Section 1.1

Supported Block: A 2D Case

1.1-1 Introduction

[1] In this section, we consider a block [2] supported by a hinge [3] and a roller [4] and find the reaction forces at the supports. Before we proceed to solve the problem using **SOLIDWORKS**, let's manually calculate the reaction forces.

From the free-body diagram [5], taking the moment equilibrium about *A*, we have

$$\sum M_A = 0$$

$$(150 \text{ N})(1 \text{ m}) + (300 \text{ N})(0.5 \text{ m}) - B_Y(1.5 \text{ m}) = 0$$

$$B_Y = 200 \text{ N}$$

Force equilibrium in *Y* direction,

$$\sum F_Y = 0$$

$$A_Y + B_Y - (300 \text{ N}) = 0 \quad (\text{where } B_Y = 200 \text{ N})$$

$$A_Y = 100 \text{ N}$$

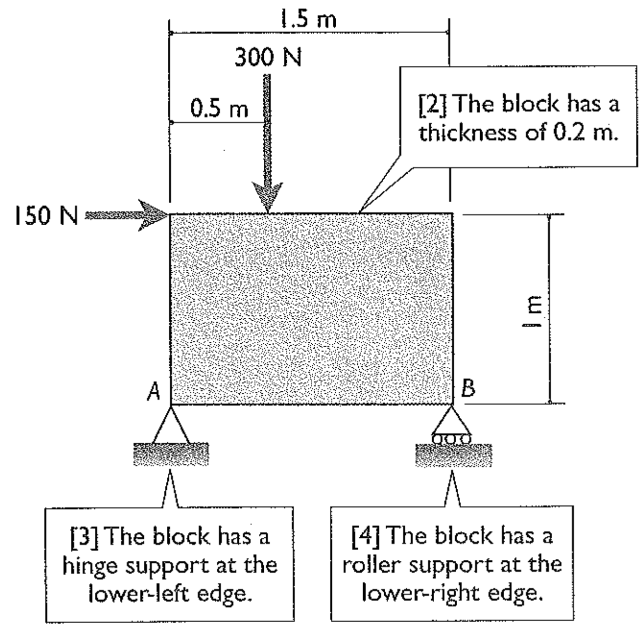
Finally, force equilibrium in *X* direction,

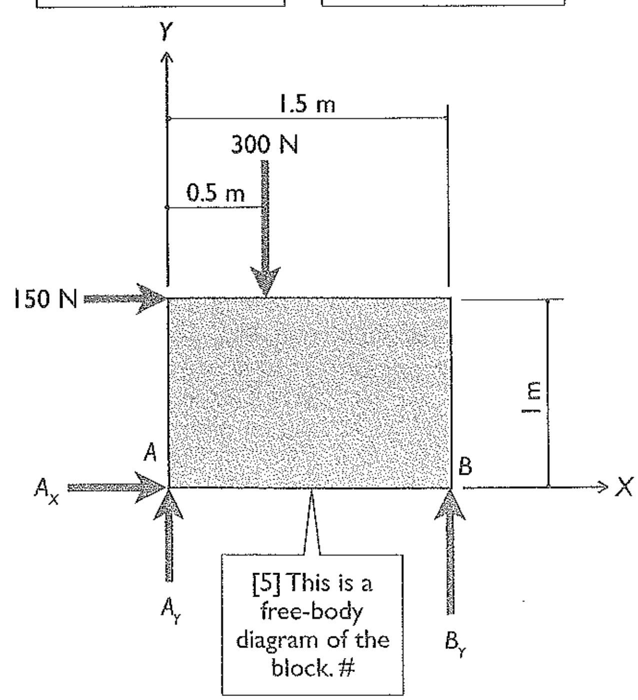
$$\sum F_X = 0$$

$$A_X + (150 \text{ N}) = 0$$

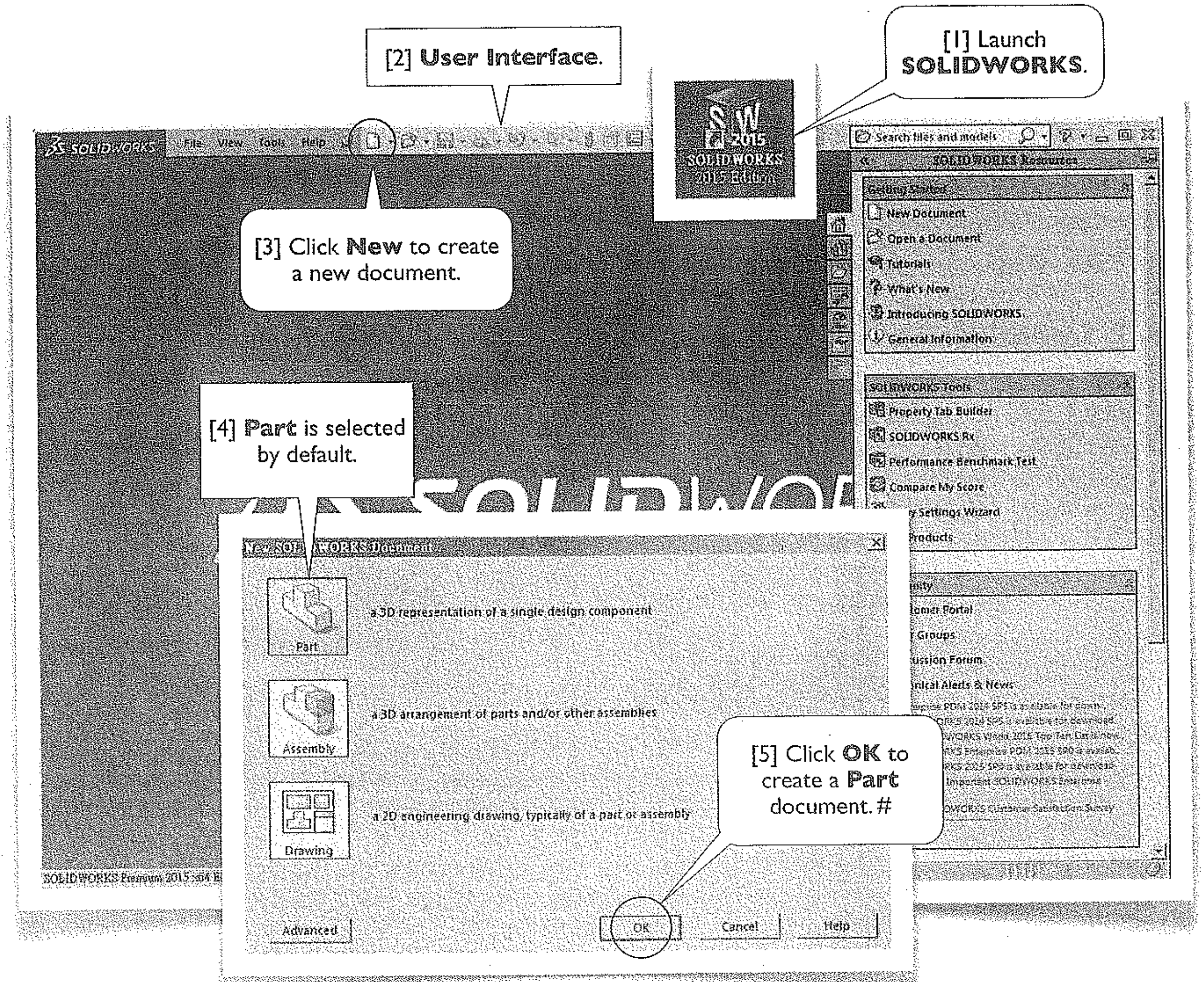
$$A_X = -150 \text{ N}$$

Note that the negative sign of A_X indicates that it is opposite to the assumed direction shown in [5]. Now, let's solve this problem with **SOLIDWORKS**. If you know how to solve a simple problem like this, you may be able to solve a much more complicated problem.





1.1-2 Launch **SOLIDWORKS** and Create a New Part



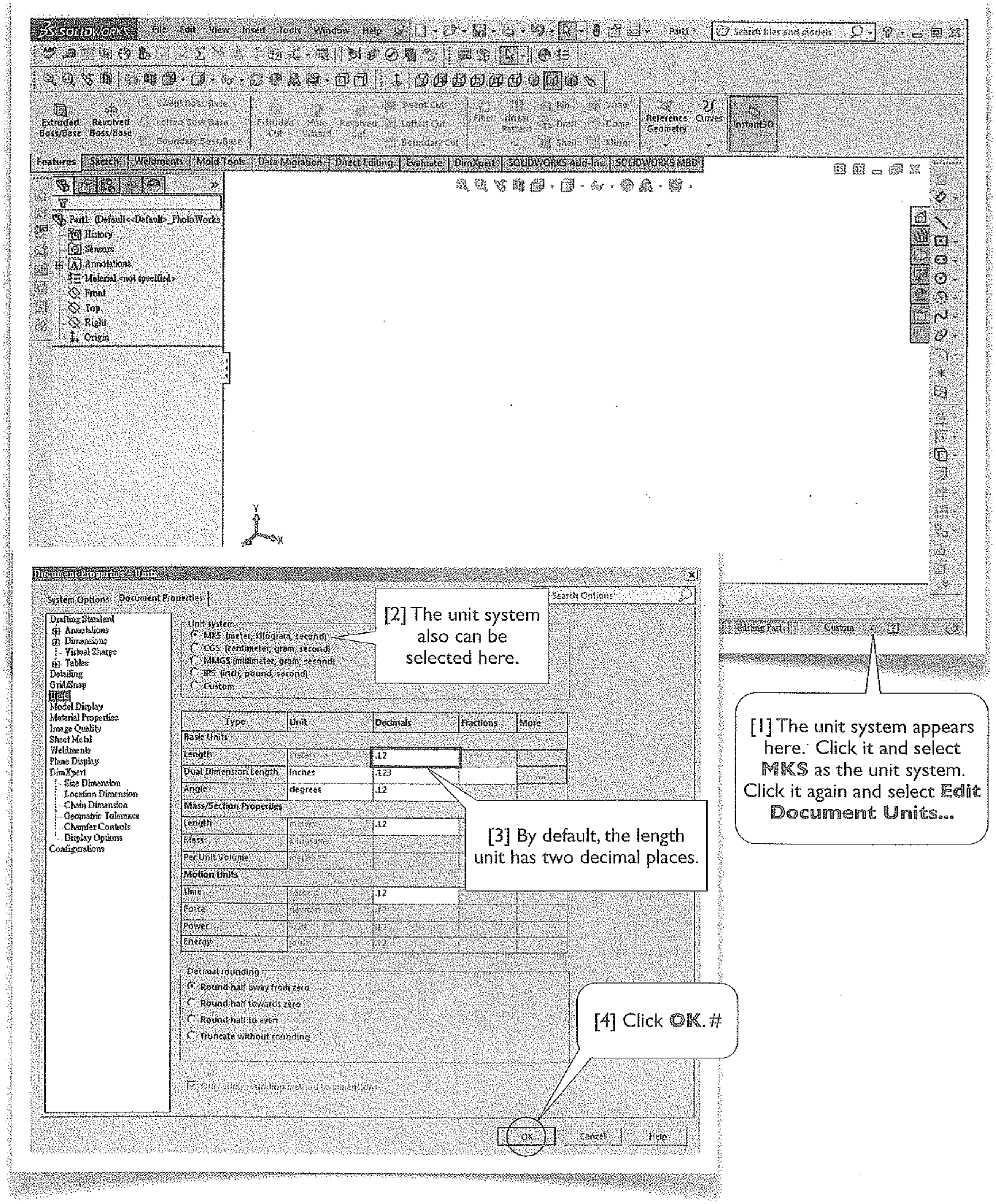
About the Textboxes

1. Within each subsection (e.g., 1.1-2), textboxes are ordered with numbers, each of which is enclosed by a pair of square brackets (e.g., [1]). When you read the contents of a subsection, please follow the order of the textboxes.
2. The textbox numbers are also used as reference numbers. Inside a subsection, we simply refer to a textbox by its number (e.g., [1]). From other subsections, we refer to a textbox by its subsection identifier and the textbox number (e.g., 1.1-2[1]).
3. A textbox is either round-cornered (e.g., [1, 3, 5]) or sharp-cornered (e.g., [2, 4]). A round-cornered textbox indicates that **mouse or keyboard actions** are needed in that step. A sharp-cornered textbox is used for commentary only; i.e., mouse or keyboard actions are not needed in that step.
4. A symbol # is used to indicate the last textbox of a subsection [5], so that you don't leave out any textboxes.

SOLIDWORKS Terms

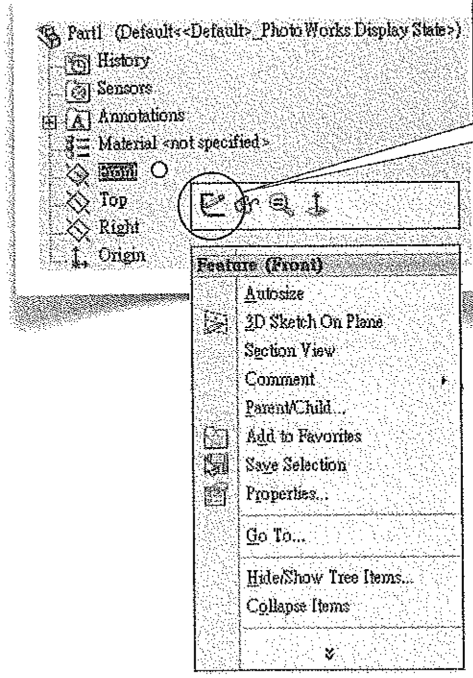
In this book, terms used in the **SOLIDWORKS** are boldfaced (e.g., **Part** in [4, 5]) to facilitate the readability.

1.1-3 Set Up Unit System

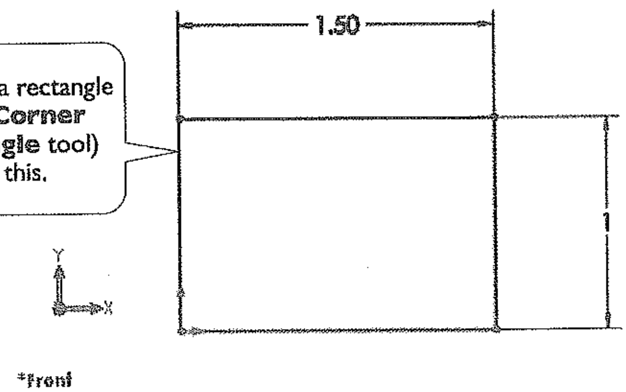


1.1-4 Create a Part: **Block**

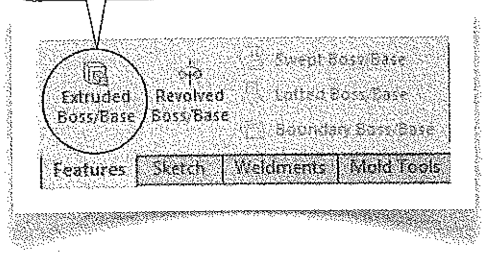
[1] In the **Features Tree** (also called **Part Tree** in this book), right-click **Front** plane and select **Sketch** from the **context menu**.

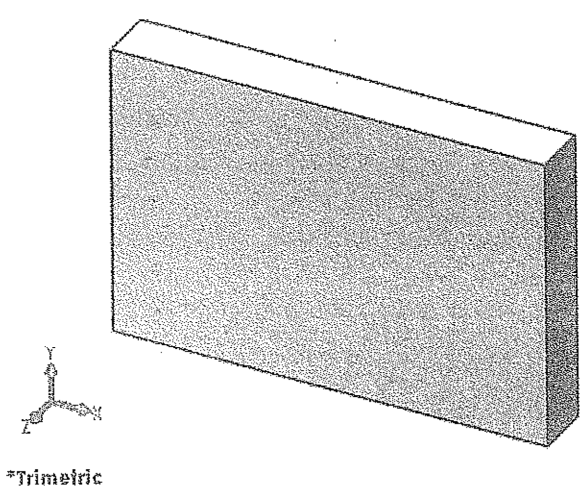


[2] Draw a rectangle (using **Corner Rectangle** tool) like this.

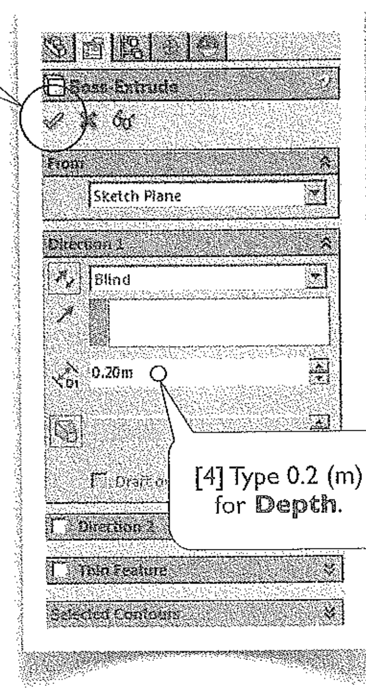


[3] In the **Features** toolbar, click **Extruded Boss/Base**.



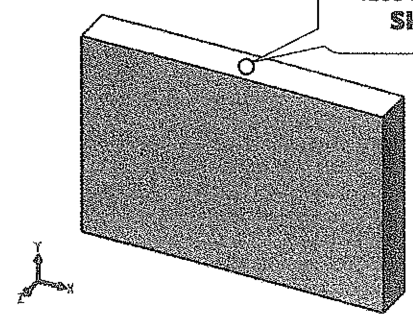


[5] Click **OK**. #

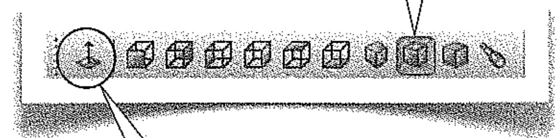


[4] Type 0.2 (m) for **Depth**.

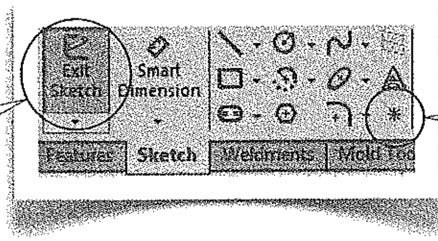
1.1-5 Create Two **Points** on the **Block**



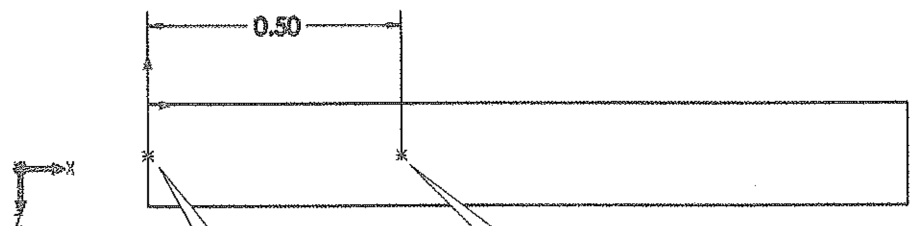
[1] Right-click this face and select **Sketch**.



[2] In the **Standard Views** toolbar, click **Normal To**.



[3] In **Sketch** toolbar, select **Point**.



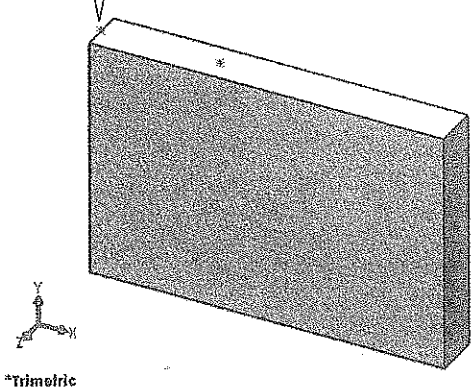
[4] Create a **Point** on the middle of this edge.

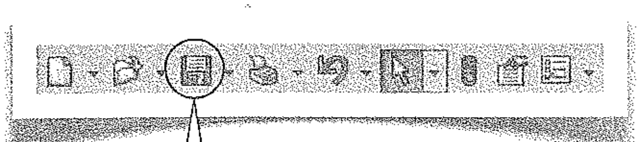
[5] Create a second **Point** like this. Impose a **Horizontal** relation between the two **Points**.

[6] Click **Exit Sketch**.

[7] Click **Trimetric**.

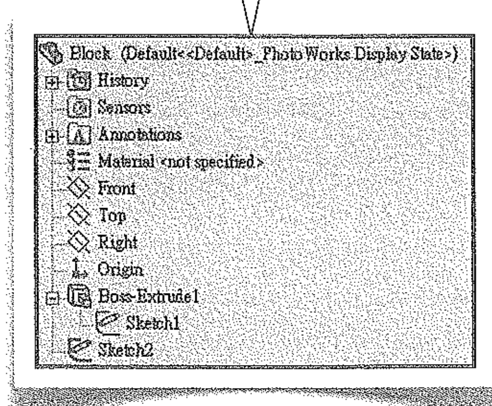
[8] The two **Points** will be used to locate the applied forces.





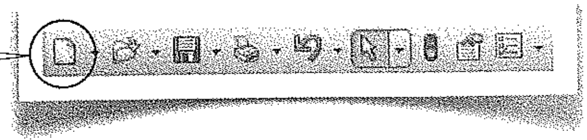
[9] Click **Save** and save the document with the name **Block**. A file **Block.SLDPRT** is created in your working folder.

[10] This is the **Features Tree**. In this book, we also call it a **Part Tree**. #

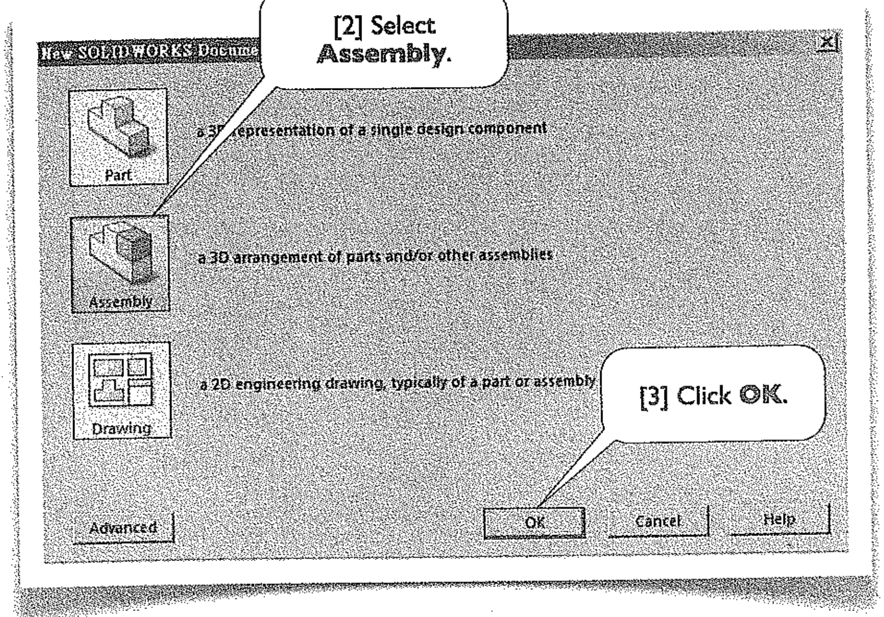


1.1-6 Create an Assembly: **BlockSupported**

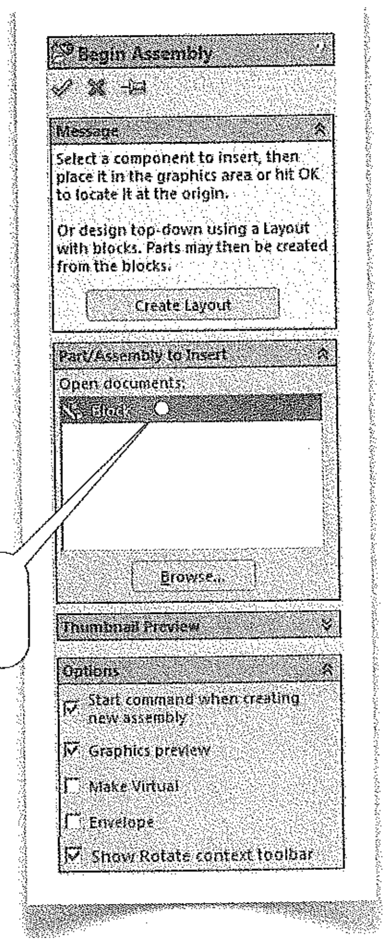
[1] Click **New**.



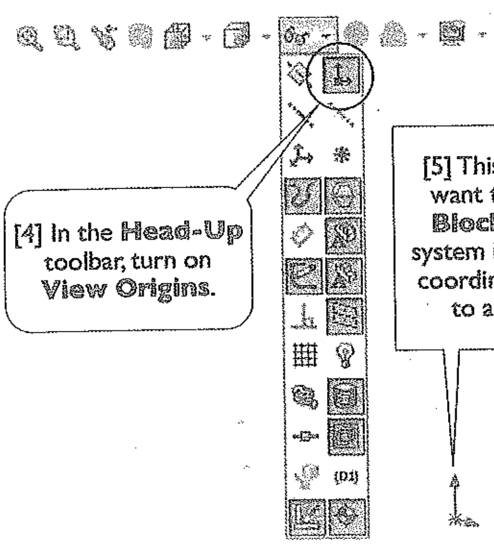
[2] Select **Assembly**.



[3] Click **OK**.



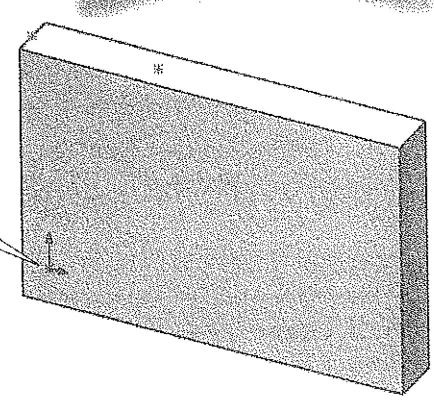
[6] In the **Begin Assembly** box, select **Block**.



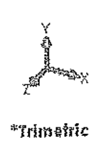
[4] In the **Head-Up** toolbar, turn on **View Origins**.

[5] This is the assembly's **Origin**. We want to show you how to insert the **Block** so that the part's coordinate system is coincident with the assembly's coordinate system, which we also refer to as the *global coordinate system*.

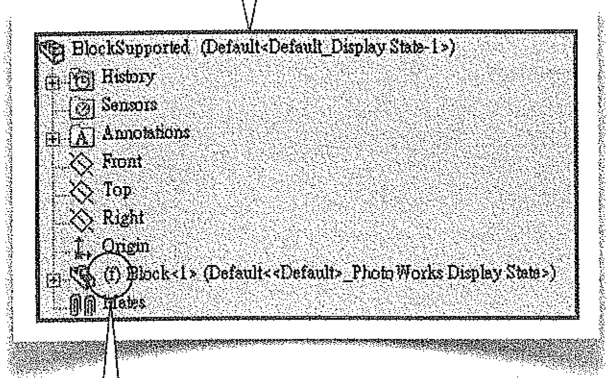
[7] Click the global **Origin**. Now the part is fixed in the space and its coordinate system is coincident with the global coordinate system.

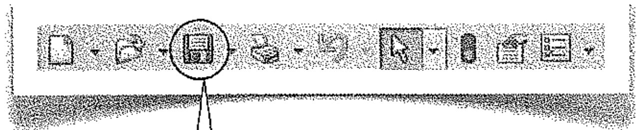


[8] Select **MKS** for the unit system with default decimal places. (1.1-3[1-4], page 7).



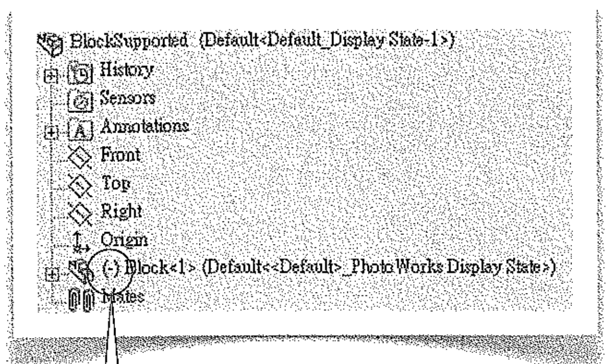
[10] This is the **Features Tree** of the **Assembly**. In this book, we simply call it an **Assembly Tree**.





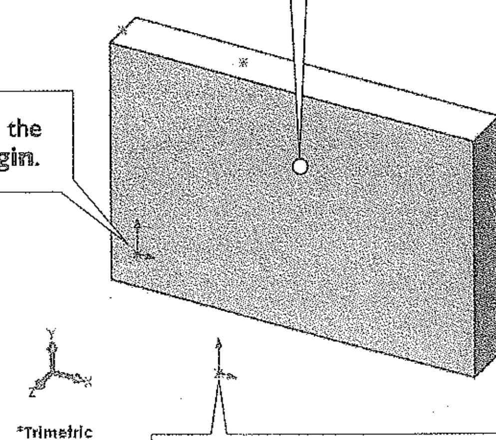
[9] Click **Save** and save the document with the name **BlockSupported**. A file **BlockSupported.SLDASM** is created in your working folder.

[11] An **(f)** sign indicates that the **Block** is fixed in the space. Now, right-click it and select **Float**.



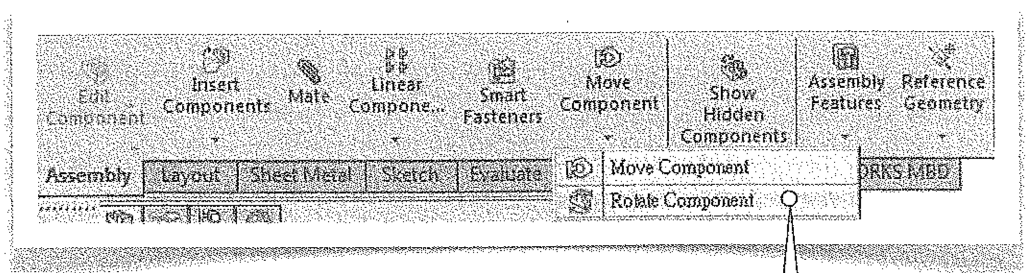
[13] Left-click-drag the body to move it around the space.

[14] This is the part's **Origin**.



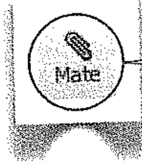
[12] The **(f)** sign changes to **(-)**, indicating that the **Block** is no more fixed. We'll show that it can be moved freely [13-16]. In 1.1-7 (next page), we'll set up constraints to fully support the **Block**.

[15] Now, the global **Origin** may not be coincident with the part's **Origin**.

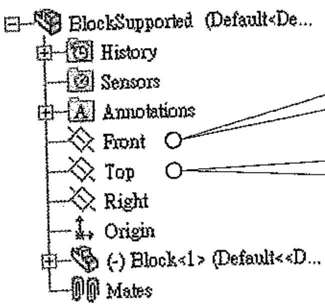


[16] Using **Move Component>Rotate Component** tool, you even can freely rotate the body. #

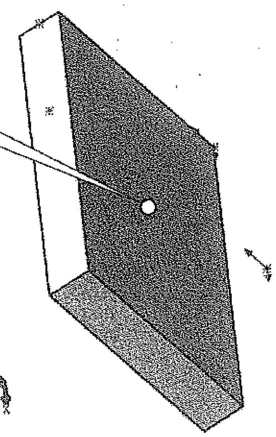
1.1-7 Set Up Supports



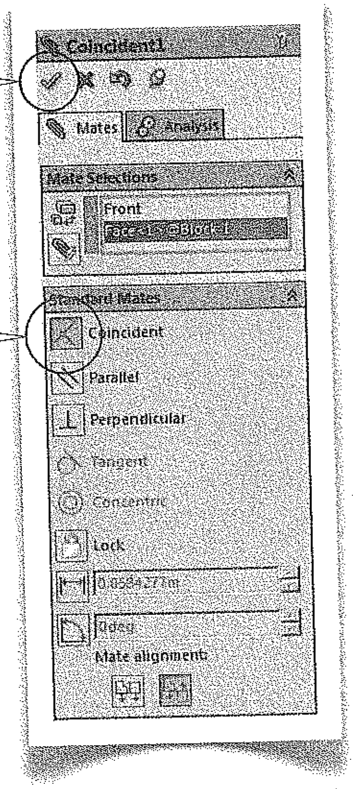
[1] In the **Assembly** toolbar, click **Mate**.



[2] In the **Graphics Area**, expand the **Assembly Tree**, and select the assembly's (global) **Front** plane...



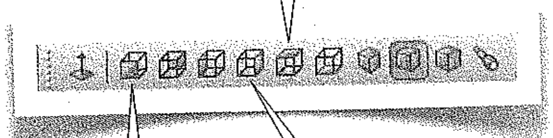
[3] And select the body's back face. You may need to rotate the view.



[4] **Coincident** mate is automatically selected.

[5] Click **OK**. Note that the **Mate** box is still open.

[6] Now, the body is constrained such that the back face is coincident with the global **Front** plane. To verify this, rotate to **Top** view, and left-click-drag the body.

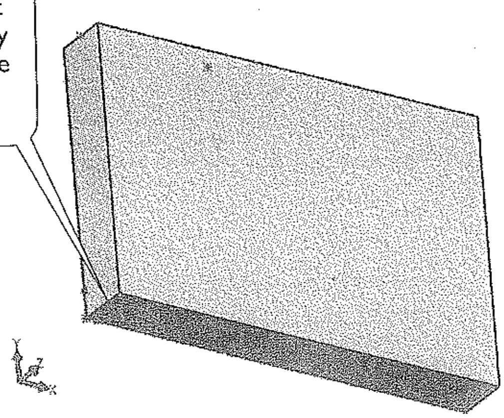


[7] Also, rotate to **Right** view, and left-click-drag the body.

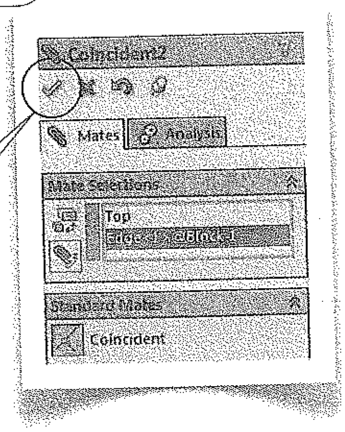
[8] Finally, rotate to **Front** view, and left-click-drag the body. We conclude that the body is indeed constrained to move in XY-space.

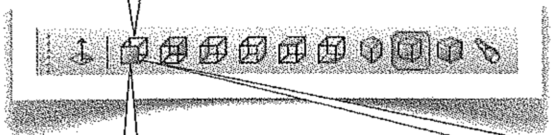
[9] Select the global **Top** plane...

[10] And select the lower-left edge. You may need to rotate the view.

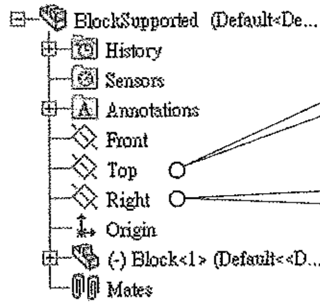


[11] Click **OK**.

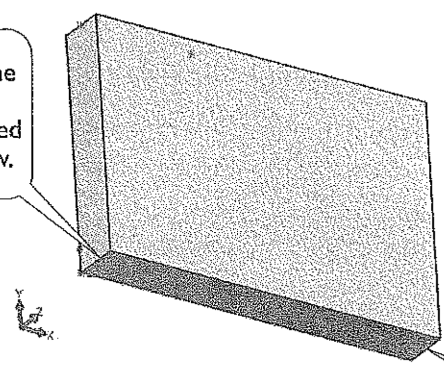




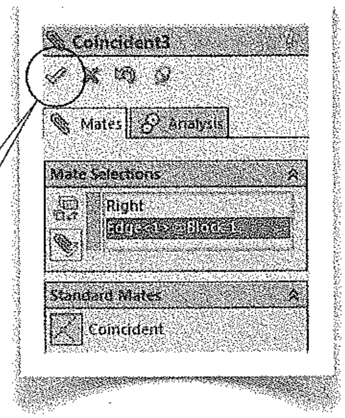
[12] Now, the body is further constrained such that the lower-left edge is coincident with the global **Top** plane. To verify this, rotate to **Front** view, and left-click-drag the body.



[13] Select the global **Right** plane...



[14] And select the lower-left edge again. You may need to rotate the view.

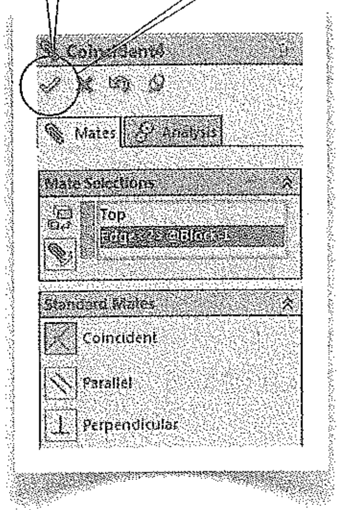


[15] Click **OK**.

[16] Now, the body is further constrained such that the lower-left edge is coincident with the global **Right** plane. To verify this, rotate to **Front** view, and left-click-drag the body. Now, the body is restricted to rotate about the Z-axis.

[17] Select the global **Top** plane...

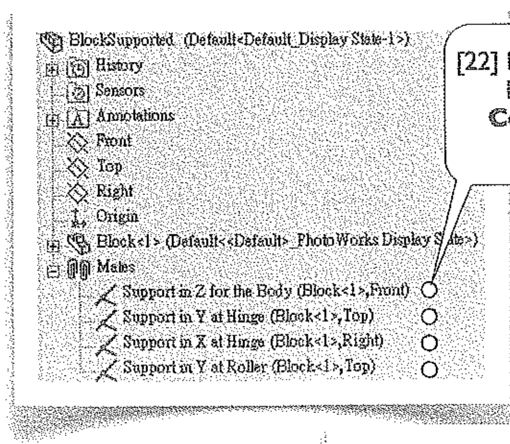
[18] And select the lower-right edge. You may need to rotate the view.



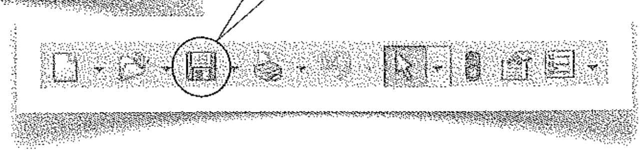
[19] Click **OK**.

[20] Now, the body is fully constrained (supported). To verify this, rotate to **Front** view again, and try to move the body. The body can't be moved now.

[21] Click **OK** again to dismiss the **Mate** box.

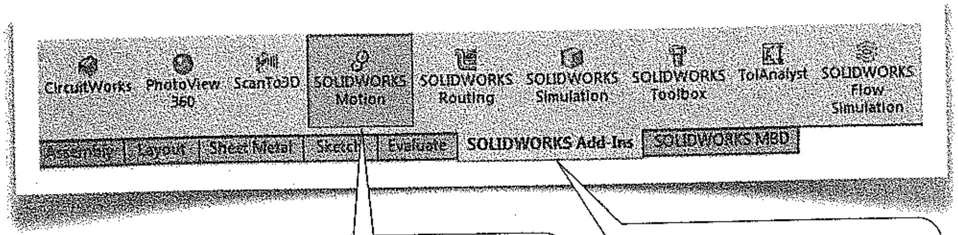


[22] In the **Assembly Tree**, expand **Mates** and rename the four **Coincident** mates like this for better readability.



[23] Click **Save**. #

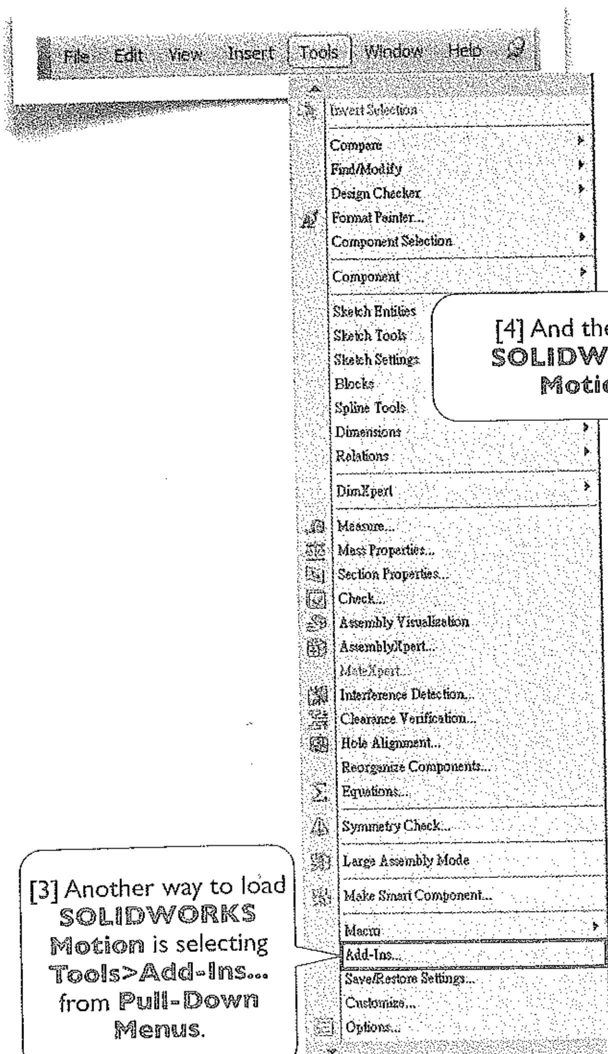
1.1-8 Load **SOLIDWORKS Motion**



[1] Click **SOLIDWORKS Add-Ins** tab.

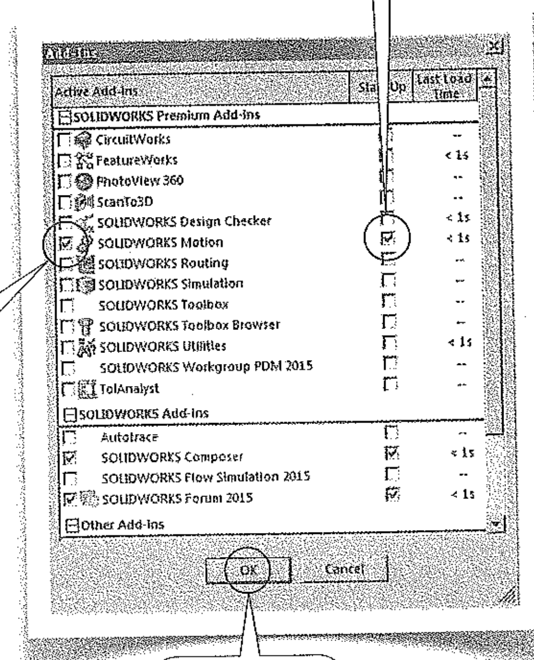
[2] If **SOLIDWORKS Motion** is highlighted, that means it has already been loaded; you may jump to next page. Otherwise, click it to load **SOLIDWORKS Motion**, or...

[3] Another way to load **SOLIDWORKS Motion** is selecting **Tools>Add-Ins...** from **Pull-Down Menus**.



[4] And then click **SOLIDWORKS Motion**.

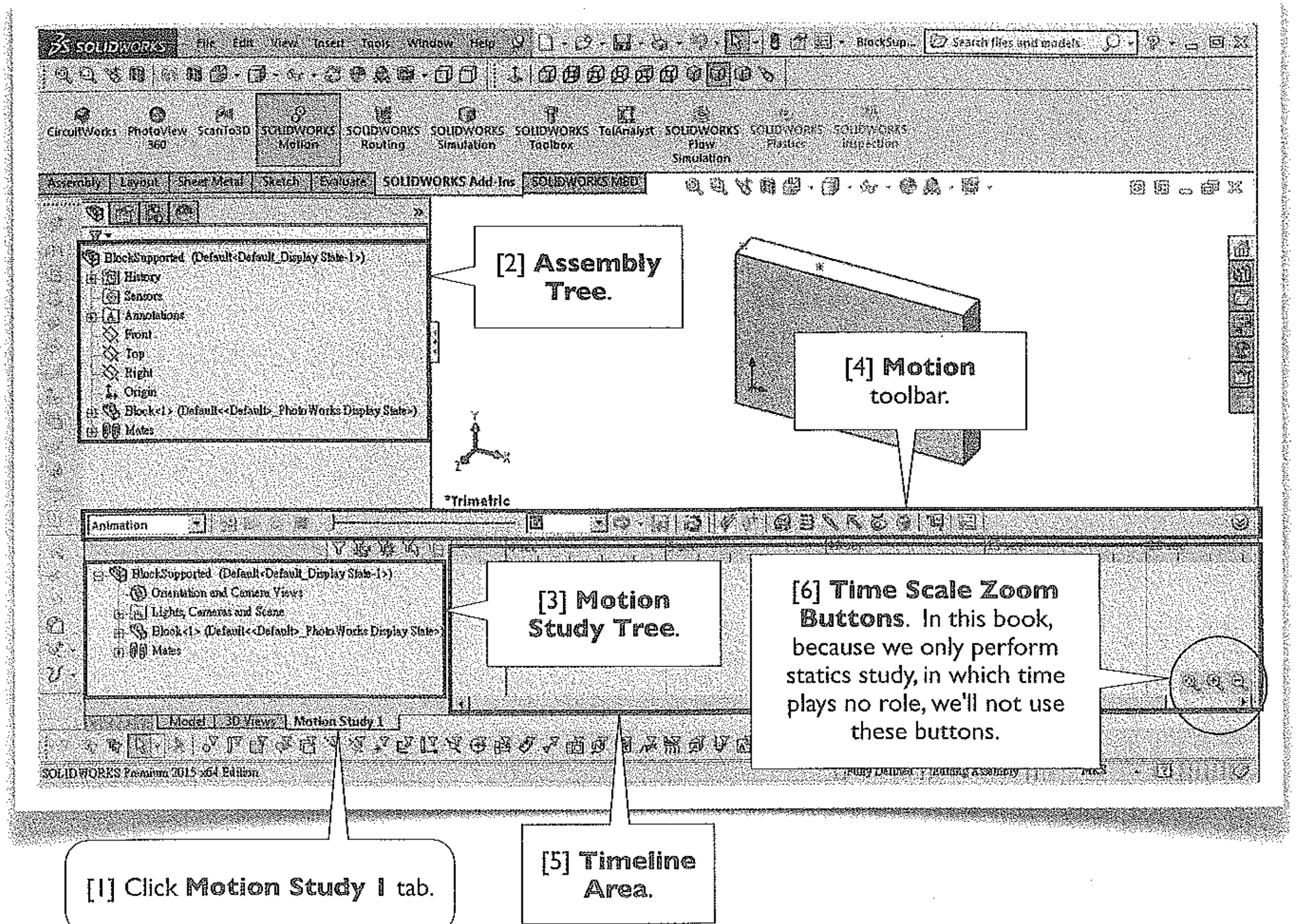
[5] Also click here so that the **Motion** will be loaded automatically each time you start up **SOLIDWORKS**. In this book, we assume that you set up this way so that the **Motion** is loaded automatically each time you start up **SOLIDWORKS**.

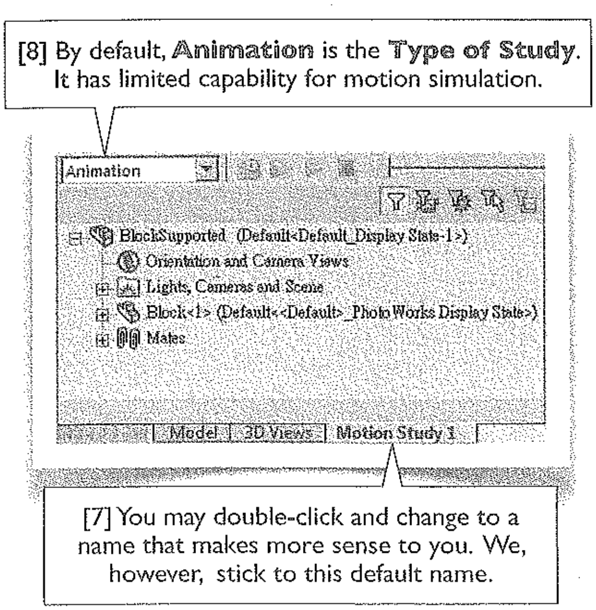


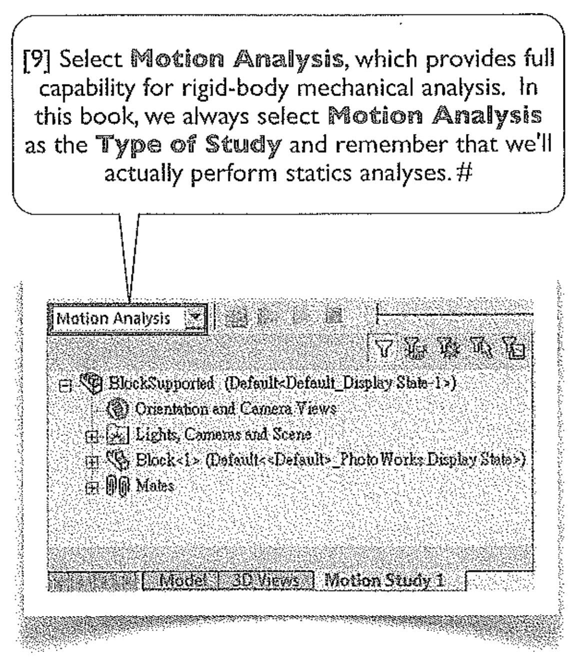
[6] Click **OK**.

[7] **SOLIDWORKS Motion** is designed to solve rigid-body mechanical problems, either static or dynamic. By rigid-body, it means the deformations of bodies are neglected. In **SOLIDWORKS Motion**, a static problem is treated as a special case (of dynamic problems) in which the response is independent of time. #

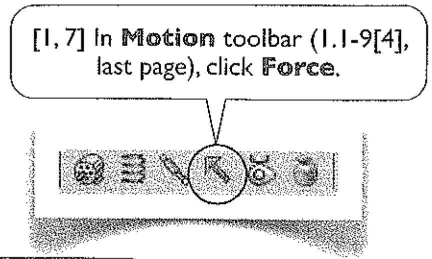
1.1-9 Create a **Motion Study**

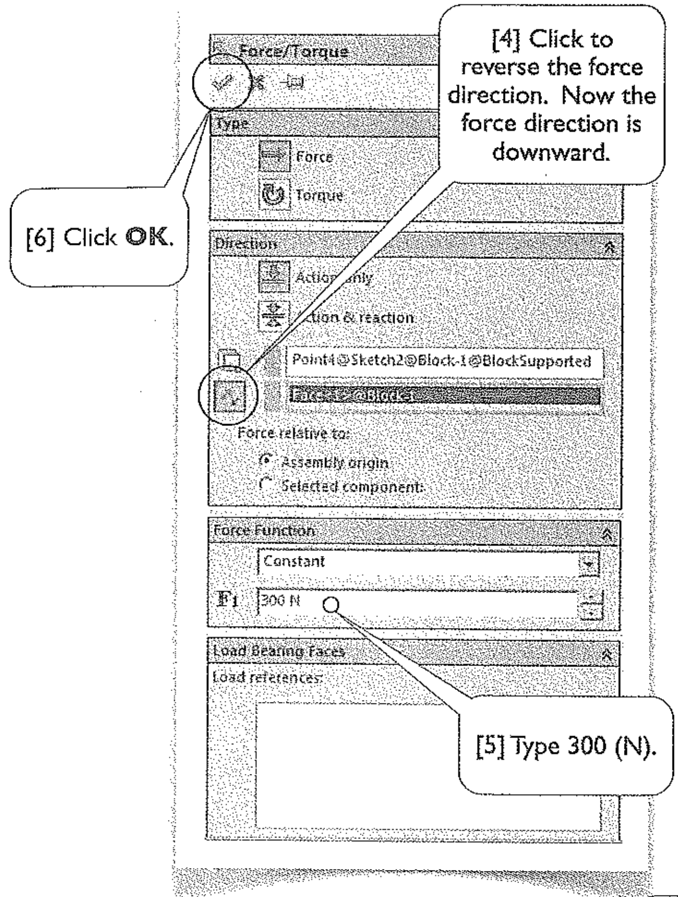


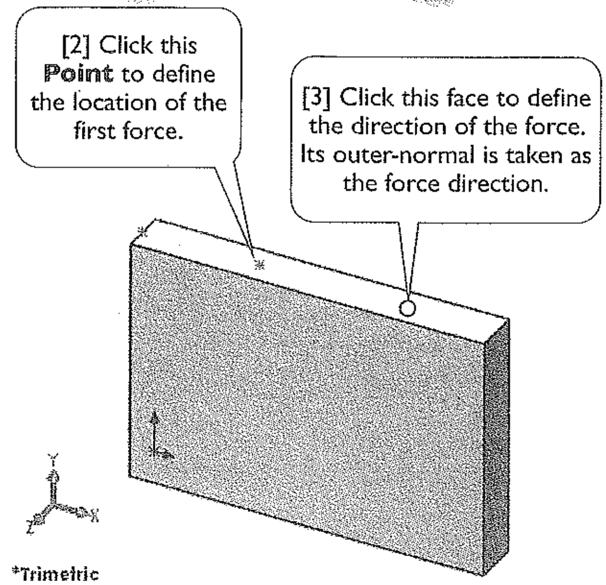


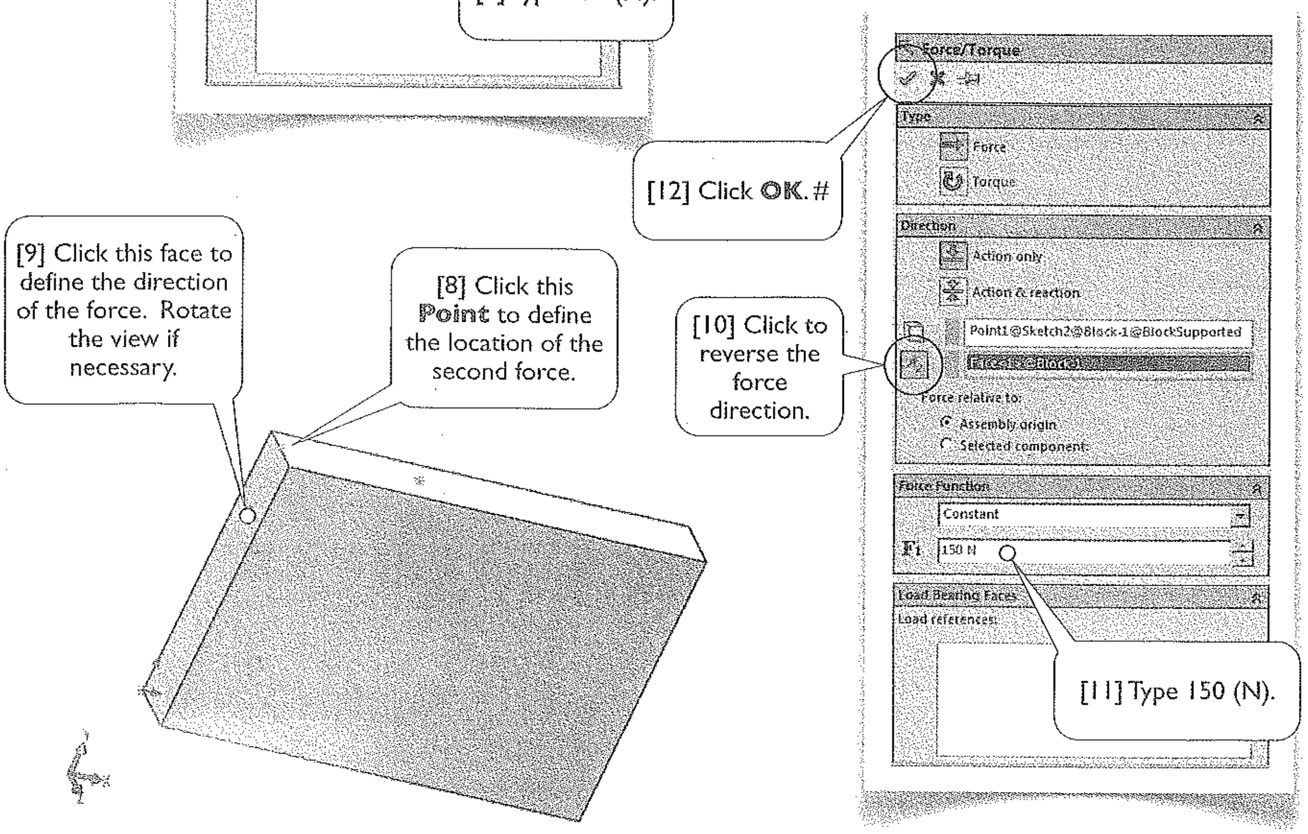


1.1-10 Set Up Forces





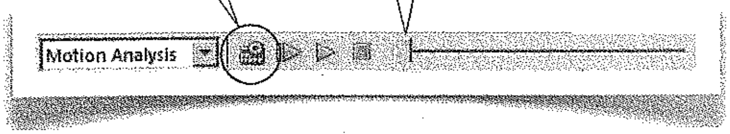




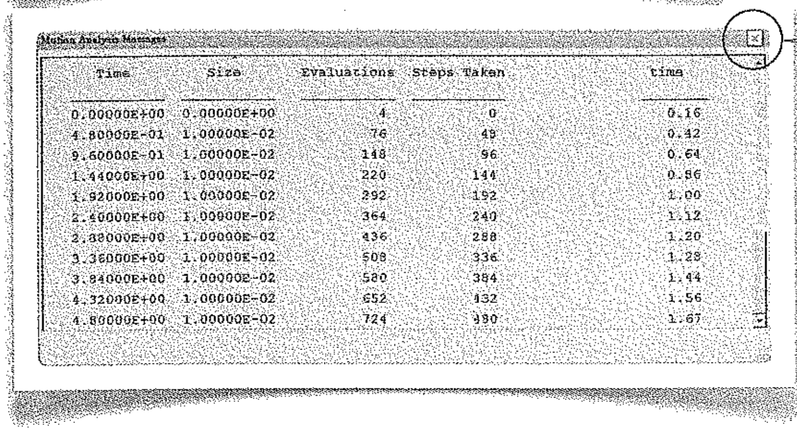
1.1-11 Calculate Results

[1] Click **Calculate**.

[3] The calculation completes in a few seconds, and the **Time Slider** proceeds to right-most position. By default, the simulation time is 5 seconds, which is an arbitrarily chosen time. Since the body is fully supported and the forces are constant, the results are time independent. We're in effect performing a static analysis. One thing you need to remember about this **Time Slider** is that whenever you want to re-define the forces, make sure the **Time Slider** is at the beginning (the left-most position). #



[2] If a **Motion Analysis Messages** window appears, close it.. In this book, always close this window right after calculating results.

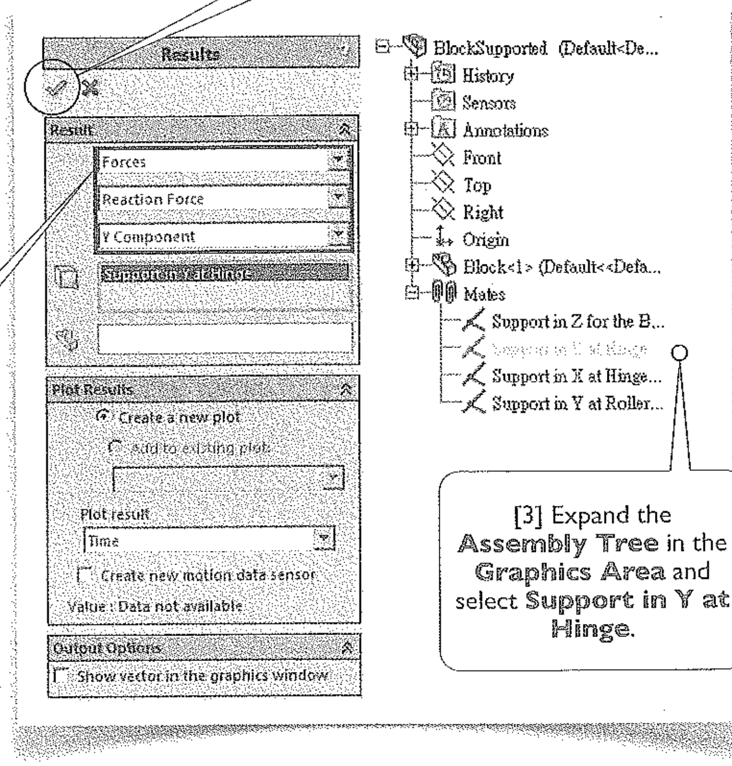


[4] Click **OK**.

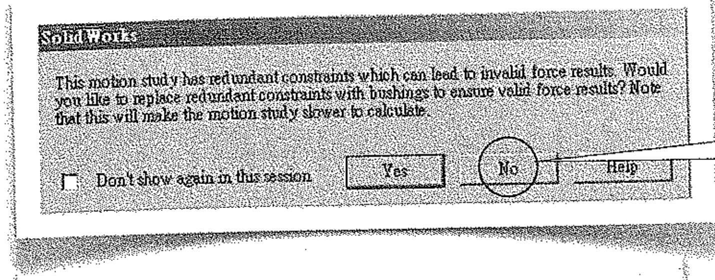
1.1-12 View the Results

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

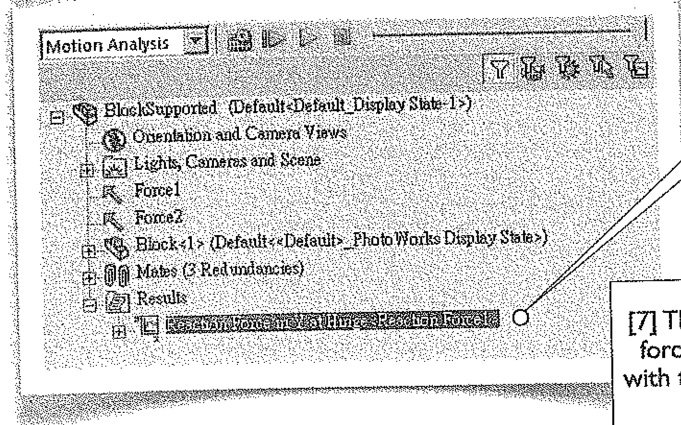
[2] Set up **Result** like this.



[3] Expand the **Assembly Tree** in the **Graphics Area** and select **Support in Y at Hinge**.

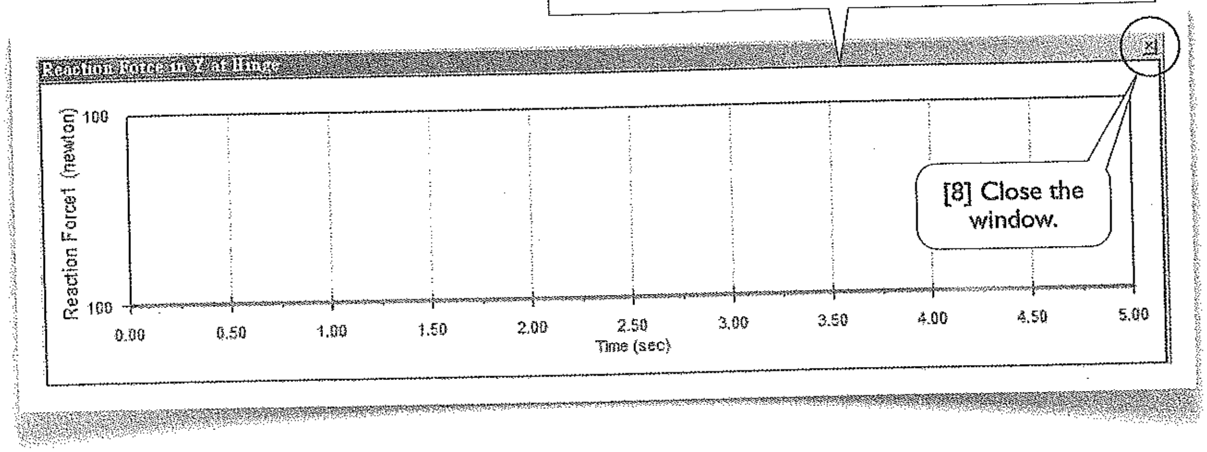


[5] Click **No**. In this book, always click **No** if this message appears.

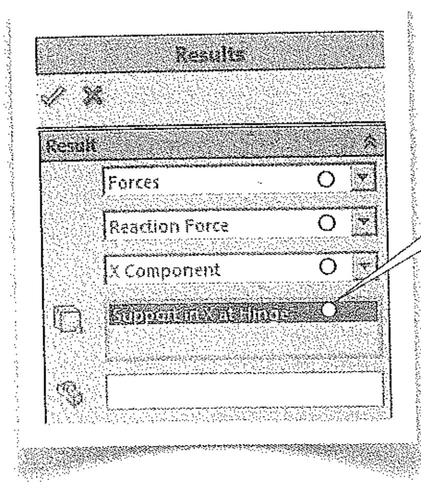


[6] In the **Motion Study Tree**, expand **Results**, click **Plot1** twice (not double-click) and change name to **Reaction Force in Y at Hinge**.

[7] The plot shows that the magnitude of the reaction force in Y-direction at the hinge is 100 N, consistent with the one calculated in 1.1-1[1] (page 5). Note that the reaction force is constant over time.

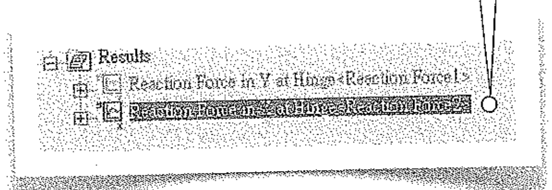


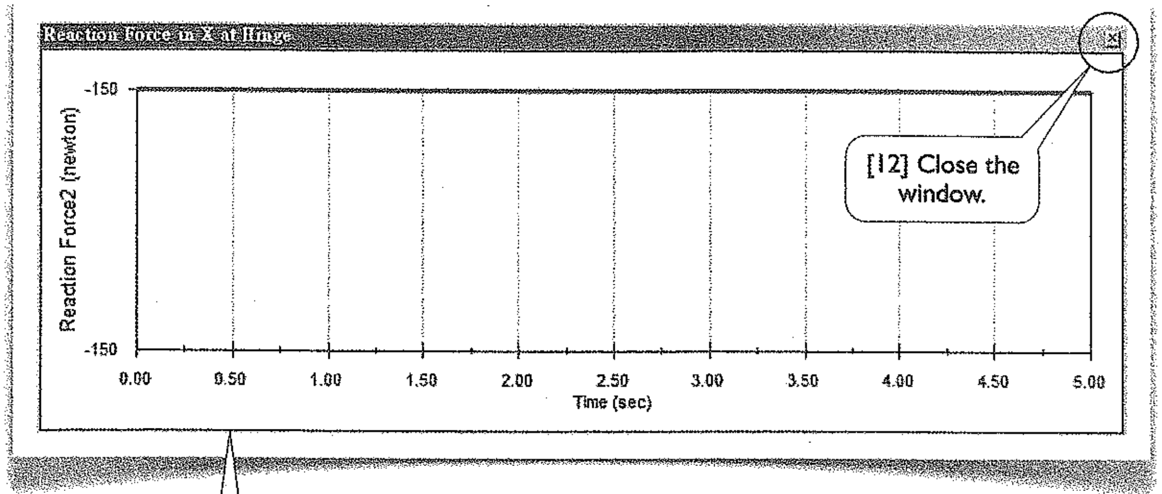
[8] Close the window.



[9] Repeat steps [1-5] except selecting **X Component** in step [2] and **Support in X at Hinge** in step [3].

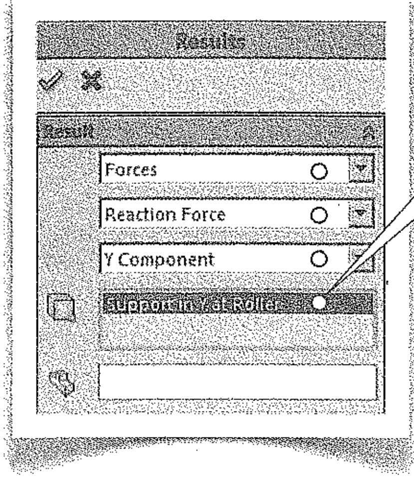
[10] In the **Motion Study Tree**, click **Plot2** twice and change name to **Reaction Force in X at Hinge**.



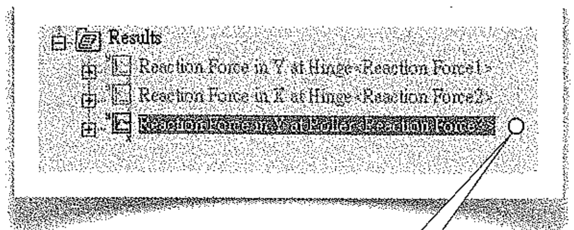


[12] Close the window.

[11] The plot shows that the magnitude of the reaction force in X-direction at the hinge is -150 N, consistent with the one calculated in 1.1-1[1] (page 5).

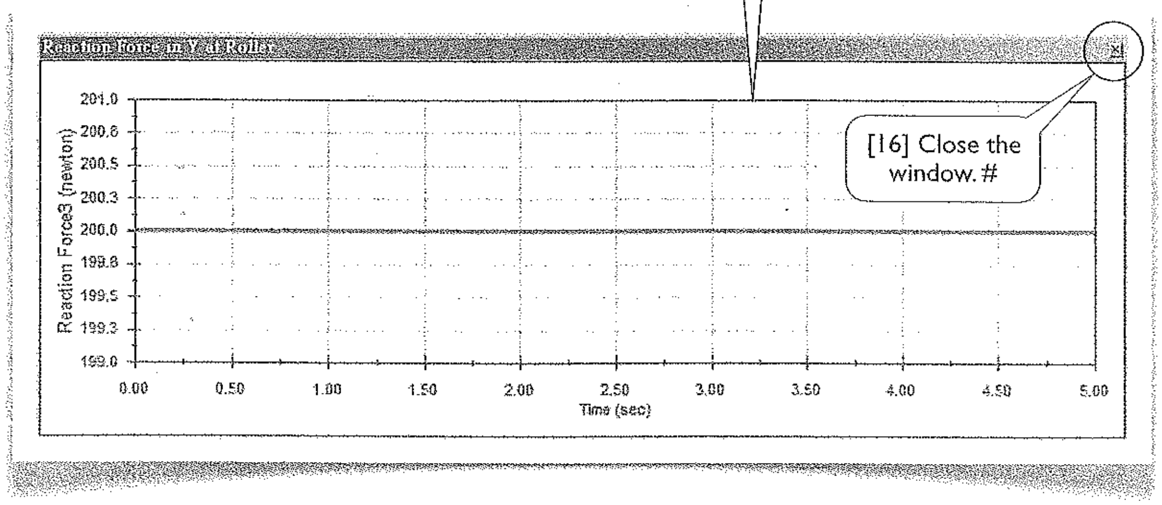


[13] Repeat steps [1-5] except selecting **Support in Y at Roller** in step [3],



[14] In the **Motion Study Tree**, click **Plot3** twice and change name to **Reaction Force in Y at Roller**.

[15] The plot shows that the magnitude of the reaction force in Y-direction at the roller is 200 N, consistent with the one calculated in 1.1-1[1] (page 5).



[16] Close the window. #

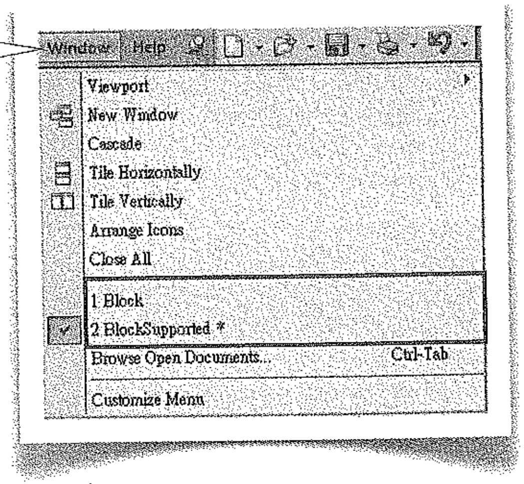
1.1-13 Do It Yourself: Validation of the Results

Do It Yourself

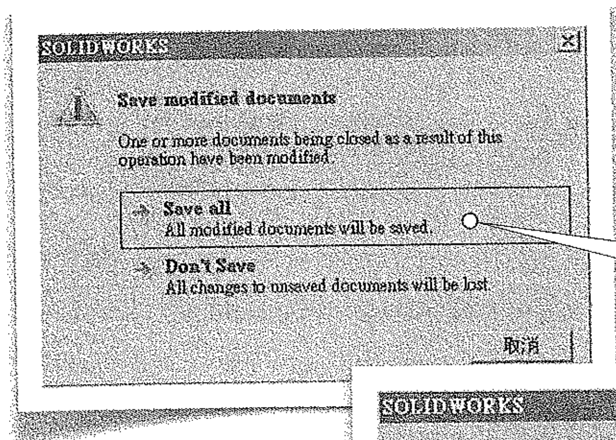
[1] To verify the validity of the results, you may check the force and moment equilibria for the body. In a 2D problem like this, you need to check 3 equilibrium equations to conclude the validity of the results. Of course, the 3 equilibrium equations must be independent. #

1.1-14 Wrap Up

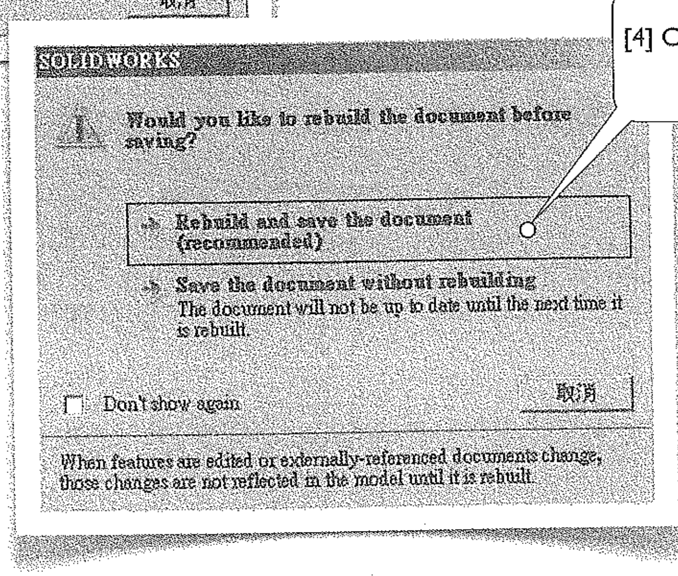
[1] From the **Pull-Down Menus**, click **Window** to see that there are two opened files: **Block** and **BlockSupported**.



[2] From the **Pull-Down Menus**, Select **File>Exit** to quit **SOLIDWORKS**.



[3] Click **Save all**.



[4] Click **Rebuild and save the document**. #

Section 1.2

Supported L-Plate: A 3D Case

1.2-1 Introduction

[1] Consider an L-shaped plate of thickness 5 mm [2] supported at three corners [3-5] and subject to a force P [6]. We want to find the reaction forces at the supports.

There are six reaction force components in this problem, namely D_X, D_Y, D_Z, B_X, B_Z, and C_Y. It is possible to establish six equations, according to force and moment equilibria, and solve these six reaction forces. However, we may calculate C_Y directly by considering the moment equilibrium about the axis passing through B and D,

$$\sum M_{BD} = 0$$

$$\vec{\lambda}_{BD} \cdot (\vec{r}_{A/B} \times \vec{P}) + \vec{\lambda}_{BD} \cdot (\vec{r}_{C/D} \times \vec{C}_Y) = 0$$

where the unit vector along BD,

$$\vec{\lambda}_{BD} = \frac{(-8\text{ cm})\vec{i} + (-9\text{ cm})\vec{j} + (12\text{ cm})\vec{k}}{\sqrt{(6^2 + 9^2 + 12^2)}\text{ cm}}$$

the position vectors,

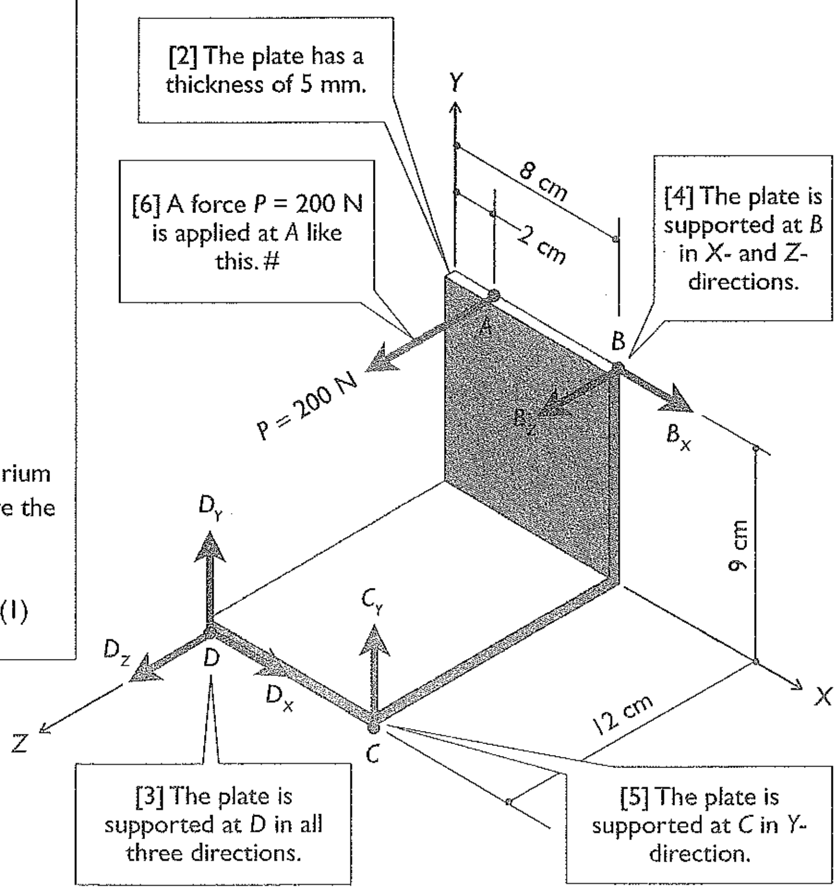
$$\vec{r}_{A/B} = (-6\text{ cm})\vec{i},\ \vec{r}_{C/D} = (8\text{ cm})\vec{i}$$

and the forces,

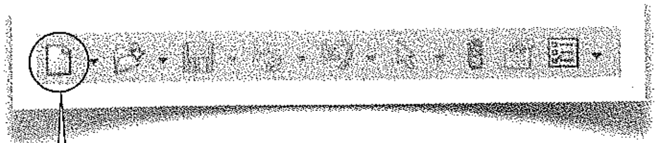
$$\vec{P} = (200\text{ N})\vec{k},\ \vec{C}_Y = (C_Y)\vec{j}$$

Substituting these into the moment equilibrium equation, and after mild calculation, we have the reaction force in Y at C,

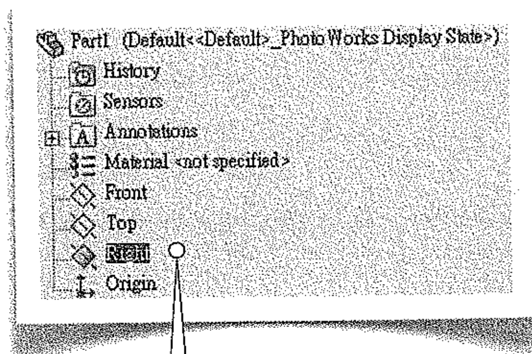
$$C_Y = 112.5\text{ N} \qquad (1)$$



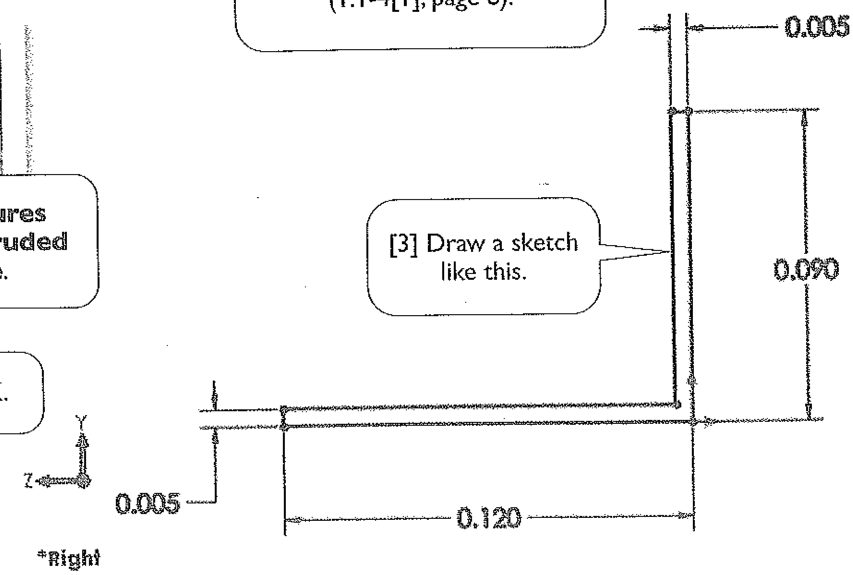
1.2-2 Start Up and Create a Part: **Plate**



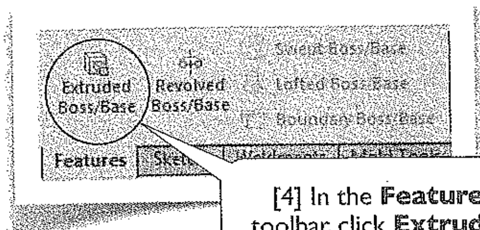
[1] Launch **SOLIDWORKS** and click **New** to create a new **Part** (1.1-2[1-5], page 6). Select **MKS** unit system with three decimal places for the length unit (1.1-3[1-4], page 7).



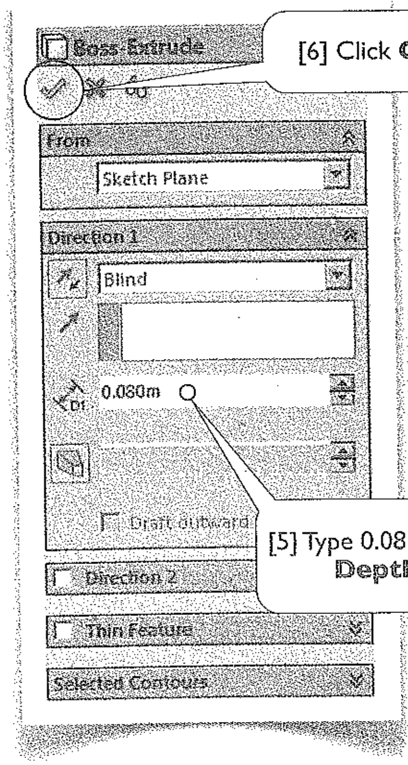
[2] In the **Part Tree**, right-click **Right** plane and select **Sketch** (1.1-4[1], page 8).



[3] Draw a sketch like this.

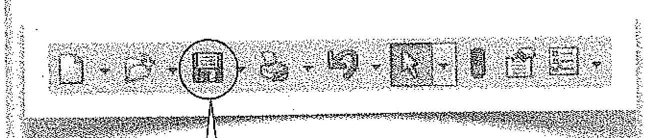


[4] In the **Features** toolbar, click **Extruded Boss/Base**.

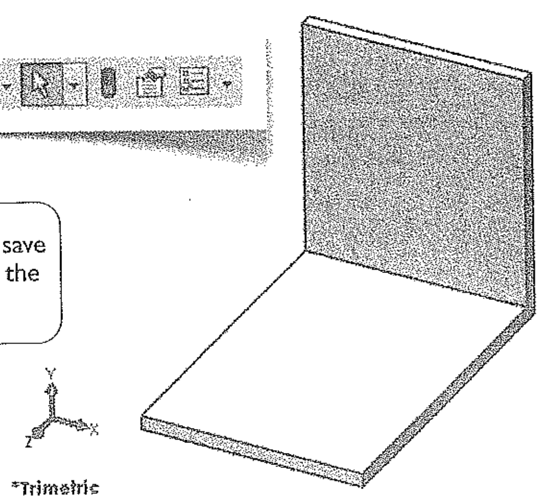


[5] Type 0.08 (m) for **Depth**.

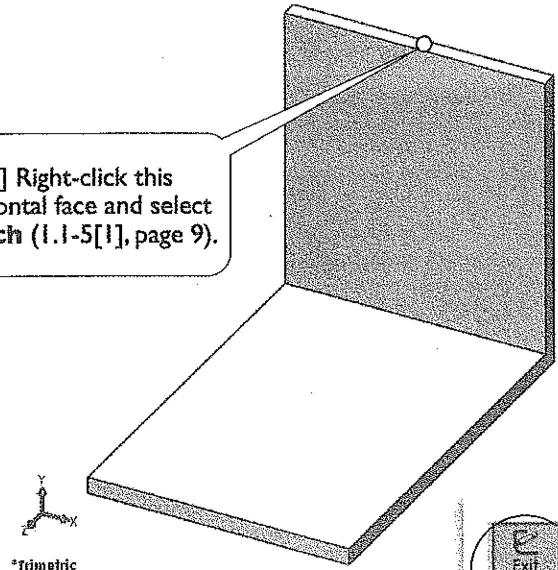
[6] Click **OK**.



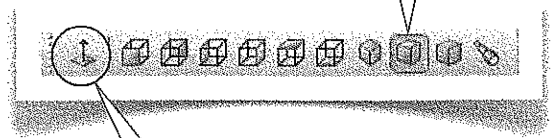
[7] Click **Save** and save the document with the name **Plate**. #



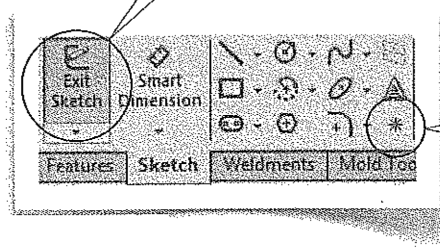
1.2-3 Create a **Point** on the **Plate**



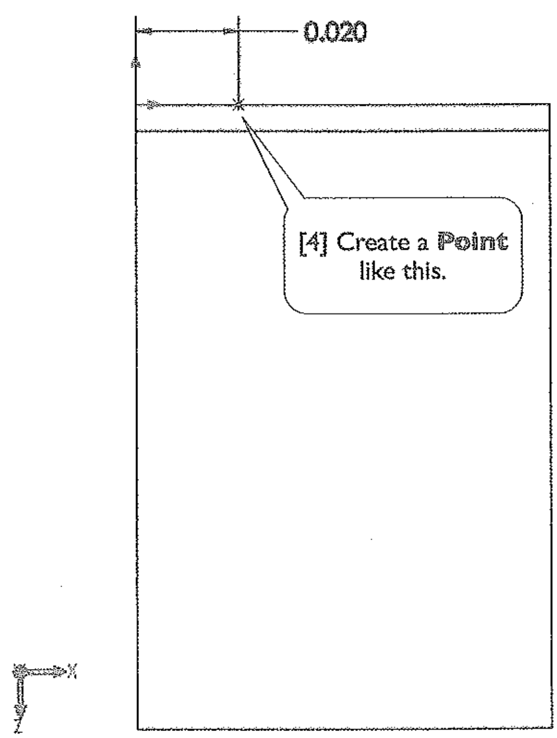
[1] Right-click this horizontal face and select **Sketch** (1.1-5[1], page 9).



[2] In the **Standard Views** toolbar, click **Normal To**.



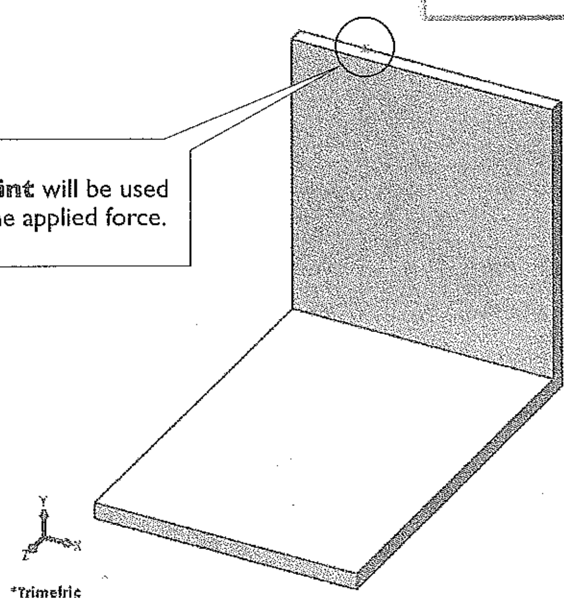
[3] In **Sketch** toolbar, select **Point**.



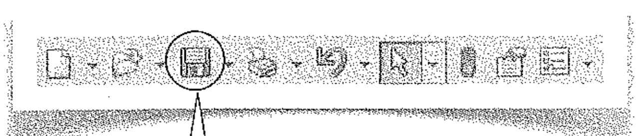
[4] Create a **Point** like this.

[5] Click **Exit Sketch**.

[6] Click **Trimetric**.

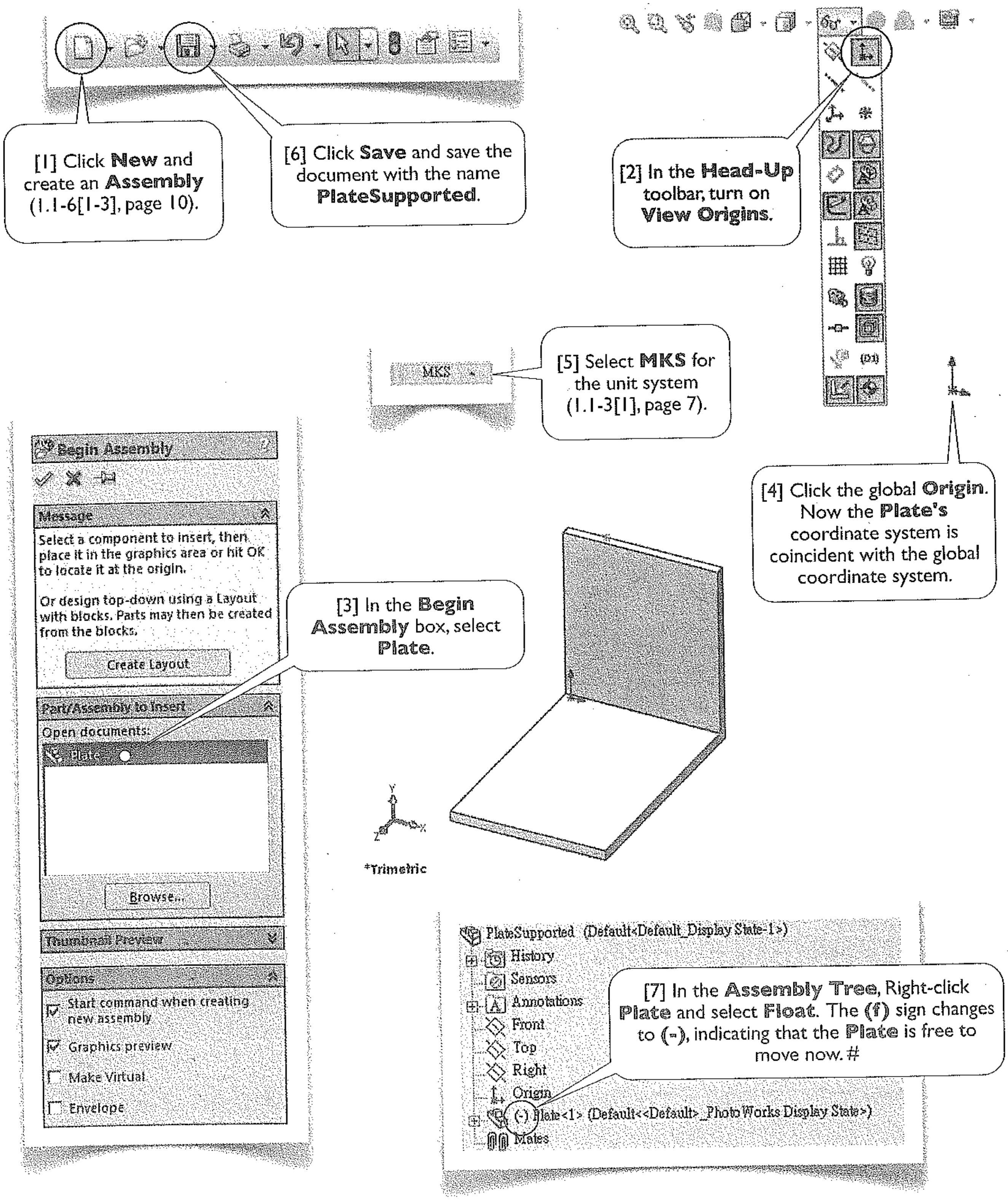


[7] This **Point** will be used to locate the applied force.

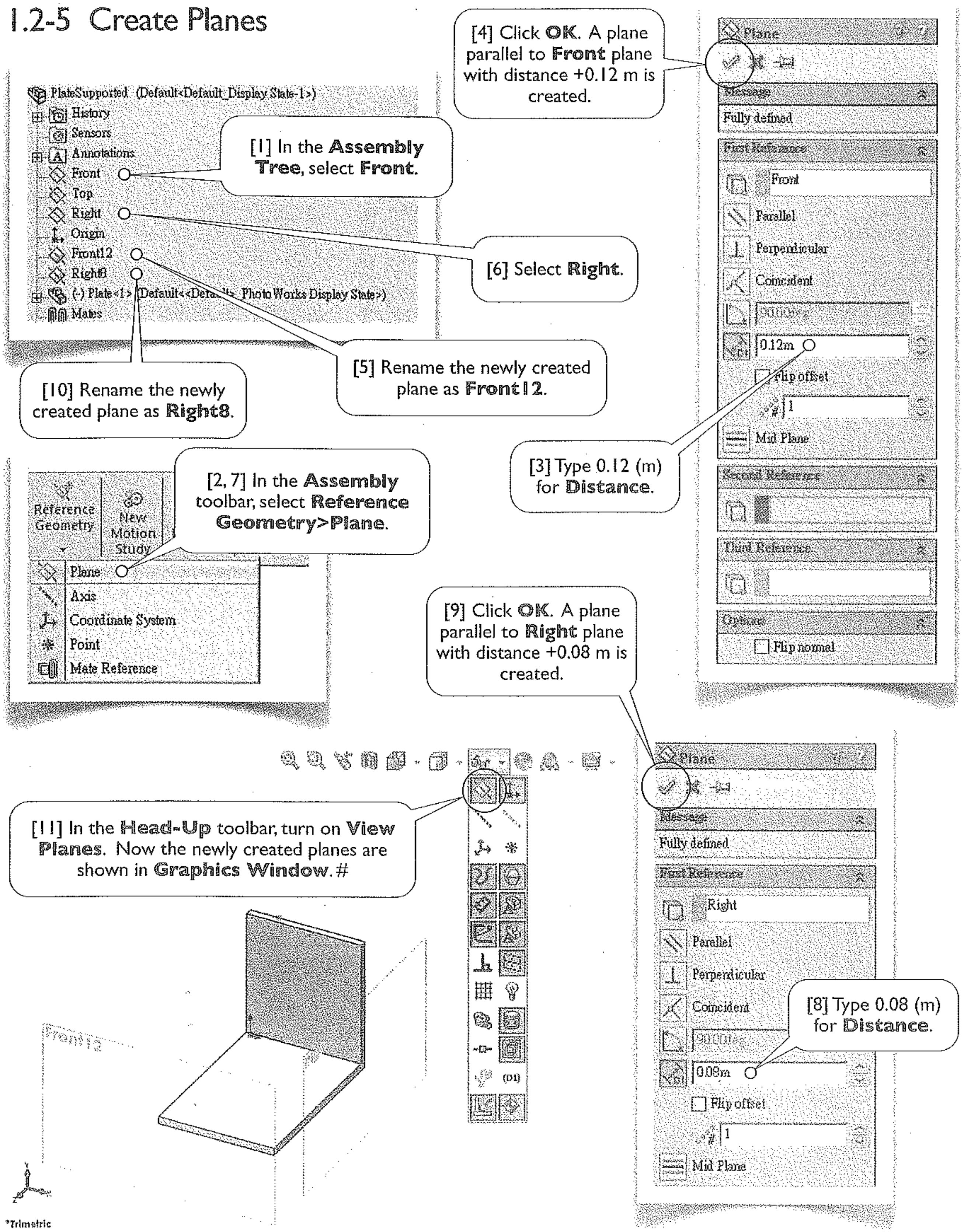


[8] Click **Save**. #

1.2-4 Create an Assembly: **PlateSupported**



1.2-5 Create Planes



[1] In the **Assembly Tree**, select **Front**.

[2, 7] In the **Assembly** toolbar, select **Reference Geometry>Plane**.

[3] Type 0.12 (m) for **Distance**.

[4] Click **OK**. A plane parallel to **Front** plane with distance +0.12 m is created.

[5] Rename the newly created plane as **Front12**.

[6] Select **Right**.

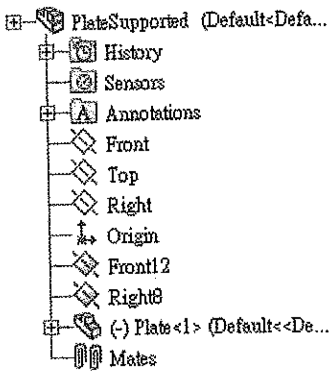
[8] Type 0.08 (m) for **Distance**.

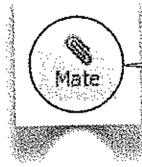
[9] Click **OK**. A plane parallel to **Right** plane with distance +0.08 m is created.

[10] Rename the newly created plane as **Right8**.

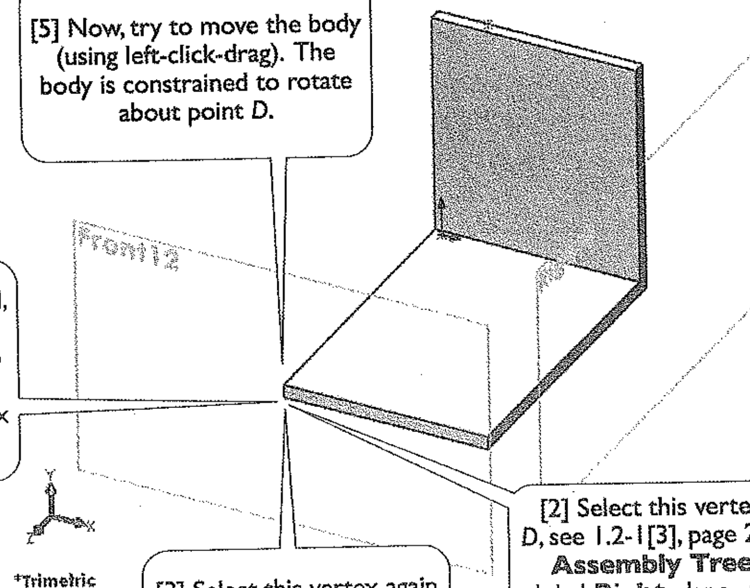
[11] In the **Head-Up** toolbar, turn on **View Planes**. Now the newly created planes are shown in **Graphics Window**.#

1.2-6 Set Up Supports





[1] In **Assembly** toolbar, click **Mate**.

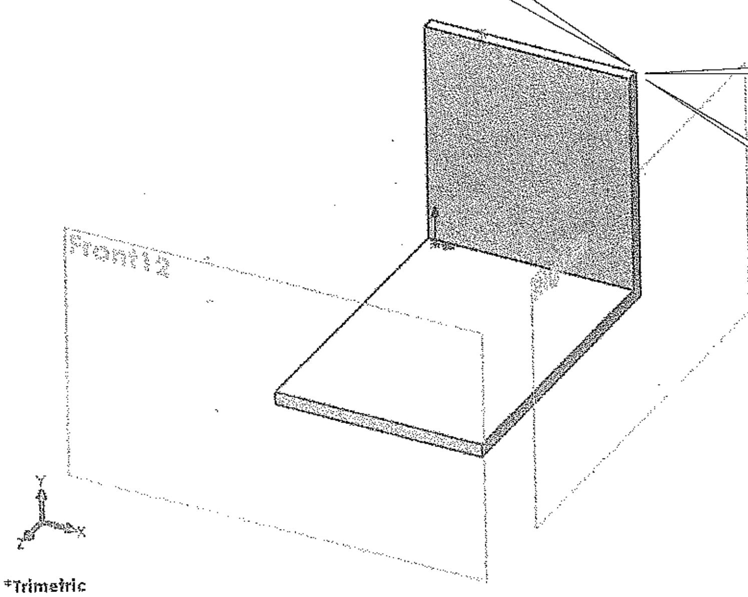


[2] Select this vertex (point *D*, see 1.2-1[3], page 21) and, in **Assembly Tree**, select global **Right** plane. Click **OK** to create **Coincident1**. This sets up a support at this vertex in *X*-direction.

[3] Select this vertex again and, in **Assembly Tree**, select global **Top** plane. Click **OK** to create **Coincident2**. This sets up a support at this vertex in *Y*-direction.

[4] Select this vertex again and, in **Assembly Tree**, select **Front12** plane. Click **OK** to create **Coincident3**. This sets up a support at this vertex in *Z*-direction.

[5] Now, try to move the body (using left-click-drag). The body is constrained to rotate about point *D*.

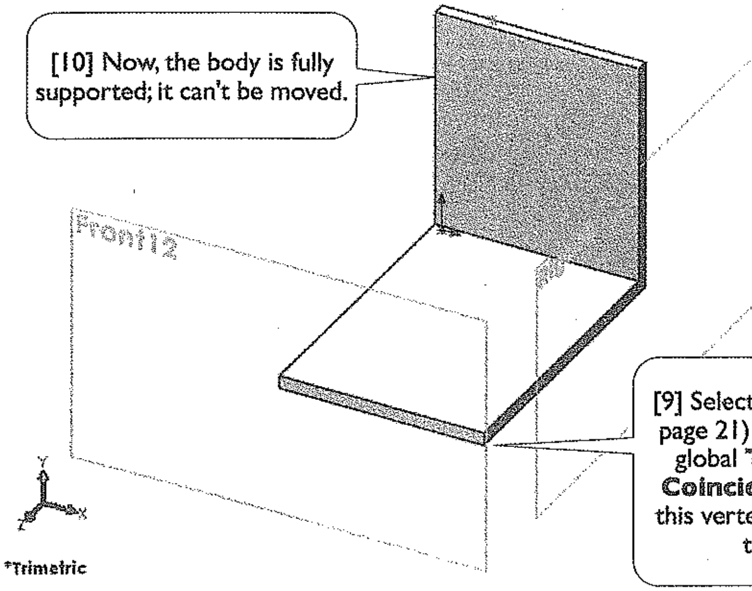


[6] Select this vertex (point *B*, see 1.2-1[4], page 21) and, in **Assembly Tree**, select **Right8** plane. Click **OK** to create **Coincident4**. This sets up a support at this vertex in *X*-direction.

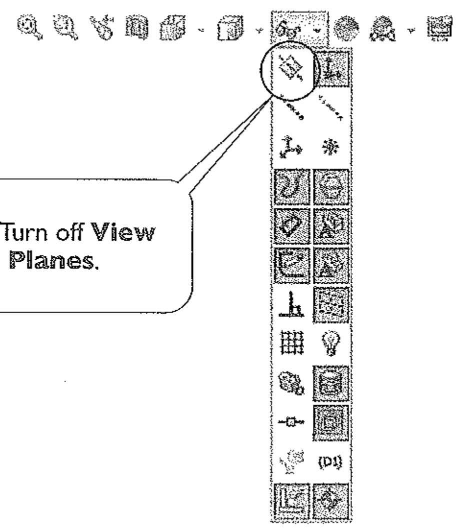
[7] Select this vertex again and, in **Assembly Tree**, select global **Front** plane. Click **OK** to create **Coincident5**. This sets up a support at this vertex in *Z*-direction.

[8] Now, try to move the body (using left-click-drag). The body is constrained to rotate about the axis passing through *BD*.

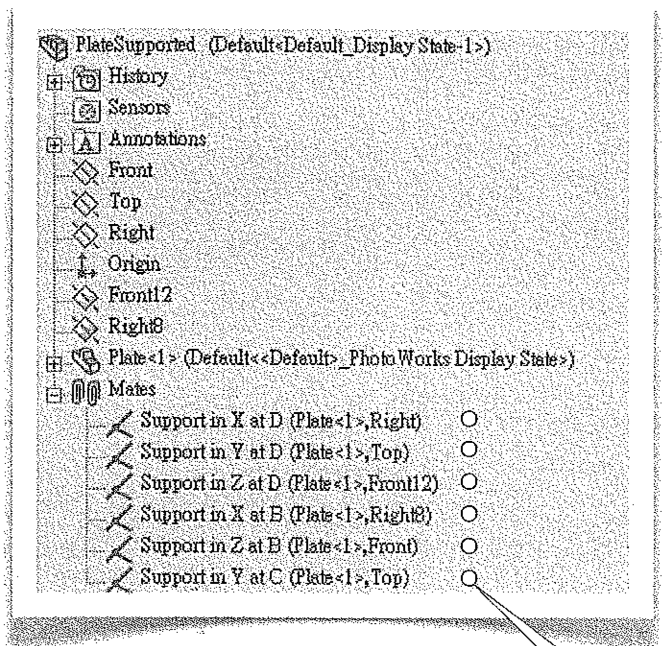
[10] Now, the body is fully supported; it can't be moved.



[9] Select this vertex (point C, see 1.2-1[5], page 21) and, in **Assembly Tree**, select global **Top** plane. Click **OK** to create **Coincident6**. This sets up a support at this vertex in Z-direction. Click **OK** again to dismiss the **Mate** box.



[11] Turn off **View Planes**.

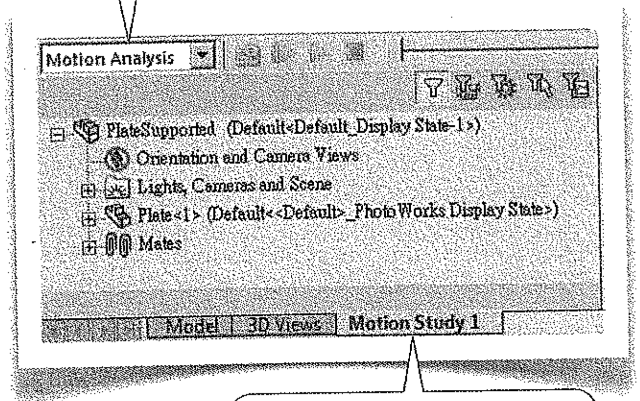


[12] In the **Assembly Tree**, expand **Mates** and rename the six **Coincident** mates like this (for better readability). #

1.2-7 Create a **Study**

[1] Load **SOLIDWORKS Motion** if it is not loaded yet (1.1-8, page 14).

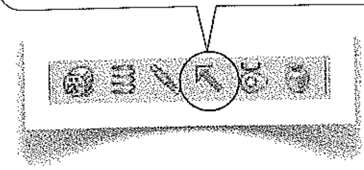
[3] Select **Motion Analysis** (1.1-9[8, 9], page 15).#



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

1.2-8 Set Up Forces

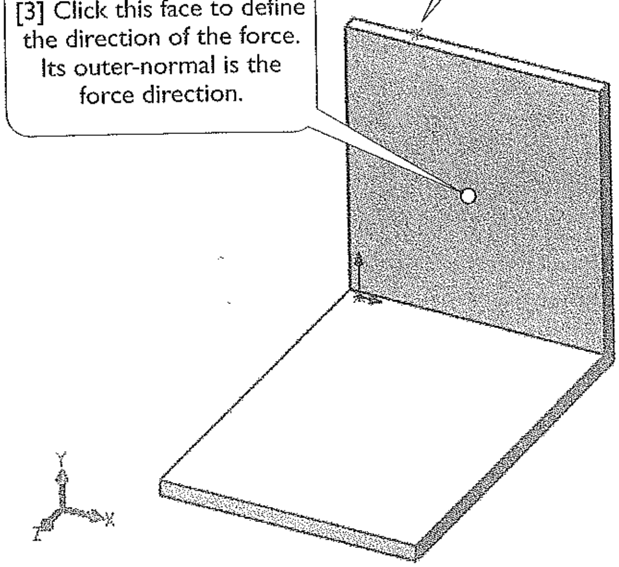
[1] In **Motion** toolbar, click **Force**.



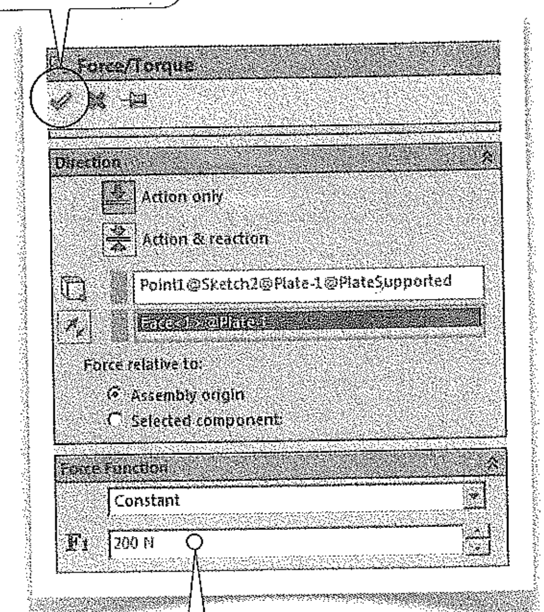
[5] Click **OK**.#

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

[3] Click this face to define the direction of the force. Its outer-normal is the force direction.



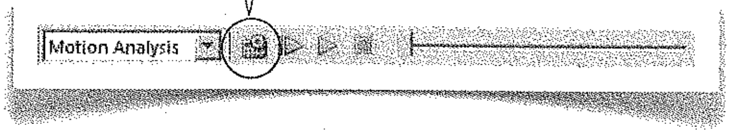
*Trimetric



[4] Type 200 (N).

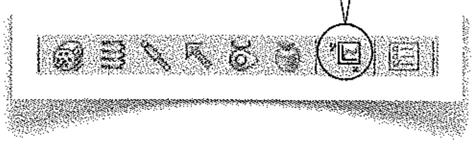
1.2-9 Calculate Results

[1] Click **Calculate**. Remember that, If a **Motion Analysis Messages** window appears, close it. #



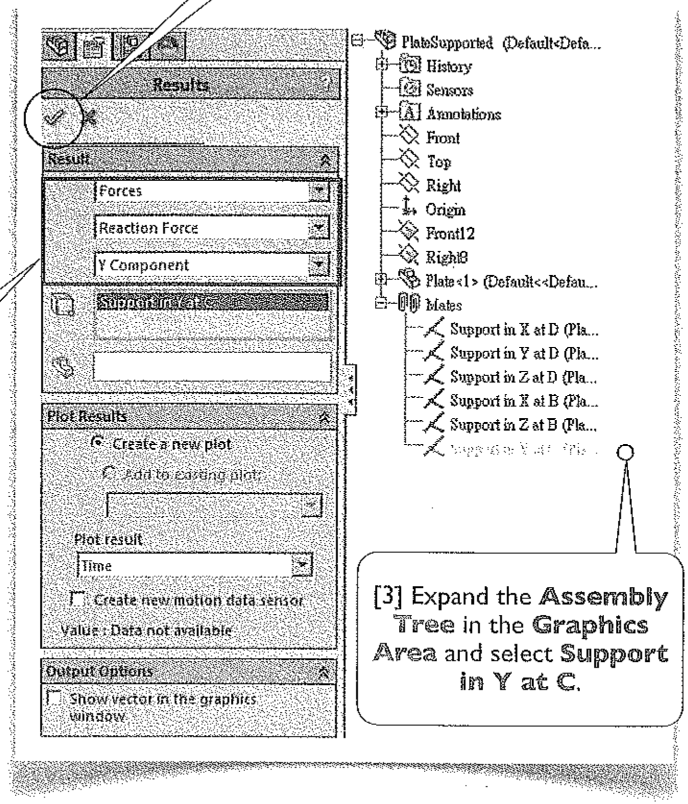
1.2-10 Retrieve the Reaction Force at *C*

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

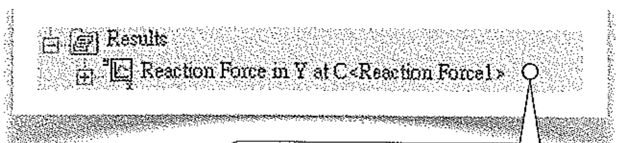


[2] Set up **Result** like this.

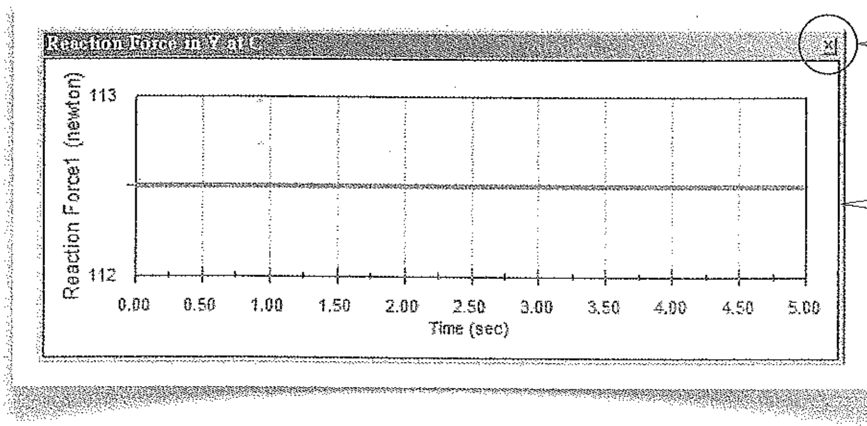
[4] Click **OK**.



[3] Expand the **Assembly Tree** in the **Graphics Area** and select **Support in Y at C**.



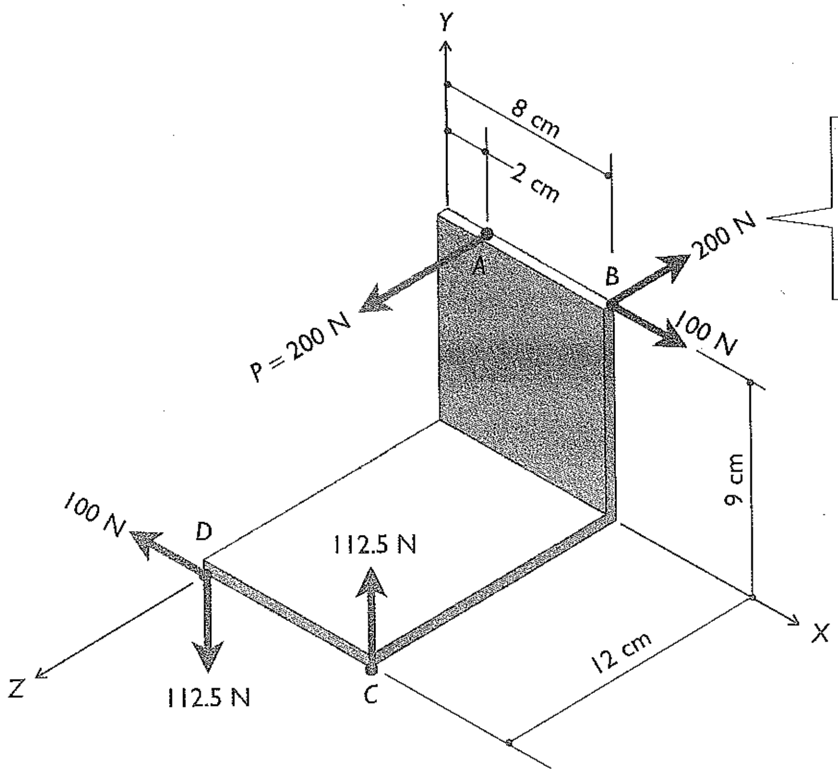
[5] In the **Motion Study Tree**, Rename **Plot1** as **Reaction Force in Y at C**.



[6] The plot shows that the reaction force in Y-direction at *C* is +112.5 N, consistent with the value in Eq. 1.2-1(1) (page 21).

[7] Close the window. #

1.2-11 Do It Yourself: Other Reaction Forces and Validation of the Results



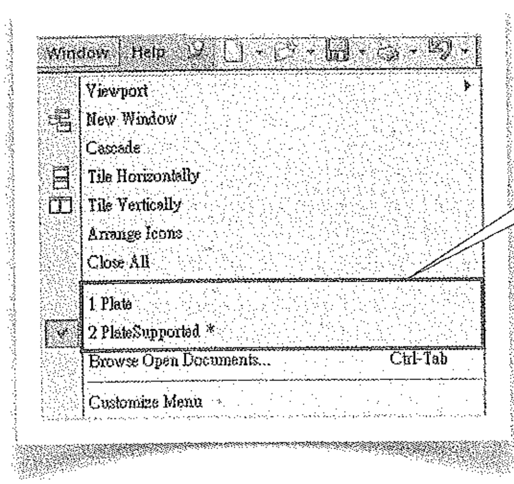
Do It Yourself

[1] It leaves you to retrieve other reaction forces. All reaction forces are summarized like this.

Do It Yourself

[2] To verify the validity of the results, we may check the force and moment equilibria for the body. A moment equilibrium can be with respect to a point or an axis. You need to check 6 equilibrium equations to conclude the validity of the results. The 6 equilibrium equations must be independent. #

1.2-12 Wrap Up



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

[2] From the **Pull-Down Menus**, Select **File>Exit** to quit **SOLIDWORKS**. Click **Save all**. Click **Rebuild and save the document**. (See 1.1-14[2-4], page 20) #