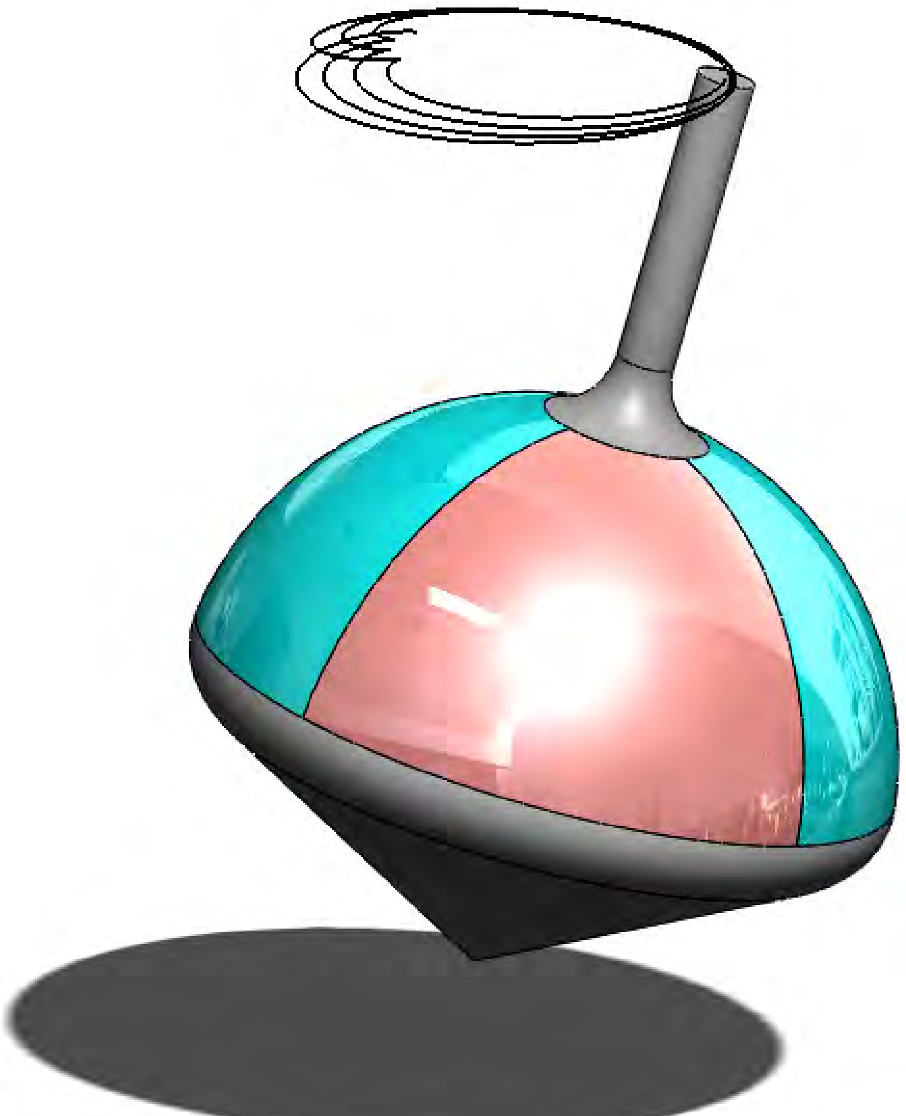
Engineering Dynamics Labs with SolidWorks® Motion 2014



Huei-Huang Lee

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Chapter 1

Particle Kinematics

Rigid Body

In the real world, all solid bodies are more or less deformable. There are no such things as **rigid bodies**. However, if the deformation of a body is not our concern and if the deformation is negligible relative to the motion of the body, we can treat the body as a **rigid body**. In this book, we assume all bodies studied in this book are **rigid bodies**. In rigid body dynamics, **springs** are the only elements that are deformable.

Particle

Similarly, in the real world, there are no such things as particles, which occupy zero volume in the space. However, when a body doesn't rotate (therefore no angular velocity, angular acceleration, angular kinetic energy, or angular momentum), we can treat the body as though its entire mass concentrates at its mass center and regard it as a **particle**.

Even when a body does rotate but its angular velocity remains constant, we still can treat the body as a particle, since its rotational quantities (angular velocity, angular acceleration, angular kinetic energy, or angular momentum) remain unchanged during the motion. For example, in the study of space mechanics, we often treat a planet as a particle, even though it does rotate. Keep in mind that *a body is treated as a particle not because of it size, but because of its insignificancy of rotation*.

Chapters 1-4 provides exercises on dynamic systems involving bodies that can be treated as particles.

Kinematics

What is kinematics? To answer this question, let's first explain how a dynamics problem is solved (either by computer or hand-calculation). Like any other engineering analysis, solving a dynamics problem involves two main steps: (a) write down a set of equations and (b) solve the equations.

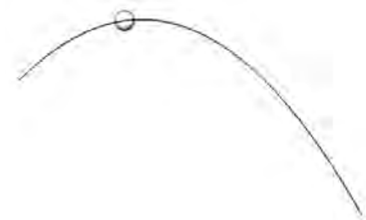
For rigid body dynamics, these equations can be divided into two groups: (a) Equations based on **physical principles**. For each body, some equilibrium equations (e.g., Newton's 2nd Law) or conservation equations (e.g., principle of work and energy) can be written down. (b) Equations describing the **kinematics relations** among bodies. That is, the relations among motions of bodies. The motions of a particle can be fully described by its **position**, **velocity**, and **acceleration**.

Particle kinematics is the study of the relations among **positions**, **velocities**, and **accelerations** of particles involved in a dynamics system. Examples of kinematics problems are: (a) If a particle has an acceleration of $\vec{a}(t)$, what are its velocity $\vec{v}(t)$ and position $\vec{r}(t)$? (b) If particle A is moving with a constant acceleration of $\vec{a}_A$, what are the acceleration, velocity, and position of particle B at time t?

Chapter 1 provides exercises on particle kinematics.

Section 1.1

Rectangular Components: Falling Ball



1.1-1 Introduction

[1] Imagine that you throw a ball with an initial velocity [2-5]. The velocity and the position of the ball at time t = 1 sec can be calculated as follows.

In X-direction, the velocity component is constant,

$$v_X = v_0 \cos\theta = (5 \text{ m/s})(\cos 45^\circ) = 3.54 \text{ m/s} \tag{1}$$

and the position is

$$X = (v_0 \cos\theta)t = (5 \text{ m/s})(\cos 45^\circ)(1 \text{ s}) = 3.54 \text{ m} \tag{2}$$

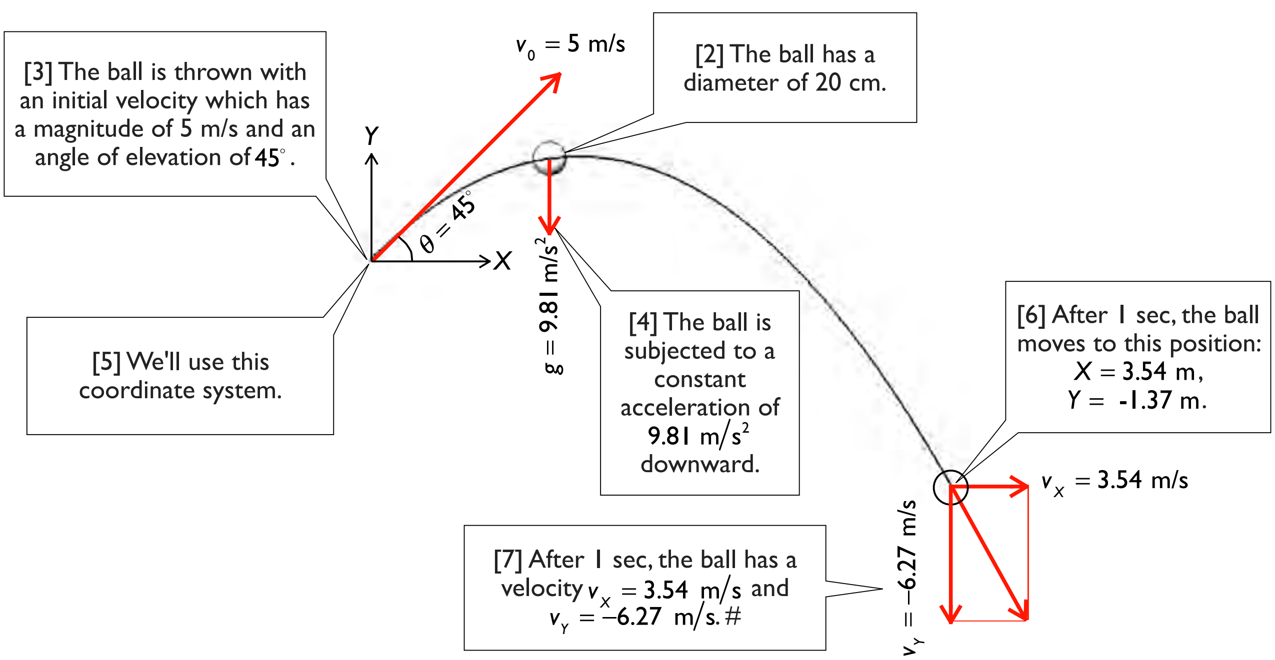
In Y-direction, the velocity component is

$$v_Y = v_0 \sin\theta - gt = (5 \text{ m/s})(\sin 45^\circ) - (9.81 \text{ m/s}^2)(1 \text{ s}) = -6.27 \text{ m/s} \tag{3}$$

and the position is

$$Y = (v_0 \sin\theta)t - \frac{1}{2}gt^2 = (5 \text{ m/s})(\sin 45^\circ)(1 \text{ s}) - \frac{1}{2}(9.81 \text{ m/s}^2)(1 \text{ s})^2 = -1.37 \text{ m} \tag{4}$$

These values are shown in [6, 7]. In this section, we'll perform a simulation for this scenario and validate the simulation results with the values in Eqs. (1-4).



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

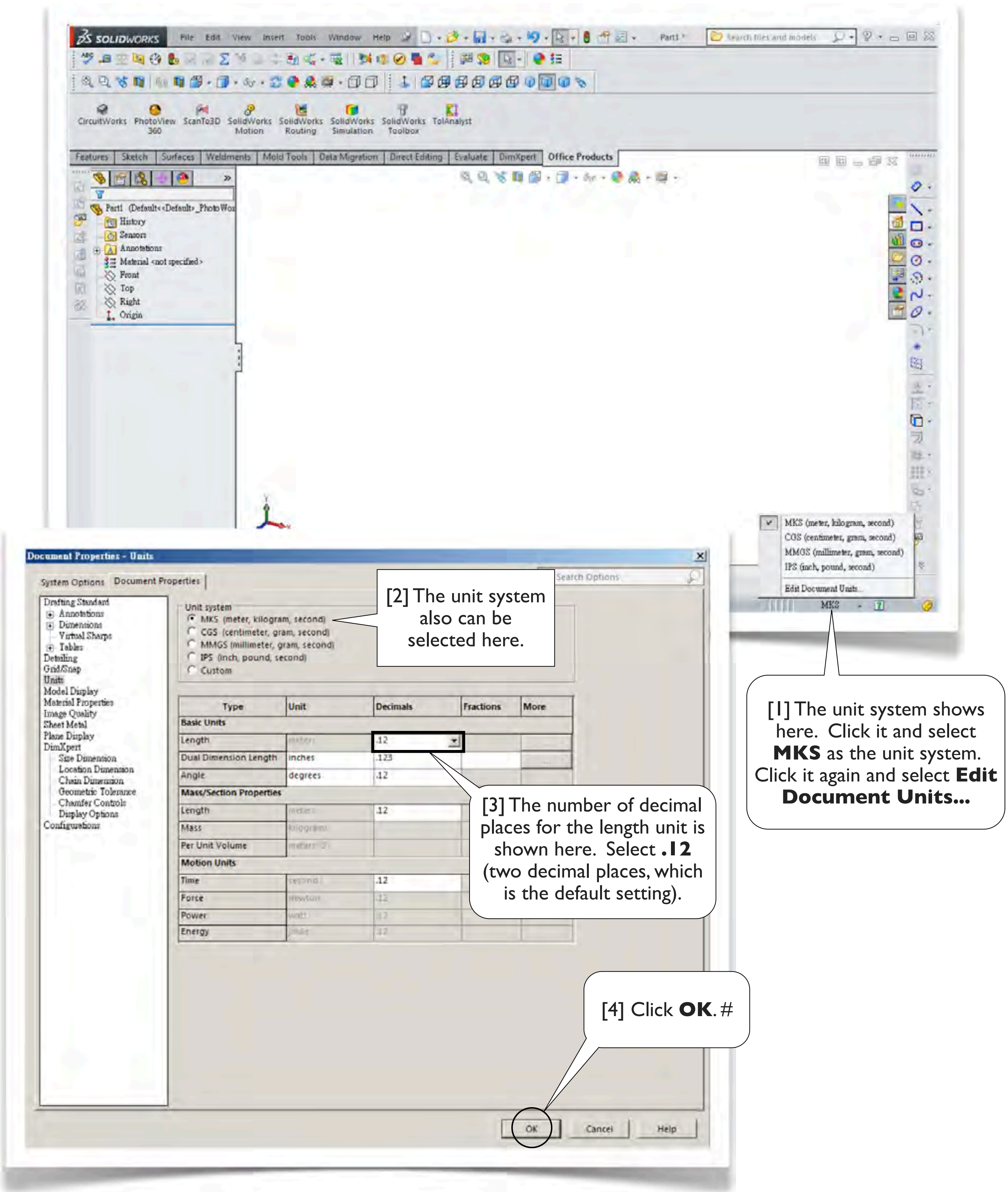
About the Text Boxes

1. Within each subsection (e.g., 1.1-2), text boxes 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 text boxes.
2. The text box numbers are also used as reference numbers. In the same subsection, we simply refer to a text box by its number (e.g., [1]). From other subsections, we refer to a text box by its subsection identifier and the text box number (e.g., 1.1-2[1]).
3. A text box is either round-cornered (e.g., [1, 3, 5]) or sharp-cornered (e.g., [2, 4]). A round-cornered box indicates that **mouse or keyboard actions** are needed in that step. A sharp-cornered box 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 text box of a subsection, so that you don't leave out any text boxes.

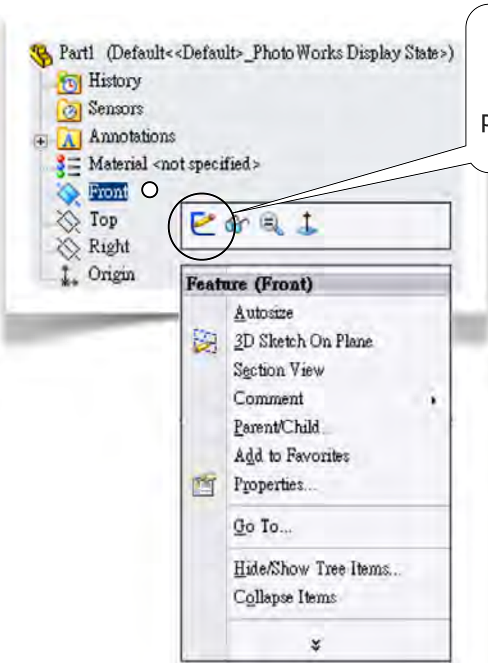
SolidWorks Terms

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



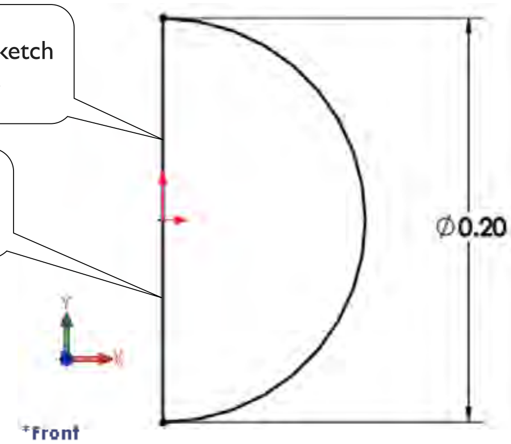
1.1-4 Create a Part: **Ball**

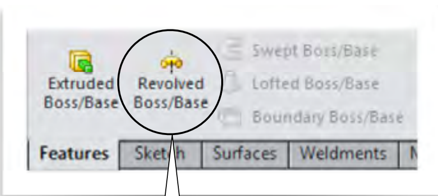


[1] In the **Features Tree** (on the left of the user interface), right-click **Front** plane and select **Sketch** from the **Context Menu**.

[2] Draw a sketch like this.

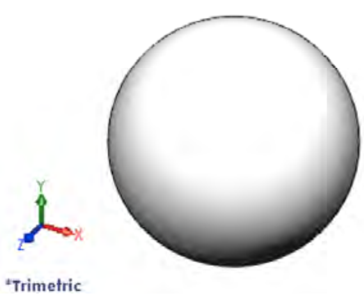
[4] Select this line as **Axis of Revolution**.

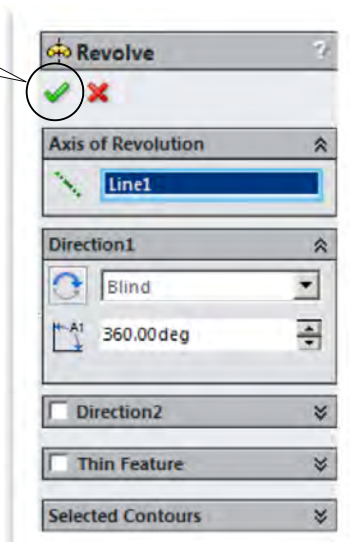




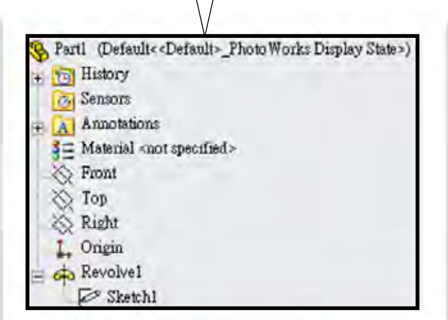
[3] In the **Features Toolbar**, click **Revolved Boss/Base**.

[5] Click **OK**.



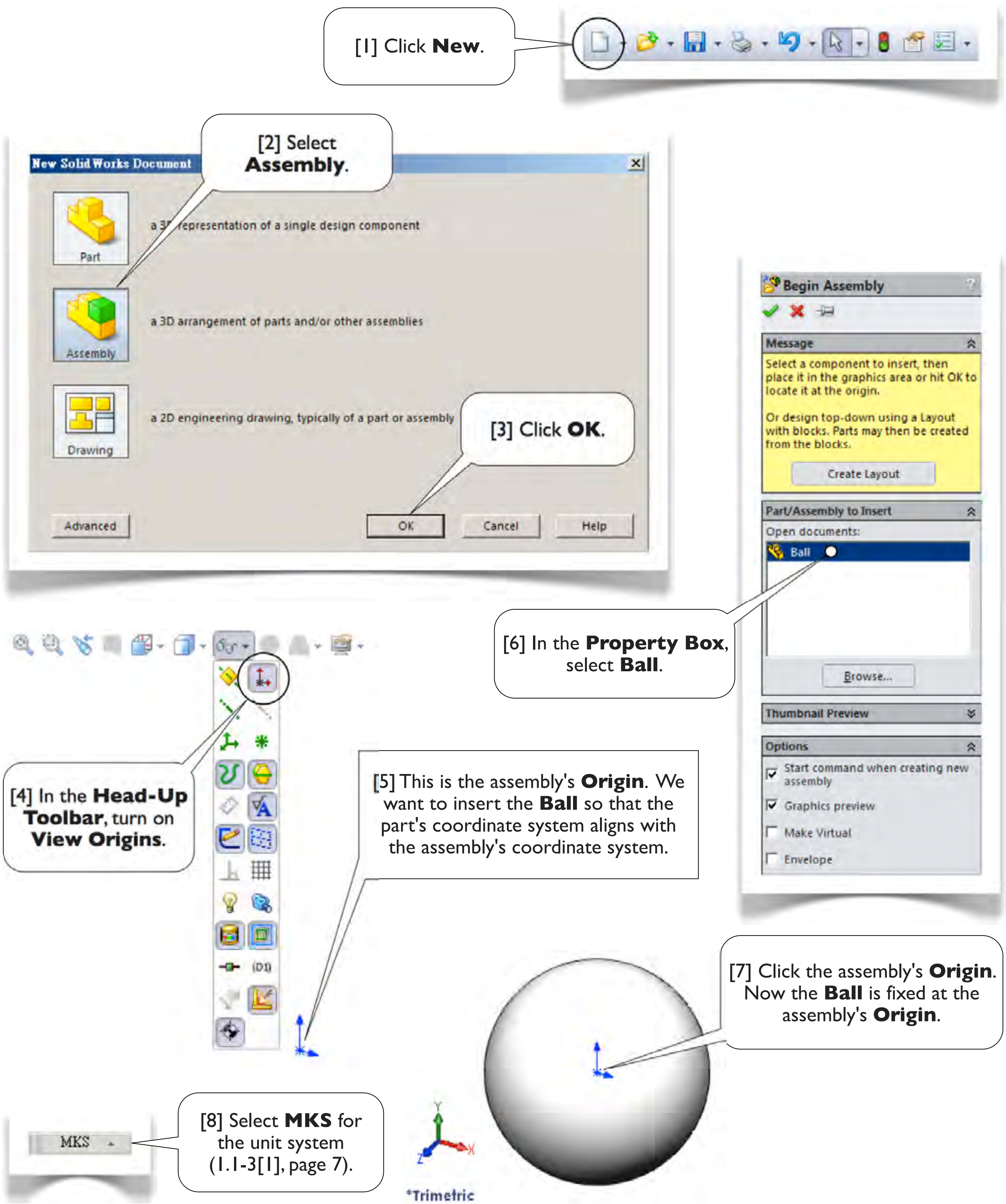


[6] This is the **Features Tree** of the **Part**. In this book, we simply call it a **Part Tree**.

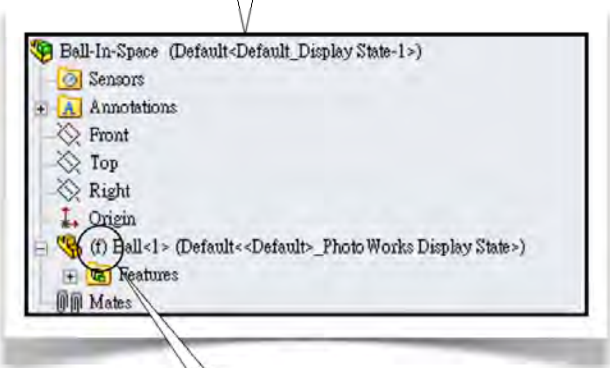


[7] Click **Save** and save the document with the name **Ball**. A file **Ball.SLDPRT** is created in your working folder. #

1.1-5 Create an Assembly: **Ball-In-Space**



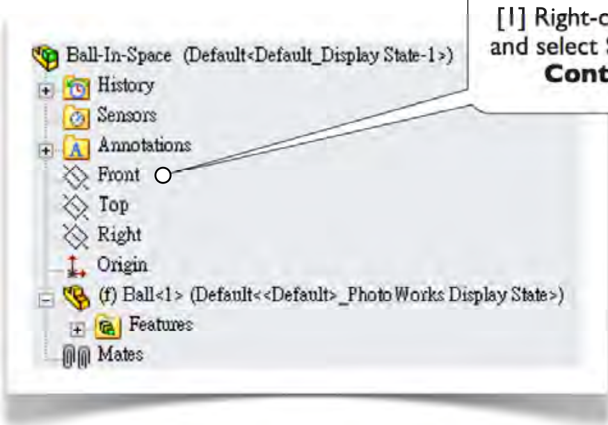
[10] This is the **Features Tree** of the **Assembly**. In this book, we simply call it the **Assembly Tree**.



[11] In the **Assembly Tree**, an **(f)** sign before **Ball<1>** indicates that the **Ball** is fixed in the space. We'll release it before running the simulation (1.1-11[11], page 14). #

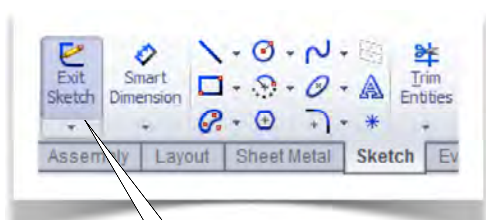
[9] Click **Save** and save the document with the name **Ball-In-Space**. A file **Ball-In-Space.SLDASM** is created in your working folder.

1.1-6 Create a **Sketch** in the **Assembly**

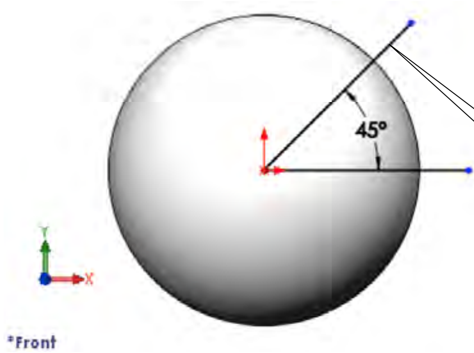


[1] Right-click **Front** plane and select **Sketch** from the **Context Menu**.

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

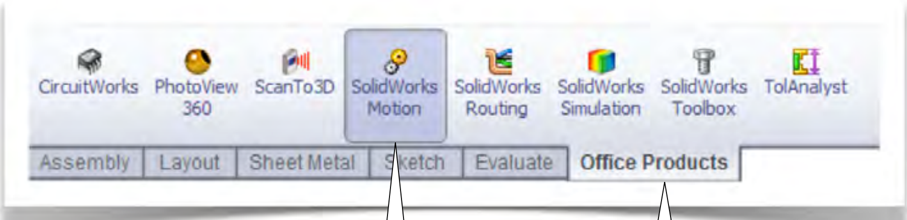


[4] Click **Exit Sketch**. #



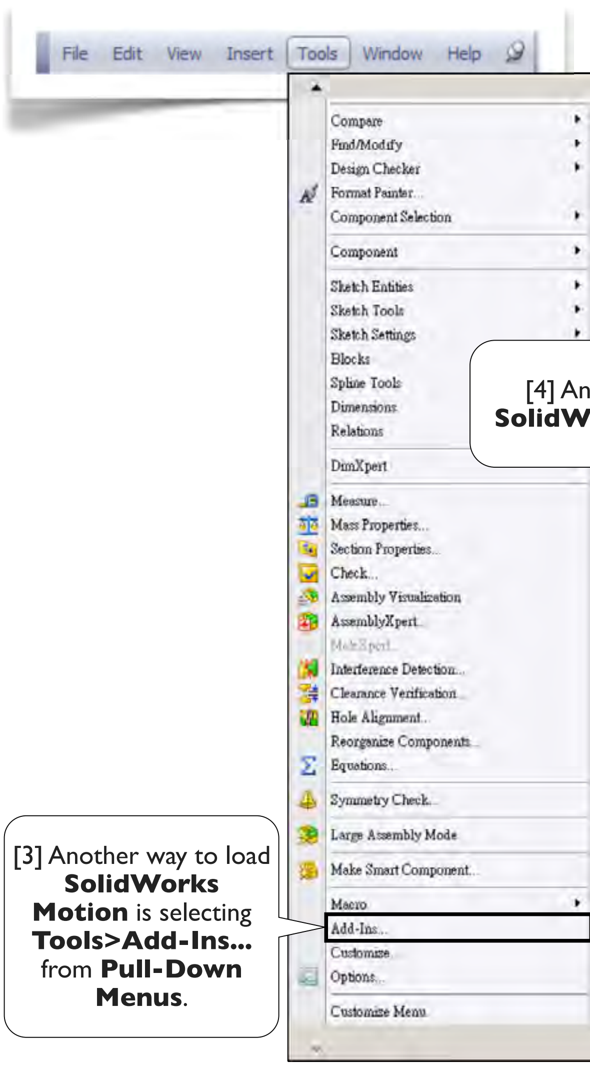
[3] Draw a sketch like this. The lengths of the lines are not relevant. We'll use this line to define the direction of the initial velocity of the **Ball**.

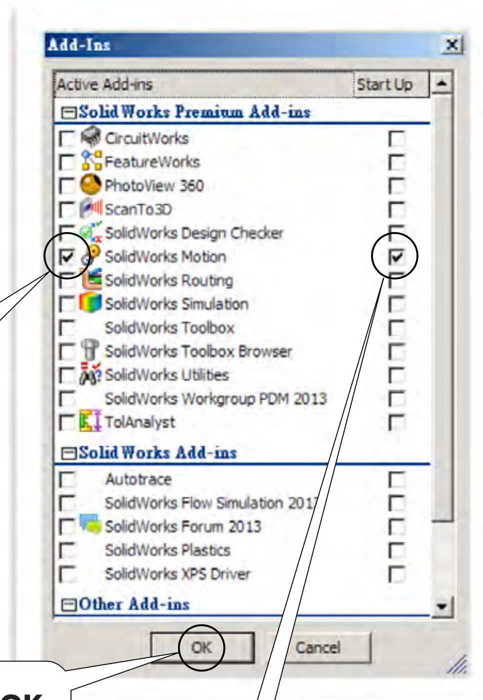
1.1-7 Load **SolidWorks Motion**



[2] If this button is highlighted, that means **SolidWorks Motion** has already been loaded, you may jump to next page. Otherwise, click to load **SolidWorks Motion**.

[1] Click **Office Products** tab.





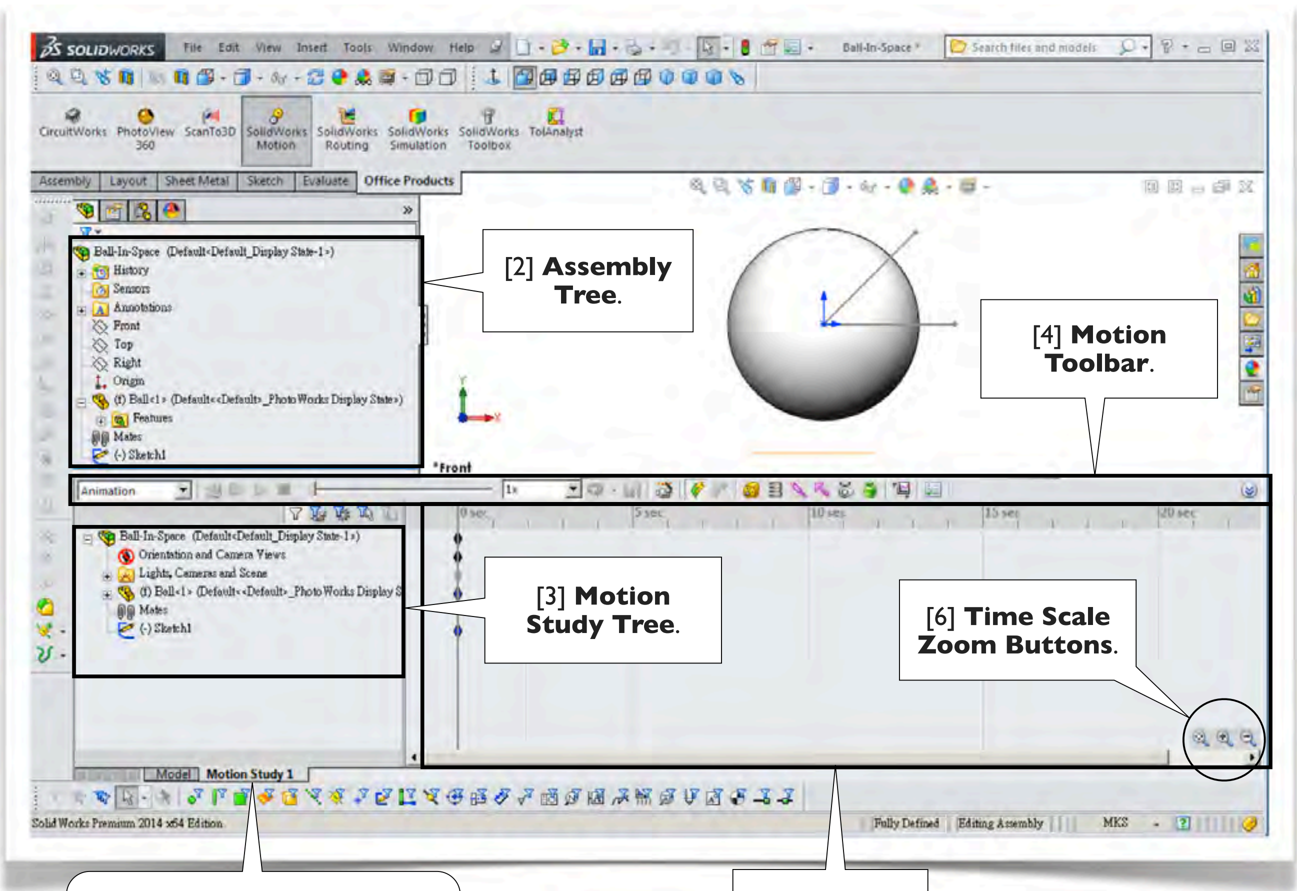
[4] And then select **SolidWorks Motion**.

[6] Click **OK**.

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

[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**. #

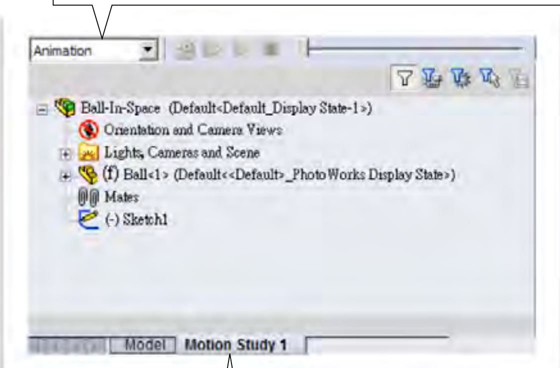
1.1-8 Create a **Motion Study**



[1] Click **Motion Study 1** tab.

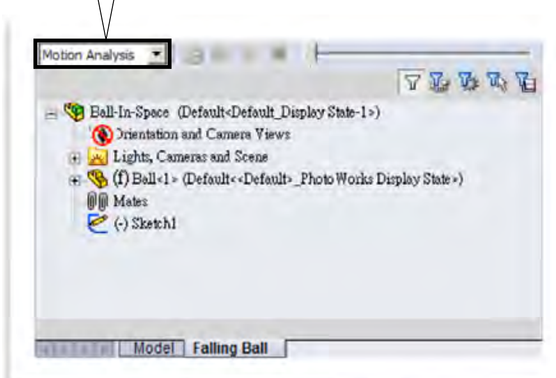
[5] **Timeline Area**.

[8] By default, **Animation** is the **Type of Study**. It has limited capability for motion simulation.



[7] Double-click **Motion Study 1** tab and change the name to **Falling Ball**.

[9] Select **Motion Analysis**, which provides full capability for motion simulation. In this book, we always select **Motion Analysis** as the **Type of Study**. #



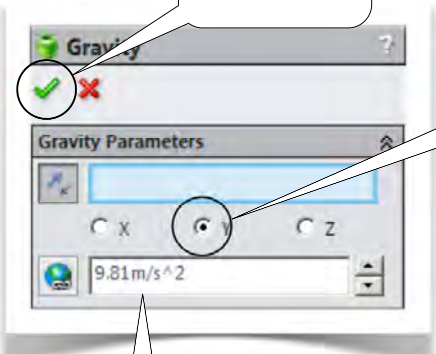
1.1-9 Set Up **Gravity**

[1] In **Motion Toolbar**, click **Gravity**.

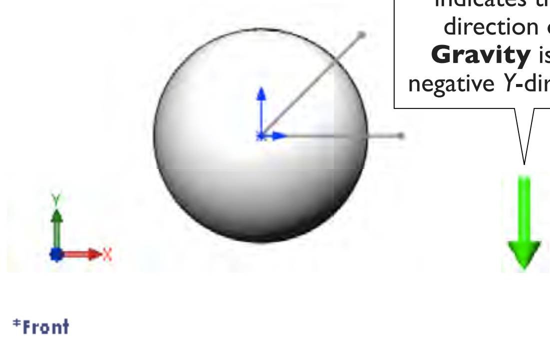
[2] The default **Gravity Value** is $9.81\ m/s^2$. Internally, it is stored as $9.80665\ m/s^2$. To display more decimal places, see 1.1-3[3], page 7.

[3] Click **Y**.

[5] Click **OK**.

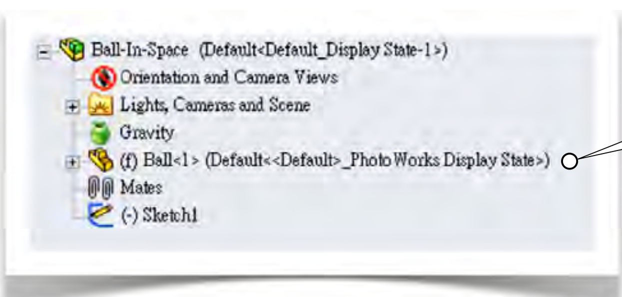


[4] An arrow in **Graphics Window** indicates that the direction of the **Gravity** is in the negative *Y*-direction. #

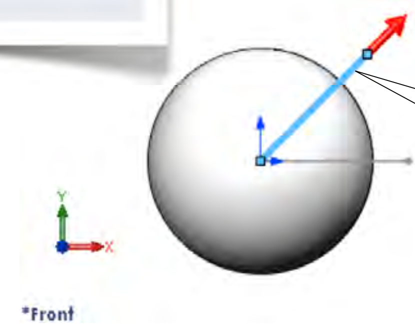


1.1-10 Set Up **Initial Velocity** for the **Ball**

[1] In **Motion Study Tree**, right-click **Ball<1>** and select **Initial Velocity**.

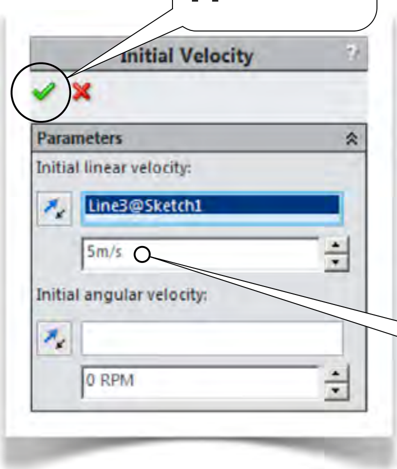


[2] Click this line (1.1-6[3], page 10). A red arrow appears, showing the direction of the **Initial Velocity**.

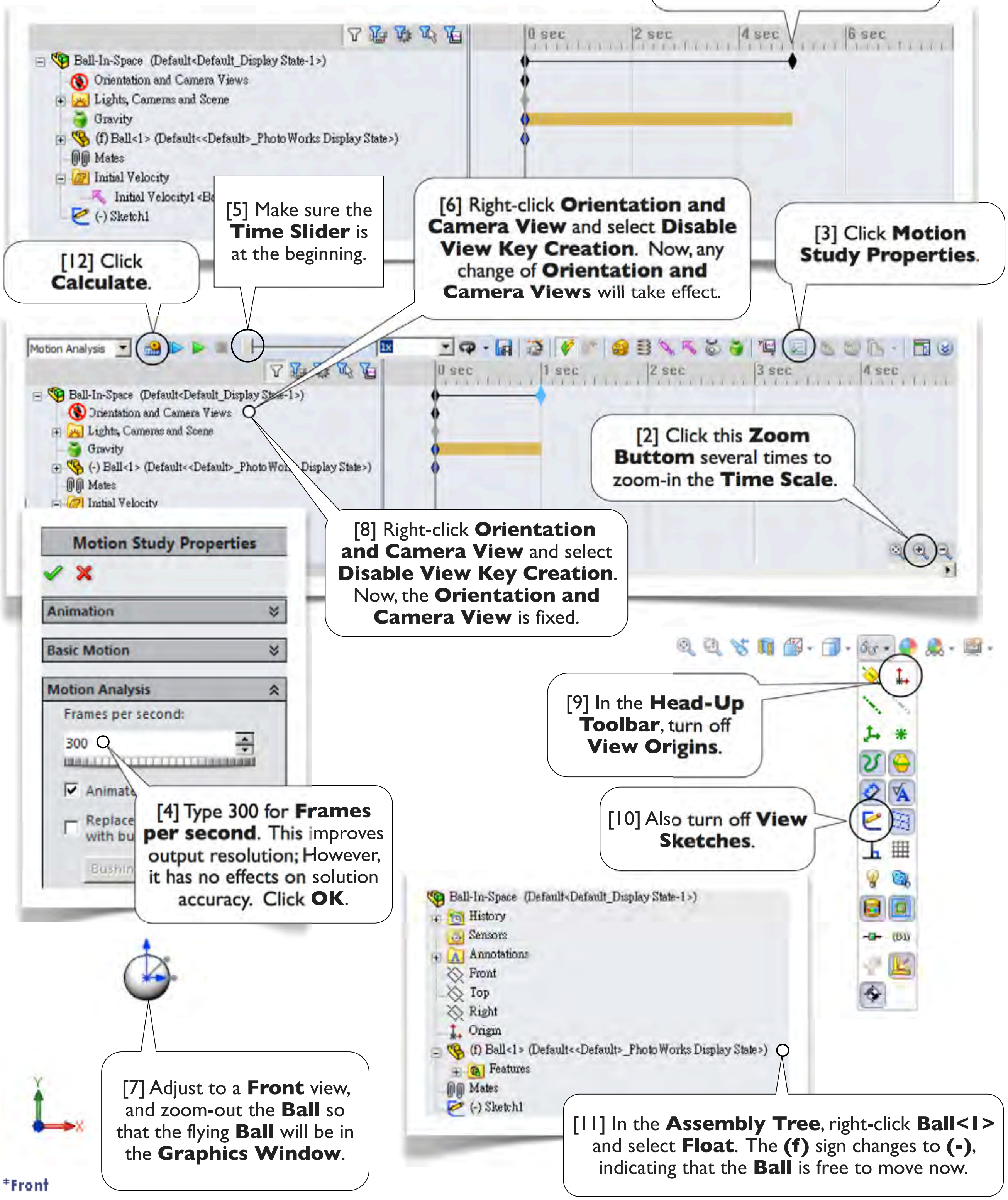


[3] Type 5 (m/s) as the magnitude of the **Initial linear Velocity**.

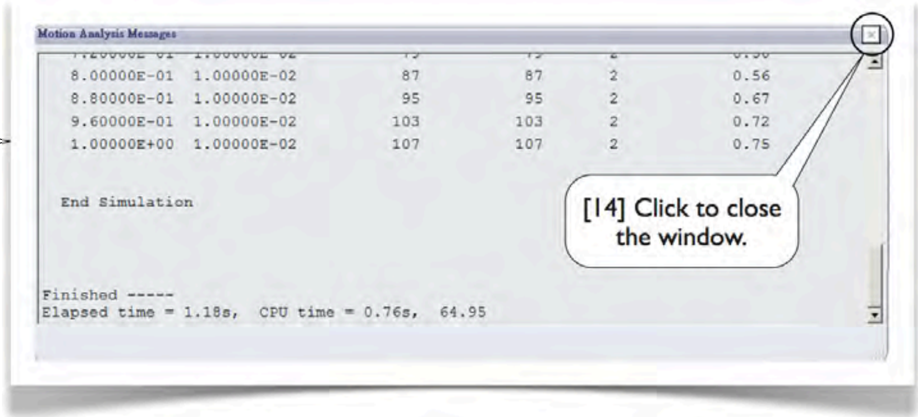
[4] Click **OK**. #



1.1-11 Calculate and Animate **Results**



[13] A **Motion Analysis Messages** window may appear with useful information. This feature can be disabled (see 2.1-9[4], page 41). If you don't see this window, never mind and skip to [15].



[14] Click to close the window.

[17] Click to **Stop** the animation. #

[16] Click **Play from Start**.

[15] Select **0.1x** for **Playback Speed**. We now play a slow motion.

1.1-12 Results: **Trace Path**

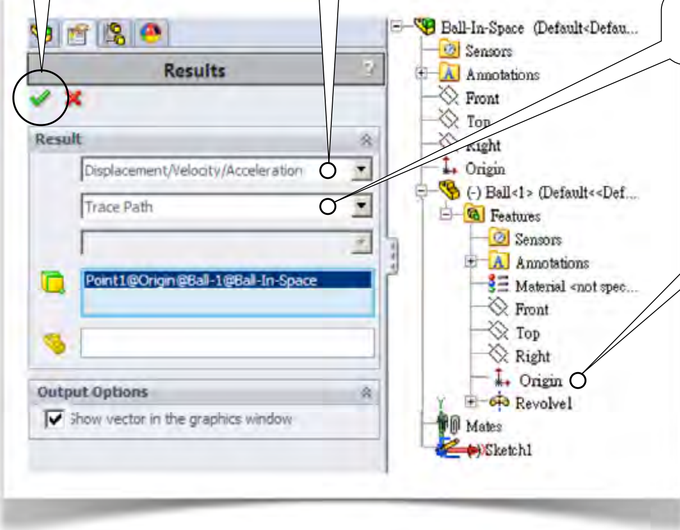
[1] In **Motion Toolbar**, click **Results and Plots**.

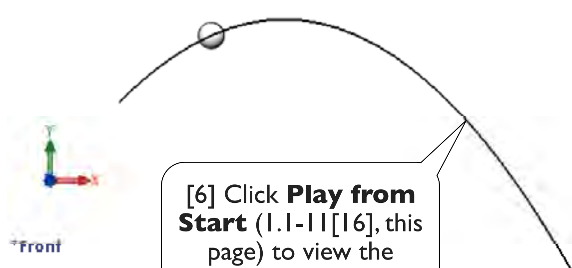
[5] Click **OK**.

[2] Select **Displacement/ Velocity/Acceleration**.

[3] Select **Trace Path**.

[4] Expand the **Assembly Tree** in the **Graphics Window** and select the **Origin** of **Ball<1>**.

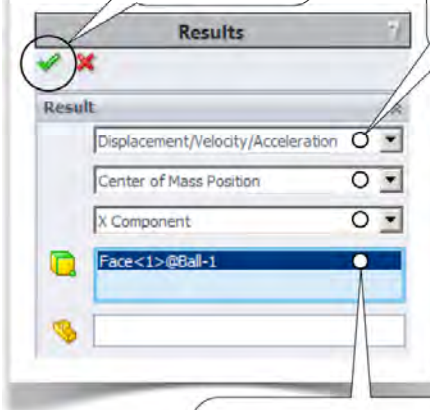




[6] Click **Play from Start** (1.1-11[16], this page) to view the animation again. #

1.1-13 Results: **Positions-X**

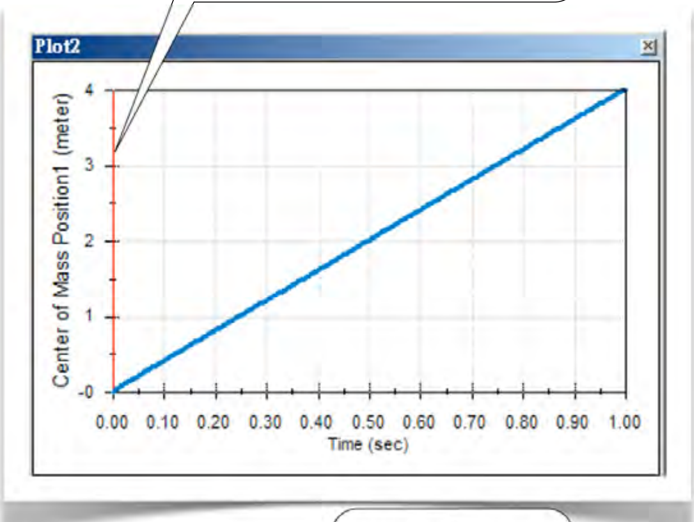
[1] In **Motion Toolbar**, click **Results and Plots**.



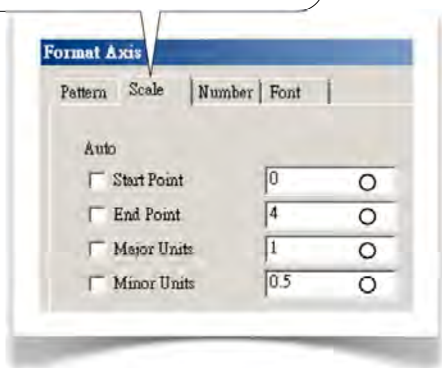
[2] Set up the **Results** like this.

[3] In the **Graphics Window**, click the **Ball**. The positions of the **Center of Mass** will be reported.

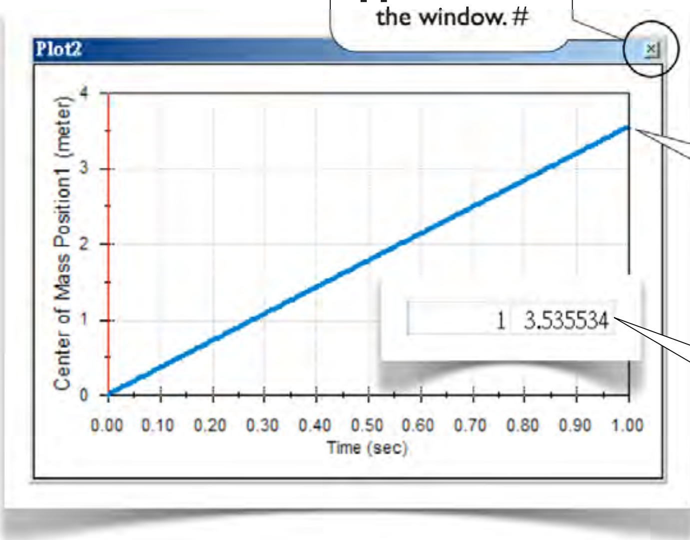
[4] Click **OK**.



[5] The scale is somehow misleading. Double-click the vertical axis.



[6] Click **Scale** tab and set the scale like this. Click **OK**.



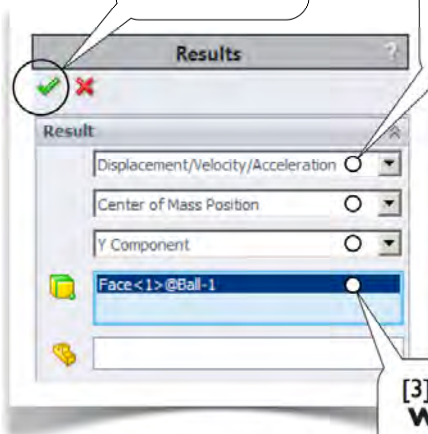
[7] Now, it looks better. Let's obtain numerical data. Right-click anywhere inside the window and select **Export CSV**. Save the file with the name **Ball-Position-X**.

[8] In your working folder, double-click to open the file **Ball-Position-X.CSV**. Look up the position at time = 1 sec, which is 3.535534 m, consistent with the value in Eq. 1.1-1(2), page 5. Close the **CSV file**.

[9] Click to close the window. #

1.1-14 Results: **Positions-Y**

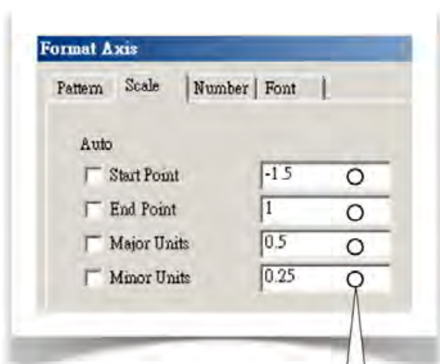
[1] In **Motion Toolbar**, click **Results and Plots**.



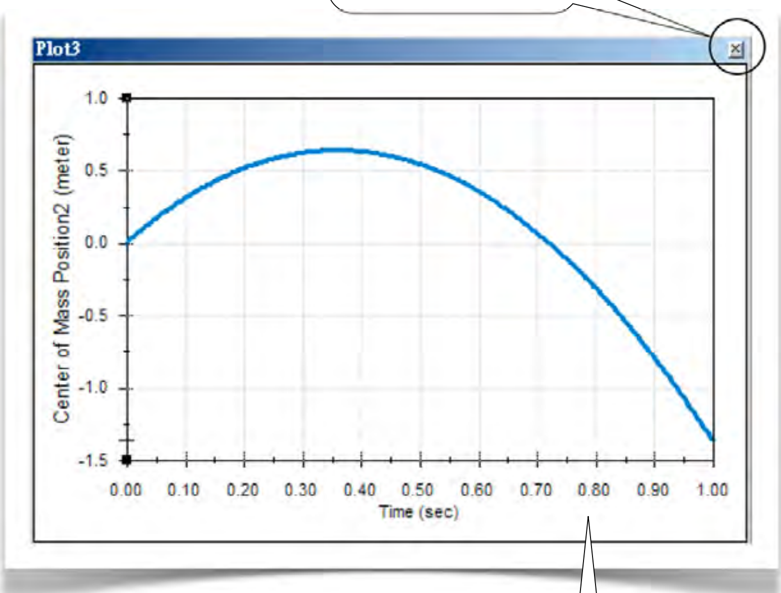
[2] Set up the **Results** like this.

[3] In the **Graphics Window**, click the **Ball**.

[4] Click **OK**.



[5] Set the scale for the vertical axis like this.

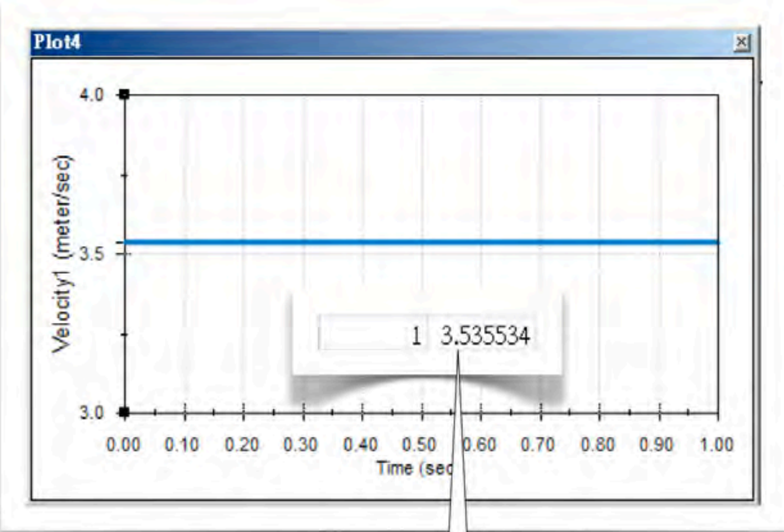


[6] Right-click anywhere inside the window and select **Export CSV**. Save the file with the name **Ball-Position-Y**.

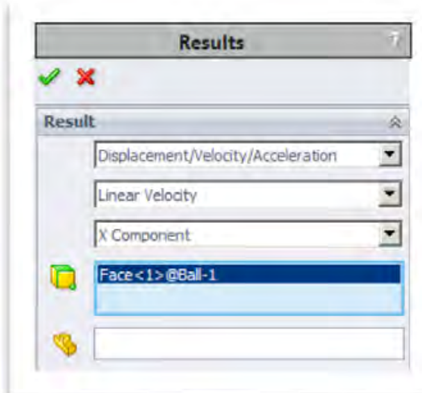
[7] In your working folder, double-click to open the file **Ball-Position-Y.CSV**. Look up the position at time = 1 sec, which is -1.36779 m, consistent with the value in Eq. 1.1-1(4), page 5. Close the **CSV** file.

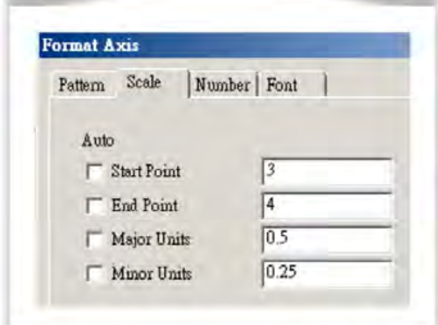
[8] Click to close the window. #

1.1-15 Results: **Velocity-X**

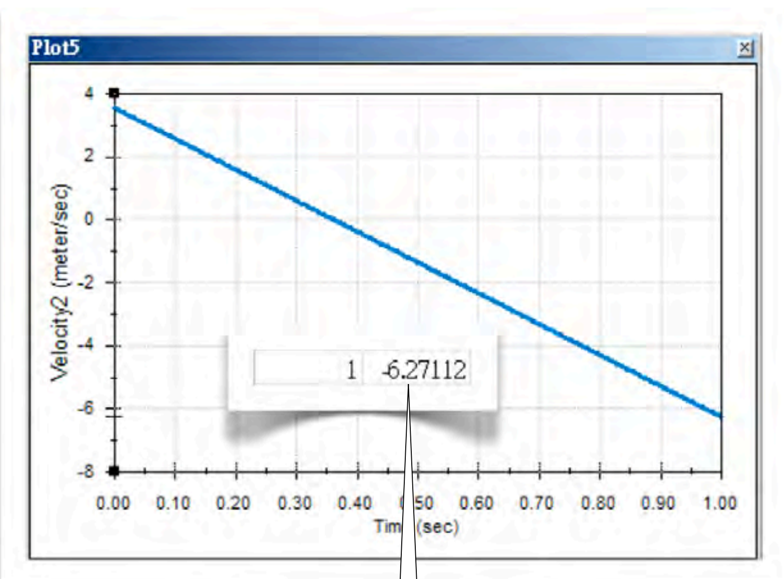


[1] Follow a similar procedure in 1.1-14 to obtain the **Ball's** velocity in *X*-direction, which is a constant (3.535534 m/s) over the time, consistent with the value in Eq. 1.1-1(1), page 5. #

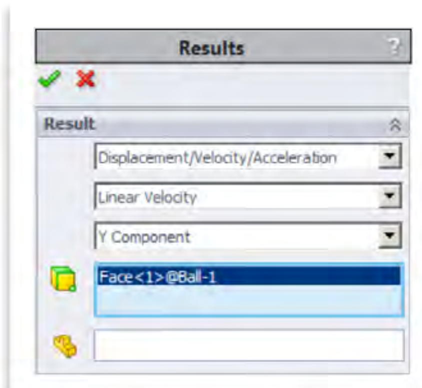


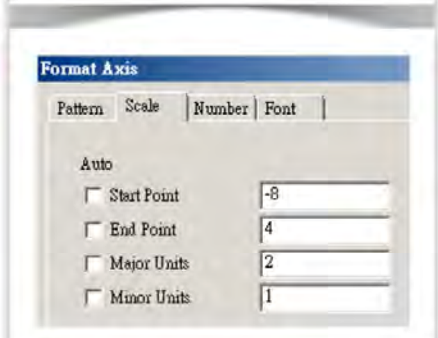


1.1-16 Results: **Velocity-Y**



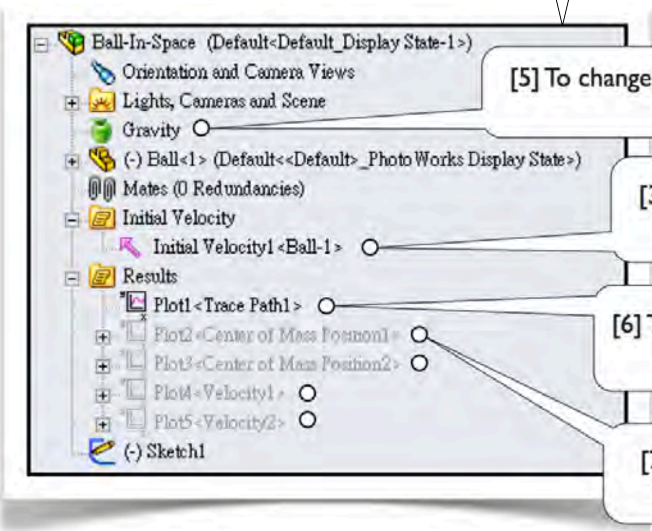
[1] Follow a similar procedure in 1.1-14 to obtain the **Ball's** velocity in *Y*-direction, which is -6.27112 m/s at time = 1 sec, consistent with the value in Eq. 1.1-1(3), page 5. #





1.1-17 Do It Yourself

[1] **Motion Study Tree**.

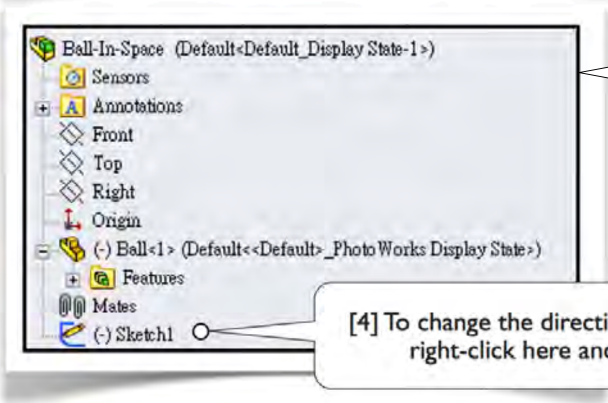


[5] To change the **Gravity**, right-click here and select **Edit Feature**.

[3] To change the magnitude of the **Initial Velocity**, right-click here and select **Edit Feature**.

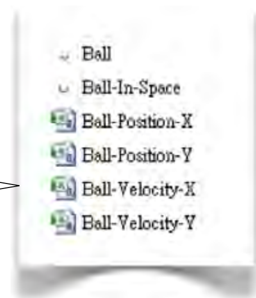
[6] To hide the **Trace Path** in the **Graphics Window**, right-click here and select **Hide Plot**.

[7] To show any of the **Plot**, right-click it and select **Show Plot**.



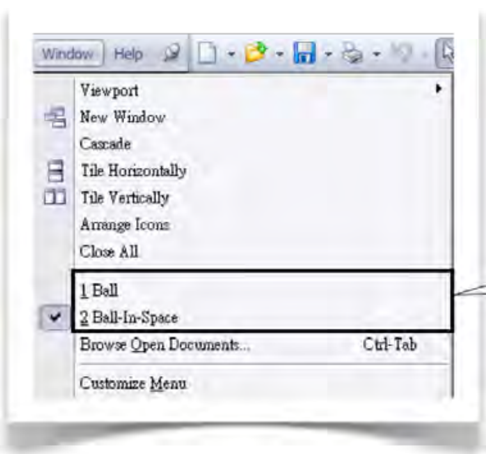
[2] **Assembly Tree**.

[8] Your working folder should contain these files. #



[4] To change the direction of the **Initial Velocity**, right-click here and select **Edit Sketch**.

1.1-18 Wrap Up



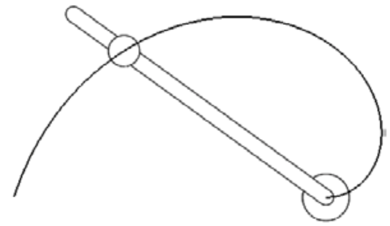
[1] From the **Pull-Down Menus**, click **Window** to see that there are two opened files.

[2] Select **Save>Save All** to save all changes in the two files. Click **Rebuild**, if a warning message window appears.

[3] From the **Pull-Down Menus**, Select **File>Exit** to quit **SolidWorks**. #

Section 1.2

Radial and Transverse Components: Sliding Collar on Rotating Arm



1.2-1 Introduction

[1] Consider an **Arm** rotating about a **Pivot** with an angular speed $\dot{\theta} = \pi$ rad/s [2-4]. A **Collar** initially aligned with the **Pivot** slides along the **Arm** with a constant speed $\dot{r} = 1.0$ m/s [5-6].

Let's use a polar coordinate system centered at the **Pivot** and let (r, θ) be the position of the **Collar's** center. Denote $\vec{e}_r$ the unit vector in radial direction and $\vec{e}_\theta$ the unit vector in transversal direction [7, 8]. Then the position, velocity, and acceleration of the **Collar's** center are respectively

$$\begin{aligned} \vec{r} &= r\vec{e}_r \\ \vec{v} &= \dot{r}\vec{e}_r + r\dot{\theta}\vec{e}_\theta \\ \vec{a} &= (\ddot{r} - r\dot{\theta}^2)\vec{e}_r + (r\ddot{\theta} + 2\dot{r}\dot{\theta})\vec{e}_\theta \end{aligned} \tag{1}$$

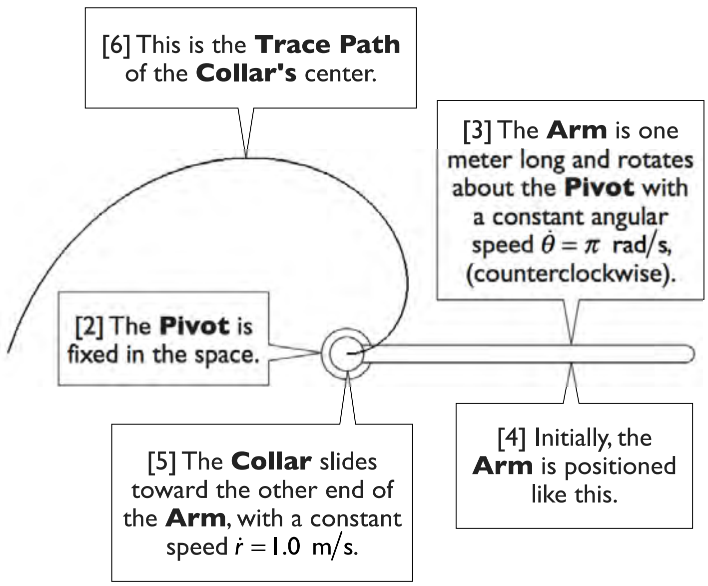
Let's calculate these values at an arbitrary time, say $t = 0.8$ s. At that time [9, 10],

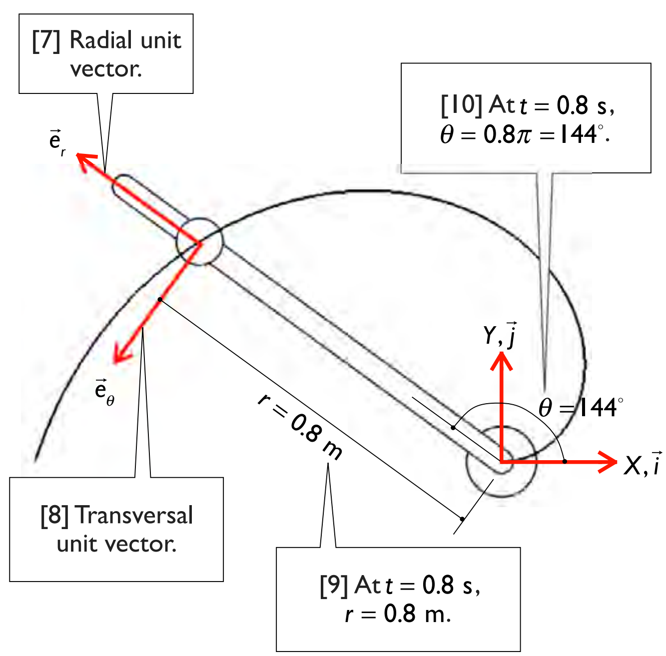
$$\begin{aligned} r &= 0.8 \text{ m} & \theta &= 0.8\pi \\ \dot{r} &= 1.0 \text{ m/s} & \dot{\theta} &= \pi \text{ rad/s} \\ \ddot{r} &= 0 \text{ m/s}^2 & \ddot{\theta} &= 0 \text{ rad/s}^2 \end{aligned}$$

Then, the position is

$$\begin{aligned} \vec{r} &= r\vec{e}_r \\ &= 0.8\vec{e}_r \\ &= 0.8(\cos 144^\circ)\vec{i} + 0.8(\sin 144^\circ)\vec{j} \\ &= -0.647\vec{i} + 0.470\vec{j} \end{aligned} \tag{2}$$

where $\vec{i}$ is the unit vector in X-direction and $\vec{j}$ is the unit vector in Y-direction. The origin of the XY-coordinate system is the same as that of the polar coordinate system.





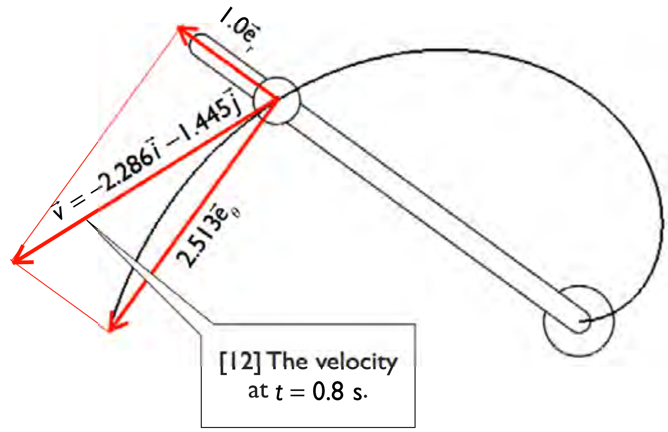
[11] The velocity is [12]

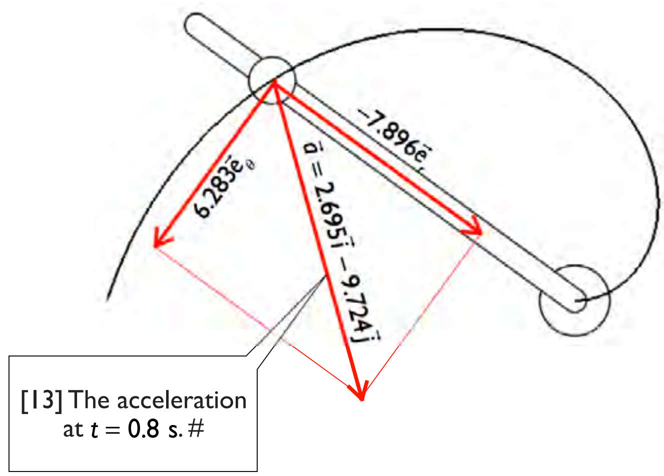
$$\begin{aligned}\vec{v} &= \dot{r}\vec{e}_r + r\dot{\theta}\vec{e}_\theta \\ &= 1.0\vec{e}_r + 0.8\pi\vec{e}_\theta \\ &= 1.0\vec{e}_r + 2.513\vec{e}_\theta \\ &= (\cos 144^\circ \vec{i} + \sin 144^\circ \vec{j}) \\ &\quad + (-2.513\sin 144^\circ \vec{i} + 2.513\cos 144^\circ \vec{j}) \\ &= -2.286\vec{i} - 1.445\vec{j}\end{aligned} \tag{3}$$

The acceleration is [13]

$$\begin{aligned}\vec{a} &= (\ddot{r} - r\dot{\theta}^2)\vec{e}_r + (r\ddot{\theta} + 2\dot{r}\dot{\theta})\vec{e}_\theta \\ &= \left[0 - 0.8(\pi)^2\right]\vec{e}_r \\ &\quad + \left[0.8(0) + 2(1.0)(\pi)\right]\vec{e}_\theta \\ &= -7.896\vec{e}_r + 6.283\vec{e}_\theta \\ &= (-7.896\cos 144^\circ \vec{i} - 7.896\sin 144^\circ \vec{j}) \\ &\quad + (-6.283\sin 144^\circ \vec{i} + 6.283\cos 144^\circ \vec{j}) \\ &= 2.695\vec{i} - 9.724\vec{j}\end{aligned} \tag{4}$$

In this section, we'll perform a simulation for this system and validate the simulation results with the values in Eqs. (2-4).

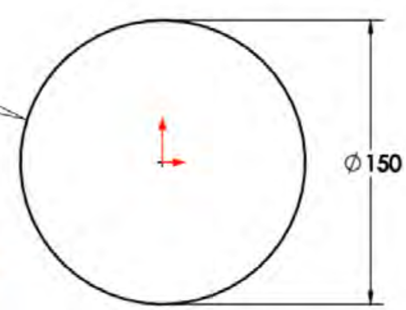


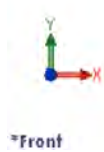


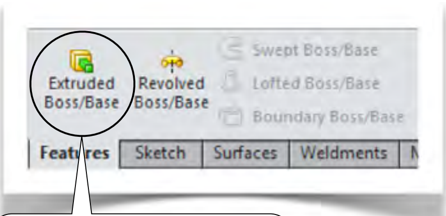
1.2-2 Start Up and Create a Part: **Pivot**

[1] Launch **SolidWorks** (1.1-2[1], page 6) and click **New** to create a new **Part**. Set up **MMGS** unit system with zero decimal places for the length unit (1.1-3, page 7).

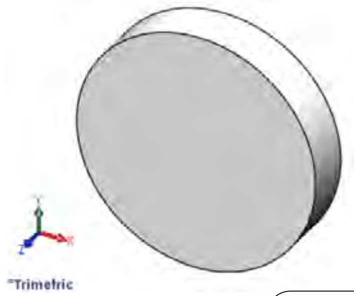
[2] On the **Front** plane, draw a circle like this.

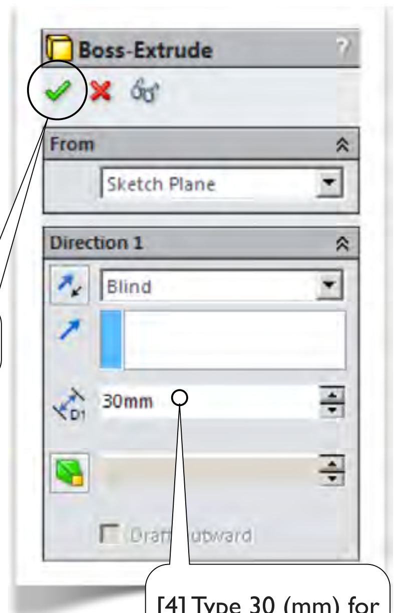






[3] In the **Features Toolbar**, click **Extruded Boss/Base**.





[5] Click **OK**.

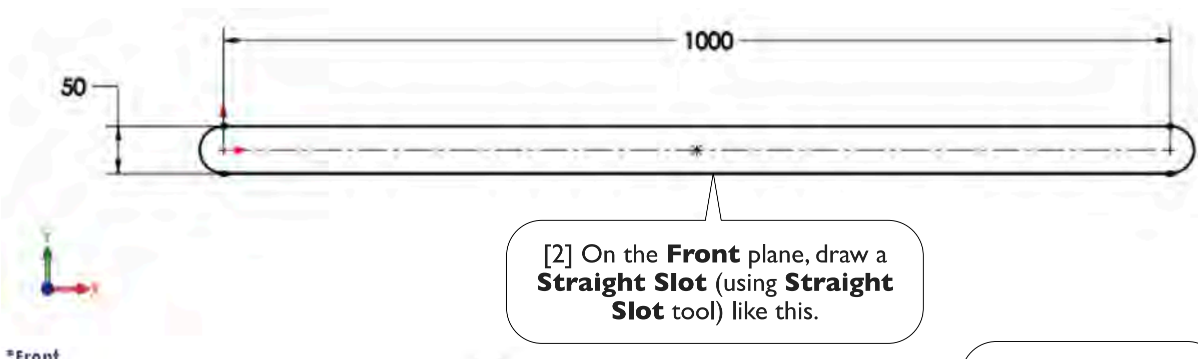
[4] Type 30 (mm) for **Depth**.

[6] Save the **Part** with the name **Pivot**. #

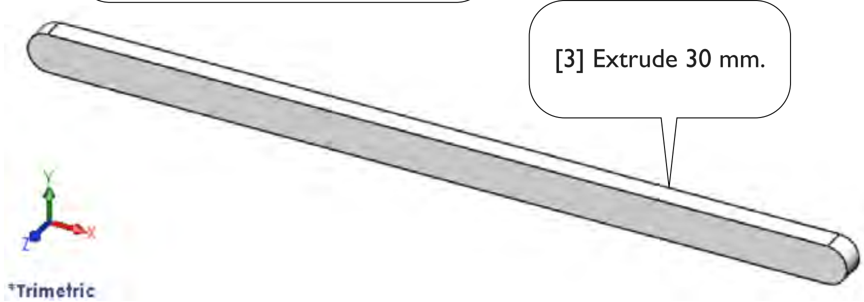
1.2-3 Create a Part: **Arm**

[1] Click to create a new **Part**. Set up **MMGS** unit system with zero decimal places for the length unit.

[4] Save the **Part** with the name **Arm**. #



[2] On the **Front** plane, draw a **Straight Slot** (using **Straight Slot** tool) like this.

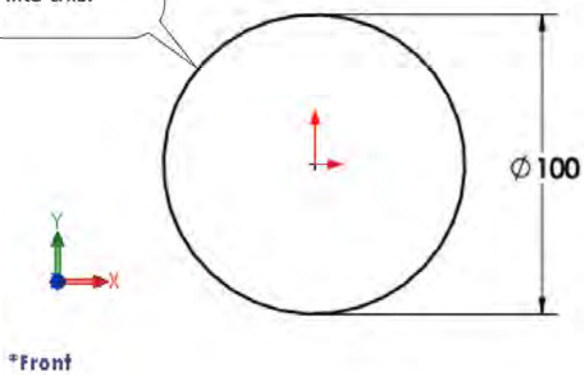


[3] Extrude 30 mm.

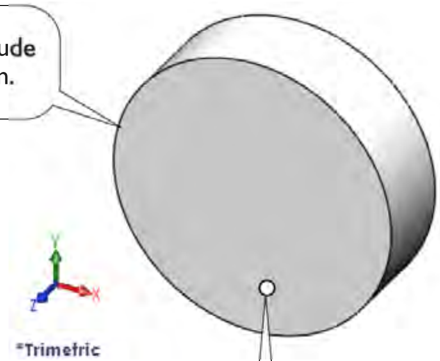
1.2-4 Create a Part: **Collar**

[1] Create a new **Part**. Set up **MMGS** unit system with zero decimal places for the length unit.

[2] On the **Front** plane, draw a circle like this.

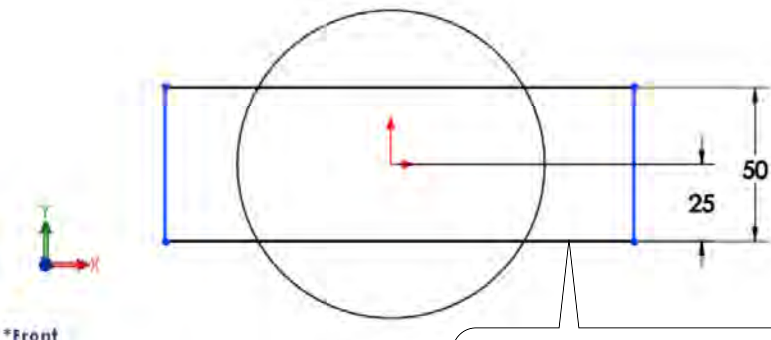


[3] Extrude 30 mm.



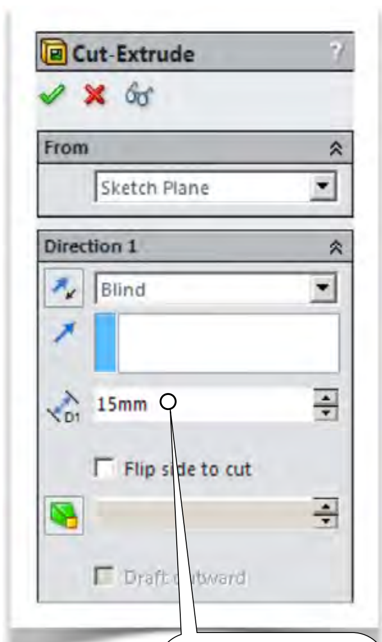
[4] Right-click this face and select **Sketch**.

[5] In the **Standard Views Toolbar**, click **Normal To** (1.1-6[2], page 10).



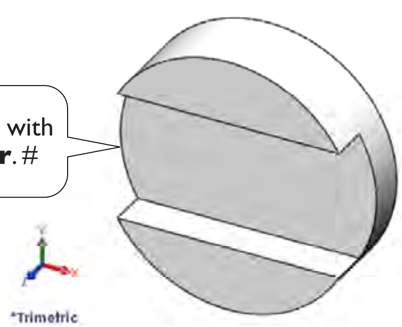
[6] Draw a rectangle like this. The width of the rectangle is not important.

[7] In **Features Toolbar**, click **Extruded Cut**.



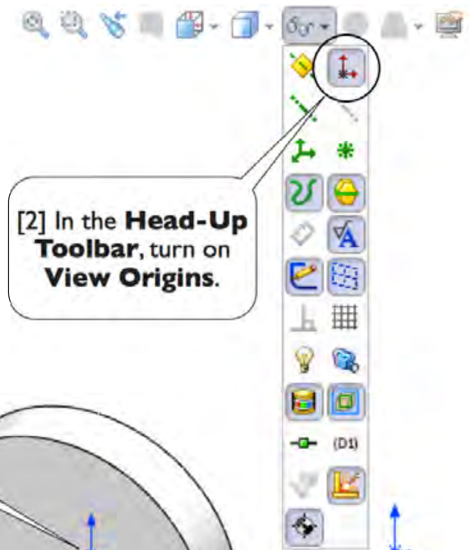
[8] Type 15 (mm). Click **OK**.

[9] Save the **Part** with the name **Collar**. #



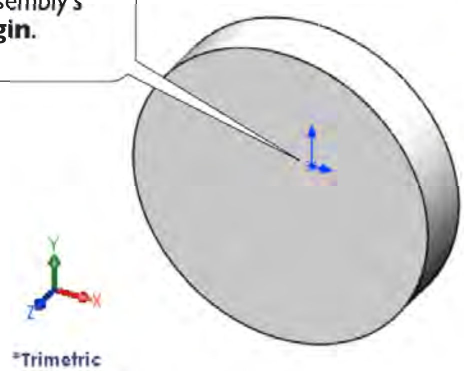
1.2-5 Create an Assembly: **Collar-On-Arm**

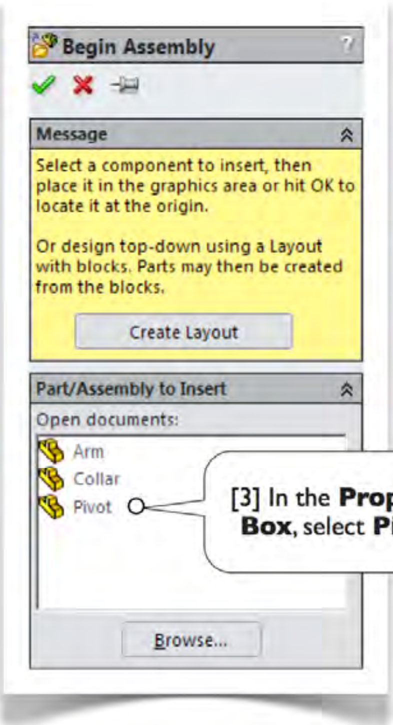
[1] Click **New** and create an **Assembly** (1.1-5[1-3], page 9).



[2] In the **Head-Up Toolbar**, turn on **View Origins**.

[4] Click the **Origin**. Now the **Pivot** is fixed at the assembly's **Origin**.

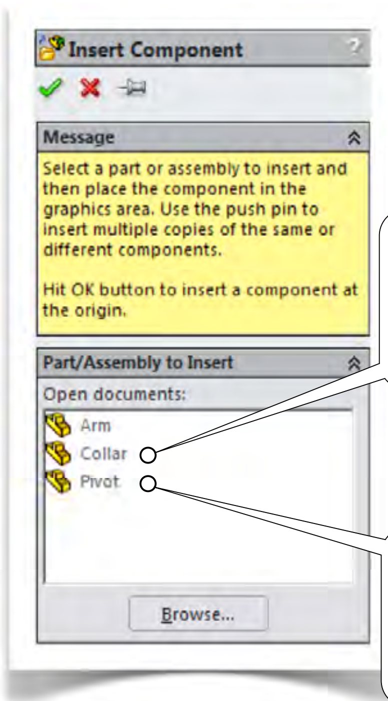




[3] In the **Property Box**, select **Pivot**.

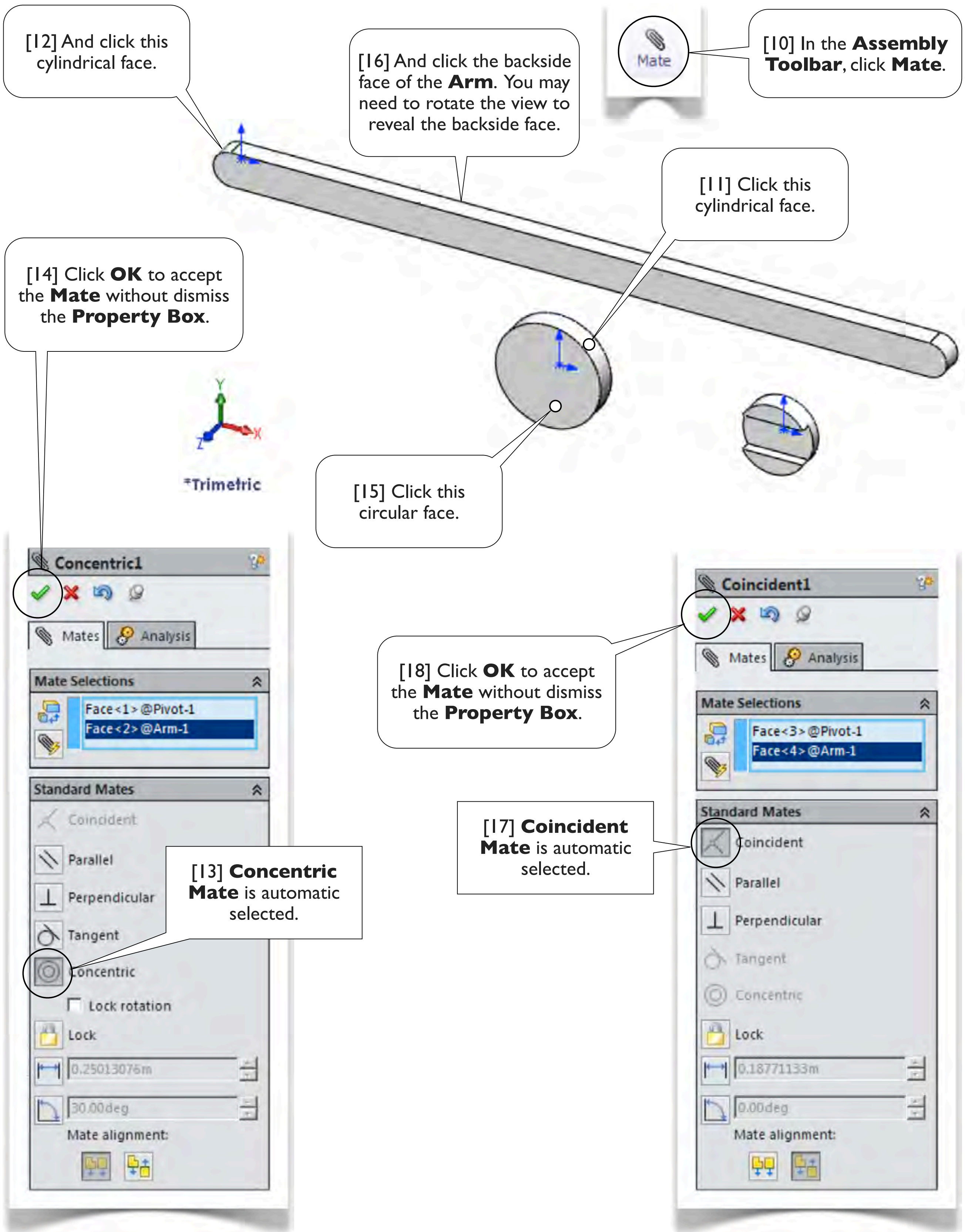
[5] Select **MKS** for the unit system (see 1.1-3[1], page 7).

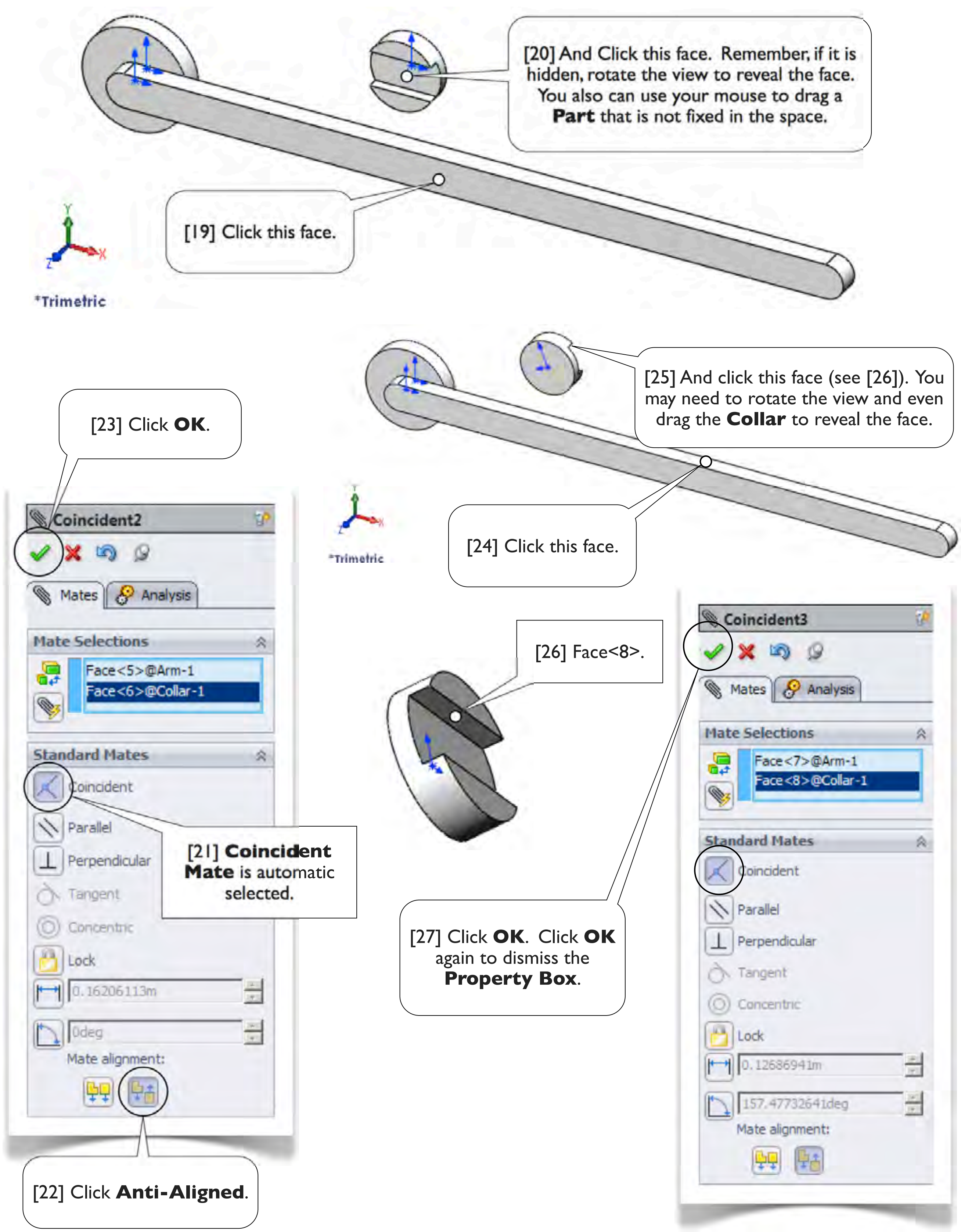
[6, 8] In the **Assembly Toolbar**, click **Insert Components**.

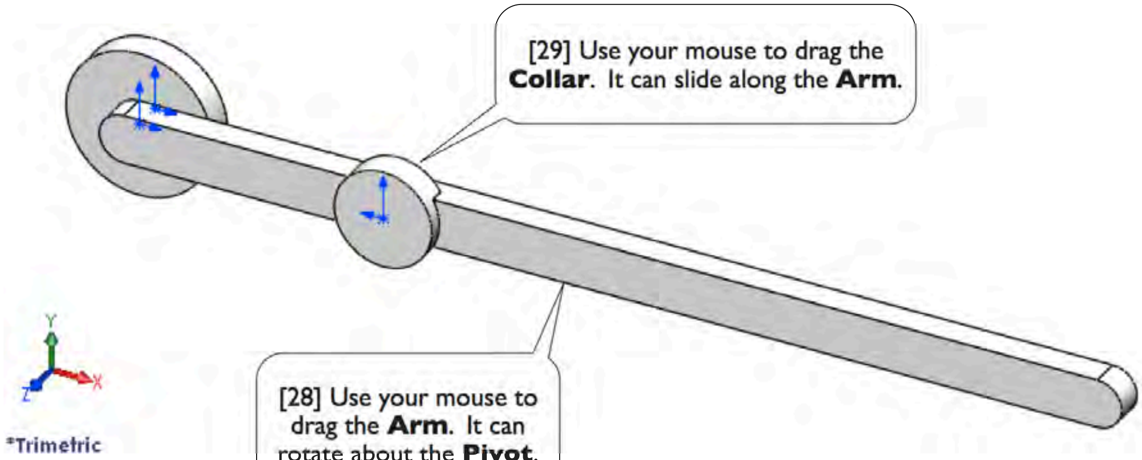


[7] In the **Property Box**, select **Arm** and click anywhere in the **Graphics Window** to temporarily park the part.

[9] In the **Property Box**, select **Collar** and click anywhere in the **Graphics Window** to temporarily park the part.

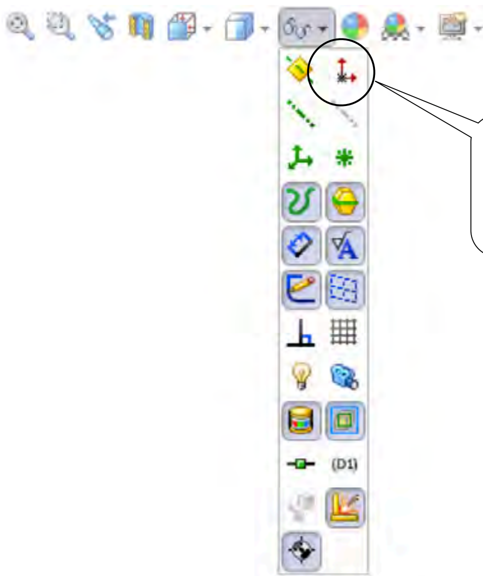

[12] And click this cylindrical face.
[16] And click the backside face of the **Arm**. You may need to rotate the view to reveal the backside face.
Mate
[10] In the **Assembly Toolbar**, click **Mate**.
[11] Click this cylindrical face.
[14] Click **OK** to accept the **Mate** without dismiss the **Property Box**.
Y
X
Z
*Trimetric
[15] Click this circular face.
Concentric1
Mates
Analysis
Mate Selections
Face<1>@Pivot-1
Face<2>@Arm-1
Standard Mates
Coincident
Parallel
Perpendicular
Tangent
Concentric
Lock rotation
Lock
0.25013076m
30.00deg
Mate alignment:
[13] **Concentric Mate** is automatic selected.
[18] Click **OK** to accept the **Mate** without dismiss the **Property Box**.
[17] **Coincident Mate** is automatic selected.
Coincident1
Mates
Analysis
Mate Selections
Face<3>@Pivot-1
Face<4>@Arm-1
Standard Mates
Coincident
Parallel
Perpendicular
Tangent
Concentric
Lock
0.18771133m
0.00deg
Mate alignment:


[20] And Click this face. Remember, if it is hidden, rotate the view to reveal the face. You also can use your mouse to drag a **Part** that is not fixed in the space.
[19] Click this face.
*Trimetric
[25] And click this face (see [26]). You may need to rotate the view and even drag the **Collar** to reveal the face.
[23] Click **OK**.
[24] Click this face.
*Trimetric
Coincident2
Mates
Analysis
Mate Selections
Face<5>@Arm-1
Face<6>@Collar-1
Standard Mates
Coincident
Parallel
Perpendicular
Tangent
Concentric
Lock
0.16206113m
0deg
Mate alignment:
[21] **Coincident Mate** is automatic selected.
[22] Click **Anti-Aligned**.
[26] Face<8>.
[27] Click **OK**. Click **OK** again to dismiss the **Property Box**.
Coincident3
Mates
Analysis
Mate Selections
Face<7>@Arm-1
Face<8>@Collar-1
Standard Mates
Coincident
Parallel
Perpendicular
Tangent
Concentric
Lock
0.12686941m
157.47732641deg
Mate alignment:

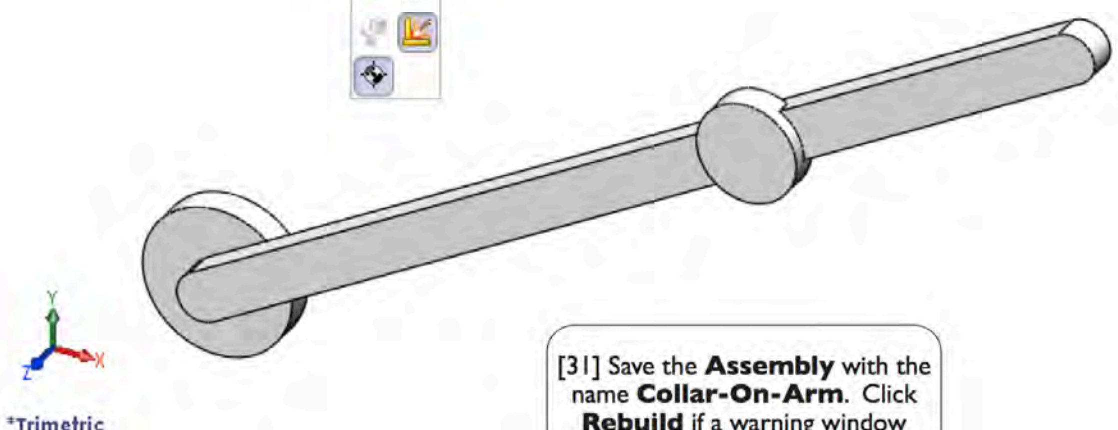


[29] Use your mouse to drag the **Collar**. It can slide along the **Arm**.

[28] Use your mouse to drag the **Arm**. It can rotate about the **Pivot**.

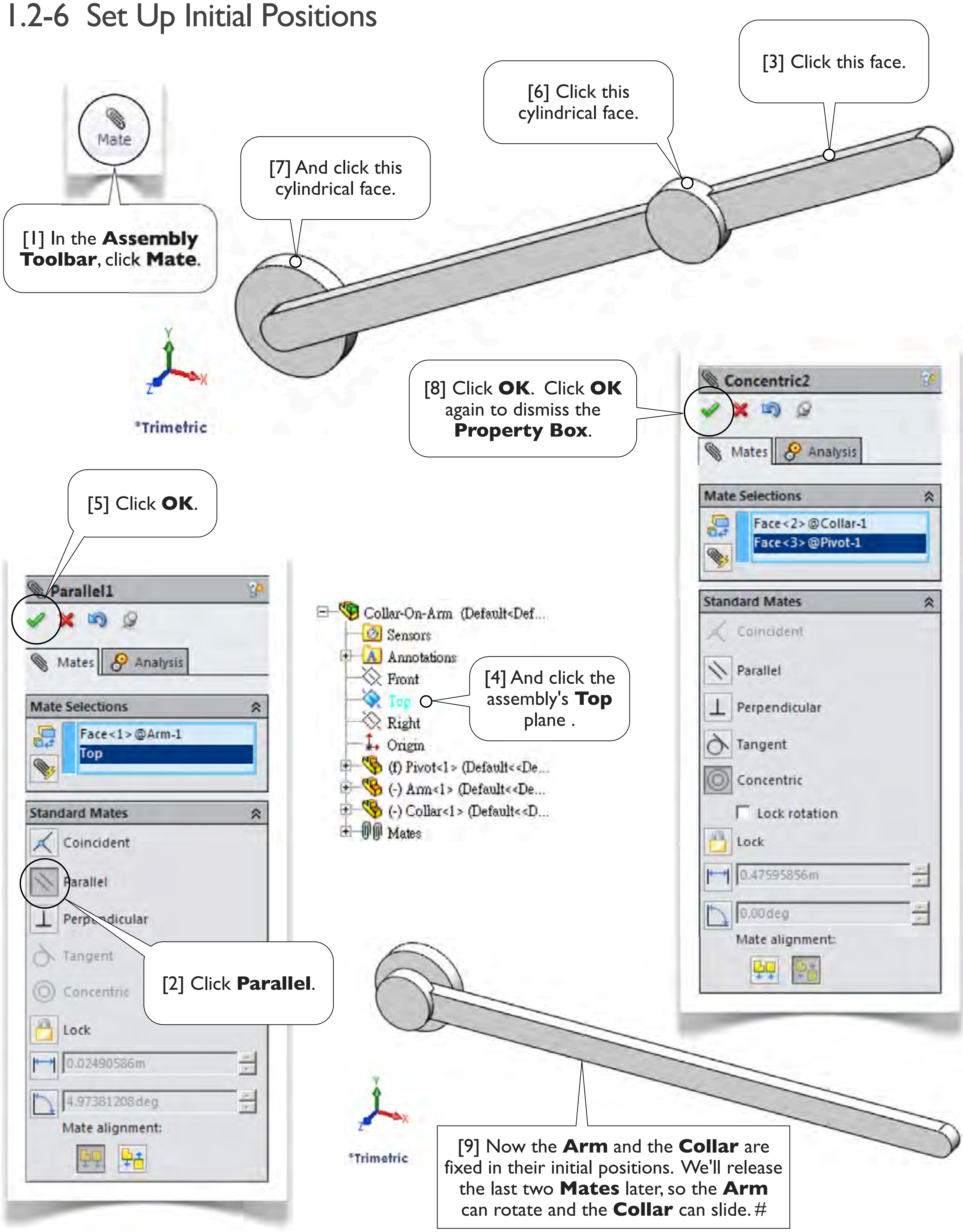


[30] In the **Head-Up Toolbar**, turn off **View Origins**.

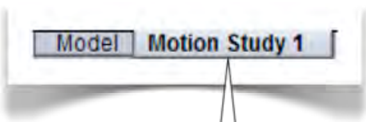


[31] Save the **Assembly** with the name **Collar-On-Arm**. Click **Rebuild** if a warning window shows up. #

1.2-6 Set Up Initial Positions

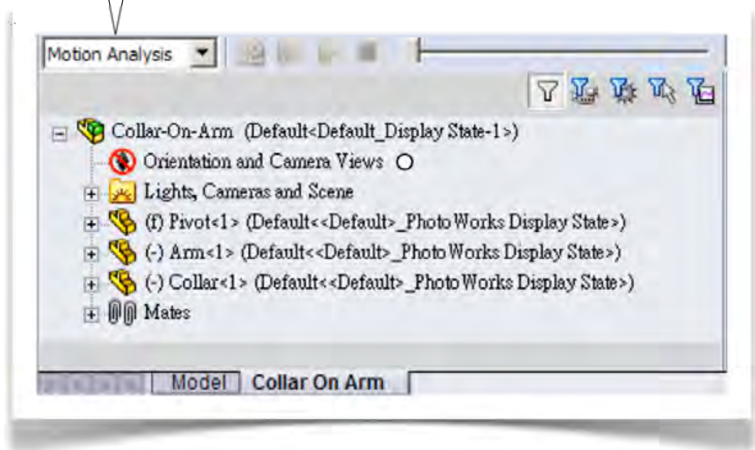


1.2-7 Create a **Motion Study**



[1] Click **Motion Study 1** tab. Double-click it and change the name to **Collar On Arm** (1.1-8[7], page 12).

[2] Select **Motion Analysis** (1.1-8[8, 9], page 12). #

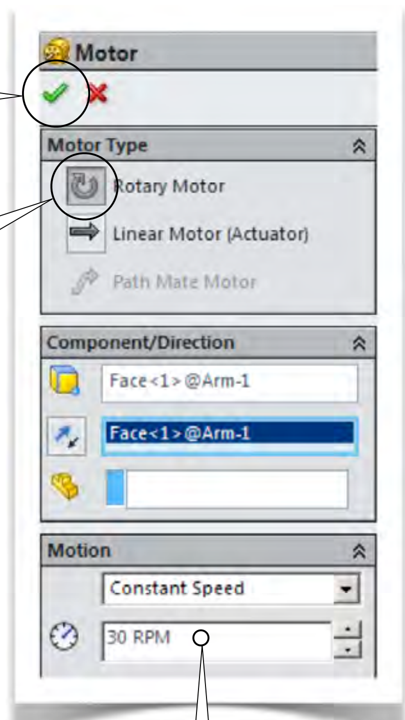


1.2-8 Set Up **Motor** at the **Arm**

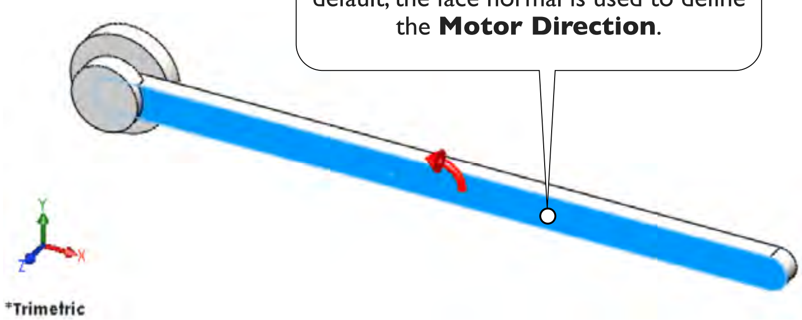
[1] In **Motion Toolbar**, click **Motor**.

[5] Click **OK**. #

[2] **Rotary Motor** is the default **Motor Type**.

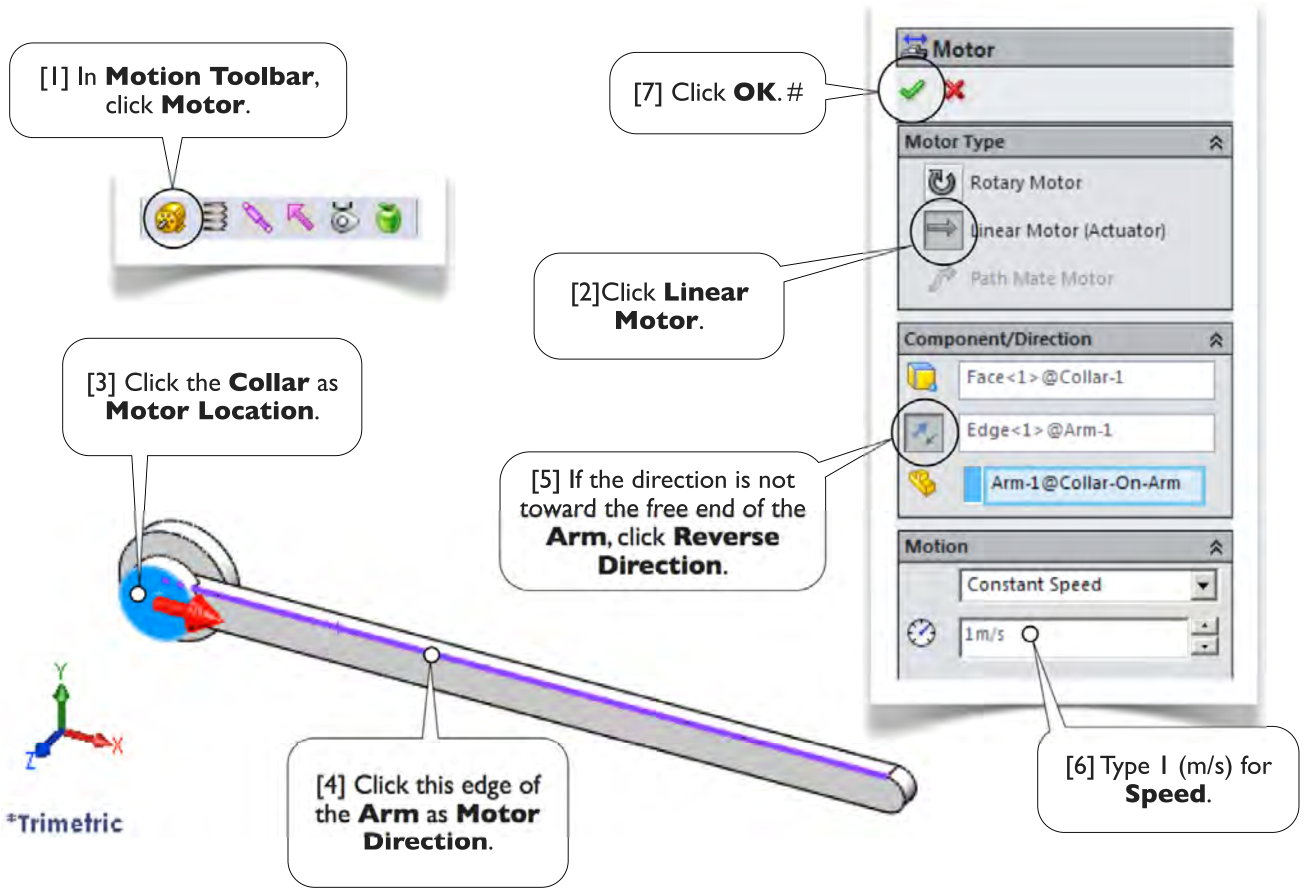


[3] Click this face of the **Arm** to define the **Motor Location** (the **Arm**). By default, the face normal is used to define the **Motor Direction**.

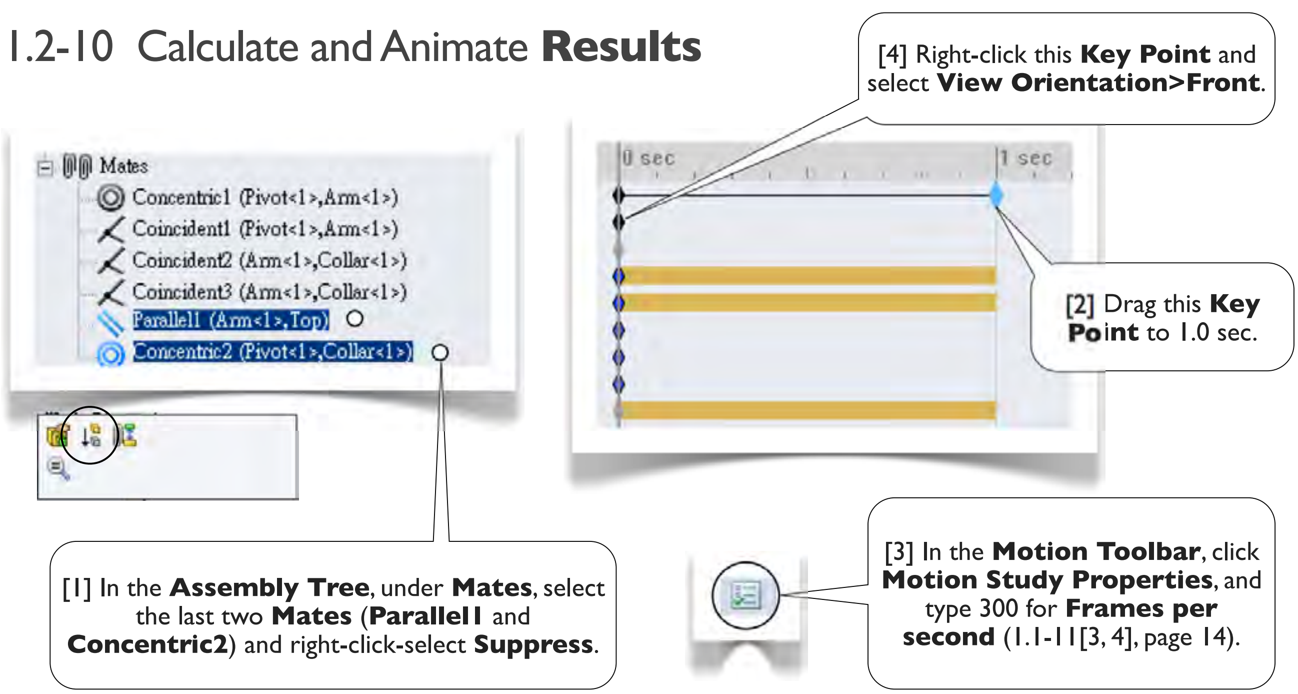


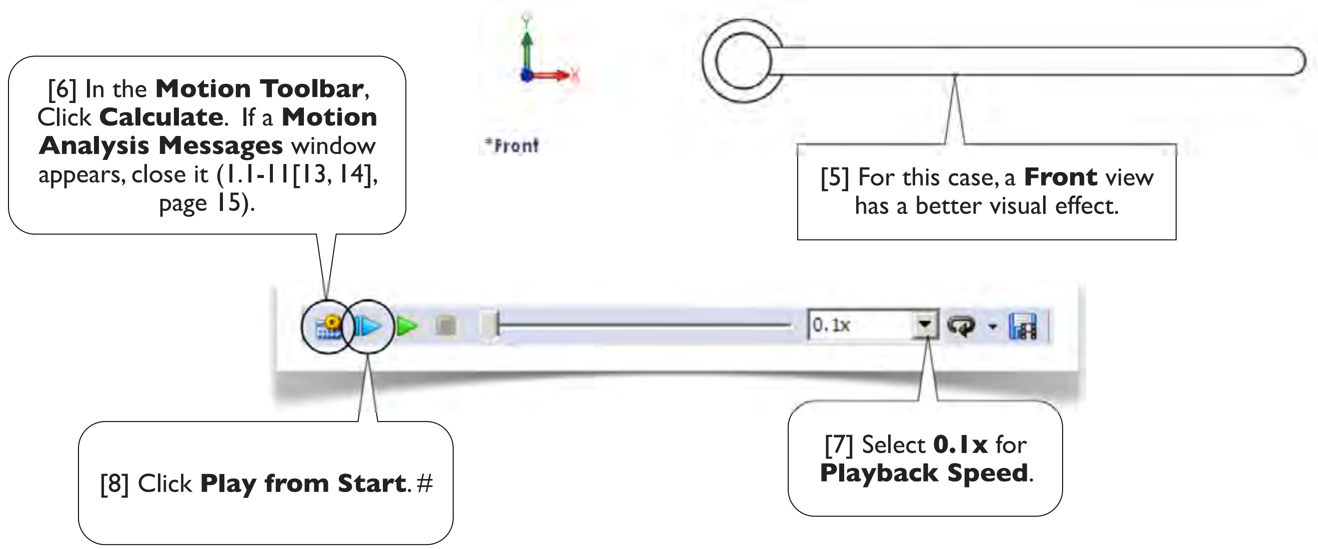
[4] Type 30 (RPM), which equals π rad/s.

1.2-9 Set Up **Motor** at the **Collar**

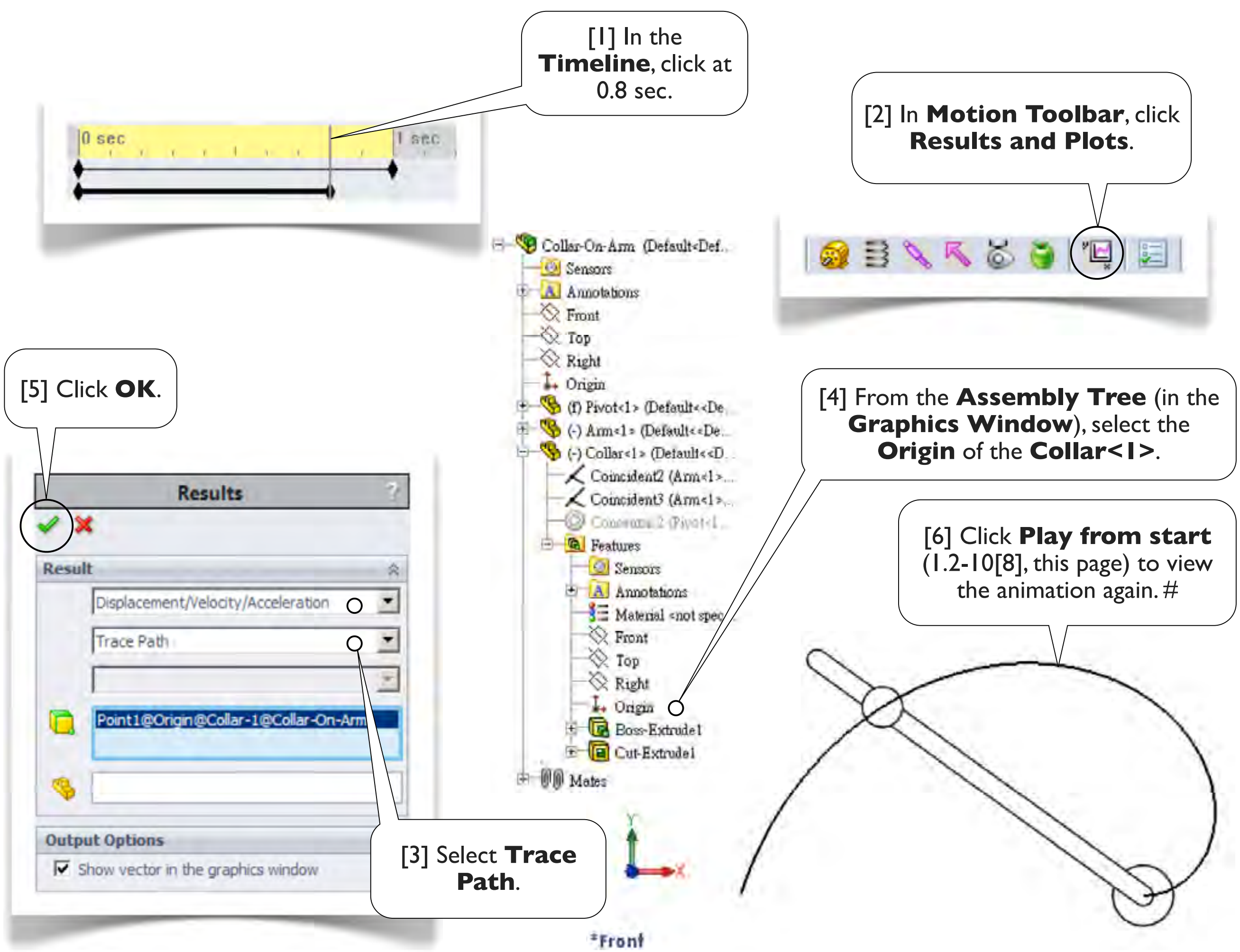


1.2-10 Calculate and Animate **Results**



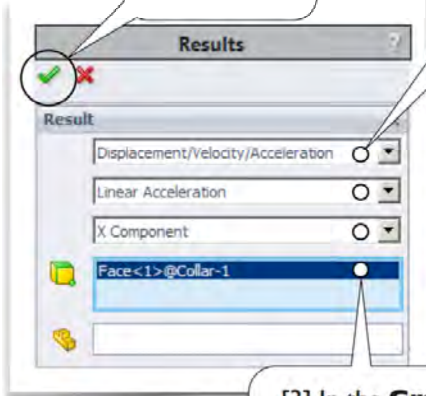


1.2-11 Results: **Trace Path**



1.2-12 Results: **Acceleration**

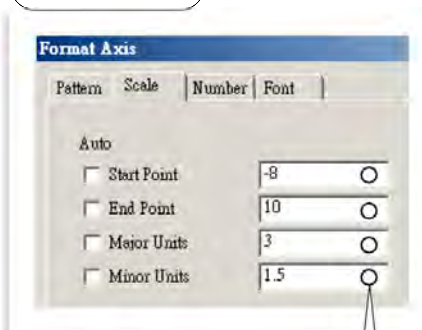
[1] In **Motion Toolbar**, click **Results and Plots**.



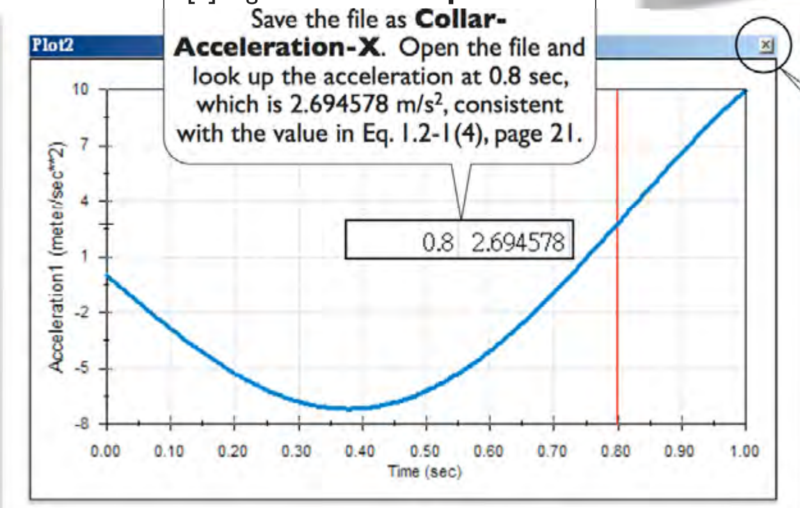
[2] Set up the **Results** like this.

[3] In the **Graphics Window**, click the **Collar**. The acceleration will be reported at the mass center of the **Collar**.

[4] Click **OK**.

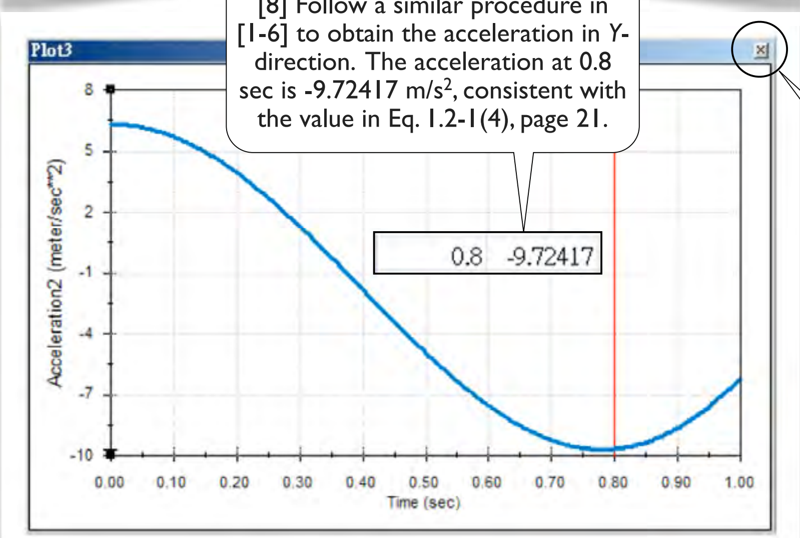


[5] Set the scale for the vertical axis like this.

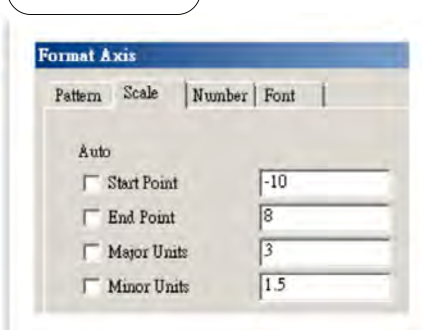


[6] Right-click-select **Export CSV**. Save the file as **Collar-Acceleration-X**. Open the file and look up the acceleration at 0.8 sec, which is 2.694578 m/s^2, consistent with the value in Eq. 1.2-1(4), page 21.

[7] Close the window.



[8] Follow a similar procedure in [1-6] to obtain the acceleration in *Y*-direction. The acceleration at 0.8 sec is -9.72417 m/s^2, consistent with the value in Eq. 1.2-1(4), page 21.

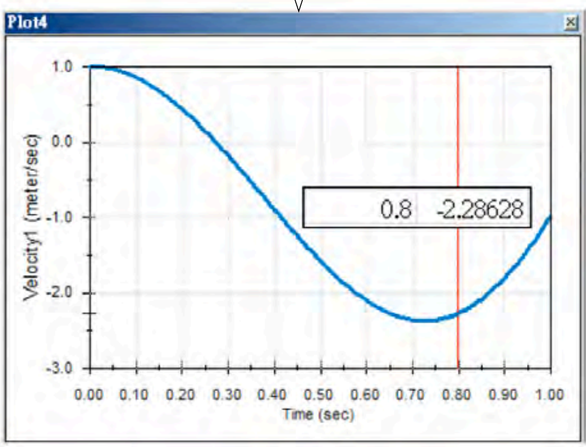


[9] Close the window. #

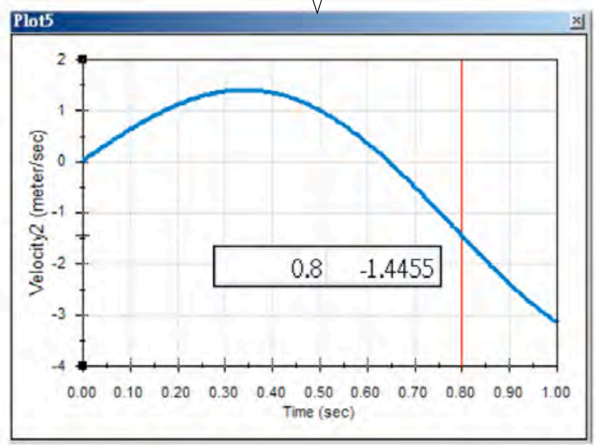
1.2-13 Do It Yourself

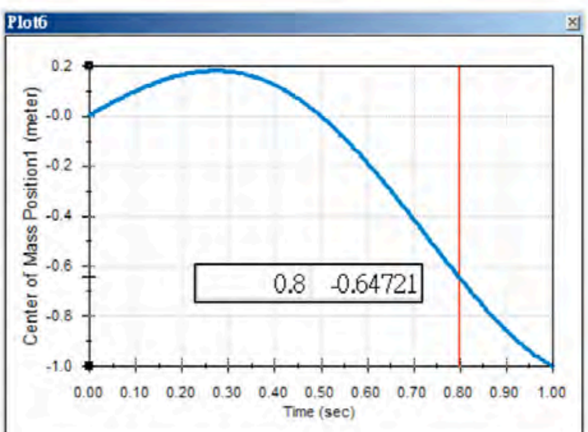
[1] We leave you to obtain the velocities (Eq. 1.2-1(3), page 21) and the positions (Eq. 1.2-1(2), page 20). These plots are shown in [2-5].

[2] Velocity in *X*-direction.

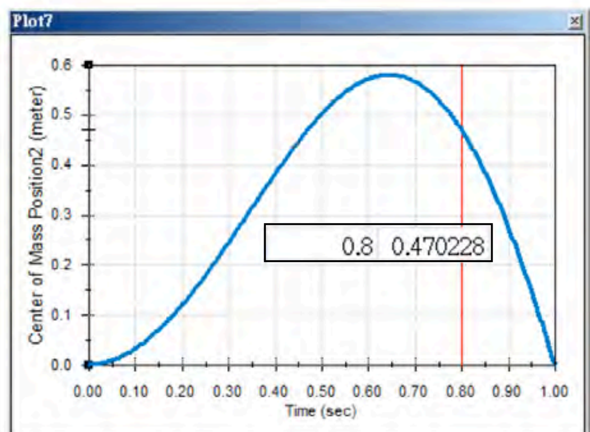


[3] Velocity in *Y*-direction.





[4] Position in *X*-direction.



[5] Position in *Y*-direction.

[6] Wrap Up

Save all files and exit **SolidWorks** (1.1-18[1-3], page 19). #