).

(Include units, use at least two decimal places.)

Clear

Clear line

?

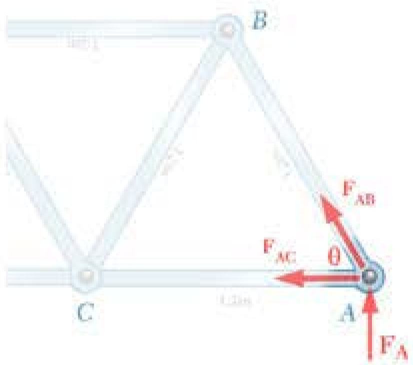
Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER



Force F_A = 73 kN and angle θ= 60 degrees.

Calculate the tension in Member AC where a negative sign (–) is used for compression.

(Include units, use at least two decimal places.)

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

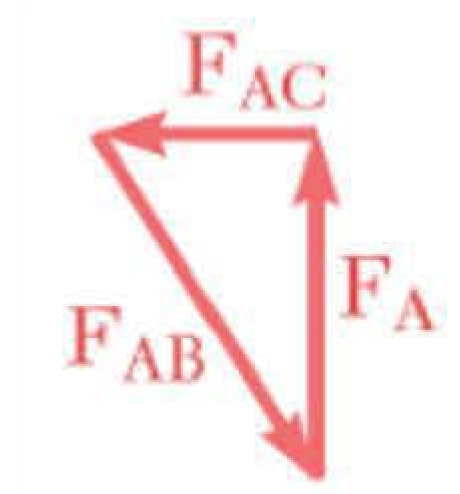
- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

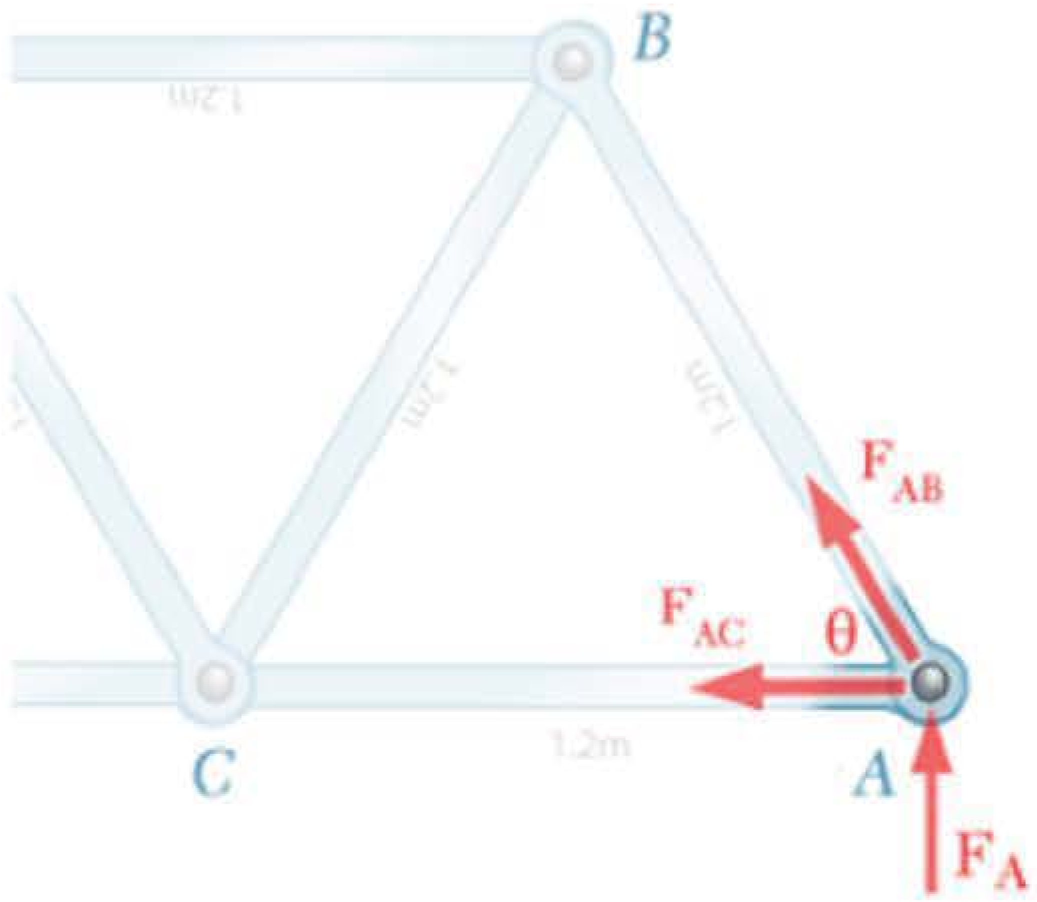
Hint

Each hint will reduce the credit received for this question

Assume θ = 60°

The Force Polygon for Joint A is shown below;

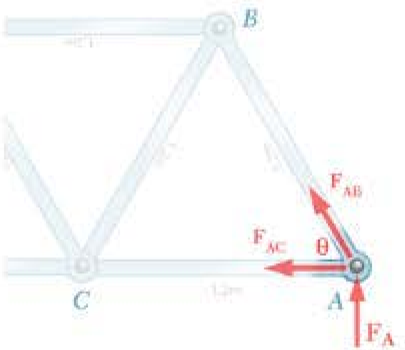




Match the correct angles (in 360° format) for each force described below:

Drag statements on the right to match the left.

300°	The force applied by Joint *A* to Member AB
180°	The force applied by Member AC to Joint A
0°	The force applied by Member AB to Joint *A*
120°	The force applied by Member AC to Joint *C*



Force F_A = 73 kN and angle θ = 60 degrees.

Force F_{BA} is the force in Member AB on the Joint B end.

Find the angle of F_{BA} in 360 degree format. (The force applied by Member AB to Joint B.)

(Do not type units, round off to nearest integer.)

Clear

Clear line

Undo

Click and type your answer here

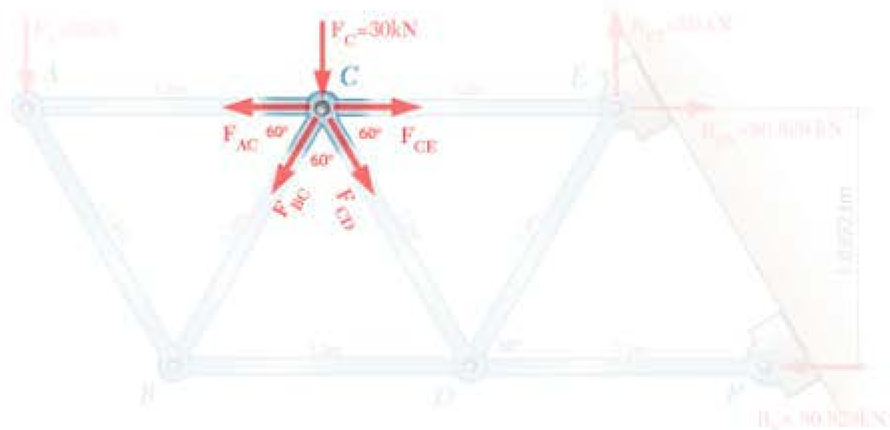
CHALLENGE SUBMIT SHOW ANSWER

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

Complete the last few joints in a truss by method of joints (mathematically)



Continuing the Method of Joints, assuming Joints A and B have been solved.

Step 1: Looking for a joint with a maximum of two unknowns, we choose Joint *C*. Draw a free body diagram of Joint *C*. (We cannot choose Joint *D* because it has three unknowns.)

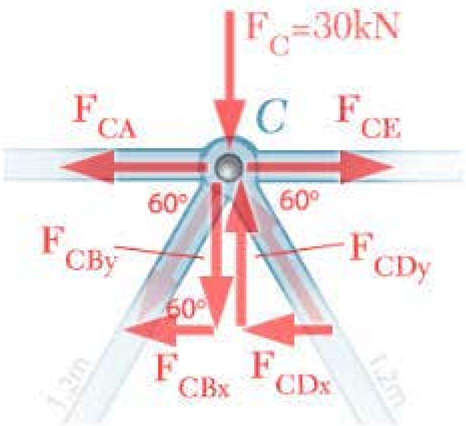
Currently known data for Joint C; $F_{CB\,x} = -11.547\ \mathrm{kN}$, $F_{CB\,y} = -20\ \mathrm{kN}$, $F_{CA} = -11.547\ \mathrm{kN}$

Step 1 (C): Find a solvable joint and draw free body diagram	Step 2 (C): Equilibrium for Joint *C*	Step 3 (C): Equilibrium for members CD, CE	Step 1 (D): Find a solvable joint and draw free body diagram	Step 2 (D): Equilibrium for Joint *D*	Step 3 (D): Equilibrium for members DE, DF	Check Joint *E*

GIVE FEEDBACK

OK

Complete the last few joints in a truss by method of joints (mathematically)



Step 2: Apply equilibrium using components at Joint *C* to find two unknowns, members CD and CE.

Equilibrium of Y components (positive is upwards):

$$\Sigma F_y = 0 = F_{CD\,y} + F_{CB\,y} + F_C = F_{CD\,y} - 20 - 30$$

$$\therefore F_{CD\,y} = 50 \text{ kN}$$

X axis (right is positive)—we know that Member CD is at 60°, so:

$$F_{CD\,x} = \frac{F_{CD\,y}}{\tan 60} = \frac{50}{1.73205} = -28.867 \text{ kN} \qquad \text{(to the left)}$$

Equilibrium of X components (positive is to the right):

$$\Sigma F_x = 0 = F_{CD\,x} + F_{CB\,x} + F_{CE} + F_{CA}$$

$$\Sigma F_x = 0 = -28.867 \text{ kN} - 11.547 \text{ kN} + F_{CE} - 11.547 \text{ kN}$$

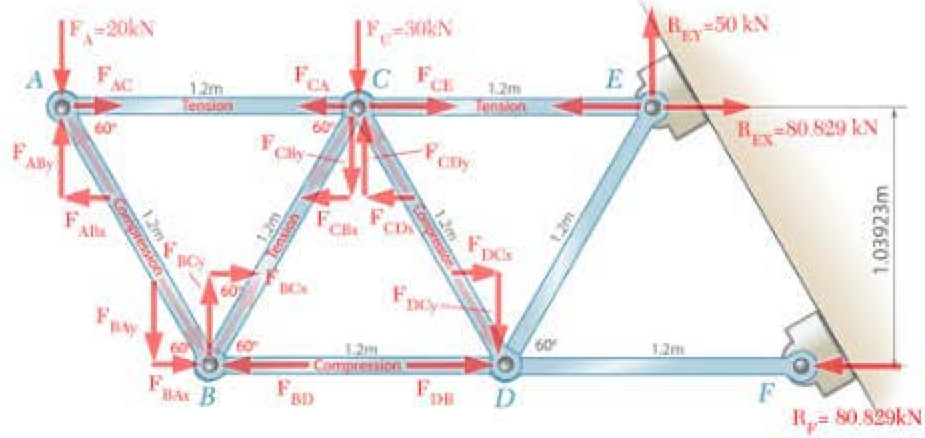
$$\therefore F_{CE} = 51.962 \text{ kN} \qquad \text{(to the right)}$$

Step 1 (C): Find a solvable joint and draw free body diagram	Step 2 (C): Equilibrium for Joint *C*	Step 3 (C): Equilibrium for members CD, CE	Step 1 (D): Find a solvable joint and draw free body diagram	Step 2 (D): Equilibrium for Joint *D*	Step 3 (D): Equilibrium for members DE, DF	Check Joint *E*

GIVE FEEDBACK

OK

Complete the last few joints in a truss by method of joints (mathematically)



Step 3: Transfer these forces from Joint *C* to adjacent joints *D* and *E* (component forces on members CD and CE must balance):

$F_{CD\,x} = -28.867$ kN so Joint D becomes: $F_{DC\,x} = 28.867$ kN

$F_{CD\,y} = 50$ kN so Joint D becomes: $F_{DC\,y} = -50$ kN

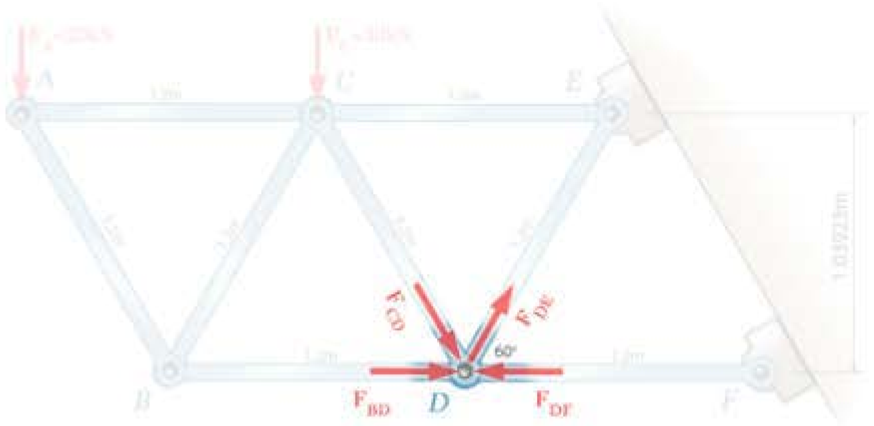
$F_{CE} = 51.962$ kN so Joint B becomes: $F_{EC} = -51.962$ kN

Step 1 (C): Find a solvable joint and draw free body diagram	Step 2 (C): Equilibrium for Joint *C*	Step 3 (C): Equilibrium for members CD, CE	Step 1 (D): Find a solvable joint and draw free body diagram	Step 2 (D): Equilibrium for Joint *D*	Step 3 (D): Equilibrium for members DE, DF	Check Joint *E*

GIVE FEEDBACK

OK

Complete the last few joints in a truss by method of joints (mathematically)



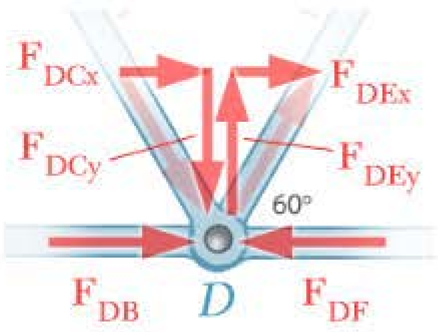
Step 1: Looking for a joint with a maximum of two unknowns, we choose Joint *D*. Draw a free body diagram of Joint *D* (we can also choose Joint *E*, with two unknowns).

Step 1 (C): Find a solvable joint and draw free body diagram	Step 2 (C): Equilibrium for Joint *C*	Step 3 (C): Equilibrium for members CD, CE	Step 1 (D): Find a solvable joint and draw free body diagram	Step 2 (D): Equilibrium for Joint *D*	Step 3 (D): Equilibrium for members DE, DF	Check Joint *E*

GIVE FEEDBACK

OK

Complete the last few joints in a truss by method of joints (mathematically)



Step 2: Apply equilibrium using components at Joint *D* to find two unknowns, members DE and DF.

Y axis (up is positive):

$\Sigma F_y = 0 = F_{DE\,y} + F_{DC\,y} = F_{DE\,y} - 50$

$\therefore F_{DE\,y} = 50\text{ kN}$

X axis (right is positive)—we know that member CD is at 60°, so:

$F_{DE\,x} = \dfrac{F_{DE\,y}}{\tan 60} = \dfrac{50}{1.73205} = 28.867\text{ kN}$ (to the right)

$\Sigma F_x = 0 = F_{DB\,x} + F_{DC\,x} + F_{DE} + F_{DF}$

$\Sigma F_x = 0 = 23.094 + 28.867 + 28.867 + F_{DF}$

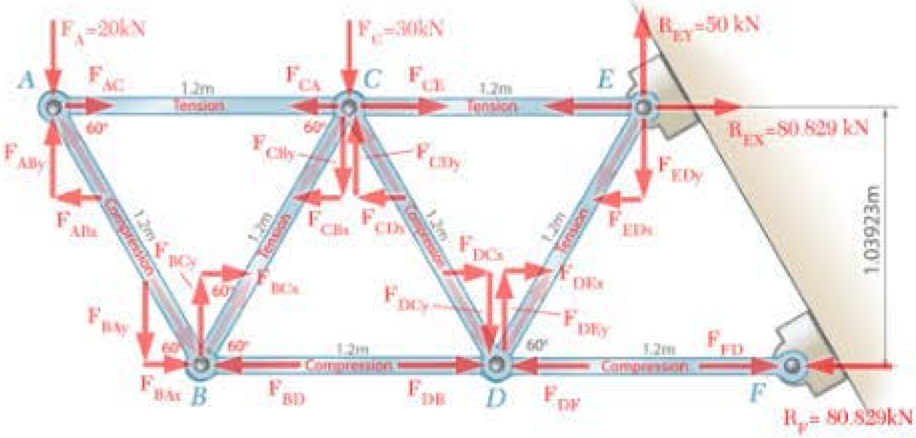
$\therefore F_{DF} = -80.829\text{ kN}$ (to the left)

Step 1 (C): Find a solvable joint and draw free body diagram	Step 2 (C): Equilibrium for Joint *C*	Step 3 (C): Equilibrium for members CD, CE	Step 1 (D): Find a solvable joint and draw free body diagram	Step 2 (D): Equilibrium for Joint *D*	Step 3 (D): Equilibrium for members DE, DF	Check Joint *E*

GIVE FEEDBACK

OK

Complete the last few joints in a truss by method of joints (mathematically)



Step 3: Transfer these forces from Joint *D* to adjacent joints *E* and *F* (component forces on members DE and DF must balance):

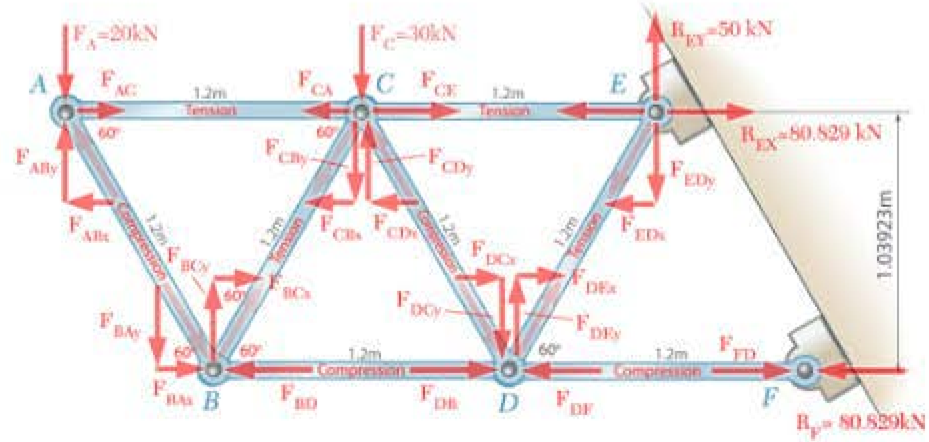
$F_{DE\ x} = 28.867$ kN so Joint D becomes: $F_{ED\ x} = -28.867$ kN
$F_{DE\ y} = 50$ kN so Joint D becomes: $F_{ED\ y} = -50$ kN
$F_{DF} = -80.829$ kN so Joint B becomes: $F_{FD} = 80.829$ kN

Step 1 (C): Find a solvable joint and draw free body diagram	Step 2 (C): Equilibrium for Joint *C*	Step 3 (C): Equilibrium for members CD, CE	Step 1 (D): Find a solvable joint and draw free body diagram	Step 2 (D): Equilibrium for Joint *D*	Step 3 (D): Equilibrium for members DE, DF	Check Joint *E*

GIVE FEEDBACK

OK

Complete the last few joints in a truss by method of joints (mathematically)



We have completed the truss. Checking is simple because reactions are shown in X and Y components. From the previous step:

$F_{ED\,x} = -28.867$ kN, $F_{ED\,y} = -50$ kN, $F_{FD} = 80.829$ kN (Joint *F* is obviously correct).

Check equilibrium at Joint *E*:

$\Sigma F\,x = F_{EC} + R_{EX} + F_{ED\,x} = -51.962 - 28.867 + 80.829 = 0$ kN (Correct)

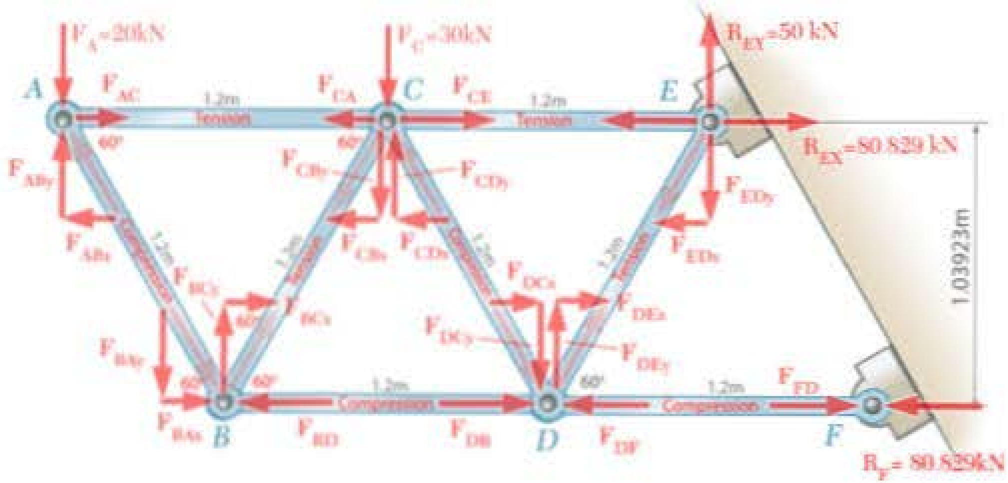
$\Sigma F\,y = R_{EY} + F_{ED\,y} = 50 - 50 = 0$ kN (Correct)

Step 1 (C): Find a solvable joint and draw free body diagram	Step 2 (C): Equilibrium for Joint *C*	Step 3 (C): Equilibrium for members CD, CE	Step 1 (D): Find a solvable joint and draw free body diagram	Step 2 (D): Equilibrium for Joint *D*	Step 3 (D): Equilibrium for members DE, DF	Check Joint *E*

GIVE FEEDBACK

OK

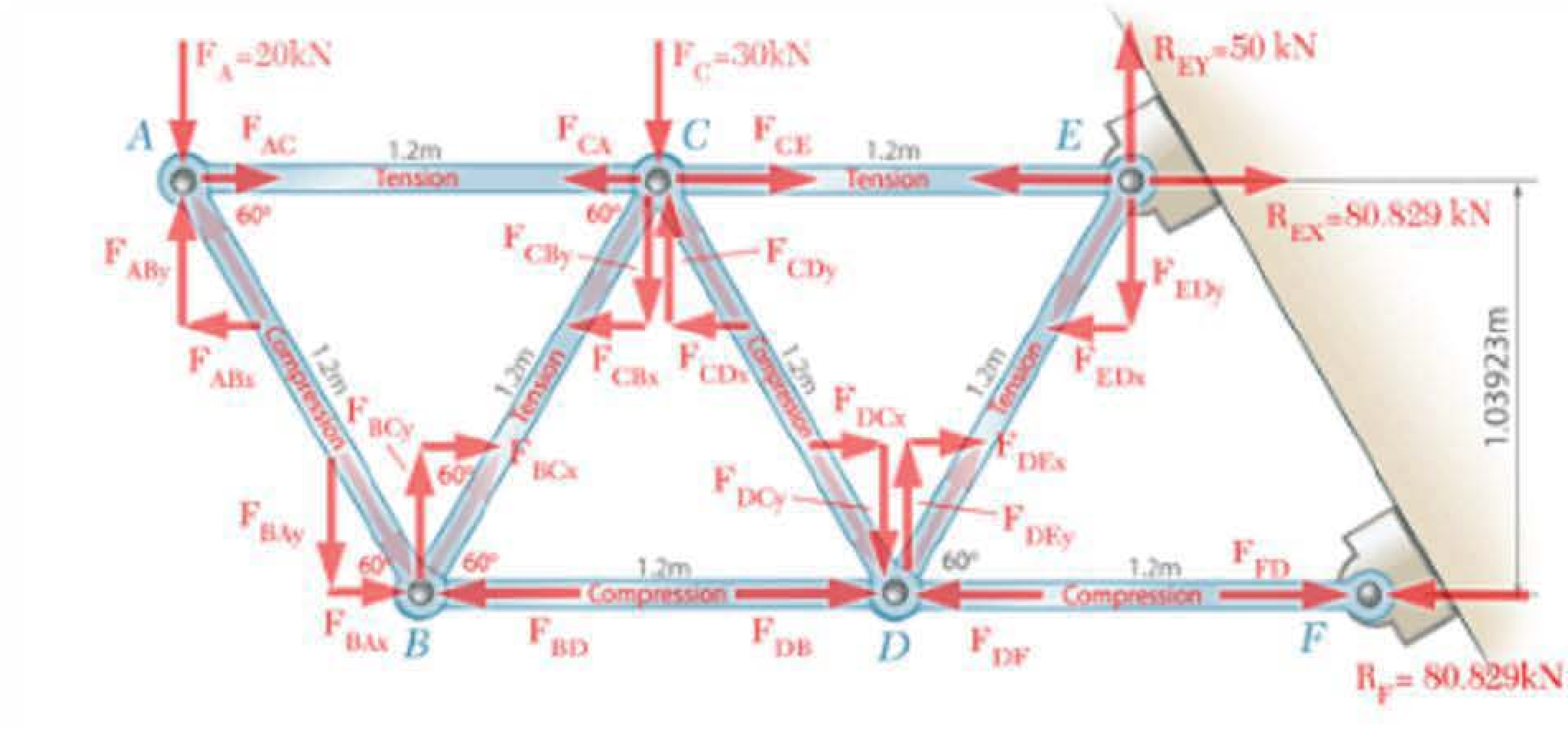
Which method(s) were most likely used to solve this truss?



Check all that apply.

- [ ] Method of joints by components (mathematical)
- [ ] Method of joints by force polygons (graphical)
- [ ] Method of sections by components (mathematical)
- [ ] Method of sections by force polygons (graphical)

Some of the forces aligned with the members are shown in a faded (faint red) colour.
What does this mean?



Click the correct answer.

Nothing, those forces still apply but are simply shown faded to make it easier to read the diagram

They are showing forces acting on the members rather than the joints

Those forces have been replaced by their X and Y components

Those members do not have forces in them

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The method of sections is quite different. Instead of solving concurrent forces at joints, the truss is divided in two and one half is solved.

The method of sections

The **method of sections** is based on the principle that if the entire truss is in equilibrium, any part of the truss must also be in equilibrium.

So far we have seen three ways to define a free body diagram in a truss:

- The whole truss in equilibrium (when finding the reactions)
- A single joint in equilibrium (during the method of joints)
- A single member in equilibrium (the mirror-forces step in the method of joints)

The fourth way is to section the truss into two and take one side as the free body diagram. This method is called the method of sections.

GIVE FEEDBACK

OK

Which of the following free body diagrams is only used in the method of sections?

Click the correct answer.

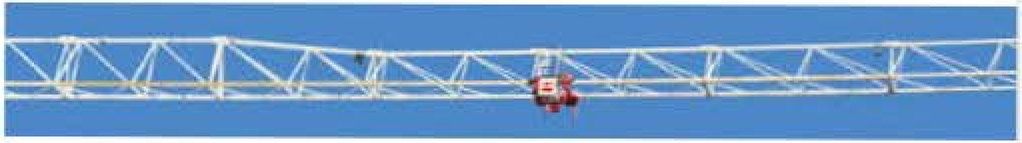
- The whole truss in equilibrium
- A single joint in equilibrium
- A single member in equilibrium
- Half of the truss in equilibrium

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The method of sections allows the designer to skip straight to the middle of the truss instead of working joint to joint from one end.

Advantages of using the method of sections



The method of sections:

1. Is ideal for situations where the forces at the centre of a truss are needed, without working through many joints to get there
2. Can be used as an alternative method which provides a way to double-check at any point during the method
3. Allows the designer to focus on a particular member while testing the effect of design variations (like changing the loads)—the force in a member anywhere in the truss can usually be isolated as a single equation

GIVE FEEDBACK

OK

Match the features of the following three methods of truss analysis.

Drag statements on the right to match the left.

Method of sections	Forces at the centre of a truss are needed, without working through many joints to get there
Method of joints (graphical)	Simple application of concurrent forces and force polygons
Method of joints (mathematical components)	A process suited to computer analysis
Method of sections	Allows the designer to focus on a particular member while testing the effect of design variations

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

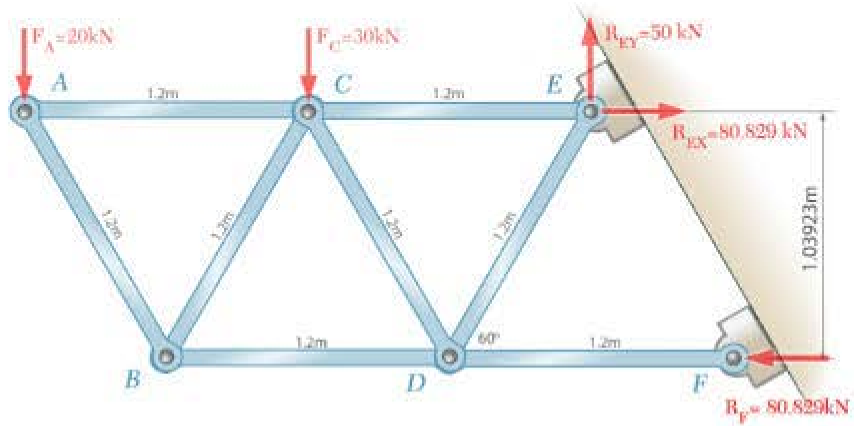
Apply the method of sections to find the force in a truss member

Find the force in Member BD.

This is the same truss we analysed using the method of joints, only this time we will use the method of sections.

As usual, we have the reactions solved before lauching into analysis of the members. However, in this particular case (cantilevered), it is possible to solve the truss without knowing the reactions first.

But reactions are still a good idea because it makes it easy to double-check our answers.



Select member	Divide truss in target area	Apply moment at smart location	Apply force equilibrium to free body diagram

GIVE FEEDBACK

OK

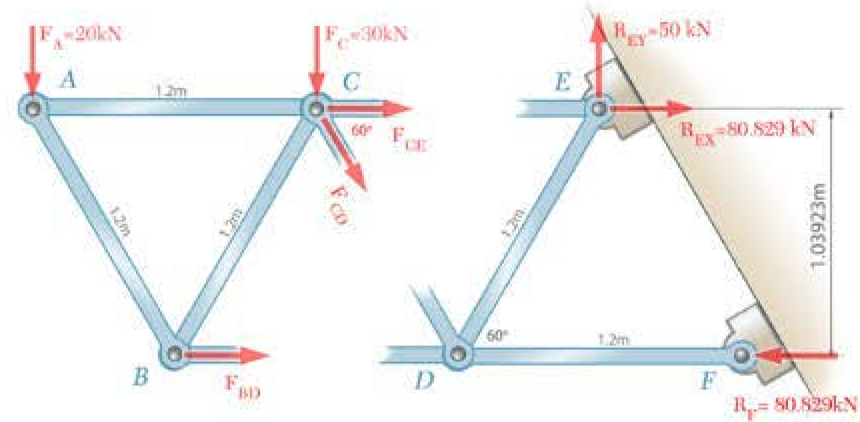
Apply the method of sections to find the force in a truss member

Cut the truss in two.

The method of sections cuts the truss into two parts. This sectioning must divide the target member in the process. Here, we place the cut to separate members CE, CD and BD (the target member).

Apply unknown forces.

The left half will be our target free body diagram. This body is exactly three members with five forces applied. Three of these forces are the unknowns that we sectioned (members CE, CD and BD). We could attempt to guess the direction of these forces, but if unsure we simply assume these are all tensile, at least for now.



Select member	Divide truss in target area	Apply moment at smart location	Apply force equilibrium to free body diagram

GIVE FEEDBACK

OK

Apply the method of sections to find the force in a truss member

Discard the rest of the truss, reactions and all. Now we have a non-concurrent force problem with three unknowns. We must use moment equilibrium to tackle this.

We are free to take moments wherever we like, but to be solvable we must choose a pivot point that eliminates two out of the three forces.
We can eliminate the moment effect of a force by having it coincide with the pivot point. Since we want to find the force F_{BD}, we look for a place where CE and CD intersect—Point C. Taking moments at Point C (kN x m):

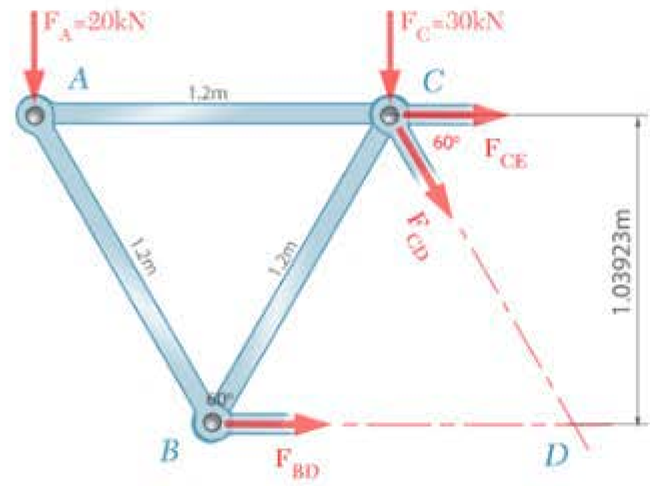
$$\Sigma M_C = -(20 \times 1.2) + (30 \times 0) + (F_{CE} \times 0) + (F_{CD} \times 0) - (F_{BD} \times 1.0392) = 0$$

$$\Sigma M_C = -(20 \times 1.2) - (F_{BD} \times 1.0392) = 0$$

$$F_{BD} = -\frac{(20 \times 1.2)}{1.0392}$$

$$\therefore F_{BD} = -23.094 \text{ kN}$$

The minus sign means we guessed the wrong direction. F_{BD} is to the left.



Taking moments at C to find F_{CD}

Select member	Divide truss in target area	Apply moment at smart location	Apply force equilibrium to free body diagram

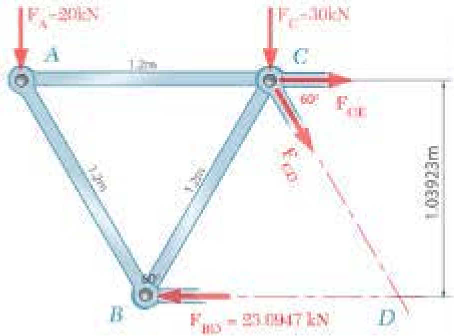
GIVE FEEDBACK

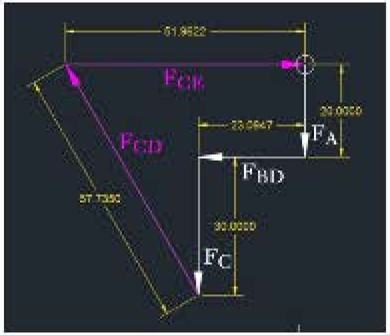
OK

Apply the method of sections to find the force in a truss member

If we want, we can quite easily solve the other cut members. Left with two unknowns, they can be solved with a force polygon, giving:

$F_{CD} = 57.735\text{ kN} @ 120°$ and $F_{CE} = 51.962\text{ kN} @ 0°$





Alternatively we could find F_{CD} and F_{CE} mathematically by components:

$$\Sigma F_Y = -20 - 30 + F_{CD}\sin 60 = 0$$

$$\therefore F_{CD} = -\frac{50}{\sin 60} = 57.735\text{ kN}$$

$$\Sigma F_x = F_{CE} - 23.0947 - F_{CD}\cos 60 = 0$$

$$F_{CE} = 23.0947 + 28.867 = 51.962\text{ kN}$$

Note that this method is not effected by the number of members. Most planar trusses can be sectioned with three to four members, and a suitable moment location will exist due to triangulation in trusses.

In this example, we could not find F_{CD} directly in one moment equation because F_{BD} and F_{CE} do not intersect anywhere.

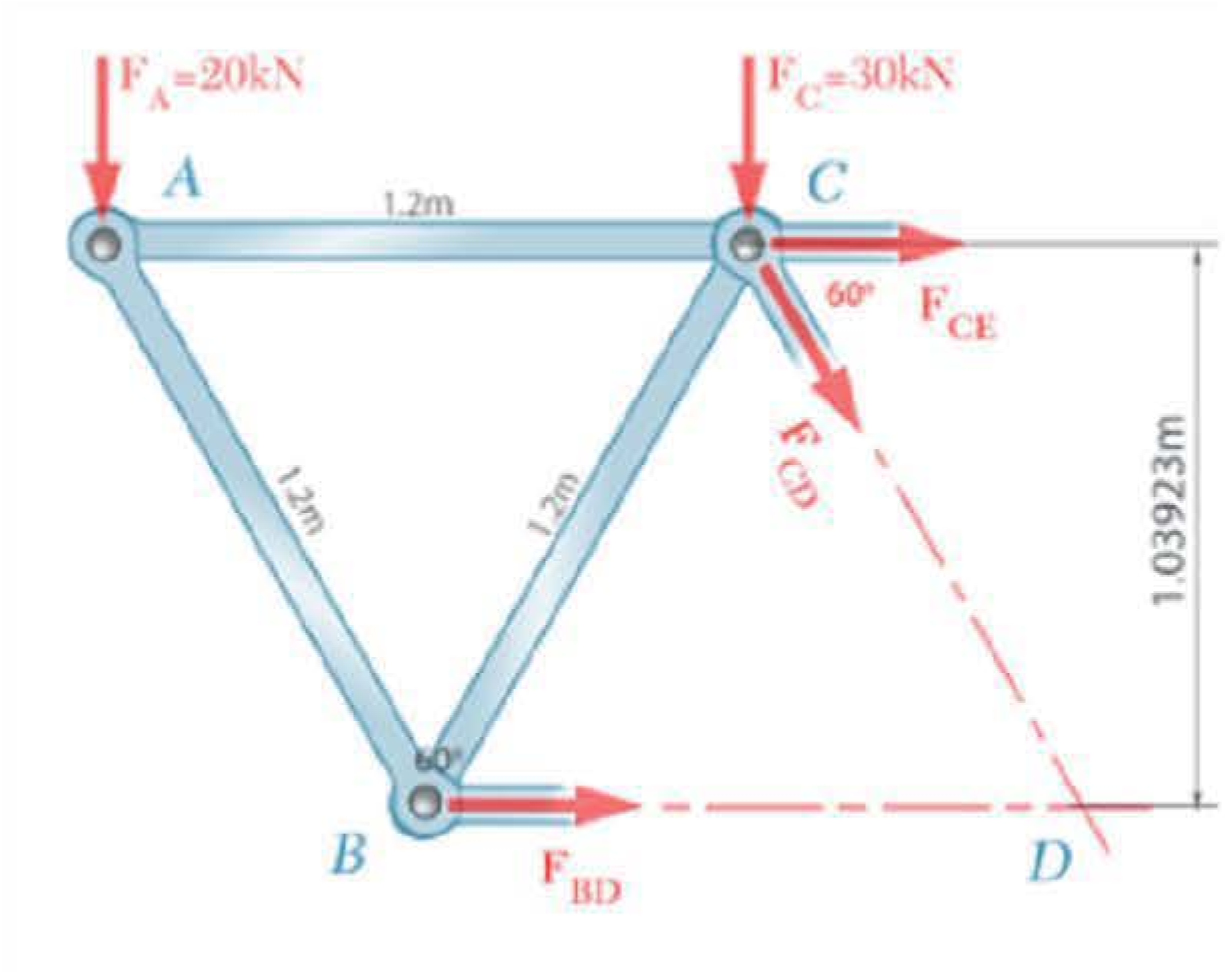
Select member	Divide truss in target area	Apply moment at smart location	Apply force equilibrium to free body diagram

GIVE FEEDBACK

OK

Member BD is being investigated.

We have cut this truss in two and have taken the left side as a free body diagram. What do we do next?



Click the correct answer.

Solve a force polygon for Body ABC

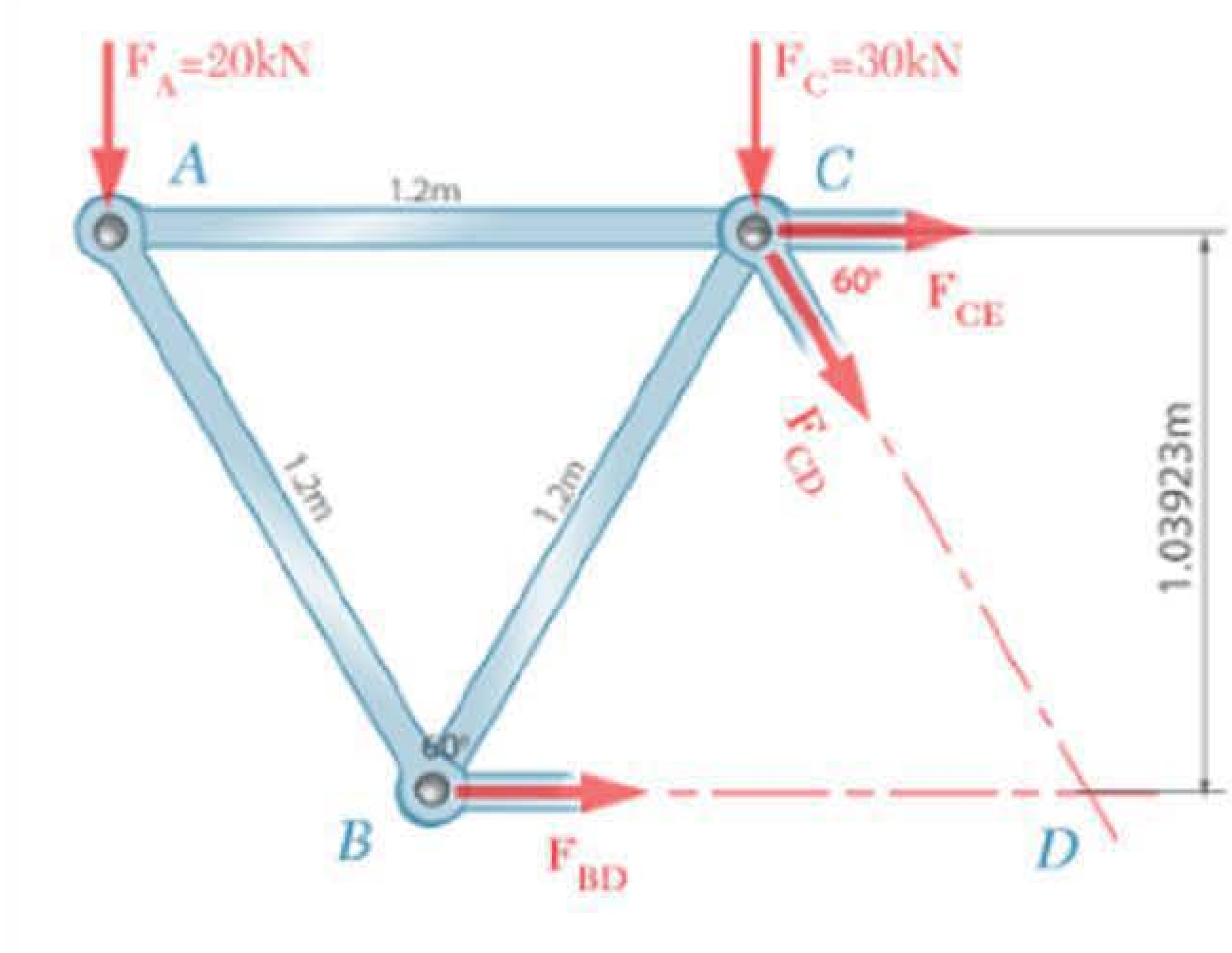
Solve X and Y components for Body ABC

Take moments at *C* for Body ABC

Take moments at *D* for Body ABC

Member CE is being investigated.

We have cut this truss in two and have taken the left side as a free body diagram. What do we do next?



Click the correct answer.

Take moments at *D* for Body ABC

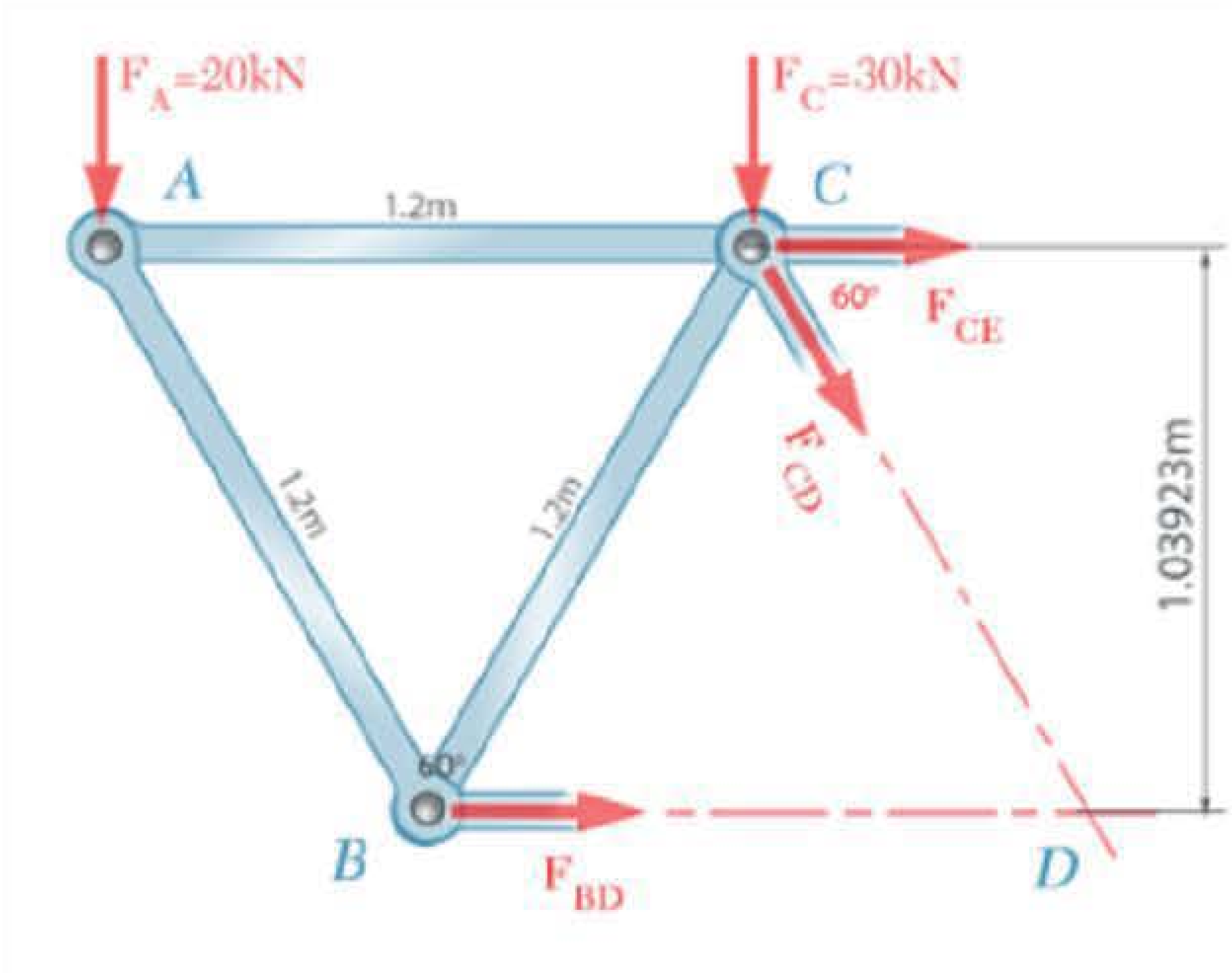
Solve X and Y components for Body ABC

Solve a force polygon for Body ABC

Take moments at *C* for Body ABC

Member CD is being investigated.

We have cut this truss in two and have taken the left side as a free body diagram. What options do we have for the next thing to do?



Check all that apply.

- [ ] Take moments at *C* for Body ABC then solve equilibrium for Body ABC
- [ ] Take moments at *D* for Body ABC
- [ ] Take moments at *A* for Body ABC
- [ ] Take moments at *D* for Body ABC then solve equilibrium for Body ABC