

Section 2.1

Plane Truss

2.1-1 Introduction

[1] In this section, we consider a plane truss supported by a hinge at the left and a roller at the right and subject to a downward force of 6000 N at node C [2, 3]. We want to find the reaction forces and the member forces.

From the free-body diagram of the entire truss [3], taking the moment equilibrium about G, we may calculate A_y ,

$$\sum M_G = 0, (A_y)(18 \text{ m}) - (6000 \text{ N})(12 \text{ m}) = 0,$$

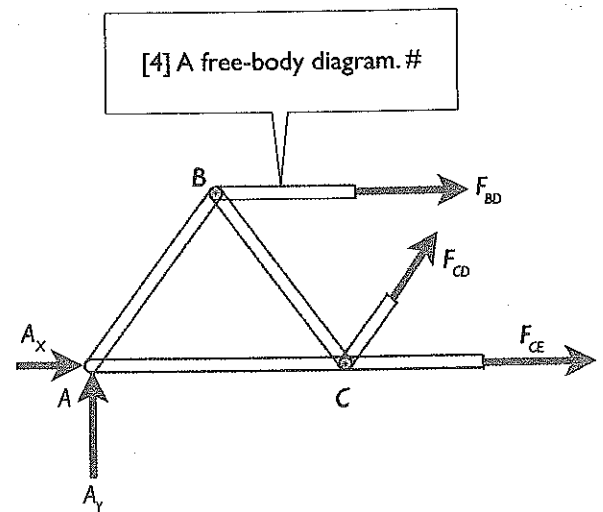
$$A_y = 4000 \text{ N} \quad (1)$$

From the free-body diagram shown in [4], taking the moment equilibrium about C, we may calculate F_{BD} ,

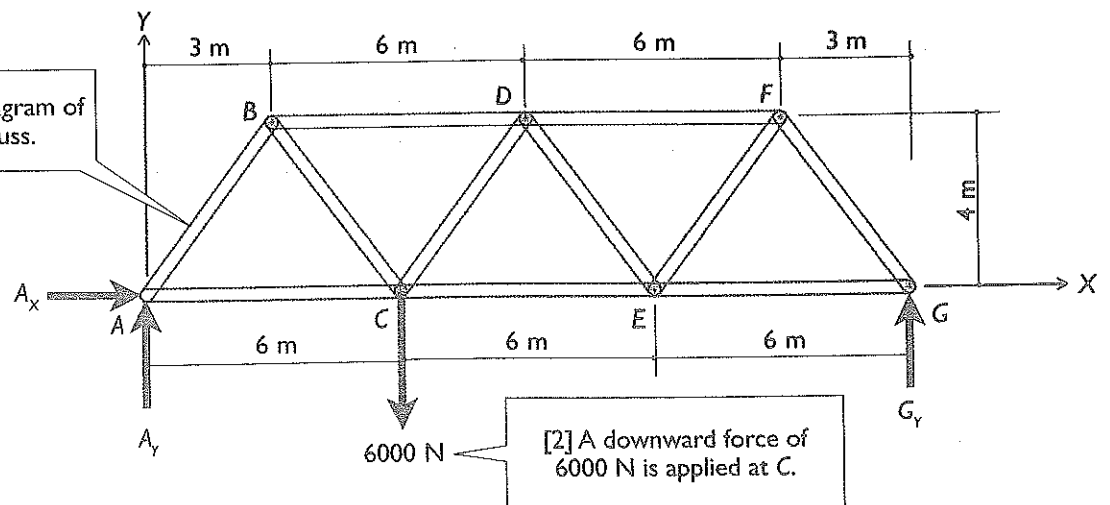
$$\sum M_C = 0, (A_y)(6 \text{ m}) + (F_{BD})(4 \text{ m}) = 0,$$

$$F_{BD} = -6000 \text{ N} \quad (2)$$

The negative sign indicates that it is a compressive force.



[3] Free-body diagram of the entire truss.



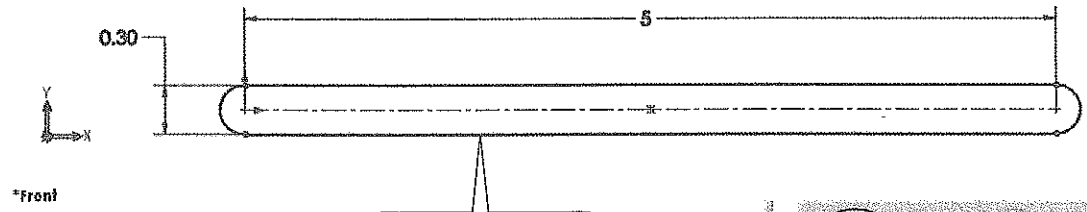
2.1-2 Start Up and Create a Part: Diagonal

[1] Launch **SOLIDWORKS**.

[2] Click **New** to create a new **Part**. Select **MKS** unit system with two decimal places for the length unit.

[3] In the **Part Tree**, right-click the **Front** plane and select **Sketch**.

[4] In the **Sketch** toolbar, select **Straight Slot**.



[5] Draw a **Straight Slot** like this.

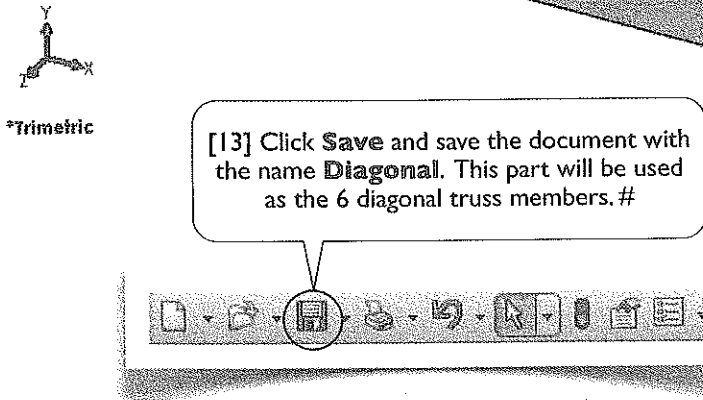
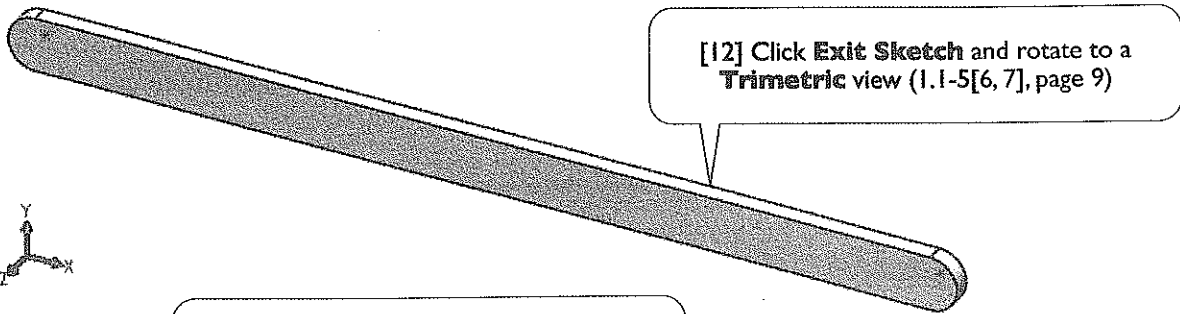
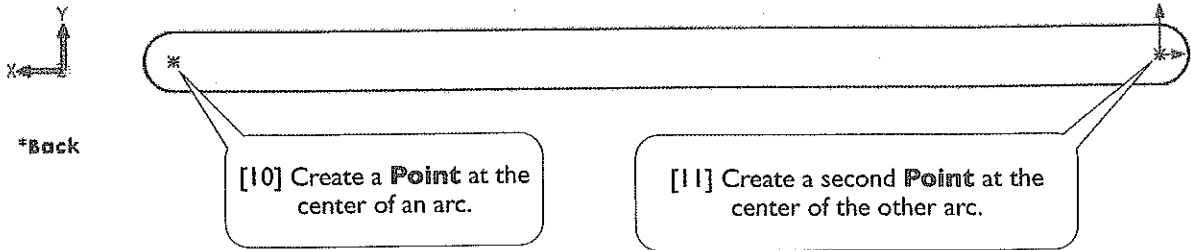
[6] In the **Features** toolbar, click **Extruded Boss/Base**.

[8] Click **OK**.

[7] Type 0.1 (m) for **Depth**.

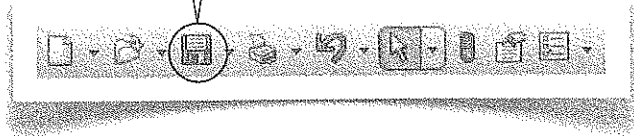
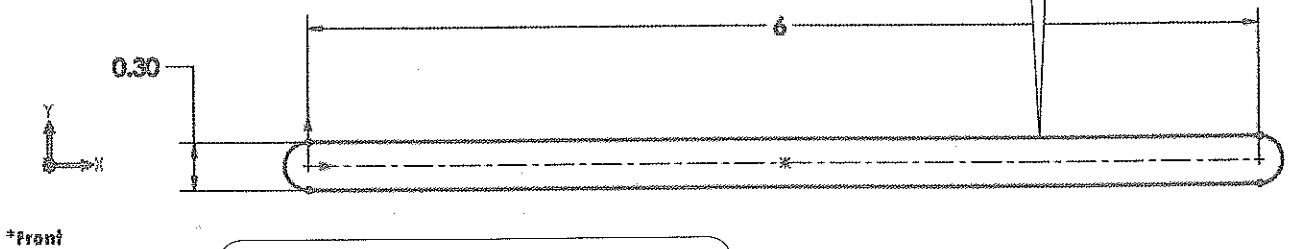
[9] Right-click the back face and select **Sketch**. You may need to rotate the view.

*Trimetric



2.1-3 Create a Part: **Horizontal**

[1] Repeat steps 2.1-2[2-12], except the length of the truss member (specified in 2.1-2[5]) is 6 meters.

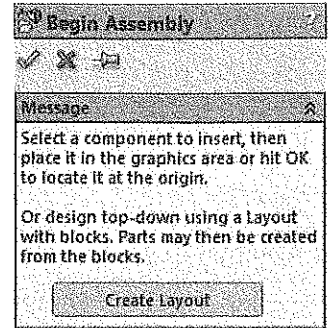


2.1-4 Create an Assembly: PlaneTruss

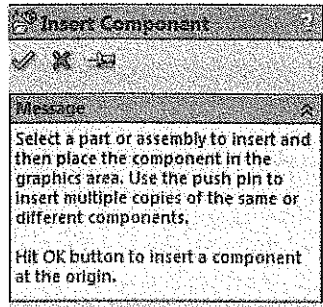


[1] Click **New** and create an **Assembly**.

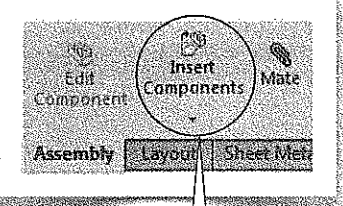
[6] Click **Save** and save the document with the name **PlaneTruss**.



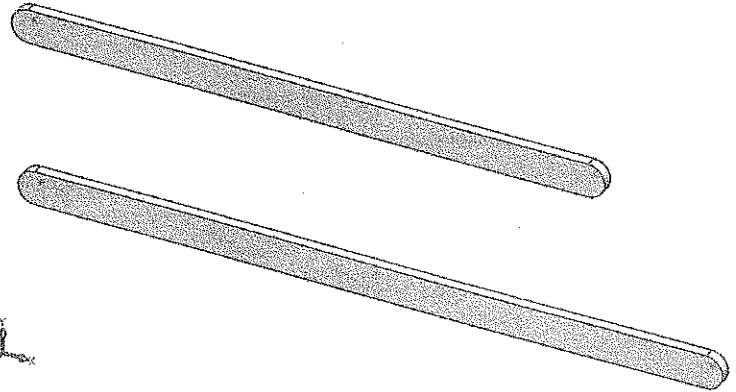
[2] In the **Begin Assembly** box, select **Horizontal**. And then click anywhere in the **Graphics Window**.



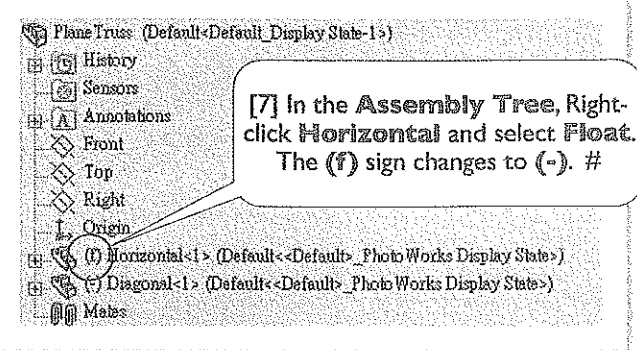
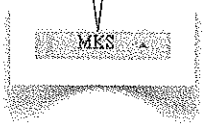
[4] Select **Diagonal**. And then click anywhere in the **Graphics Window**.



[3] In the **Assembly** toolbar, click **Insert Components**.

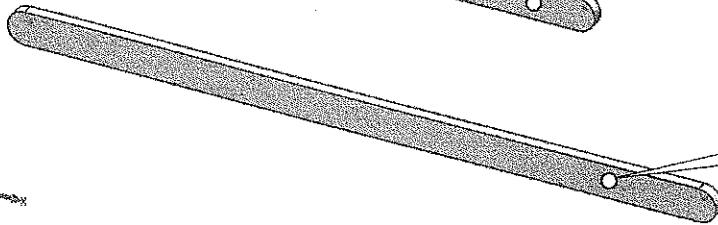
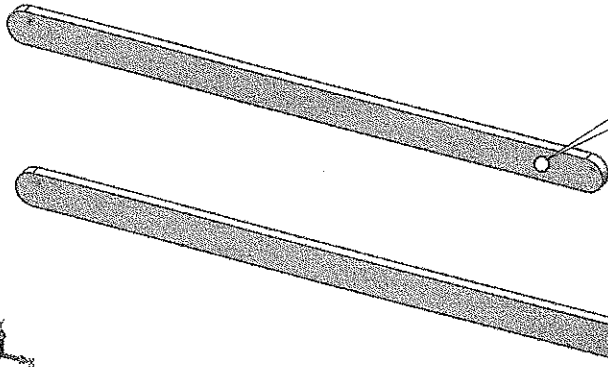


[5] Select **MKS** for the unit system.

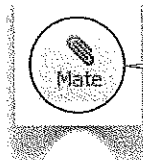


[7] In the **Assembly Tree**, Right-click **Horizontal** and select **Float**. The **(f)** sign changes to **(-)**. **#**

2.1-5 Duplicate Parts and Constrain all Members in XY-Space

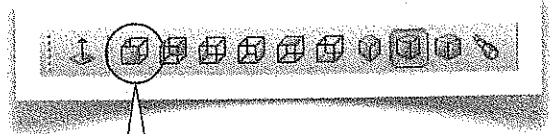
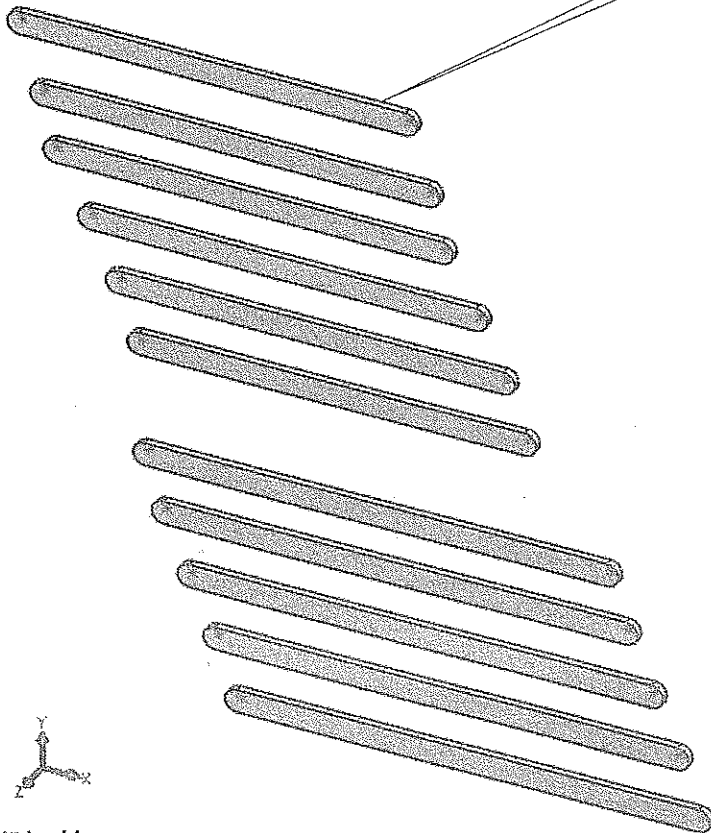


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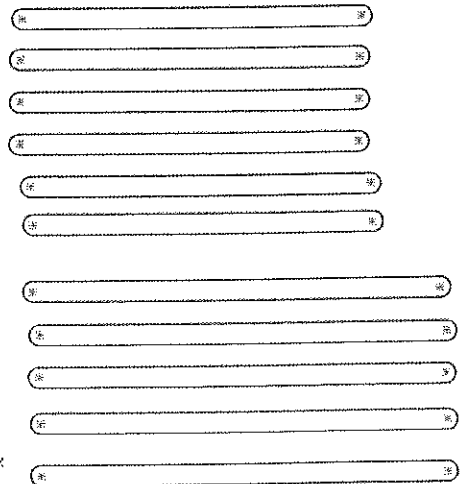


[3] Make sure none of the parts are selected (highlighted) and, in the Assembly toolbar, click **Mate**.

[4] Select the back face of a Part (you need to rotate the view) and, in the Assembly Tree, select global Front plane. Click **OK**. This constrains the Part in XY-space. Repeat this for the other 10 parts. Finally Click **OK** to dismiss the **Mate** box.



[5] Rotate to **Front** view. #

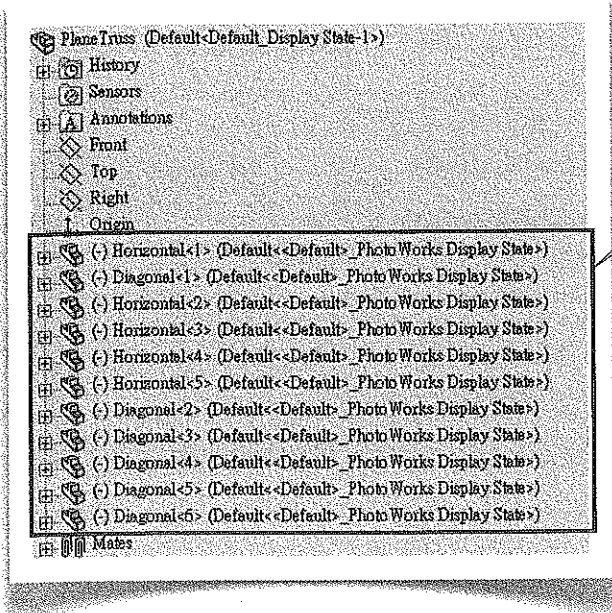


*front

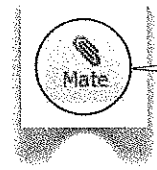


*Trimetric

2.1-6 Set Up Lower Horizontal Members and Supports



[1] In the **Assembly Tree**, each **Part** is identified with a name **Part-Name<Number>**, e.g., **Horizontal<1>**. Move your mouse over each **Part**; the corresponding **Part** in the **Graphics Window** is highlighted. This way, you can identify each of 11 members as shown in [2].



[3] In the **Assembly toolbar**, click **Mate**.

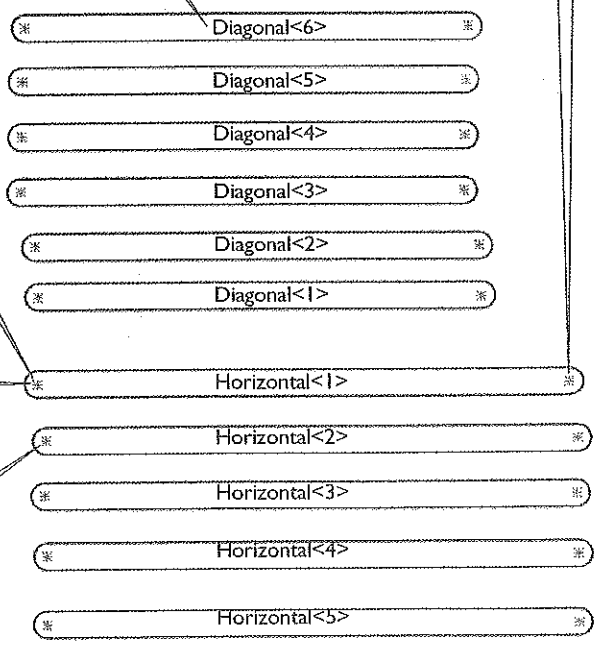
[2] Each member has an identification name like this.

[7] And select the right **Point** of **Horizontal<1>**. Click **OK**. Now the two members are connected with a **revolute joint**. Try to move the newly joined member (using left-click-drag). It is constrained to rotate about its left end, which is free to move.

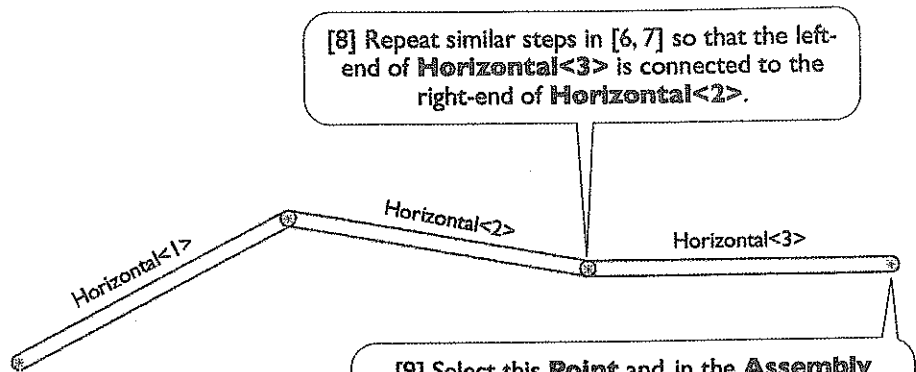
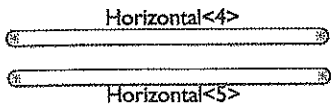
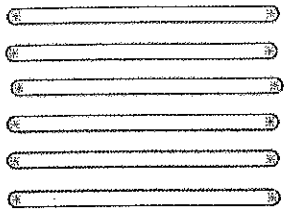
[4] Select the left **Point** of **Horizontal<1>** and, in the **Assembly Tree**, select global **Right** plane. Click **OK**. This sets up a support in X-direction at the left end of the truss.

[5] Select the left **Point** of **Horizontal<1>** again and, in the **Assembly Tree**, select global **Top** plane. Click **OK**. This sets up a support in Y-direction at the left end of the truss. Now try to move this member (using left-click-drag). The member is constrained to rotate about the left end.

[6] Select the left **Point** of **Horizontal<2>**.



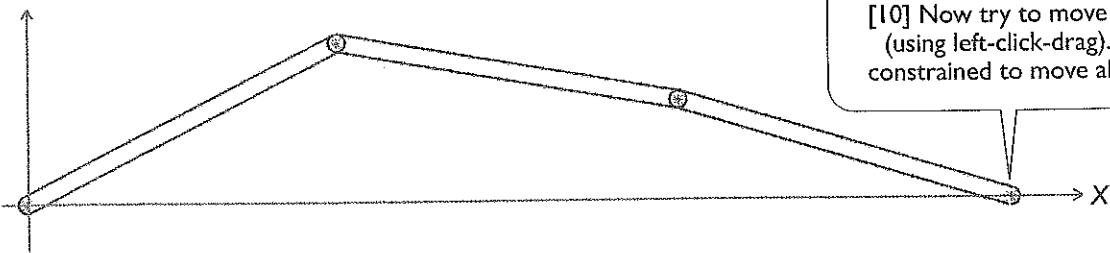
*Front



[8] Repeat similar steps in [6, 7] so that the left-end of **Horizontal<3>** is connected to the right-end of **Horizontal<2>**.

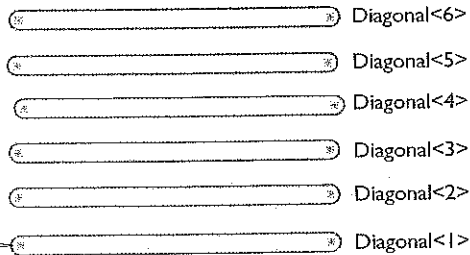
[9] Select this **Point** and, in the **Assembly Tree**, select global **Top** plane. Click **OK**. This sets up a support in Y-direction at the right end of the truss.

Y

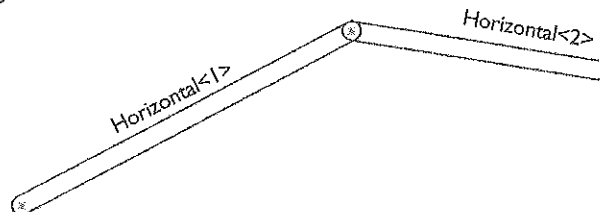
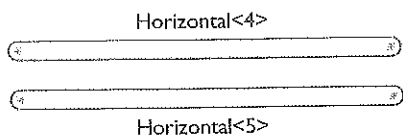


[10] Now try to move the assembly (using left-click-drag). This end is constrained to move along X-axis. #

2.1-7 Assemble other Truss Members



[1] Select this **Point**...



[2] And select this **Point**. Click **OK**.

[4] Select this Point...

- Diagonal<6>
- Diagonal<5>
- Diagonal<4>
- Diagonal<3>
- Diagonal<2>

- Horizontal<4>
- Horizontal<5>

[3] Rotate Diagonal<1> so that it is ABOVE Horizontal<1>.

[5] And select this Point. Click OK.

- Diagonal<6>
- Diagonal<5>
- Diagonal<4>
- Diagonal<3>

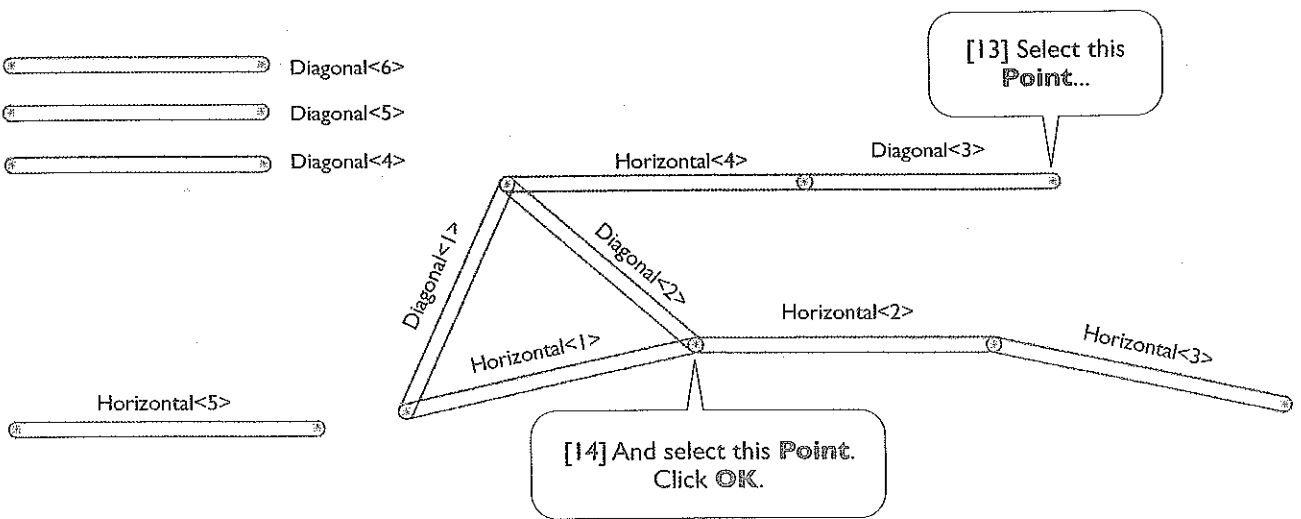
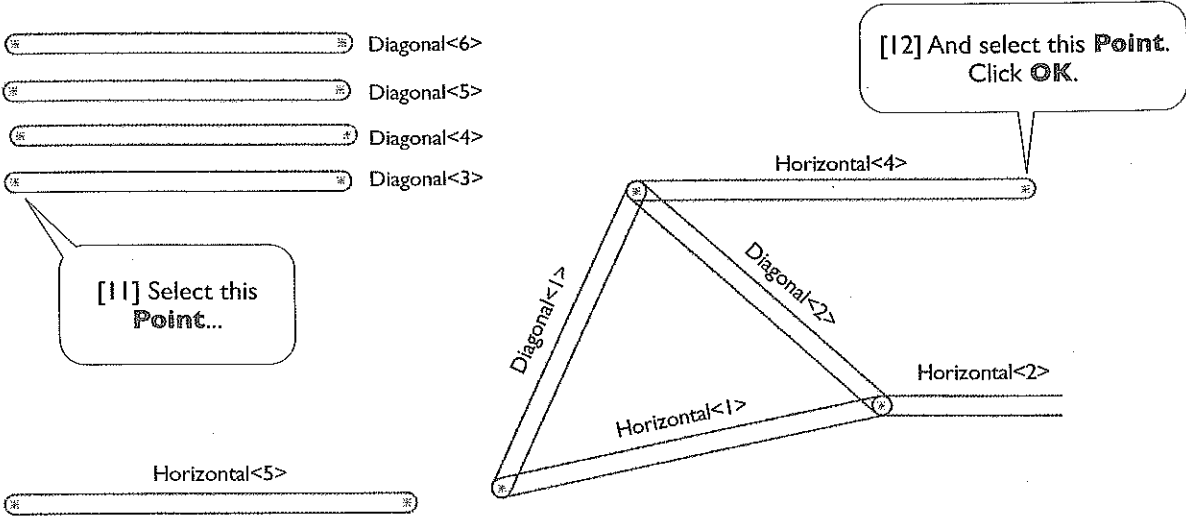
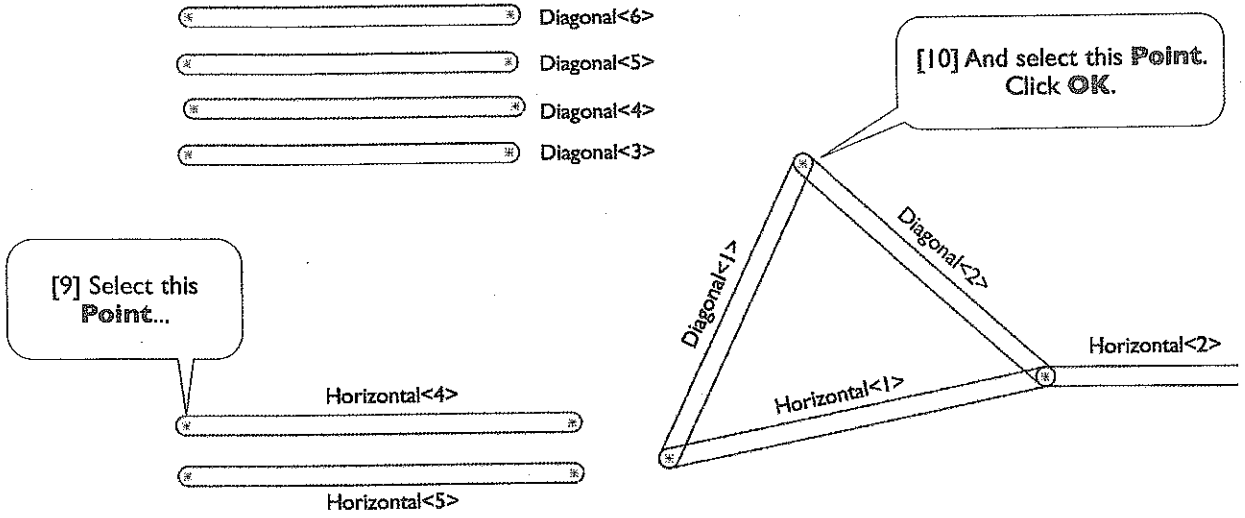
- Horizontal<4>
- Horizontal<5>

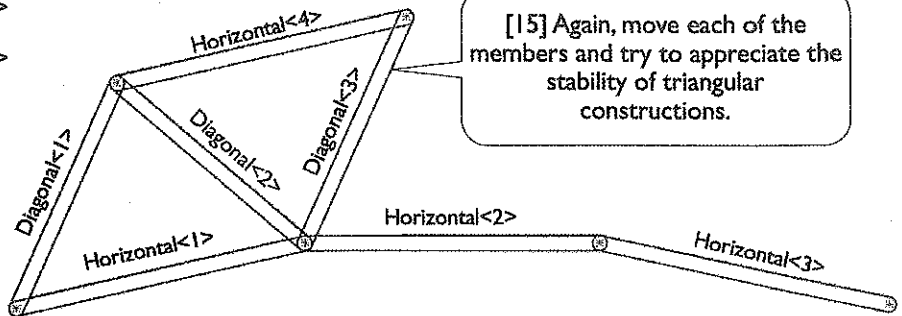
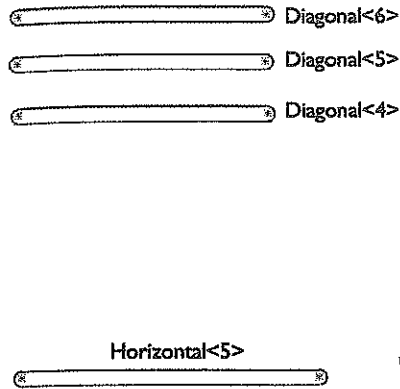
[6] Select this Point...

[7] And select this Point. Click OK.

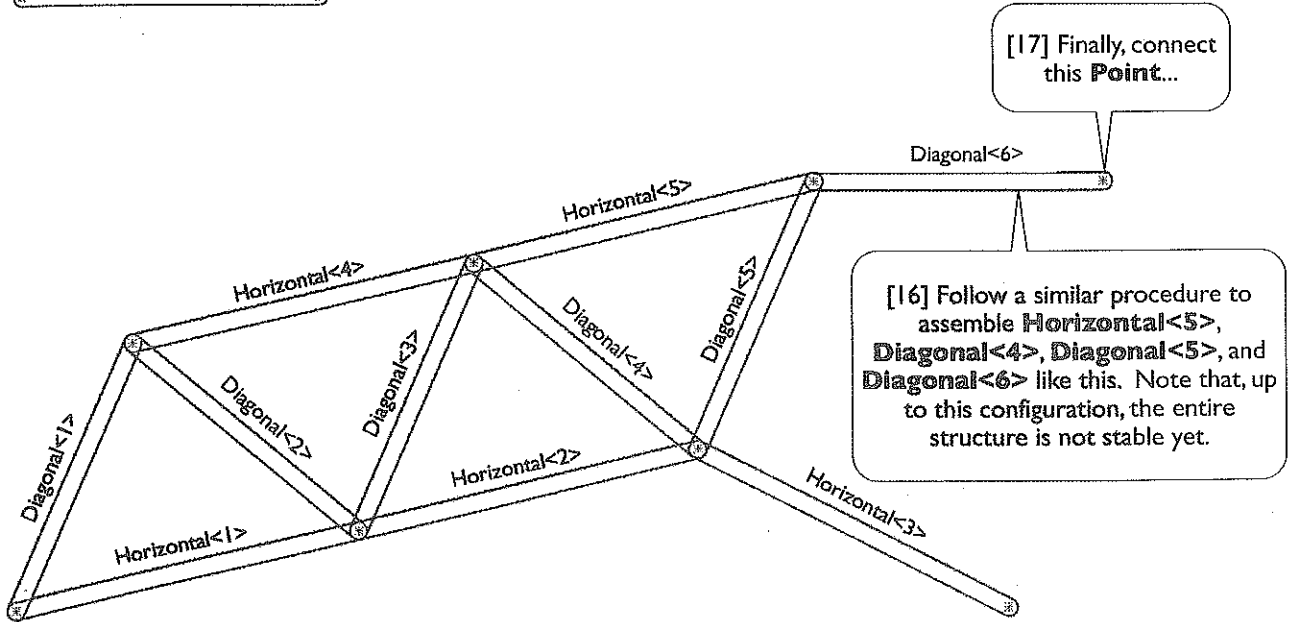
- Horizontal<6>
- Horizontal<5>
- Horizontal<4>
- Horizontal<3>

[8] Try to move the members and you'll see that the three members forming the triangle move as if they are rigidly connected; a triangle is a stable structural construction.





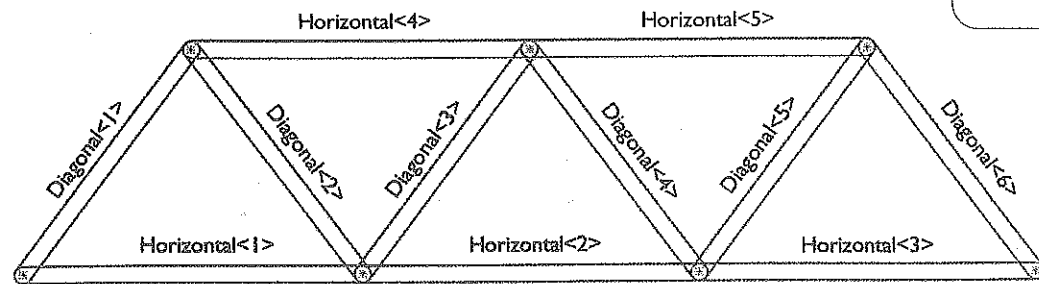
[15] Again, move each of the members and try to appreciate the stability of triangular constructions.



[17] Finally, connect this Point...

[16] Follow a similar procedure to assemble Horizontal<5>, Diagonal<4>, Diagonal<5>, and Diagonal<6> like this. Note that, up to this configuration, the entire structure is not stable yet.

[18] And this Point.



[19] Now the truss structure is stable; it can't be moved. Dismiss the Mate box.

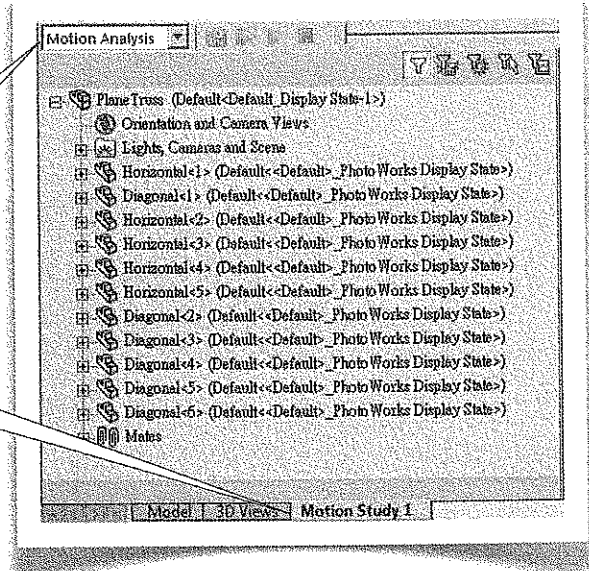
[20] Click Save. #



2.1-8 Create a Study

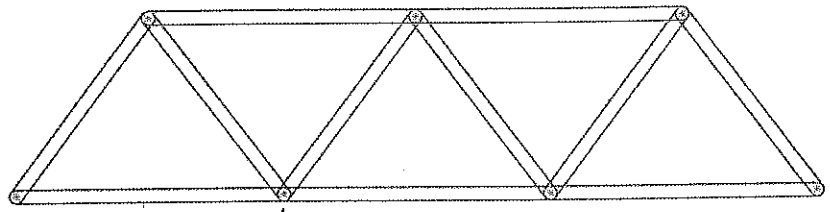
[2] Select **Motion Analysis**. #

[1] Click **Motion Study 1** tab to create a new Study.

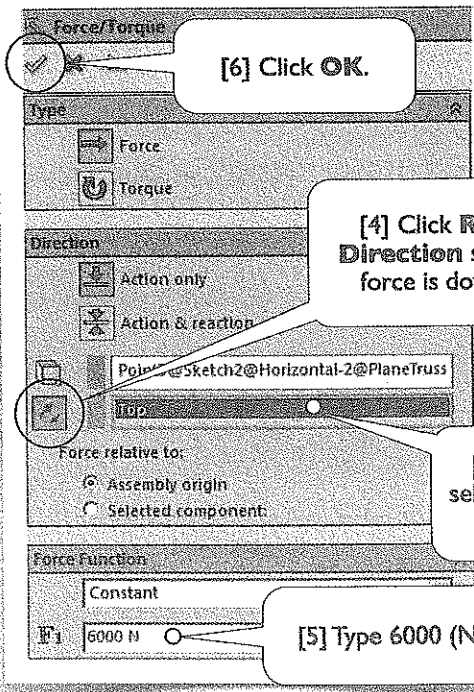


2.1-9 Set Up Forces and Calculate Results

[1] In **Motion** toolbar, click **Force**.



[2] Click this **Point** to define the location of the force.



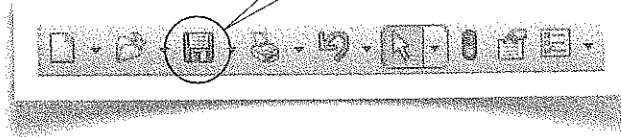
[6] Click **OK**.

[4] Click **Reverse Direction** so that the force is downward.

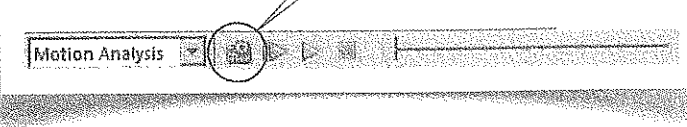
[3] In the **Assembly Tree**, select global **Top** plane to define the direction of the force.

[5] Type **6000 (N)**.

[7] Click **Save**. #



[8] Click **Calculate**. #



2.1-10 View the Reaction Forces

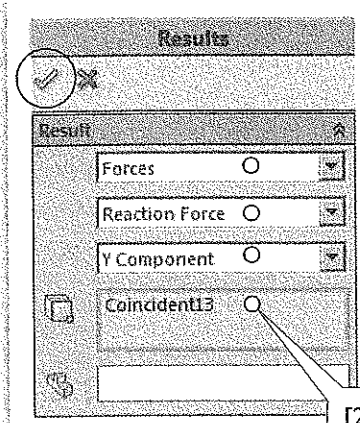


[1, 5] In **Motion** toolbar, click **Results and Plots**.

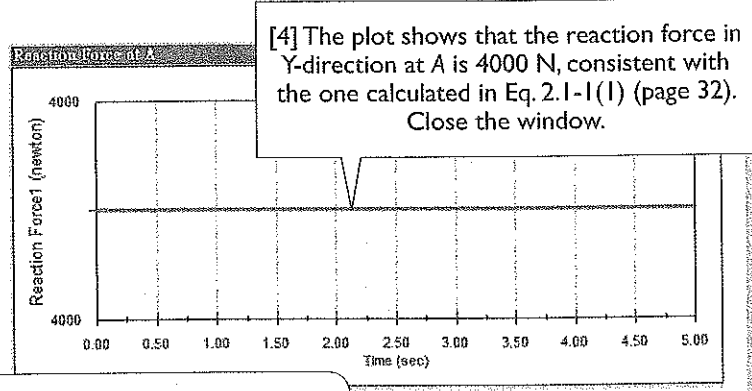
- Mates
- Coincident1 (Diagonal<6>,Front)
- Coincident2 (Diagonal<5>,Front)
- Coincident3 (Diagonal<4>,Front)
- Coincident4 (Diagonal<3>,Front)
- Coincident5 (Diagonal<2>,Front)
- Coincident6 (Diagonal<1>,Front)
- Coincident7 (Horizontal<1>,Front)
- Coincident8 (Horizontal<2>,Front)
- Coincident9 (Horizontal<3>,Front)
- Coincident10 (Horizontal<4>,Front)
- Coincident11 (Horizontal<5>,Front)
- Coincident12 (Horizontal<1>,Right)
- Coincident13 (Horizontal<1>,Top)
- Coincident14 (Horizontal<1>,Horizontal<2>)
- Coincident15 (Horizontal<2>,Horizontal<3>)
- Coincident16 (Horizontal<3>,Top)
- Coincident17 (Horizontal<1>,Diagonal<1>)
- Coincident19 (Diagonal<1>,Diagonal<2>)

[3] This **Mate** corresponds to the support in Y-direction at A.

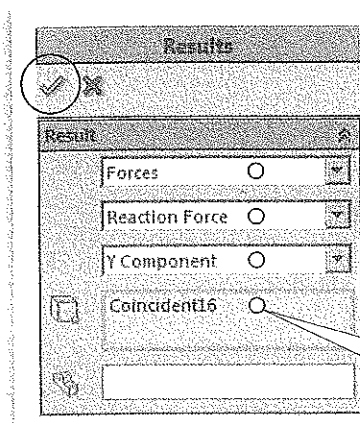
[7] This **Mate** corresponds to the support in Y-direction at G.



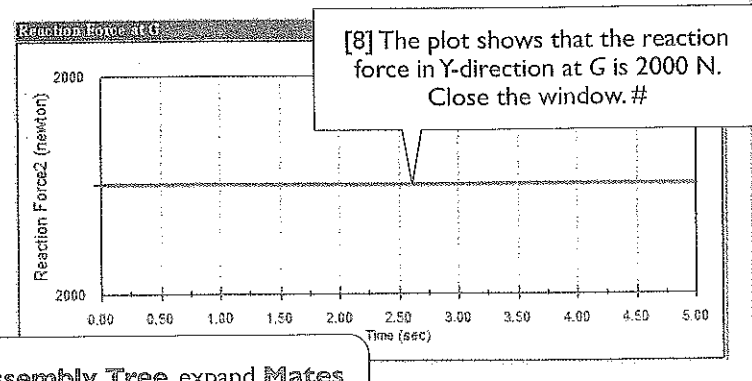
[2] In the **Assembly Tree**, expand **Mates** and select the **Coincident** mate (**Horizontal<1>, Top**) [3]. Click **OK**. Remember to click **No** if a message box appears (1.1-12[5], page 18).



[4] The plot shows that the reaction force in Y-direction at A is 4000 N, consistent with the one calculated in Eq. 2.1-1(1) (page 32). Close the window.



[6] In the **Assembly Tree**, expand **Mates** and select the **Coincident** mate (**Horizontal<3>, Top**) [7]. Click **OK**.




[8] The plot shows that the reaction force in Y-direction at G is 2000 N. Close the window. #

2.1-11 View the Member Force of Horizontal<4>

Mates

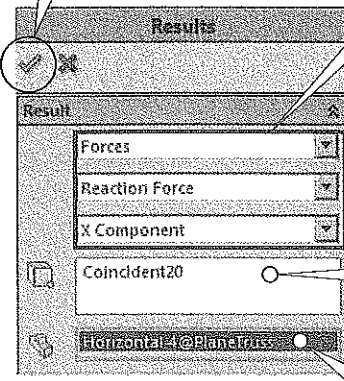
- Coincident1 (Diagonal<6>,Front)
- Coincident2 (Diagonal<5>,Front)
- Coincident3 (Diagonal<4>,Front)
- Coincident4 (Diagonal<3>,Front)
- Coincident5 (Diagonal<2>,Front)
- Coincident6 (Diagonal<1>,Front)
- Coincident7 (Horizontal<1>,Front)
- Coincident8 (Horizontal<2>,Front)
- Coincident9 (Horizontal<3>,Front)
- Coincident10 (Horizontal<4>,Front)
- Coincident11 (Horizontal<5>,Front)
- Coincident12 (Horizontal<1>,Right)
- Coincident13 (Horizontal<1>,Top)
- Coincident14 (Horizontal<1>,Horizontal<2>)
- Coincident15 (Horizontal<2>,Horizontal<3>)
- Coincident16 (Horizontal<3>,Top)
- Coincident17 (Horizontal<1>,Diagonal<1>)
- Coincident18 (Diagonal<1>,Diagonal<2>)
- Coincident19 (Horizontal<2>,Diagonal<2>)
- Coincident20 (Diagonal<1>,Horizontal<4>)
- Coincident21 (Horizontal<4>,Diagonal<3>)
- Coincident22 (Horizontal<2>,Diagonal<3>)
- Coincident23 (Horizontal<4>,Horizontal<5>)
- Coincident24 (Horizontal<4>,Diagonal<4>)
- Coincident25 (Horizontal<2>,Diagonal<4>)
- Coincident26 (Horizontal<5>,Diagonal<5>)
- Coincident27 (Diagonal<4>,Diagonal<5>)
- Coincident28 (Diagonal<5>,Diagonal<6>)
- Coincident29 (Horizontal<3>,Diagonal<6>)

[1] These 4 Mates involve **Horizontal<4>**. (Yours may not be the same as mine. If so, find all mates involving **Horizontal<4>**.) Let's retrieve these reaction forces and calculate the resultant forces on **Horizontal<4>**. Note that, when two **Parts** are involved in a **Mate**, the reported reaction force is the force acting on the first **Part** by the second **Part**.



[2] In **Motion** toolbar, click **Results and Plots**.

[6] Click **OK**.



[3] Select **X Components of Reaction Force**.

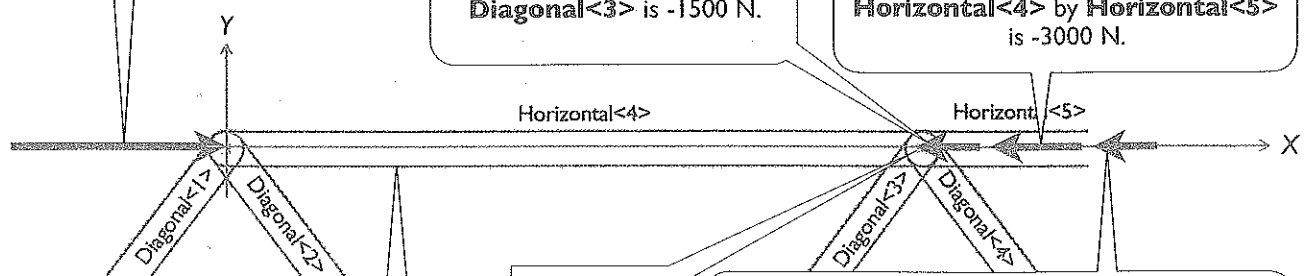
[4] In the **Assembly Tree**, select the first **Mate** involving **Horizontal<4>** (see [1]).

[5] Click here, and in the **Graphics Window**, click **Horizontal<4>**. **Reaction Force** in its **X-direction** (i.e., axial direction) will be reported.

[7] In my case, the reported **Reaction Force** is -6000 N, which is the force acting on **Diagonal<1>** by **Horizontal<4>**. Therefore, the force acting on **Horizontal<4>** by **Diagonal<1>** is +6000 N.

[8] Repeat steps [2-6], except, in step [4], selecting second **Mate** involving **Horizontal<4>** (see [1]). In my case, the reported force acting on **Horizontal<4>** by **Diagonal<3>** is -1500 N.

[9] Repeat steps [2-6], except, in step [4], selecting third **Mate** involving **Horizontal<4>** (see [1]). In my case, the reported force acting on **Horizontal<4>** by **Horizontal<5>** is -3000 N.

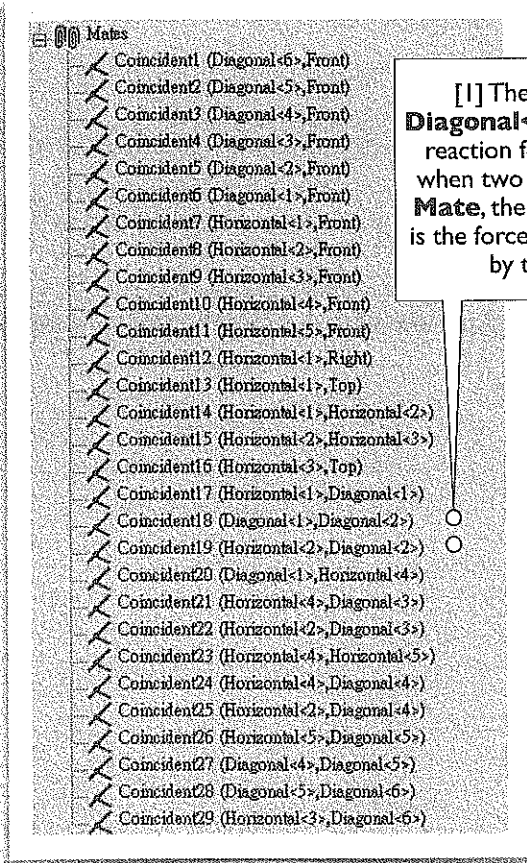


[12] We conclude that **Horizontal<4>** is subject to a compressive force of 6000 N, consistent with the calculated value in Eq. 2.1-1(2) (page 32). #

[11] Total force at this end is -6000 N.

[10] Repeat steps [2-6], except, in step [4], selecting fourth **Mate** involving **Horizontal<4>** (see [1]). In my case, the reported force acting on **Horizontal<4>** by **Diagonal<4>** is -1500 N.

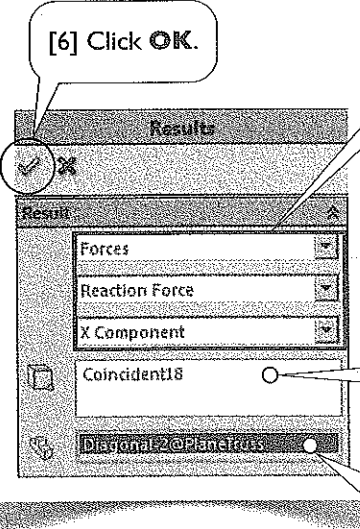
2.1-12 View the Member Force of Diagonal<2>



[1] These 2 Mates involve **Diagonal<2>**. Let's retrieve these reaction forces. Remember that, when two Parts are involved in a Mate, the reported reaction force is the force acting on the first Part by the second Part.



[2] In **Motion** toolbar, click **Results and Plots**.



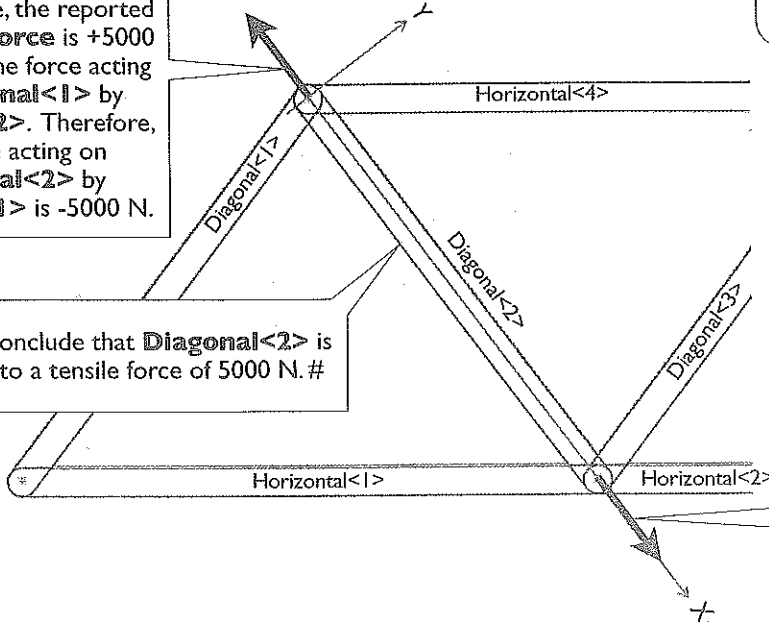
[6] Click **OK**.

[3] Select **X Components of Reaction Force**.

[4] In the **Assembly Tree**, select the first Mate involving **Diagonal<2>** (see [1]).

[5] Click here, and in the **Graphics Window**, click **Diagonal<2>**. **Reaction Force** along the axial direction will be reported.

[7] In my case, the reported **Reaction Force** is +5000 N, which is the force acting on **Diagonal<1>** by **Diagonal<2>**. Therefore, the force acting on **Diagonal<2>** by **Diagonal<1>** is -5000 N.



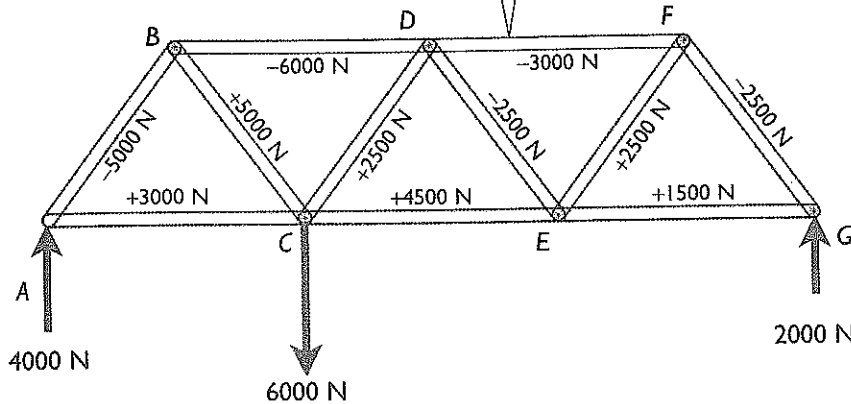
[9] We conclude that **Diagonal<2>** is subject to a tensile force of 5000 N. #

[8] Repeat steps [2-6], except, in step [4], selecting the second Mate involving **Diagonal<2>** (see [1]). In my case, the reported force acting on **Horizontal<2>** by **Diagonal<2>** is -5000 N. Therefore, the force acting on **Diagonal<2>** by **Horizontal<2>** is +5000 N.

2.1-13 Do It Yourself: Other Member Forces and Validation of the Results

Do It Yourself

[1] It leaves you to explore the other member forces. All member forces, along with the reaction forces at supports, are summarized like this.



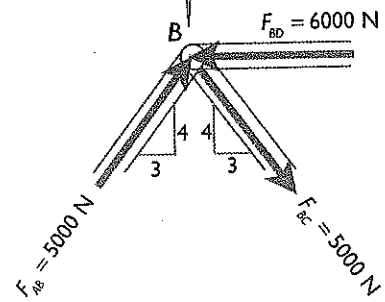
Do It Yourself

[2] To verify the validity of the results, we may check the force equilibria at each node. For example, at node B,

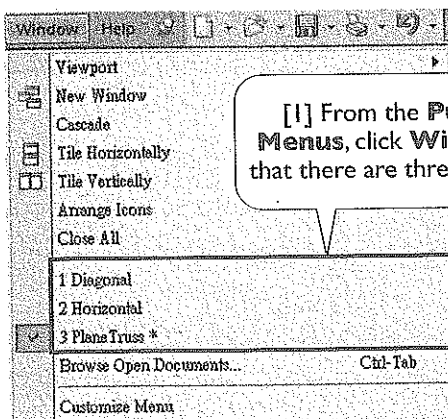
$$\sum F_x = \frac{3}{5}(5000 \text{ N}) + \frac{3}{5}(5000 \text{ N}) - (6000 \text{ N}) = 0,$$

$$\sum F_y = \frac{4}{5}(5000 \text{ N}) - \frac{4}{5}(5000 \text{ N}) = 0.$$

It leaves you to check the force balance at other nodes. #



2.1-14 Wrap Up



[1] From the **Pull-Down Menu**, click **Window** to see that there are three opened files.

[2] From the **Pull-Down Menu**, Select **File>Exit** to quit **SOLIDWORKS**. Click **Save all**. Click **Rebuild** and save the document.

Remark

[3] It seems, from 2.1-11 [8-11] (page 44), that the compressive force 6000 N acting on the right-end of **Horizontal<4>** consists of three forces (1500 N, 3000 N, and 1500 N) which come from three members respectively. That may not be true. There is no way to know how much portion of force is from a specific member.

There are more than one way to "mate" the members at a specific joint. And they end up with different force components. However, the total force acting on the end of a member is always the same. #