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,

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

$$A_Y = 4000\text{ N} \qquad (1)$$

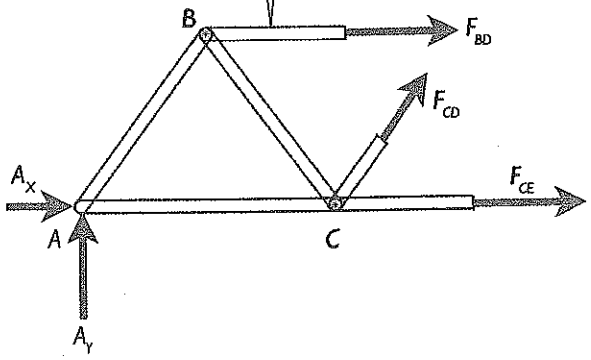
From the free-body diagram shown in [4], taking the moment equilibrium about C, we may calculate F_{BD},

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

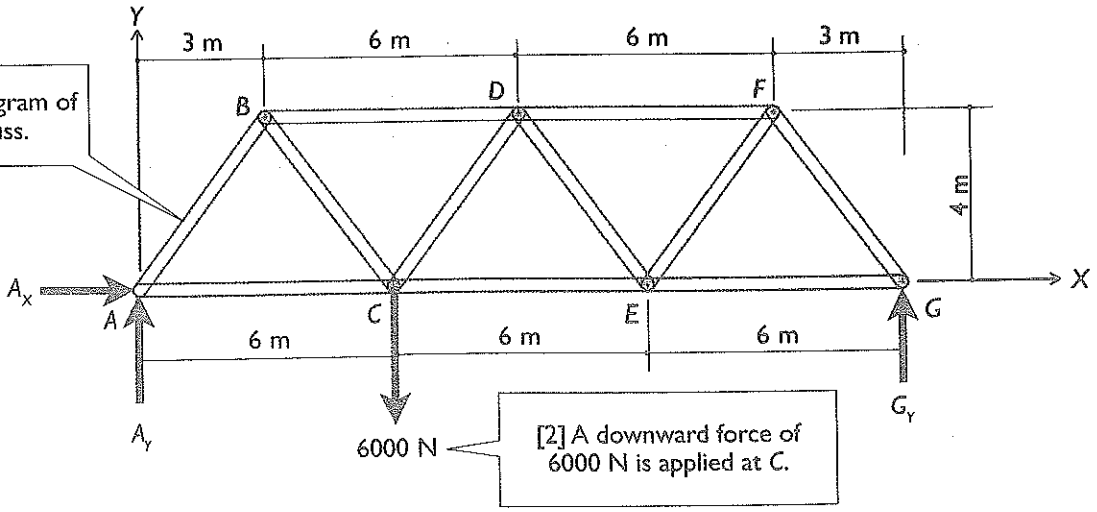
$$F_{BD} = -6000\text{ N} \qquad (2)$$

The negative sign indicates that it is a compressive force.

[4] A free-body diagram. #

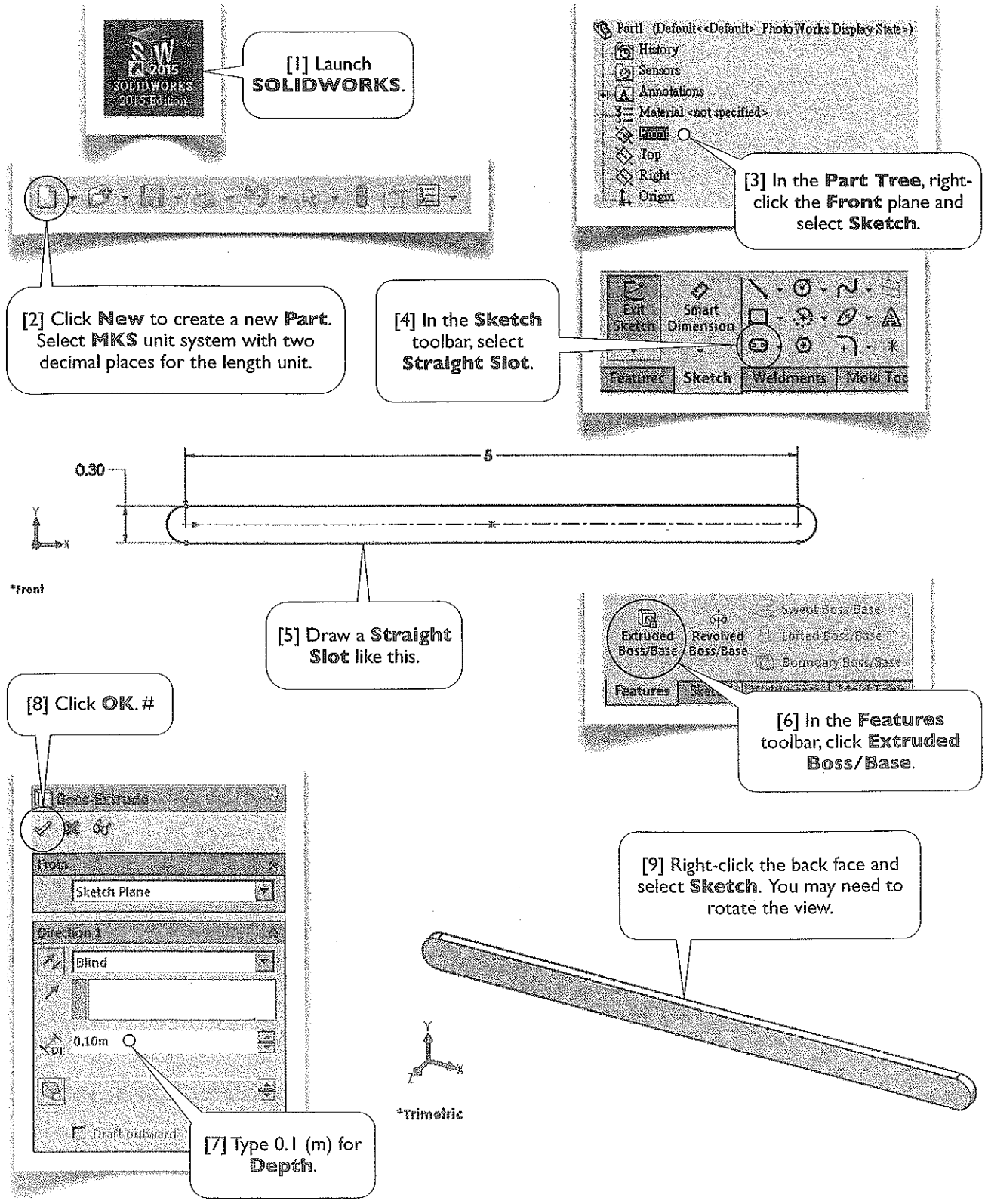


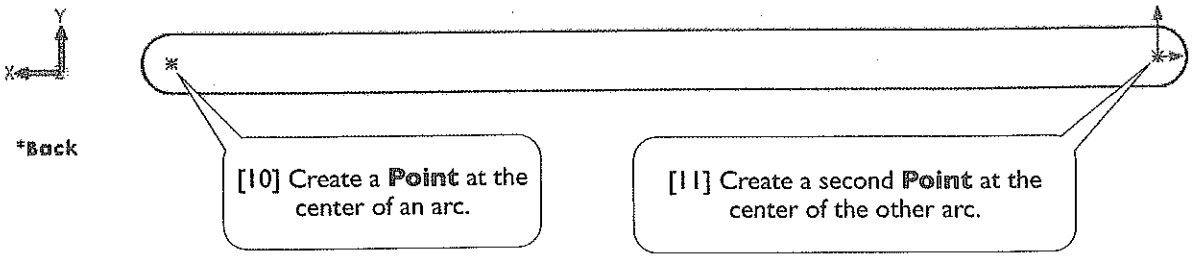
[3] Free-body diagram of the entire truss.

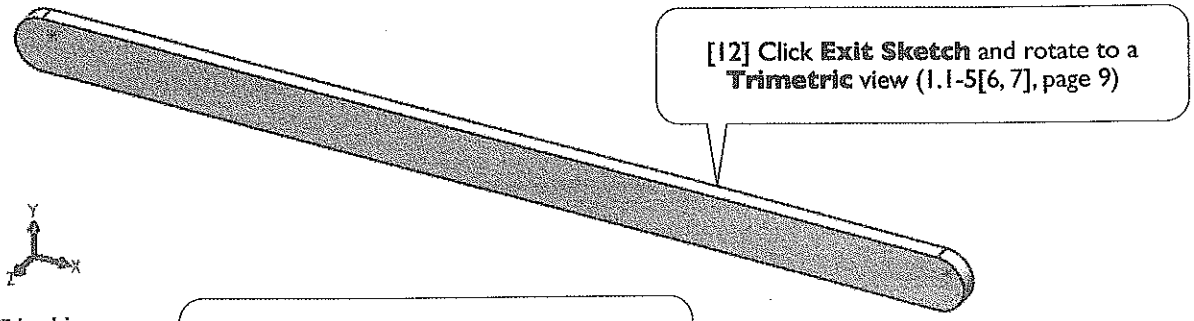


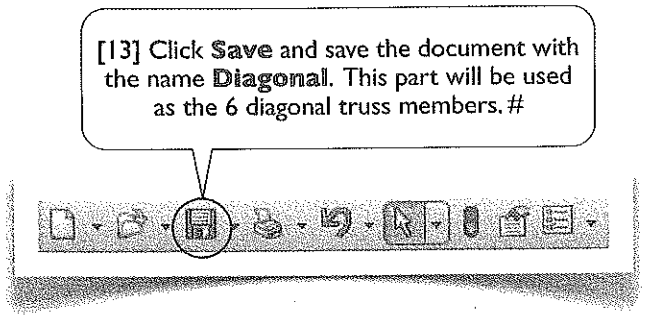
[2] A downward force of 6000 N is applied at C.

2.1-2 Start Up and Create a Part: **Diagonal**

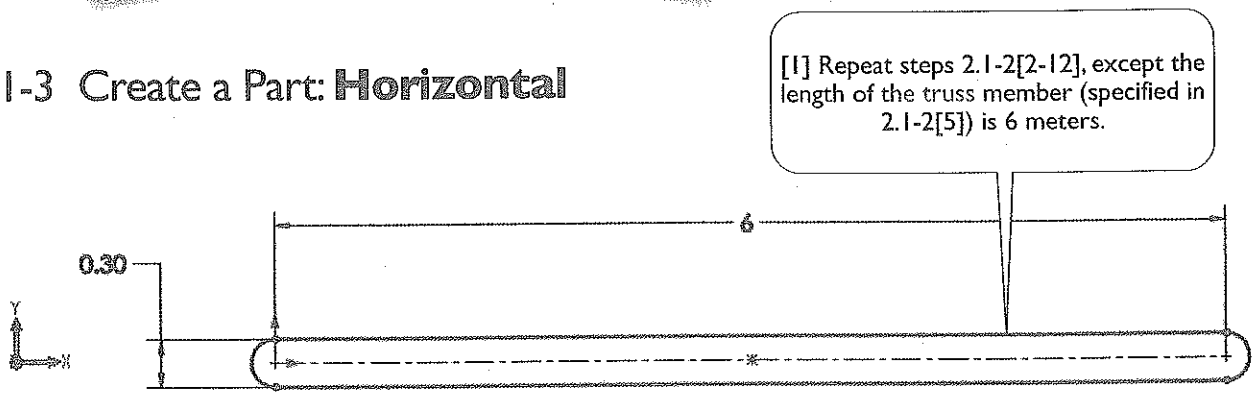


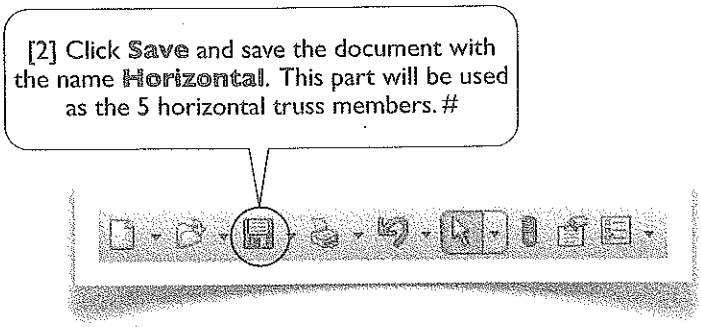




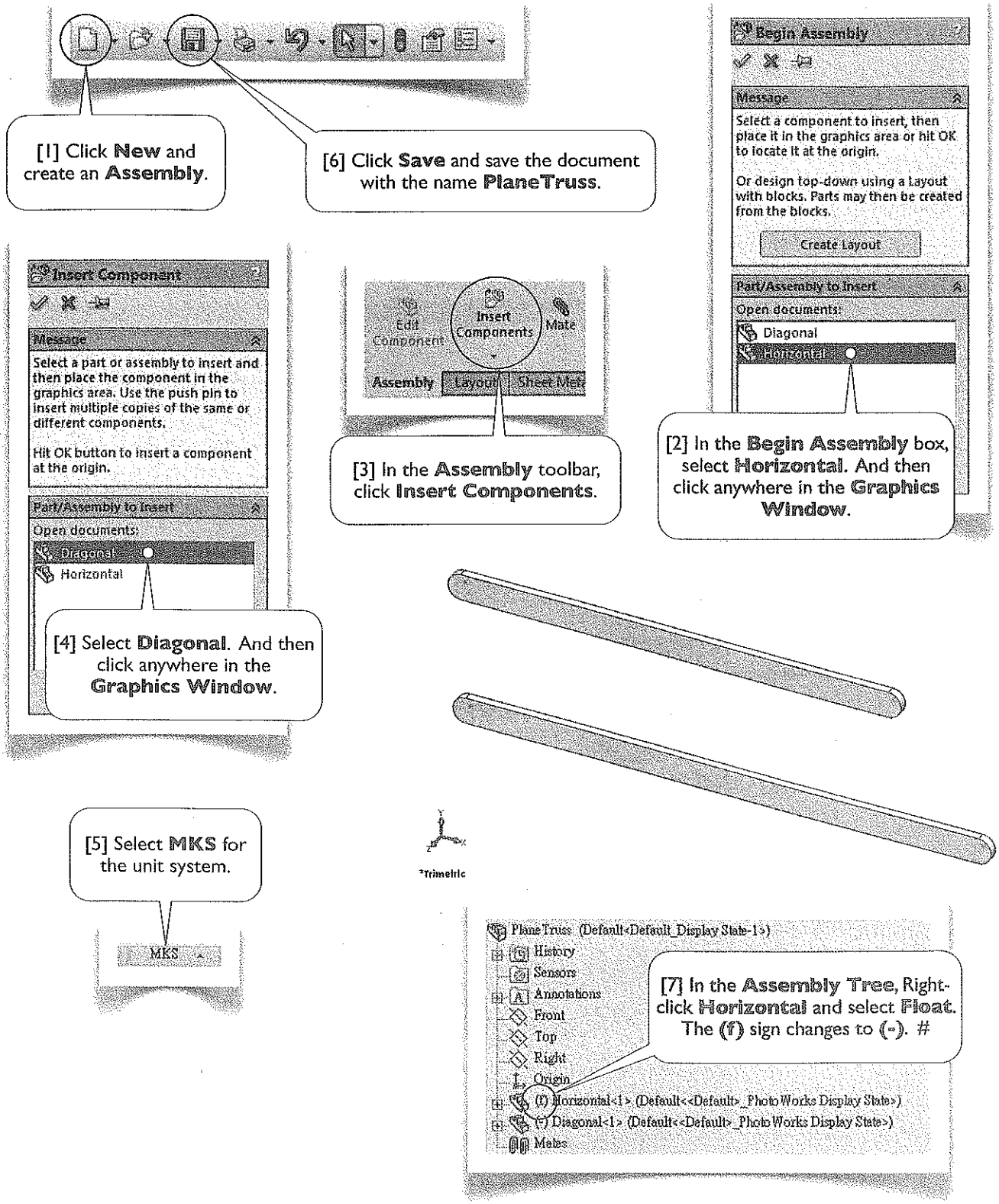


2.1-3 Create a Part: **Horizontal**

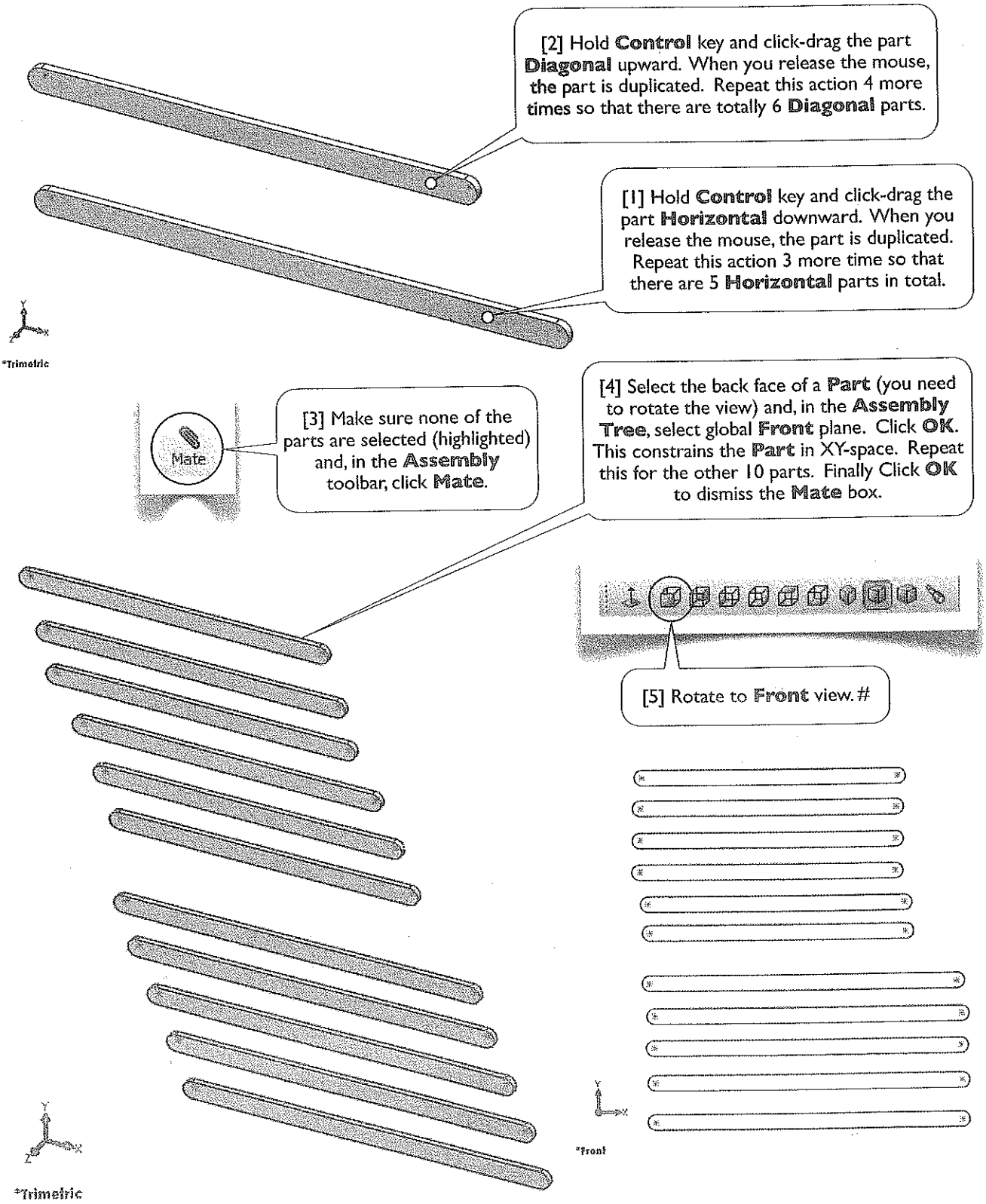




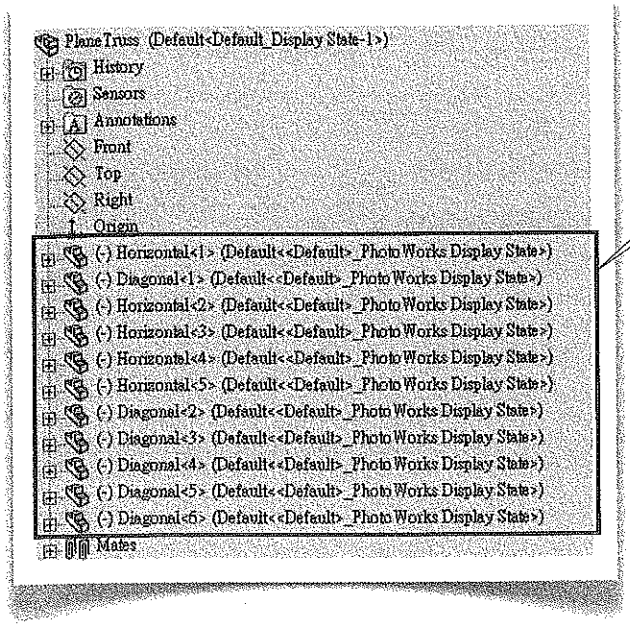
2.1-4 Create an Assembly: **PlaneTruss**



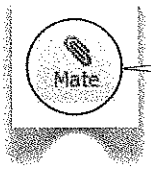
2.1-5 Duplicate **Parts** and Constrain all Members in XY-Space



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**.

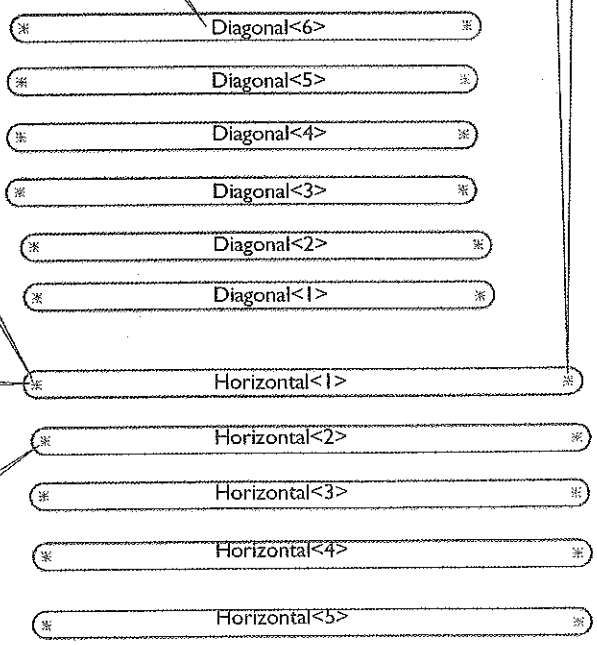
[2] Each member has an identification name like this.

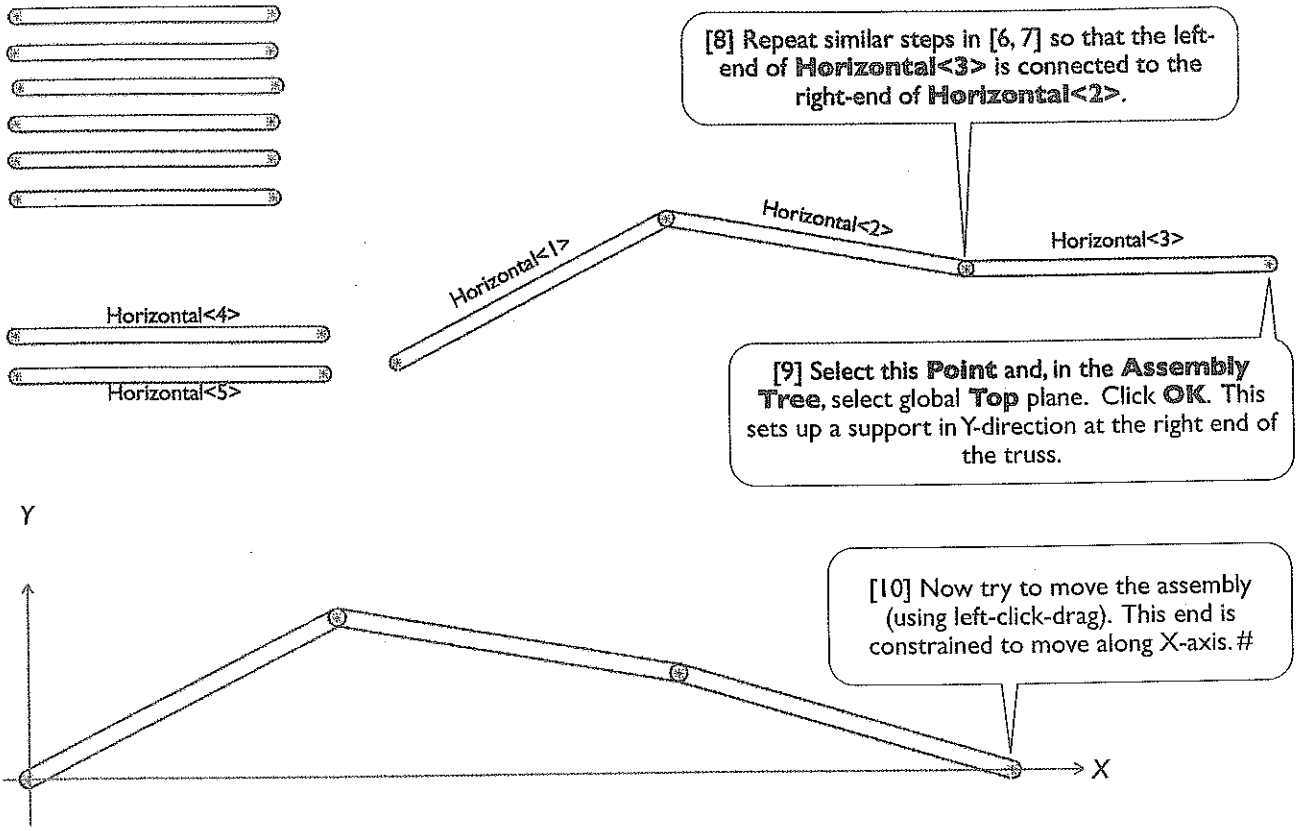
[4] Select the left **Point** of **Horizontal<1>** and, in the **Assembly Tree**, select global **Right** plane. Click **OK**. This sets up a support in X-direction at the left end of the truss.

[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.

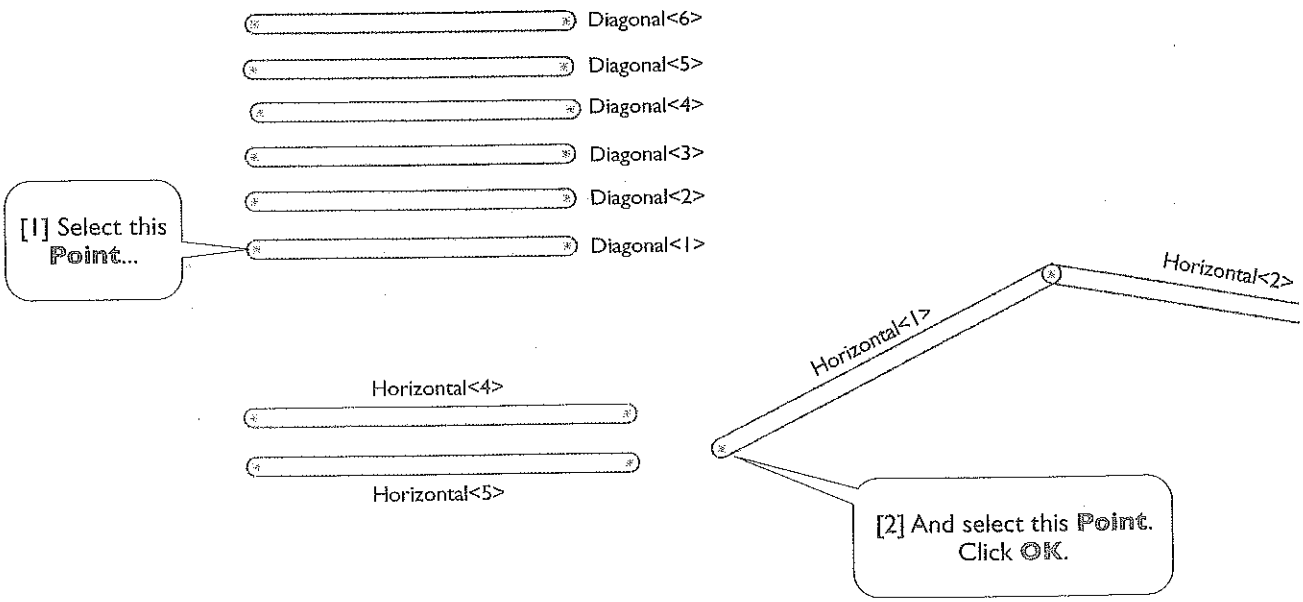
[6] Select the left **Point** of **Horizontal<2>**.

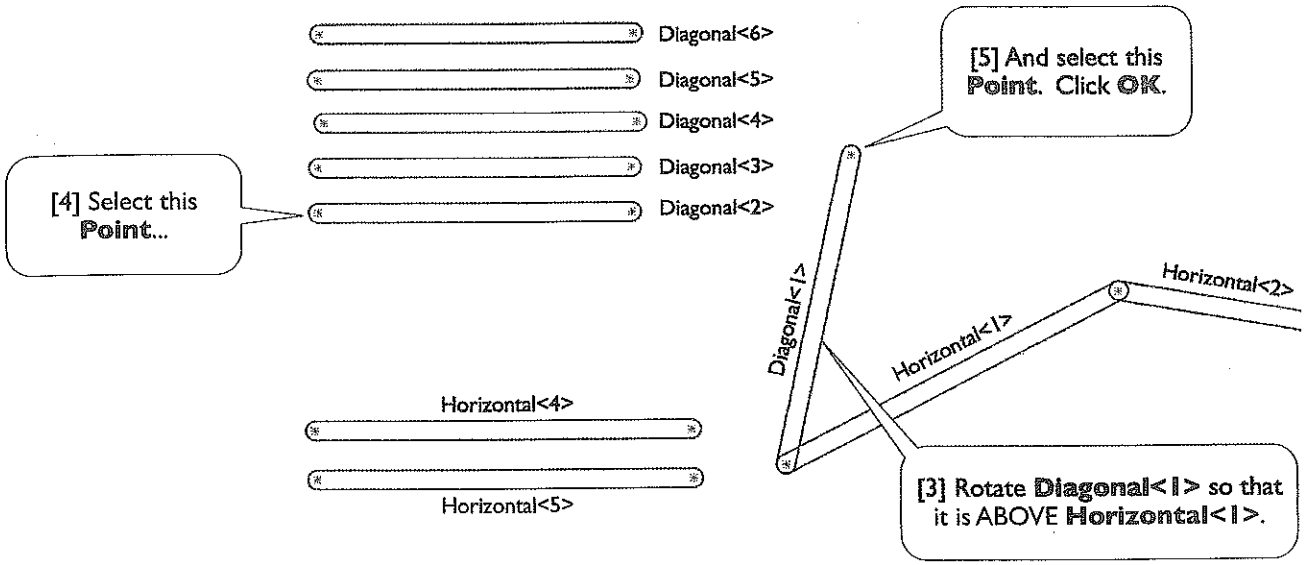
[7] And select the right **Point** of **Horizontal<1>**. Click **OK**. Now the two members are connected with a **revolute joint**. Try to move the newly joined member (using left-click-drag). It is constrained to rotate about its left end, which is free to move.

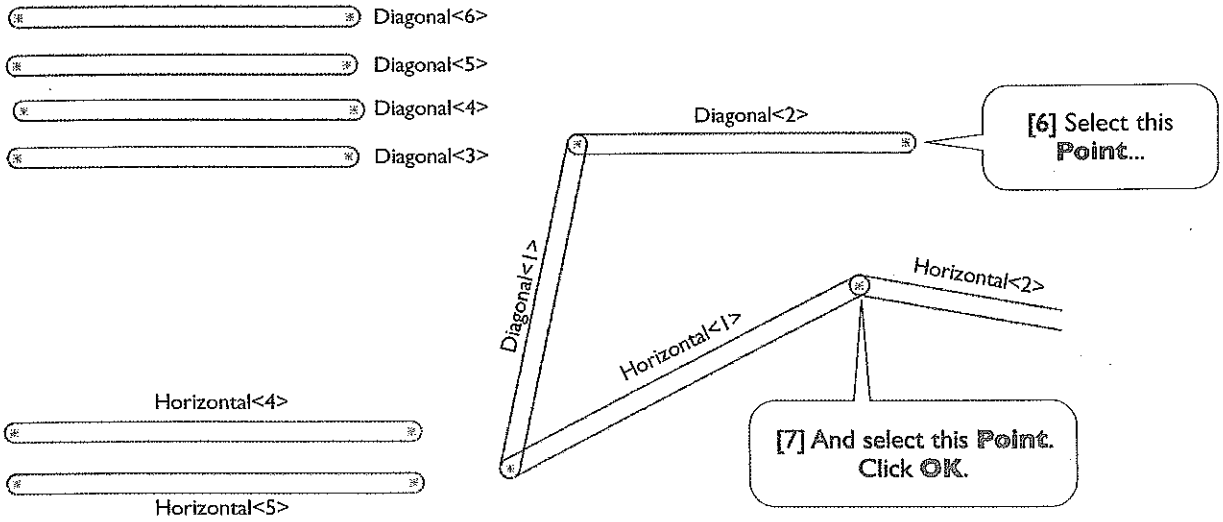


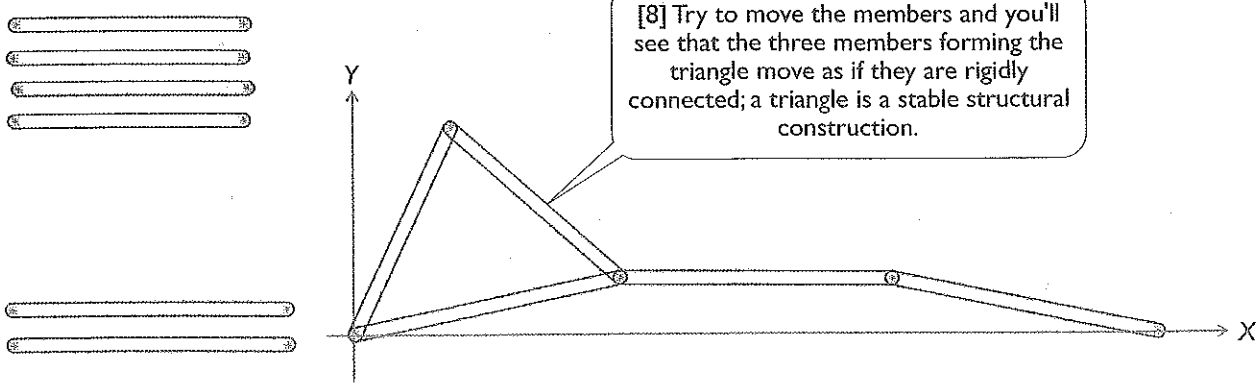


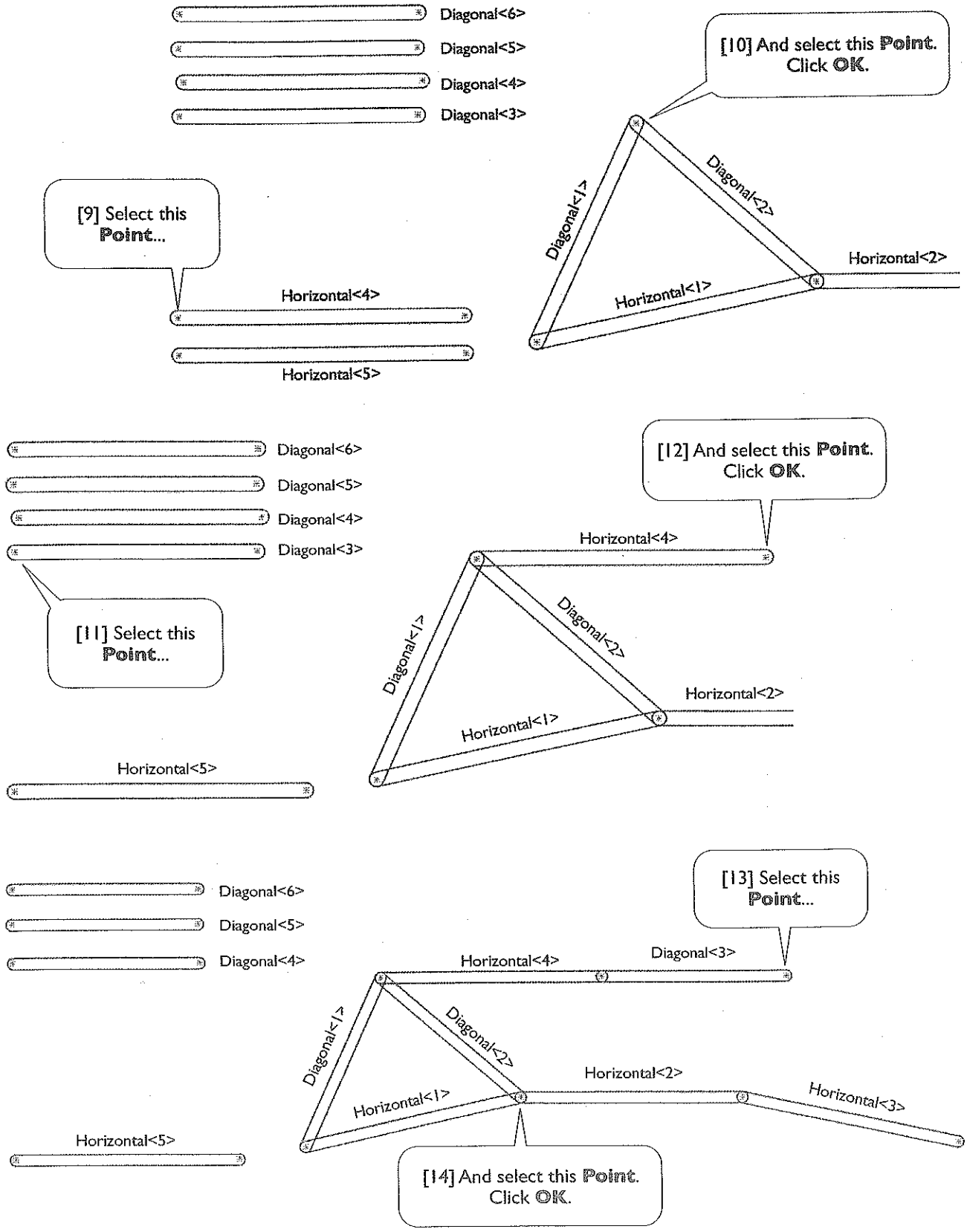
2.1-7 Assemble other Truss Members

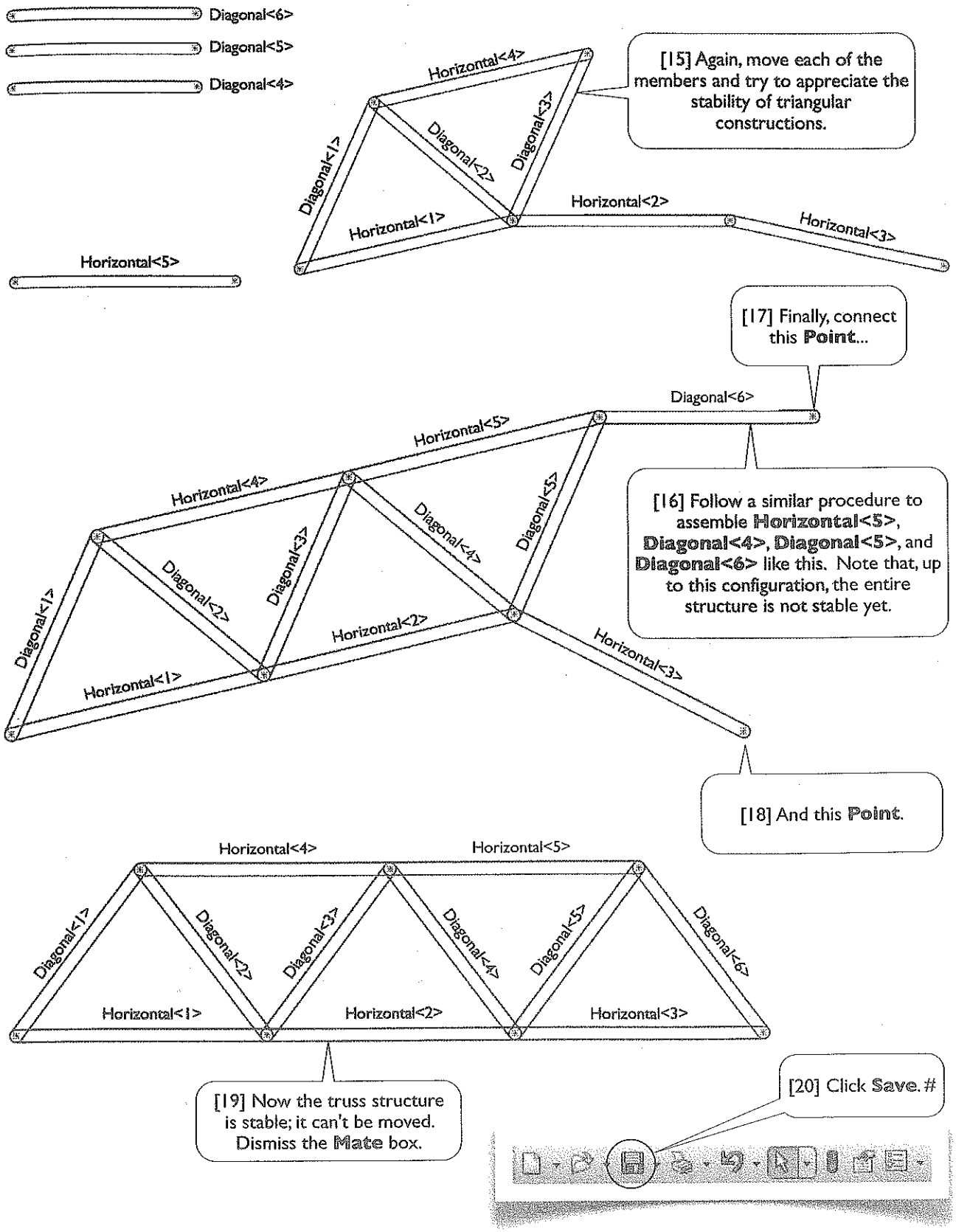



Diagonal<6>
Diagonal<5>
Diagonal<4>
Diagonal<3>
Diagonal<2>
[4] Select this Point...
[5] And select this Point. Click OK.
Diagonal<1>
Horizontal<1>
Horizontal<2>
Horizontal<4>
Horizontal<5>
[3] Rotate Diagonal<1> so that it is ABOVE Horizontal<1>.

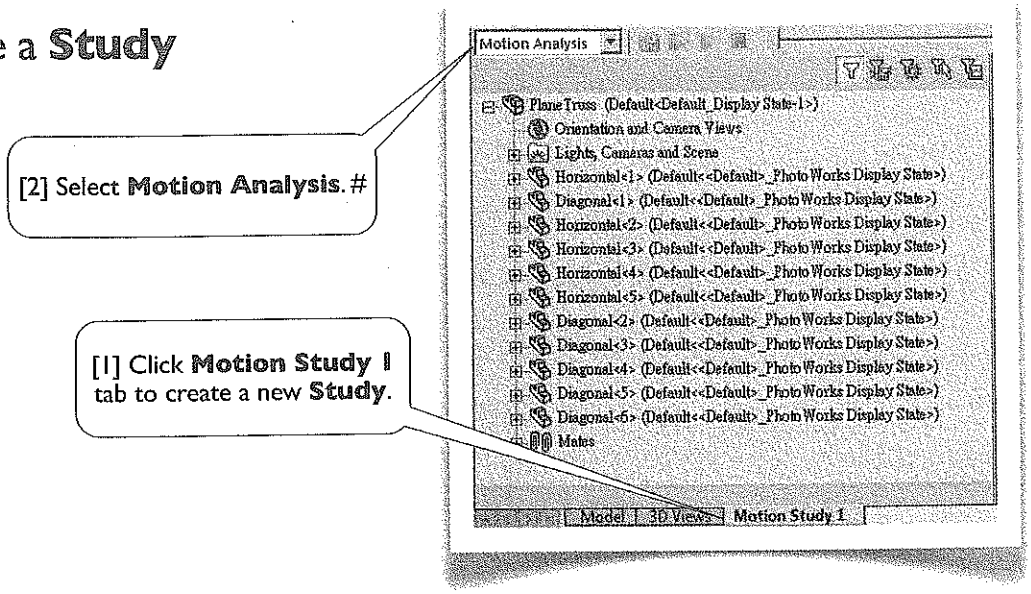

Diagonal<6>
Diagonal<5>
Diagonal<4>
Diagonal<3>
Diagonal<2>
[6] Select this Point...
Diagonal<1>
Horizontal<1>
Horizontal<2>
Horizontal<4>
Horizontal<5>
[7] And select this Point. Click OK.


[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.
Y
X

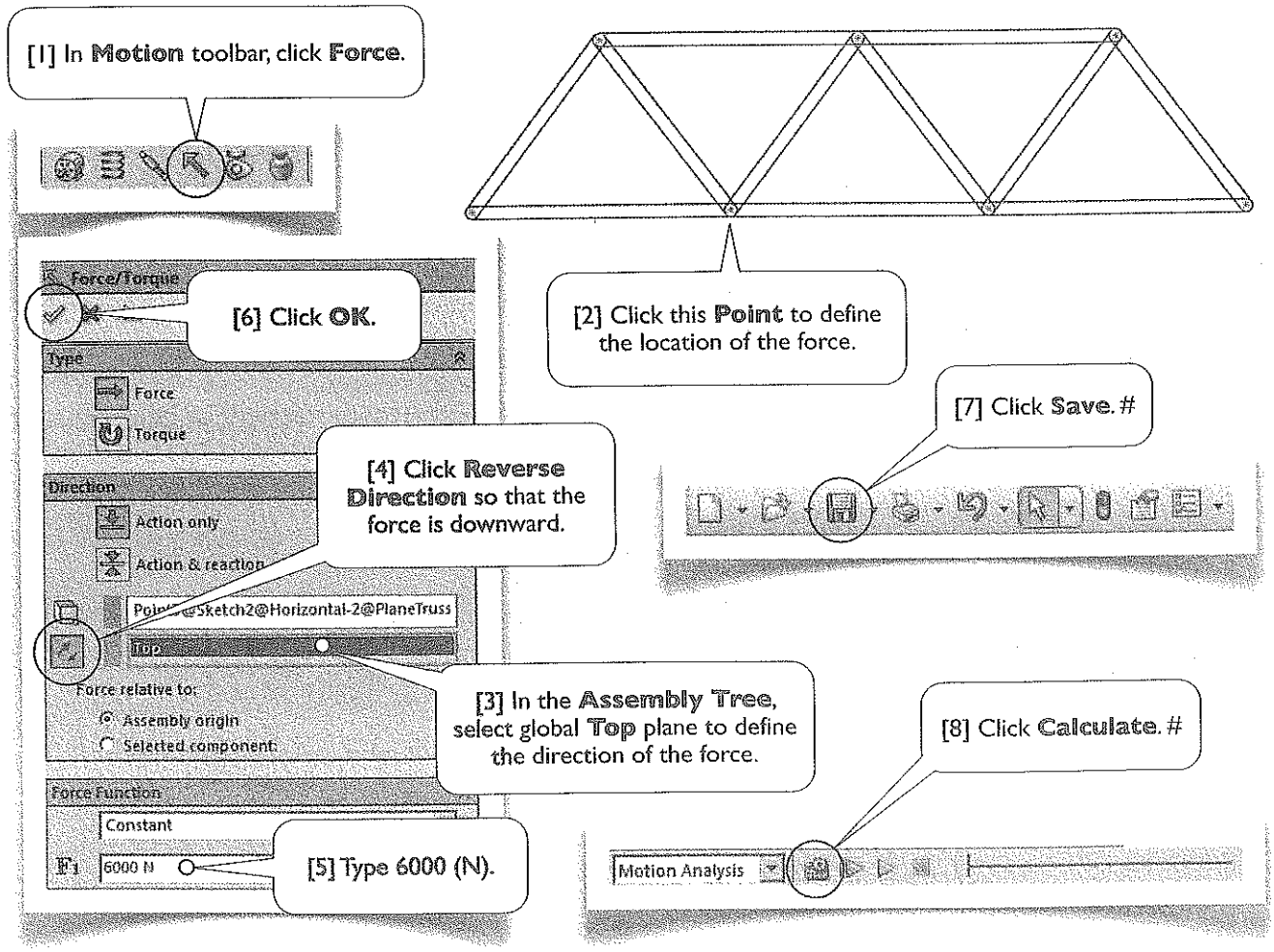

Diagonal<6>
Diagonal<5>
Diagonal<4>
Diagonal<3>
[9] Select this Point...
Horizontal<4>
Horizontal<5>
[10] And select this Point. Click OK.
Diagonal<1>
Diagonal<2>
Horizontal<2>
Horizontal<1>
Diagonal<6>
Diagonal<5>
Diagonal<4>
Diagonal<3>
[11] Select this Point...
Horizontal<5>
[12] And select this Point. Click OK.
Horizontal<4>
Diagonal<1>
Diagonal<2>
Horizontal<2>
Horizontal<1>
Diagonal<6>
Diagonal<5>
Diagonal<4>
[13] Select this Point...
Horizontal<4>
Diagonal<3>
Diagonal<1>
Diagonal<2>
Horizontal<2>
Horizontal<1>
Horizontal<3>
Horizontal<5>
[14] And select this Point. Click OK.


Diagonal<6>
Diagonal<5>
Diagonal<4>
Horizontal<5>
Horizontal<4>
Diagonal<1>
Diagonal<2>
Diagonal<3>
Horizontal<1>
Horizontal<2>
Horizontal<3>
[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. #

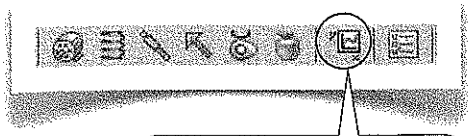
2.1-8 Create a **Study**



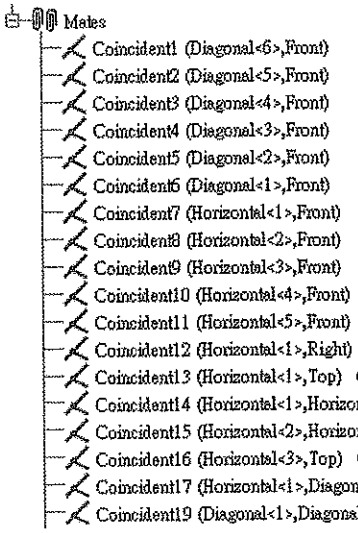
2.1-9 Set Up Forces and Calculate Results



2.1-10 View the Reaction Forces

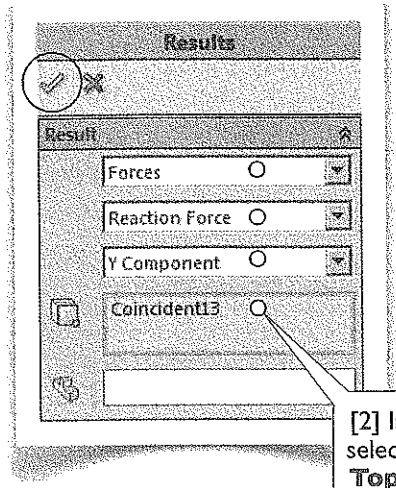


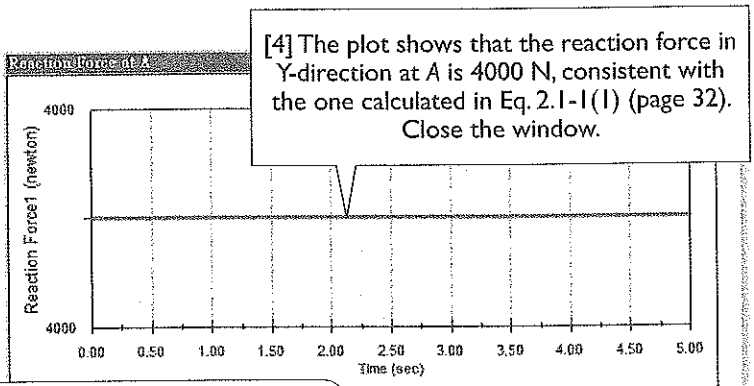
[1, 5] In **Motion** toolbar, click **Results and Plots**.



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

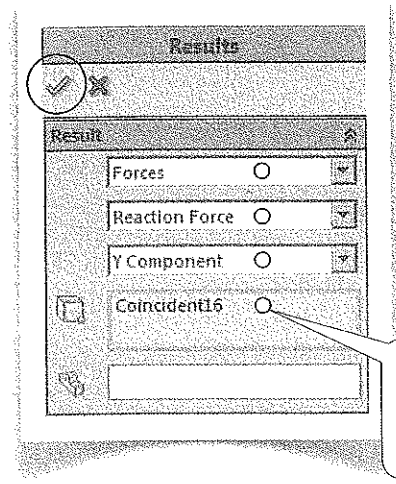
[7] This **Mate** corresponds to the support in Y-direction at *G*.

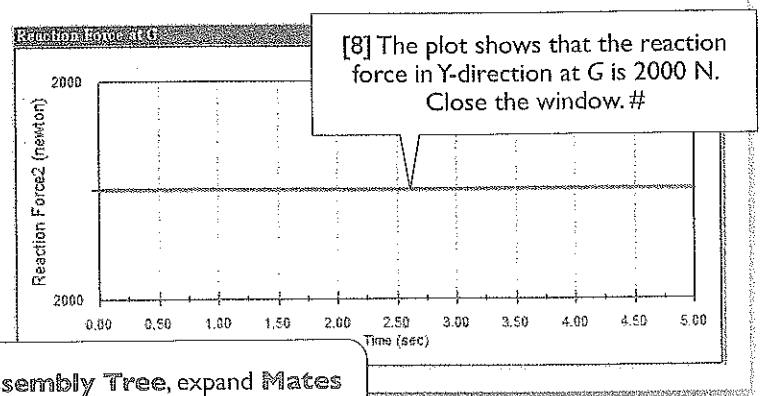




[4] The plot shows that the reaction force in Y-direction at *A* is 4000 N, consistent with the one calculated in Eq. 2.1-1(1) (page 32). Close the window.

[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).

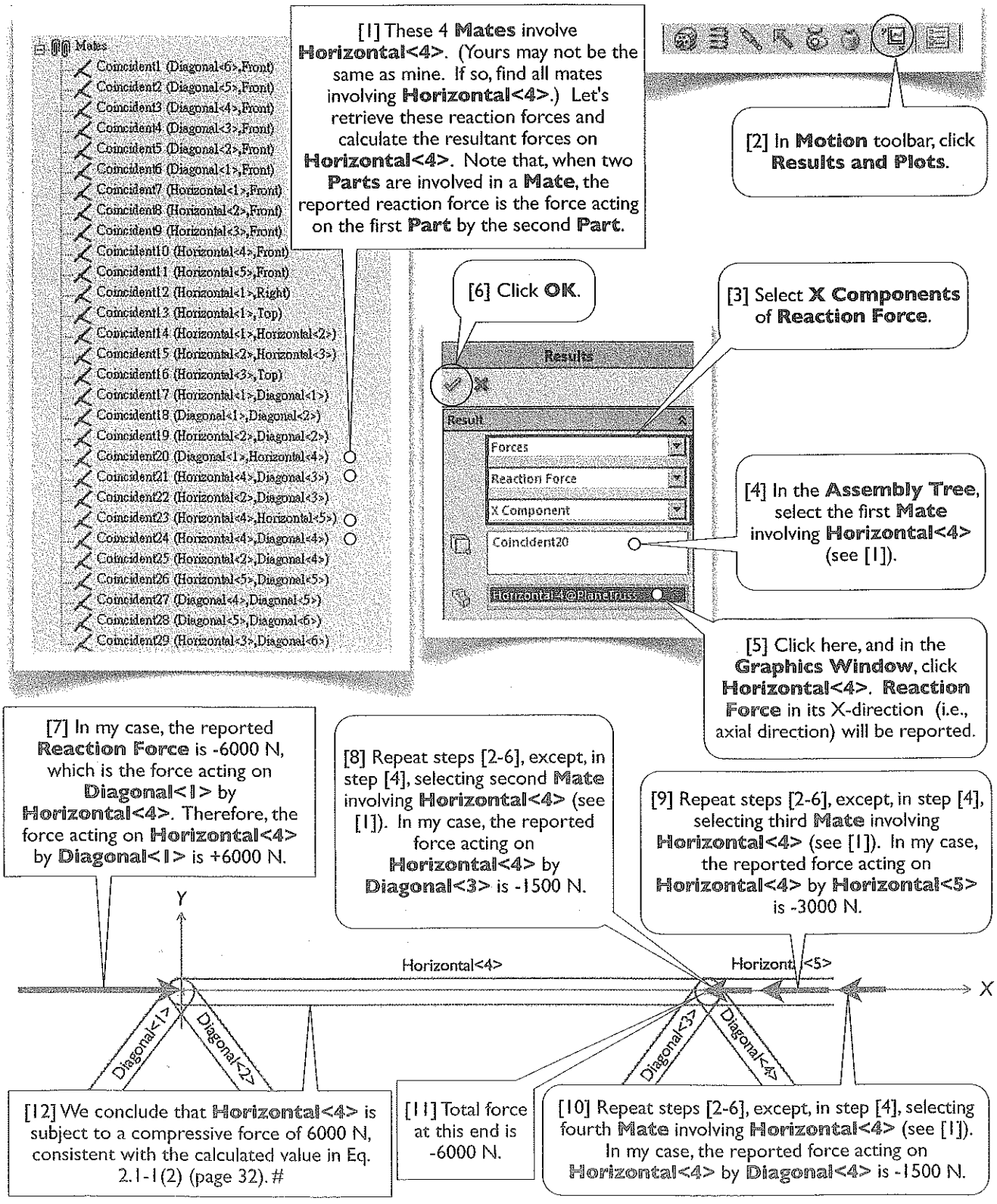




[8] The plot shows that the reaction force in Y-direction at *G* is 2000 N. Close the window. #

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

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



[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**.

[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.

[6] Click **OK**.

[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.

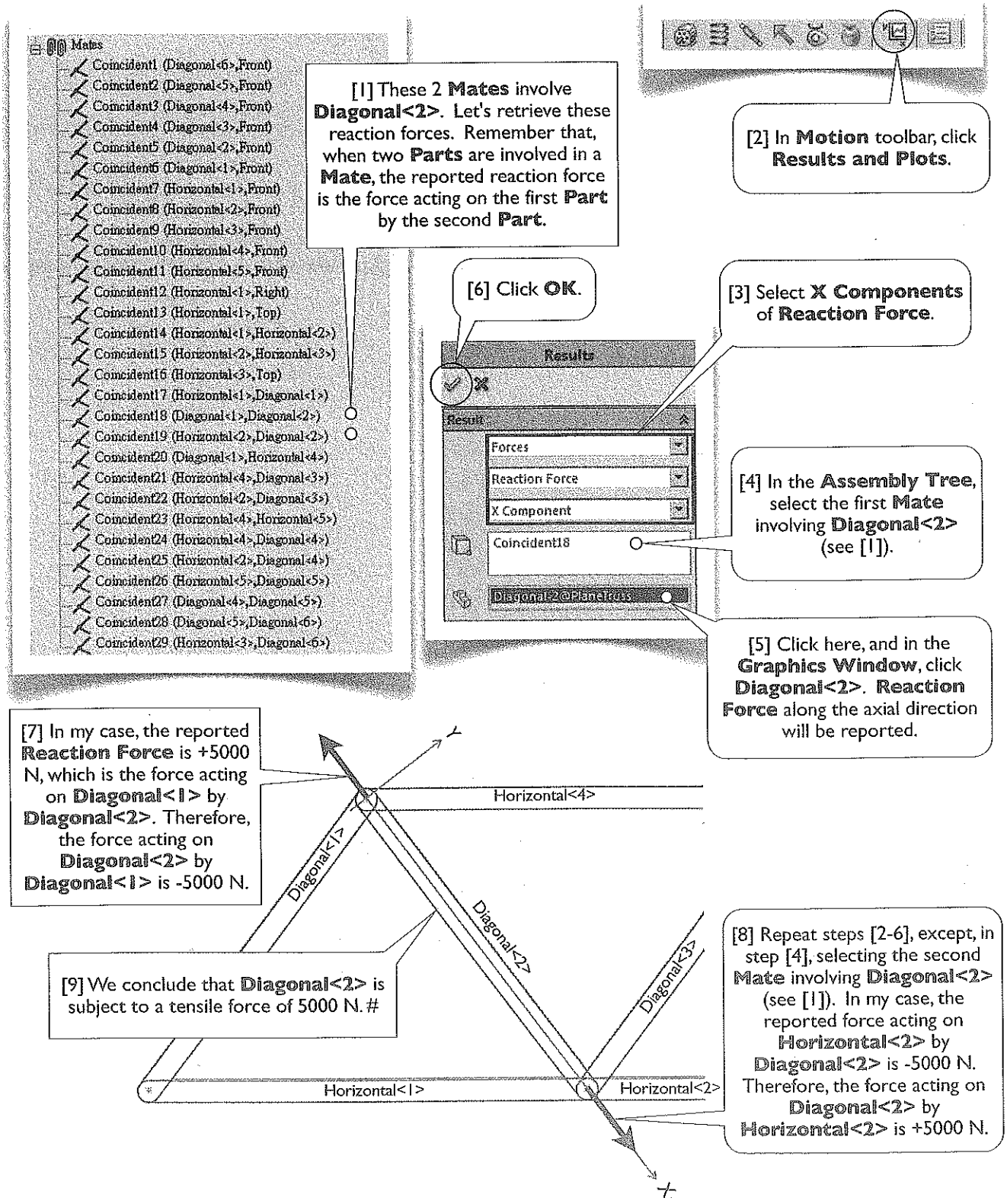
[9] Repeat steps [2-6], except, in step [4], selecting third **Mate** involving **Horizontal<4>** (see [1]). In my case, the reported force acting on **Horizontal<4>** by **Horizontal<5>** is -3000 N.

[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.

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

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



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.

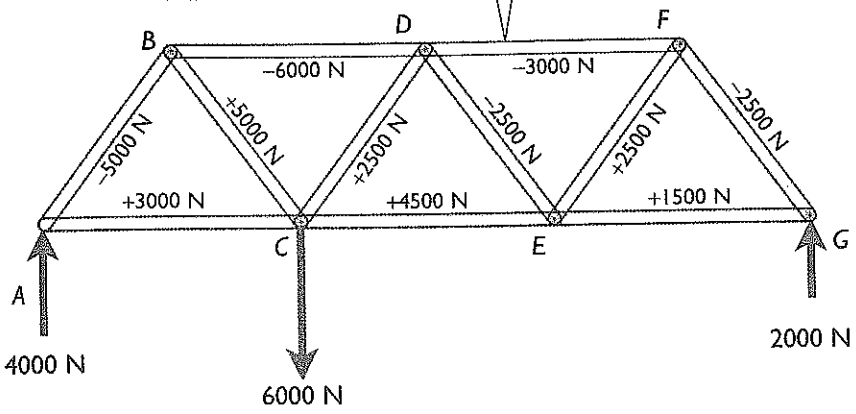
Do It Yourself

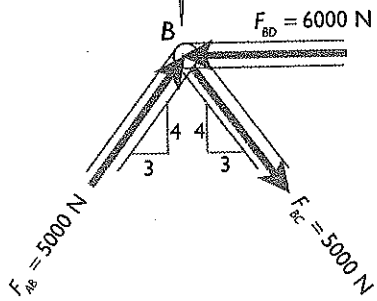
[2] To verify the validity of the results, we may check the force equilibria at each node. For example, at node *B*,

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

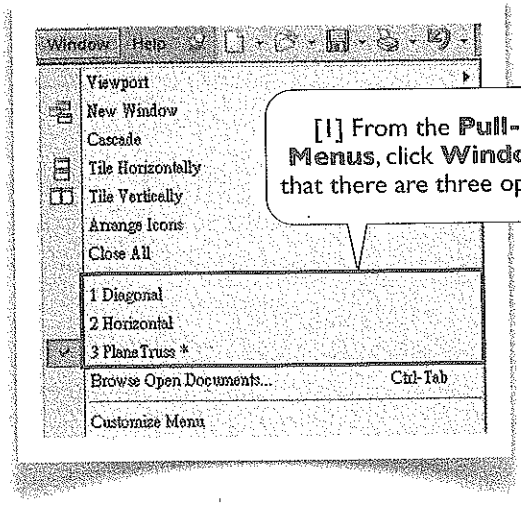
$$\sum F_Y = \frac{4}{5}(5000\text{ N}) - \frac{4}{5}(5000\text{ N}) = 0.$$

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





2.1-14 Wrap Up



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

[2] From the **Pull-Down Menus**, 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. #