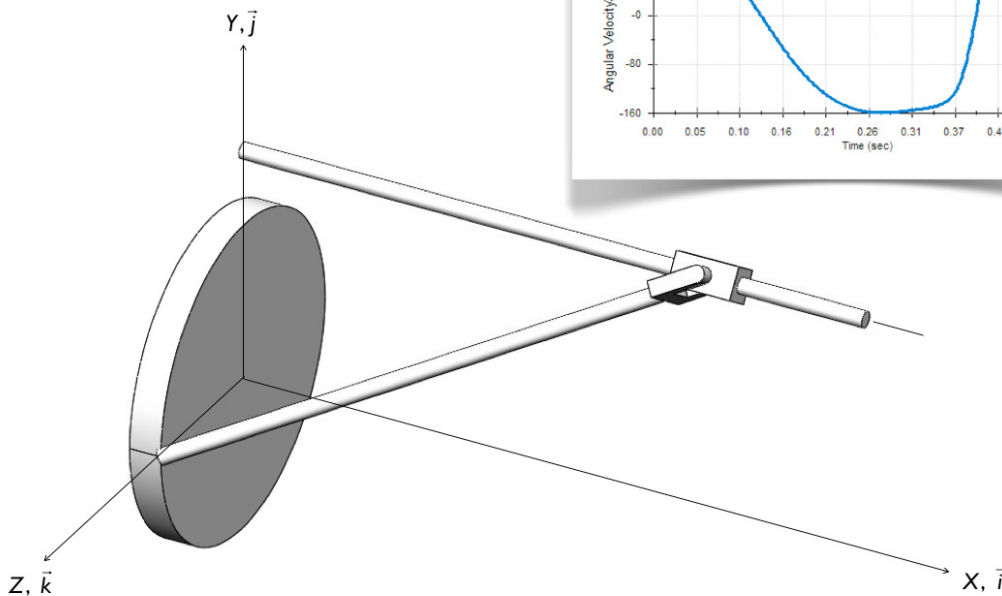
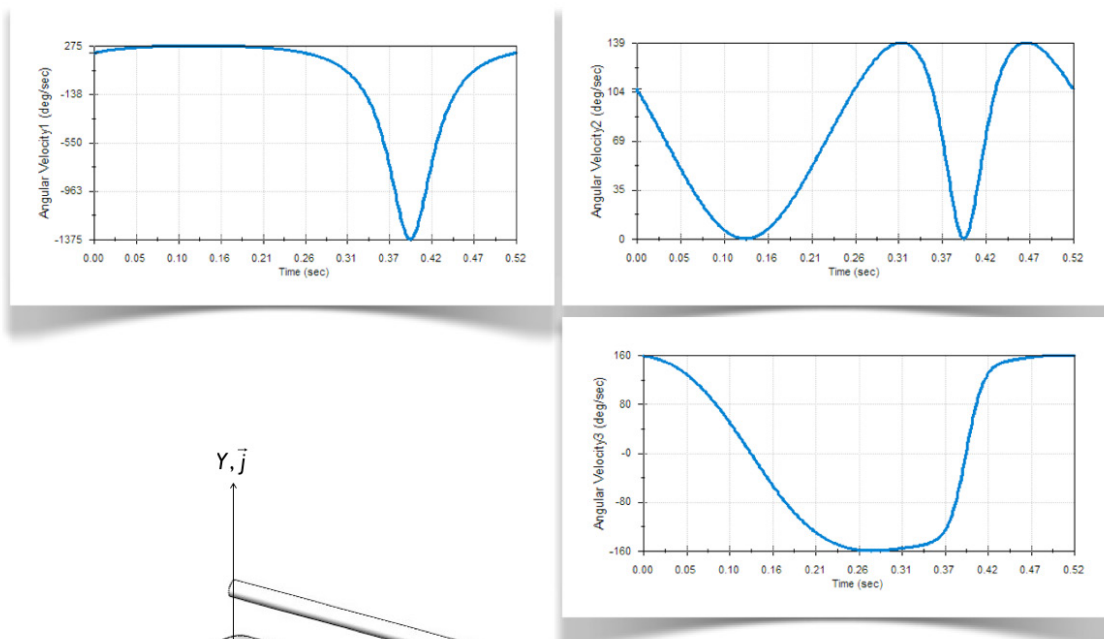


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Chapter I

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 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 its size, but because of its insignificance of rotation.*

Chapters I-4 provide 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.

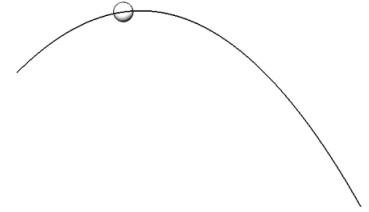
For rigid body dynamics, these equations can be divided into two groups: (a) Equations based on **physical principles**. For each body, some equilibrium equations (e.g., Newton's 2nd Law) or conservation equations (e.g., principle of work and energy) can be written down. (b) Equations describing the **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 $\bar{a}(t)$, what is its velocity $\bar{v}(t)$ and position $\bar{r}(t)$? (b) If particle *A* is moving with a constant acceleration of \bar{a}_A , what is the acceleration, velocity, and position of particle *B* at time *t*?

Chapter I 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,

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

and the position is

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

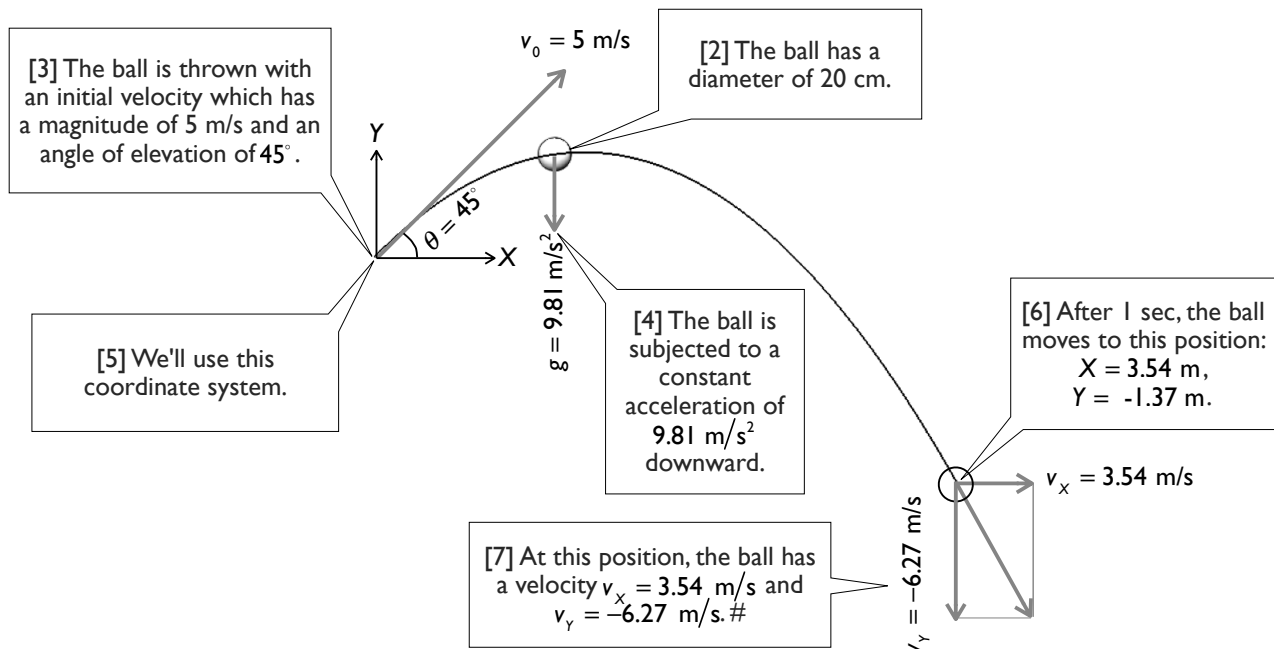
In Y-direction, the velocity component is

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

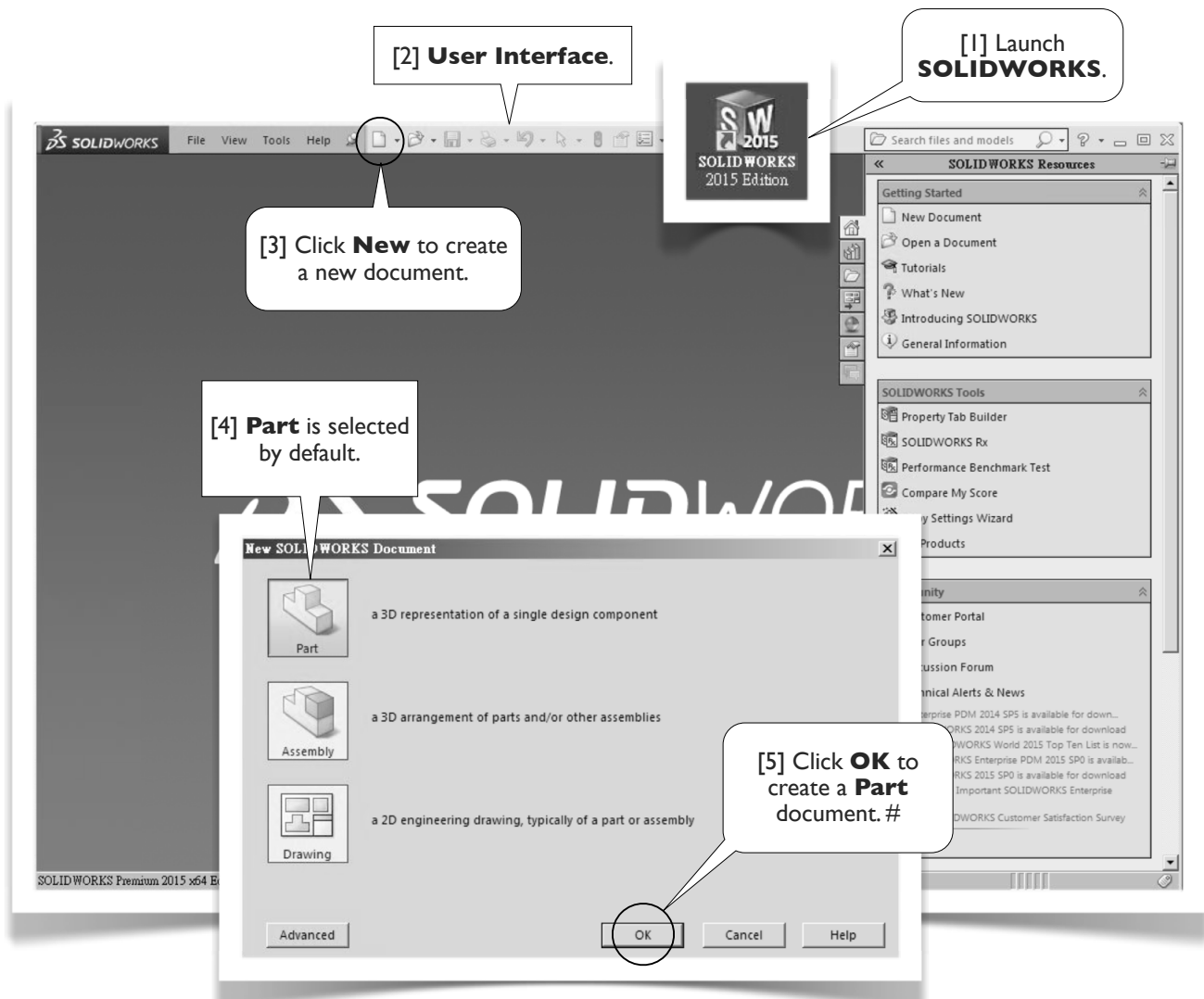
and the position is

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

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



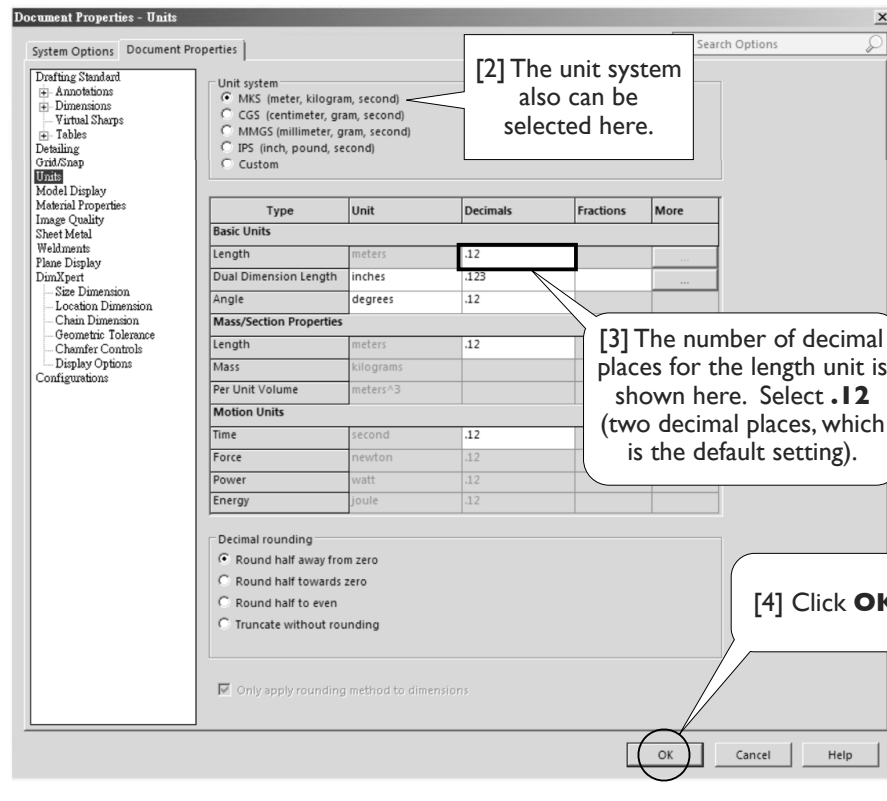
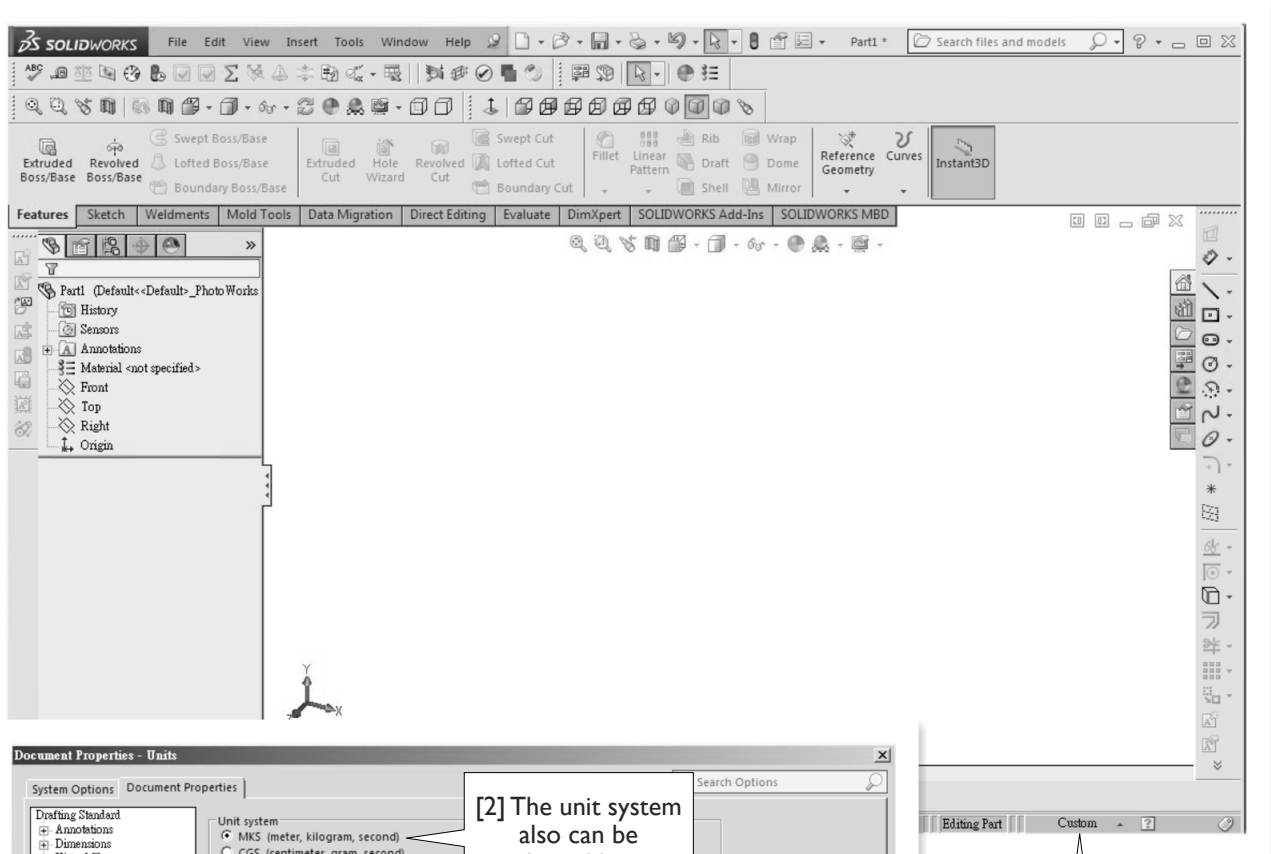
About the TextBoxes

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] The unit system shows here. Click it and select **MKS** as the unit system. Click it again and select **Edit Document Units...**

I.1-4 Create a Part: **Ball**

[1] In the **Features Tree**, 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**

[1] Click **New**.

[2] Select **Assembly**.

[3] Click **OK**.

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

[5] This is the assembly's **Origin**. We want to insert the **Ball** so that the part's coordinate system aligns with the assembly's coordinate system.

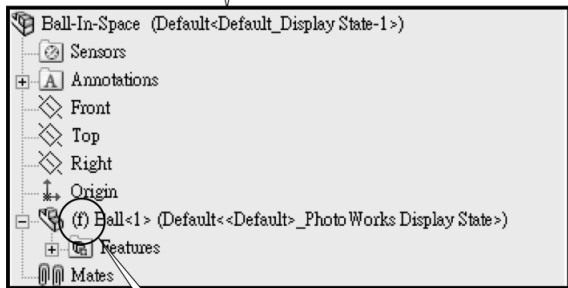
[6] In the **Property Box**, select **Ball**.

[7] Click the assembly's **Origin**. Now the **Ball** is fixed at the assembly's **Origin**.

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

*Trimetric

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

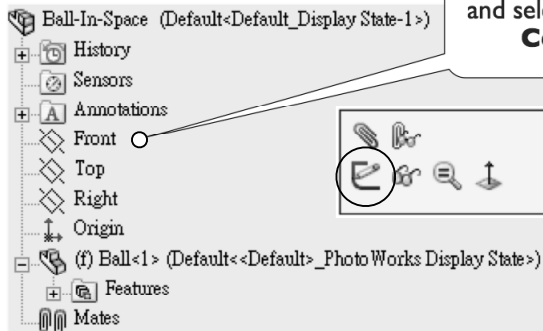


[11] In the **Assembly Tree**, an **(f)** sign before **Ball<1>** indicates that the **Ball** is fixed in the space. We'll release it before running the simulation (1.1-11[11], page 14). #



[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**

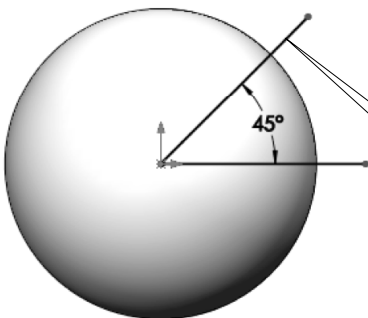


[1] Right-click **Front** plane and select **Sketch** from the **Context Menu**.

[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**.

*Front

1.1-7 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 the 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**.

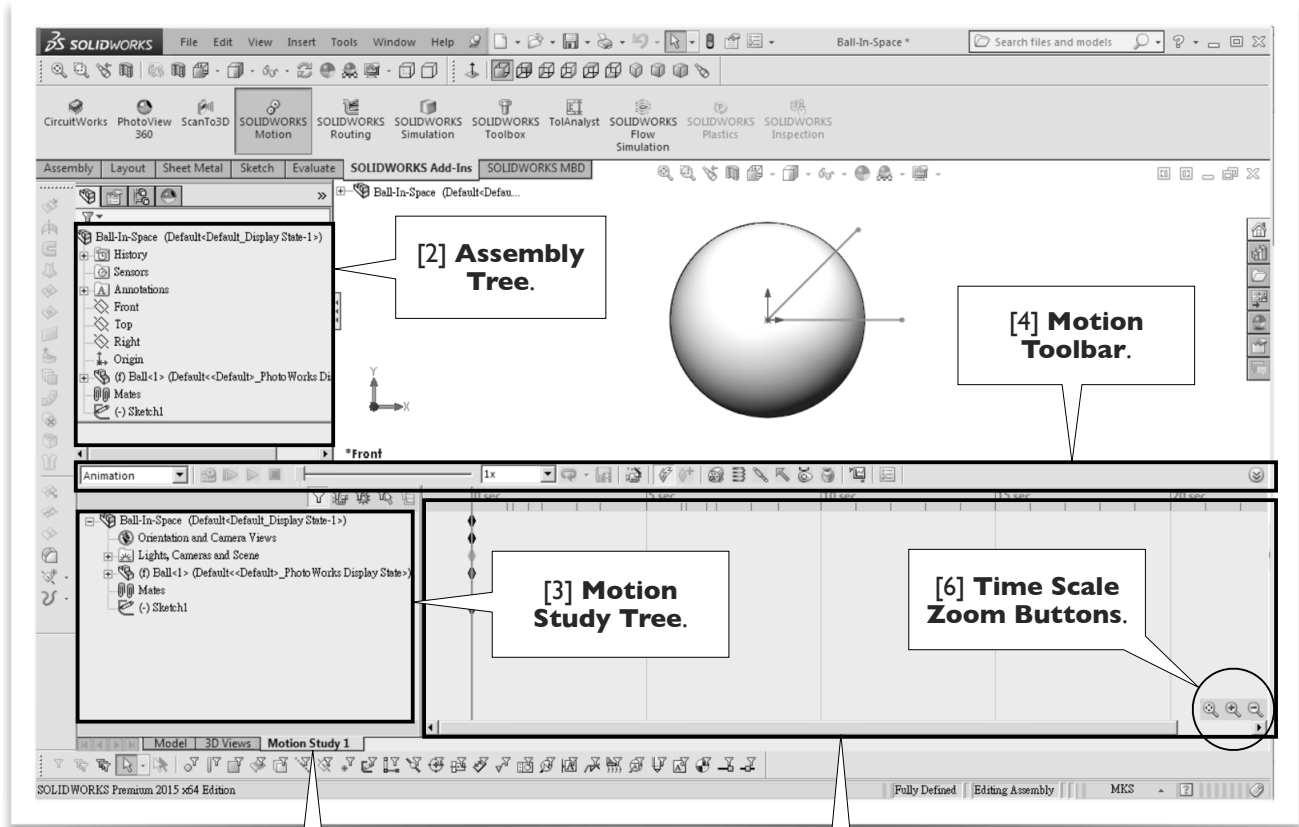
[4] And then click **SOLIDWORKS Motion**.

[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**. #

Add-in Name	Status	Up	Last Load Time
SOLIDWORKS Premium Add-ins			
<input type="checkbox"/> CircuitWorks			--
<input type="checkbox"/> FeatureWorks			< 1s
<input type="checkbox"/> PhotoView 360			--
<input type="checkbox"/> ScanTo3D			--
<input checked="" type="checkbox"/> SOLIDWORKS Design Checker			< 1s
<input checked="" type="checkbox"/> SOLIDWORKS Motion			< 1s
<input checked="" type="checkbox"/> SOLIDWORKS Routing			--
<input type="checkbox"/> SOLIDWORKS Simulation			--
<input type="checkbox"/> SOLIDWORKS Toolbox			--
<input type="checkbox"/> SOLIDWORKS Toolbox Browser			--
<input type="checkbox"/> SOLIDWORKS Utilities			< 1s
<input type="checkbox"/> SOLIDWORKS Workgroup PDM 2015			--
<input type="checkbox"/> TolAnalyst			--
SOLIDWORKS Add-ins			
<input type="checkbox"/> Autotrace			--
<input checked="" type="checkbox"/> SOLIDWORKS Composer			< 1s
<input type="checkbox"/> SOLIDWORKS Flow Simulation 2015			--
<input checked="" type="checkbox"/> SOLIDWORKS Forum 2015			< 1s
Other Add-ins			

1.1-8 Create a **Motion Study**

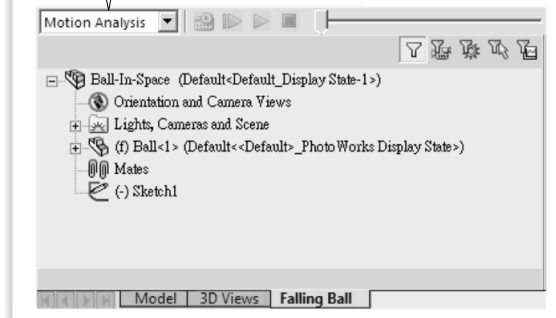
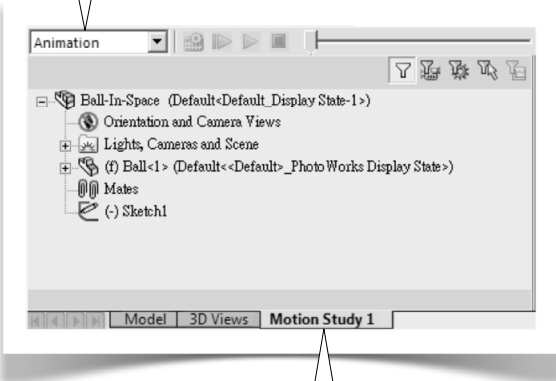


[1] Click **Motion Study I** tab.

[5] **Timeline Area.**

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

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



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

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**.

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

[5] Click **OK**. #

*Front

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**. #

*Front

I.1-II Calculate and Animate Results

[1] By default, the simulation time is set to 5 sec. Drag this **Key Point** to 1.0 sec.

[2] Click this **Zoom Button** several times to zoom-in the **Time Scale**.

[3] Click **Motion Study Properties**.

[4] Type 300 for **Frames per second**. This improves output resolution. It has no effects on solution accuracy. Click **OK**.

[5] Make sure the **Time Slider** is at the beginning.

[6] Right-click **Orientation and Camera View** and select **Disable View Key Creation**. Now, any change of **Orientation and Camera Views** will take effect.

[7] Adjust to a **Front** view, and zoom-out the **Ball** so that the flying **Ball** will be in the **Graphics Window**.

[8] Right-click **Orientation and Camera View** and select **Disable View Key Creation**. Now, the **Orientation and Camera View** is fixed.

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

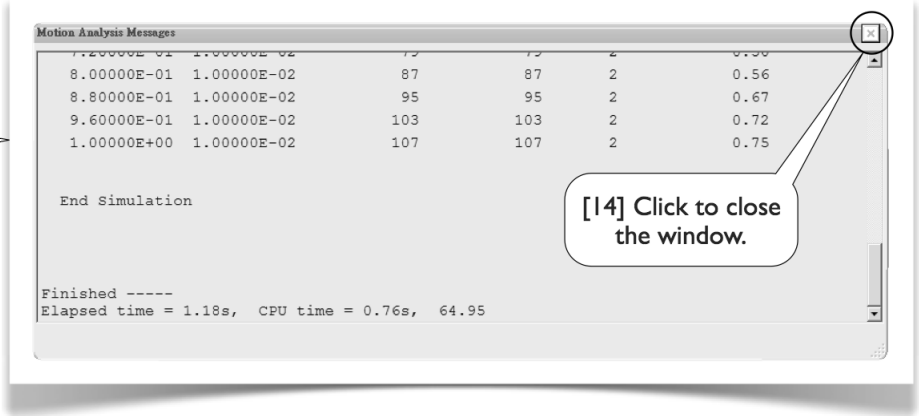
[10] Also turn off **View Sketches**.

[11] In the **Assembly Tree** (NOT the **Motion Study Tree**) right-click **Ball<1>** and select **Float**. The **(f)** sign changes to **(-)**, indicating that the **Ball** is free to move now.

[12] Click **Calculate**.

*Front

[13] A **Motion Analysis Messages** window may appear with useful information. This feature can be disabled (see 2.1-9[2, 4], page 41). If you don't see this window, disregard 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.

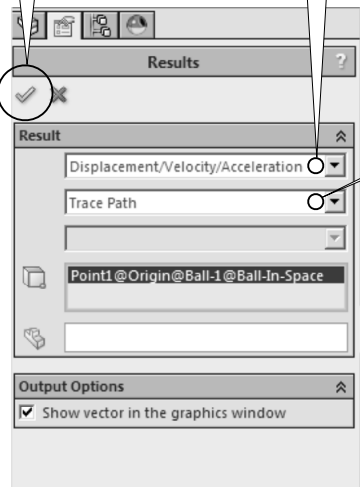
[1] In **Motion Toolbar**, click **Results and Plots**.

1.1-12 Results: **Trace Path**



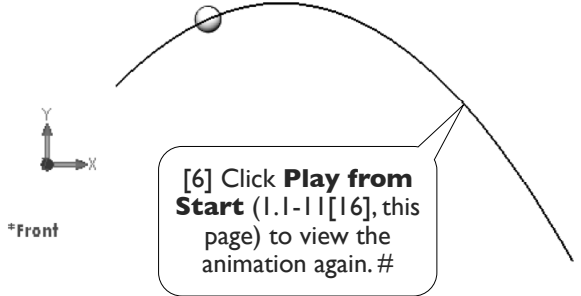
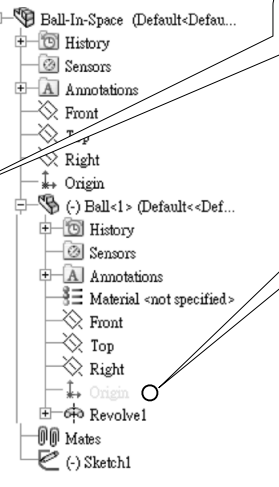
[5] Click **OK**.

[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. #

I.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. I.1-1(2), page 5. Close the **CSV file**.

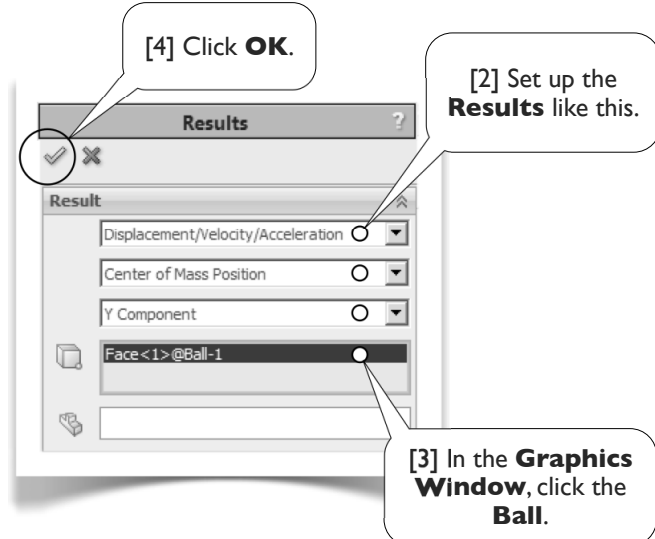
[9] Click to close the window. #

Time (sec)	Center of Mass Position1 (meter)
0.00	0.00
0.10	0.35
0.20	0.71
0.30	1.06
0.40	1.42
0.50	1.77
0.60	2.13
0.70	2.48
0.80	2.84
0.90	3.19
1.00	3.55

I.I-14 Results: **Positions-Y**



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

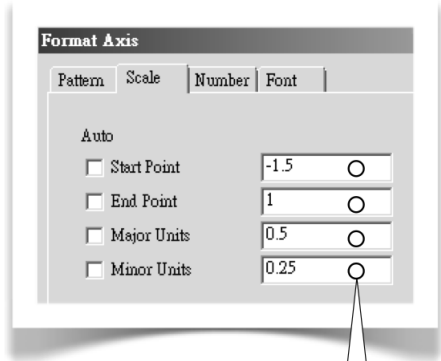
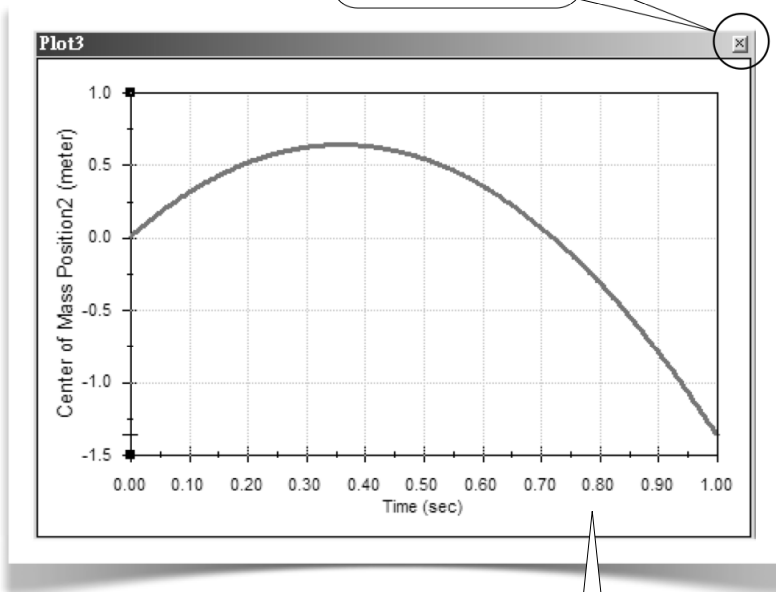


[4] Click **OK**.

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

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

[8] Click to close the window. #



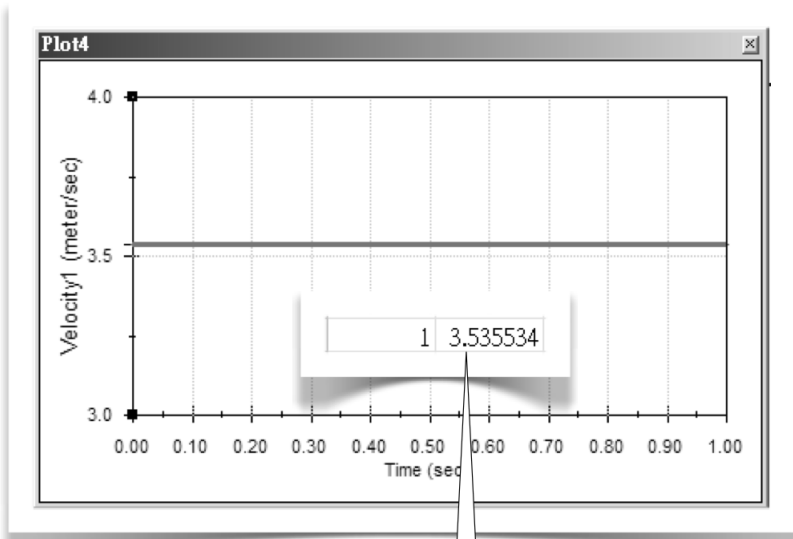
[5] Set the scale for the vertical axis like this.

[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. I.I-1(4), page 5. Close the **CSV** file.

I.1-15 Results: **Velocity-X**



[1] Follow a similar procedure in I.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. I.1-1(1), page 5. #

Results ?

✓ ✕

Result

Displacement/Velocity/Acceleration ▾

Linear Velocity ▾

X Component ▾

Face<1>@Ball-1

Format Axis

Pattern Scale Number Font

Auto

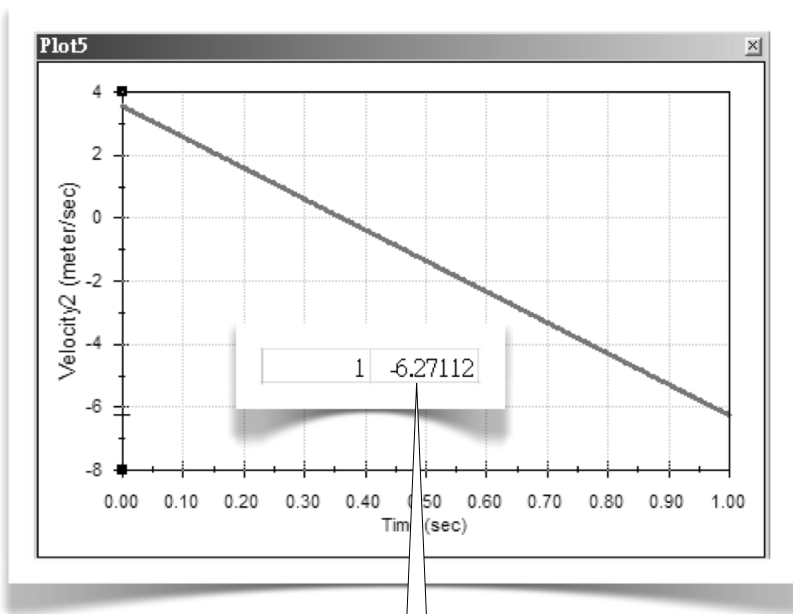
Start Point 3

End Point 4

Major Units 0.5

Minor Units 0.25

I.1-16 Results: **Velocity-Y**



[1] Follow a similar procedure in I.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. I.1-1(3), page 5. #

Results ?

✓ ✕

Result

Displacement/Velocity/Acceleration ▾

Linear Velocity ▾

Y Component ▾

Face<1>@Ball-1

Format Axis

Pattern Scale Number Font

Auto

Start Point -8

End Point 4

Major Units 2

Minor Units 1

1.1-17 Wrap Up

[1] From the **Pull-Down Menu**, 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. #

1.1-18 Do It Yourself

[1] **Motion Study Tree.**

[2] **Assembly Tree.**

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

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

[5] To change the **Gravity**, 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**.

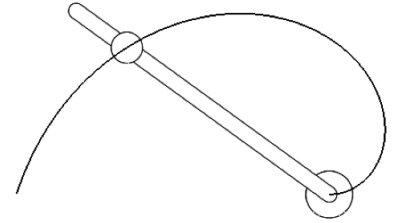
[8] From the **Pull-Down Menu**, Select **File>Exit** to quit **SOLIDWORKS**.

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

- Ball
- Ball-In-Space
- Ball-Position-X
- Ball-Position-Y
- Ball-Velocity-X
- Ball-Velocity-Y

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 \bar{e}_r the unit vector in radial direction and \bar{e}_θ the unit vector in transversal direction [7, 8]. Then the position, velocity, and acceleration of the **Collar's** center are respectively

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

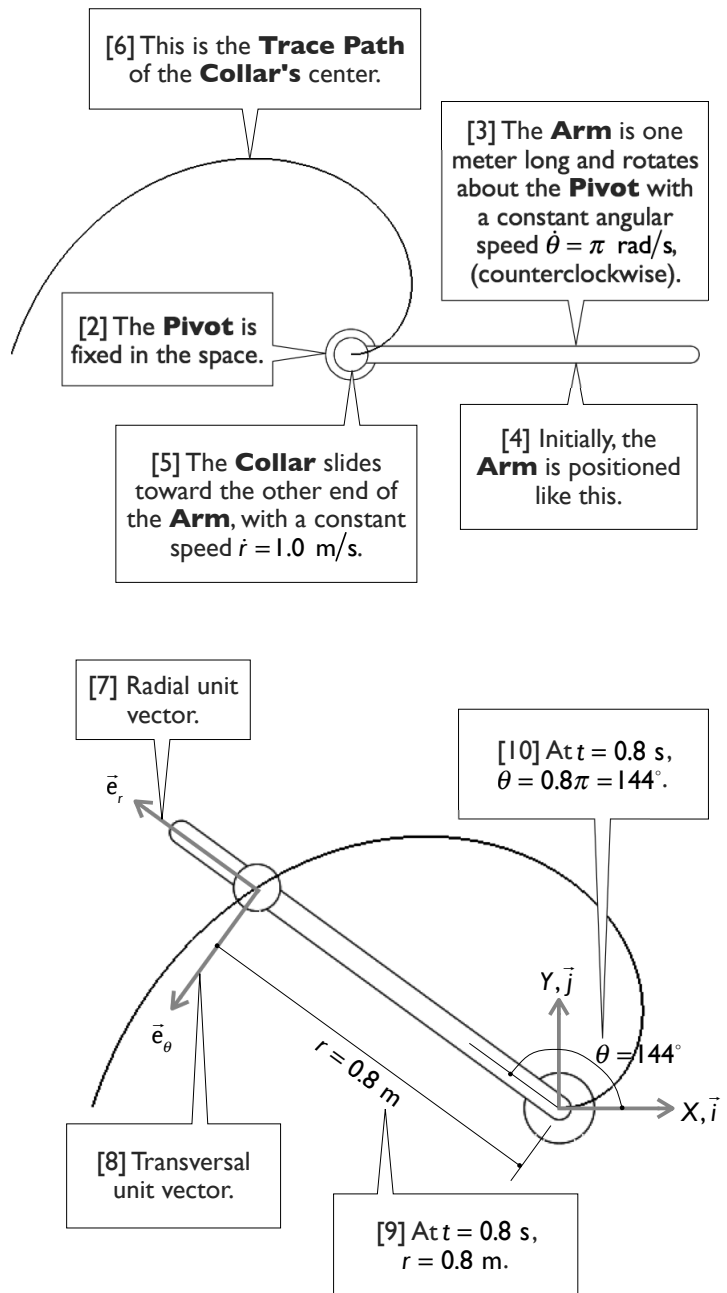
Let's calculate these values at an arbitrary time, say $t = 0.8$ s. At that time [9, 10],

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

Then, the position is

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

where \bar{i} is the unit vector in X-direction and \bar{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.



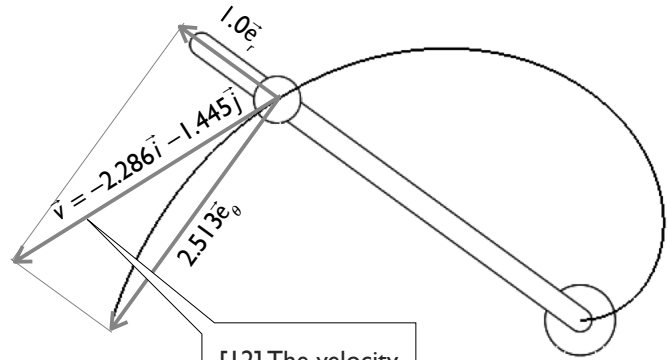
[11] The velocity is [12]

$$\begin{aligned}
 \vec{v} &= \dot{r}\vec{e}_r + r\dot{\theta}\vec{e}_\theta \\
 &= 1.0\vec{e}_r + 0.8\pi\vec{e}_\theta \\
 &= 1.0\vec{e}_r + 2.513\vec{e}_\theta \\
 &= (\cos 44^\circ \vec{i} + \sin 44^\circ \vec{j}) \\
 &\quad + (-2.513\sin 44^\circ \vec{i} + 2.513\cos 44^\circ \vec{j}) \\
 &= -2.286\vec{i} - 1.445\vec{j}
 \end{aligned}
 \tag{3}$$

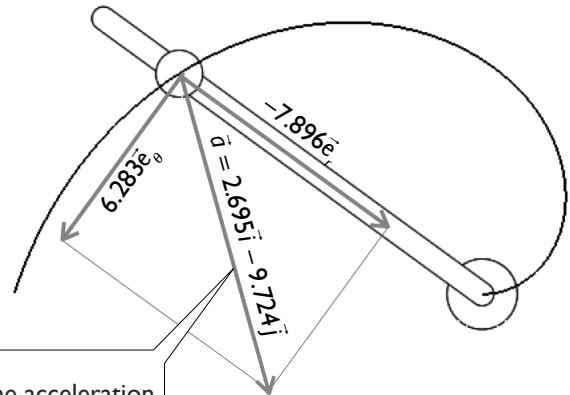
The acceleration is [13]

$$\begin{aligned}
 \vec{a} &= (\ddot{r} - r\dot{\theta}^2)\vec{e}_r + (r\ddot{\theta} + 2\dot{r}\dot{\theta})\vec{e}_\theta \\
 &= [0 - 0.8(\pi)^2]\vec{e}_r \\
 &\quad + [0.8(0) + 2(1.0)(\pi)]\vec{e}_\theta \\
 &= -7.896\vec{e}_r + 6.283\vec{e}_\theta \\
 &= (-7.896\cos 44^\circ \vec{i} - 7.896\sin 44^\circ \vec{j}) \\
 &\quad + (-6.283\sin 44^\circ \vec{i} + 6.283\cos 44^\circ \vec{j}) \\
 &= 2.695\vec{i} - 9.724\vec{j}
 \end{aligned}
 \tag{4}$$

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



[12] The velocity at $t = 0.8$ s.



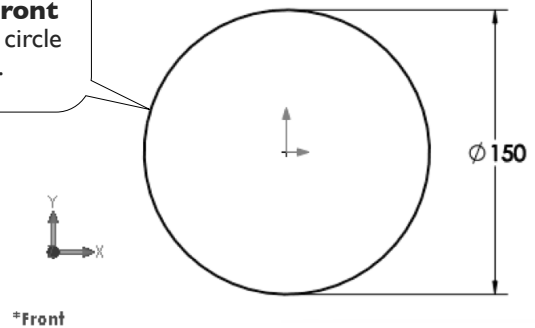
[13] The acceleration at $t = 0.8$ s. #

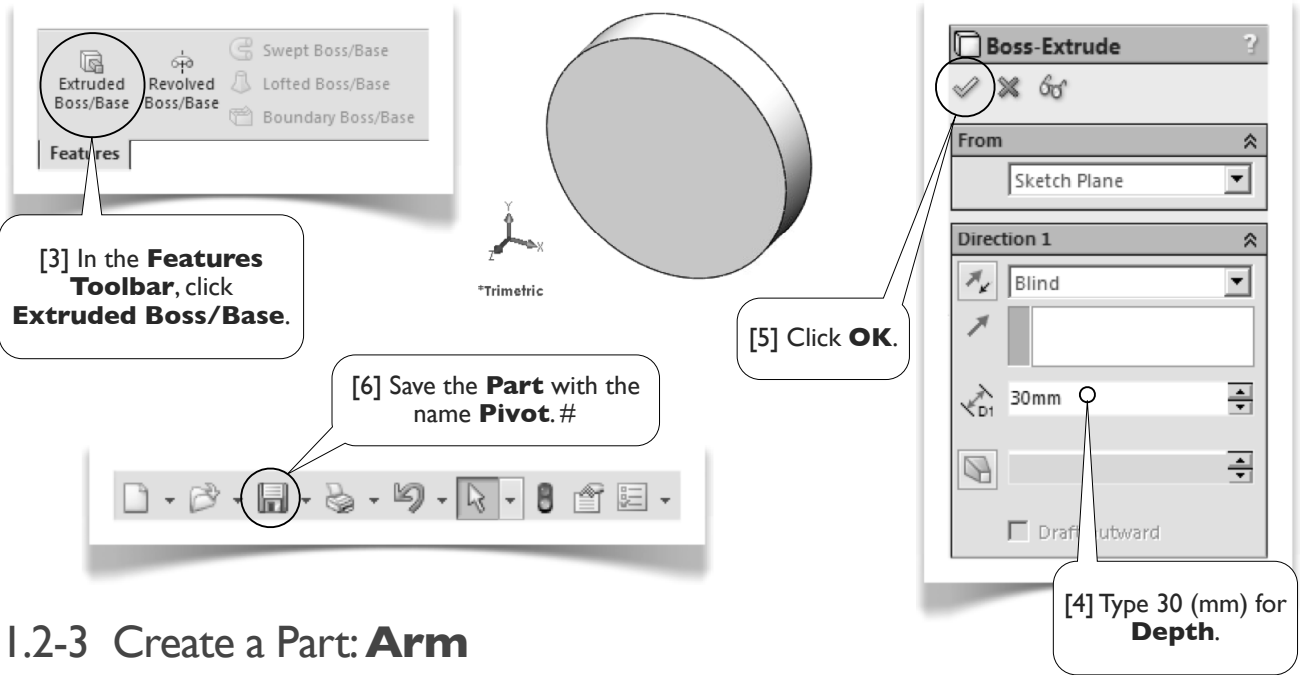
1.2-2 Start Up and Create a Part: **Pivot**



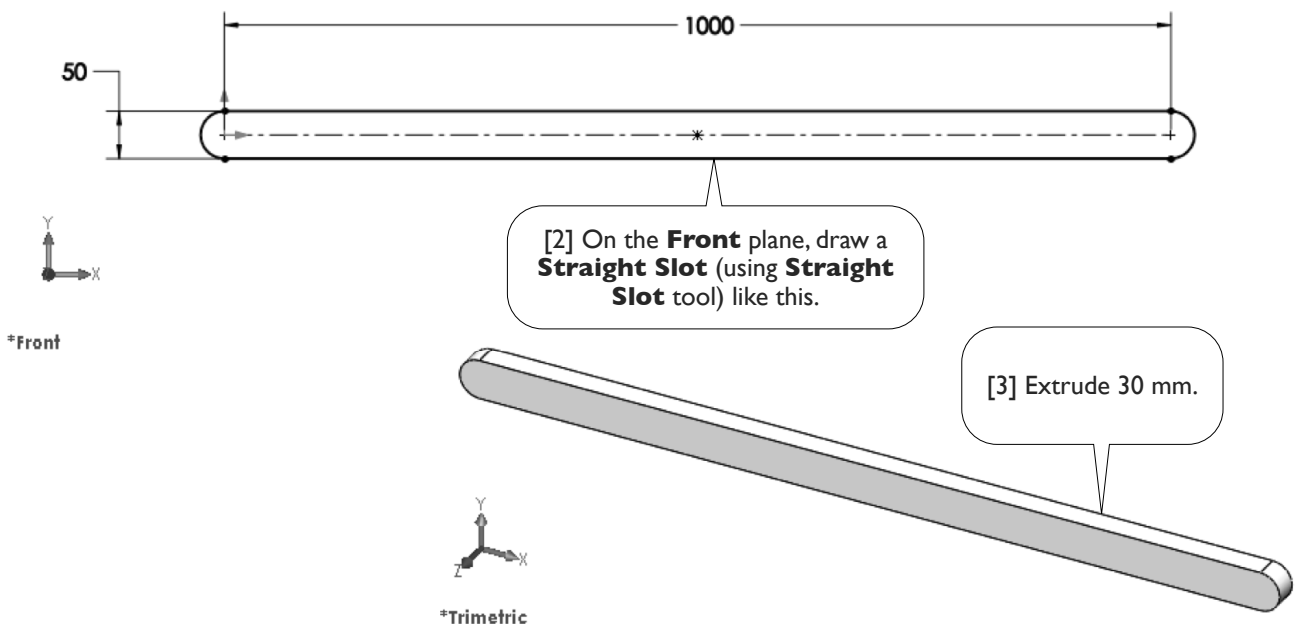
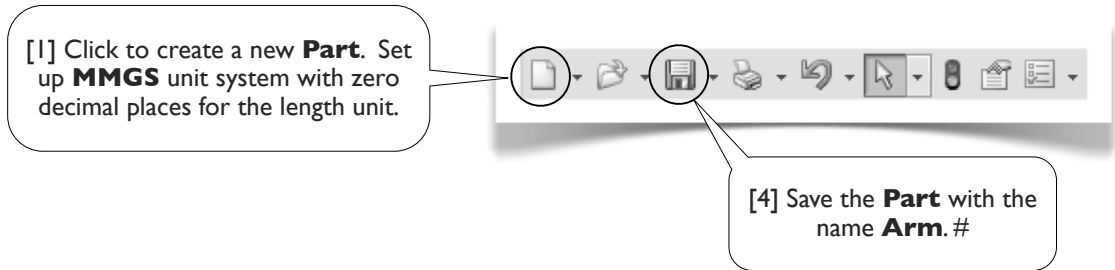
[1] Launch **SOLIDWORKS** (1.1-2[1], page 6) and click **New** to create a new **Part**. Set up **MMGS** unit system with zero decimal places for the length unit (1.1-3, page 7).

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



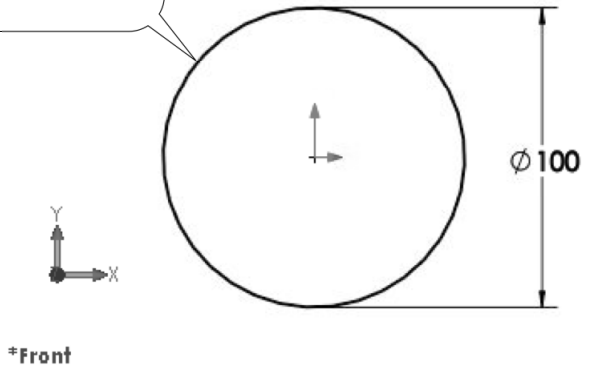


1.2-3 Create a Part: **Arm**



1.2-4 Create a Part: Collar

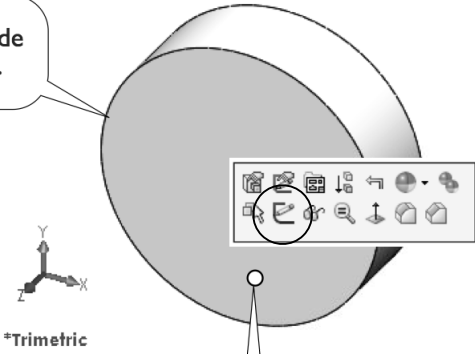
[2] On the **Front** plane, draw a circle like this.



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

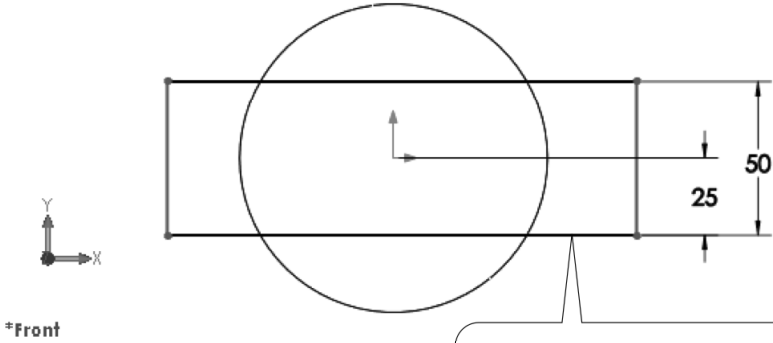


[3] Extrude 30 mm.



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

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

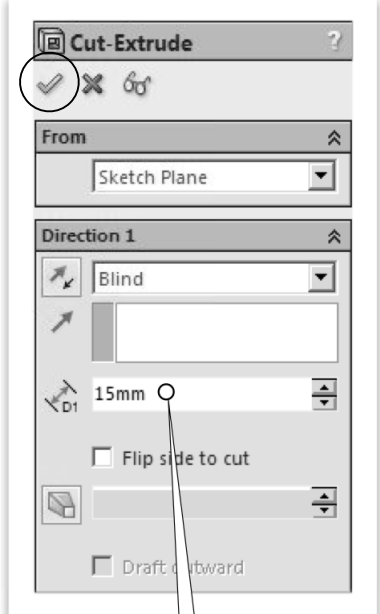
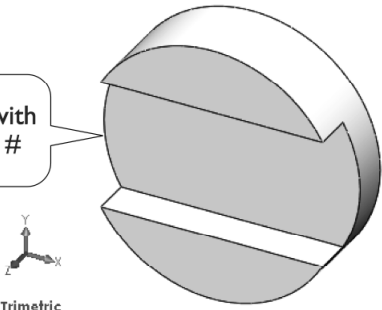


[6] Draw a rectangle like this. The width of the rectangle is not important.

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



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



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

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**.

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

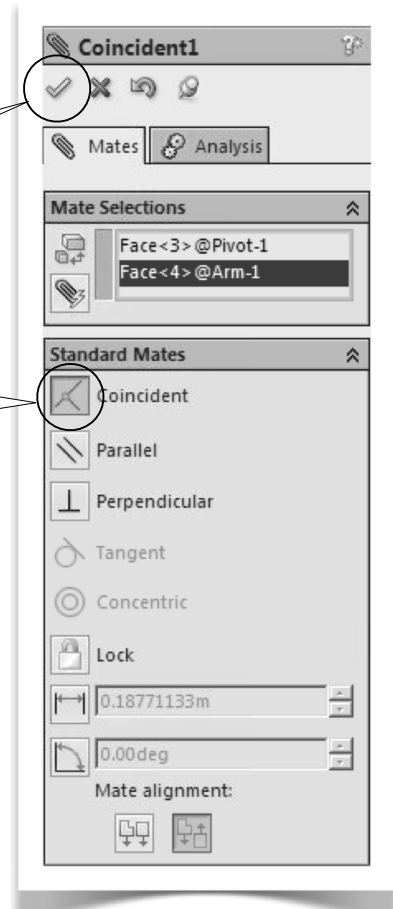
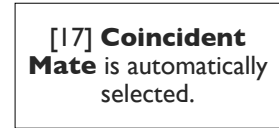
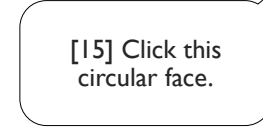
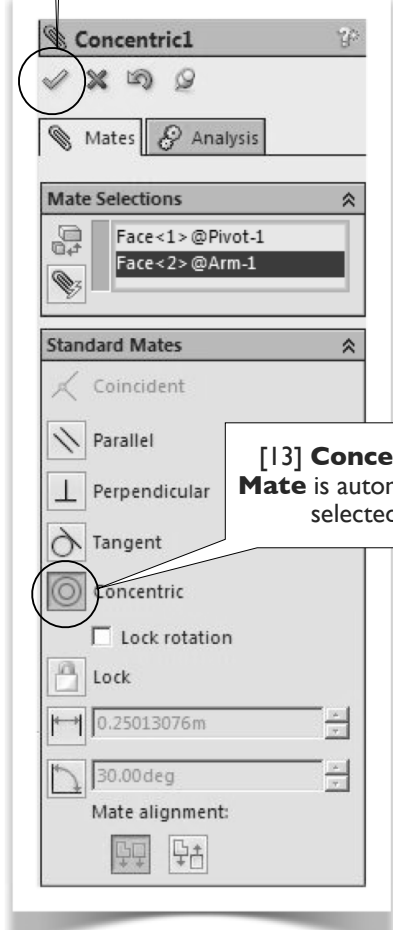
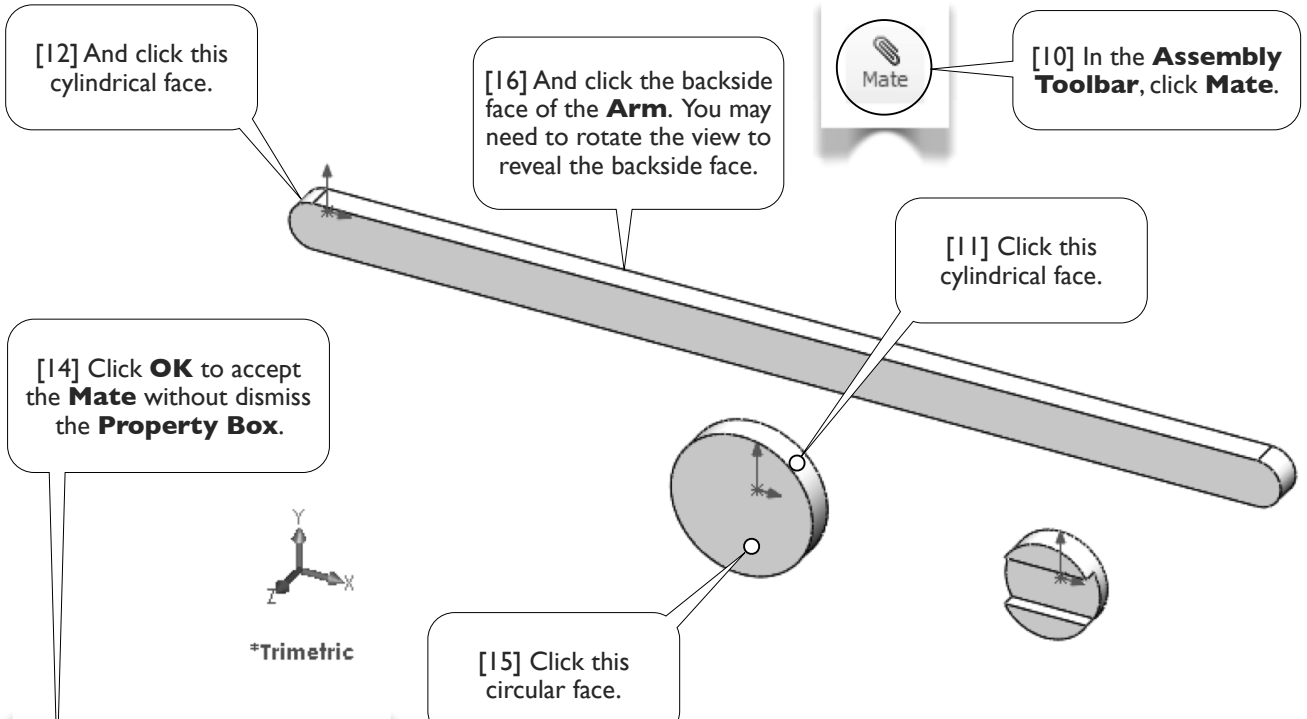
[4] Click the **Origin**. Now the **Pivot** is fixed at the assembly's **Origin**.

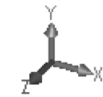
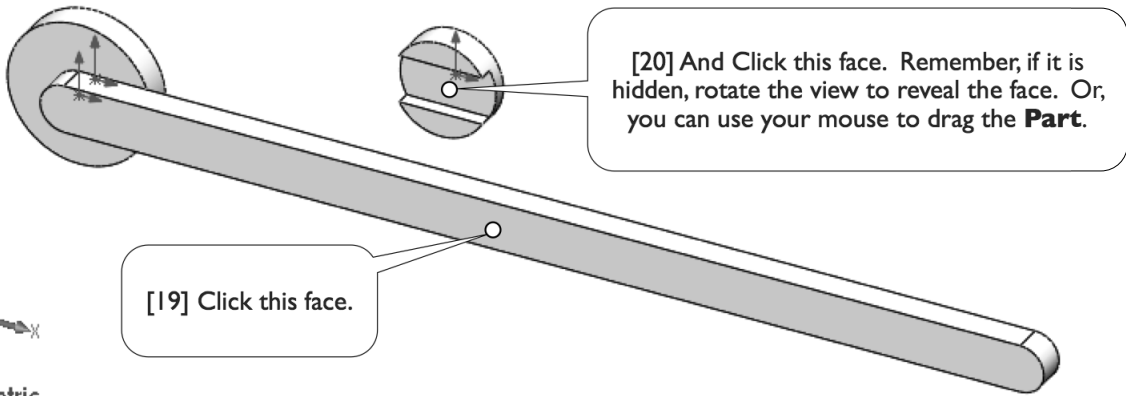
[5] Select **MKS** for the unit system (see 1.1-3[1], page 7).

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

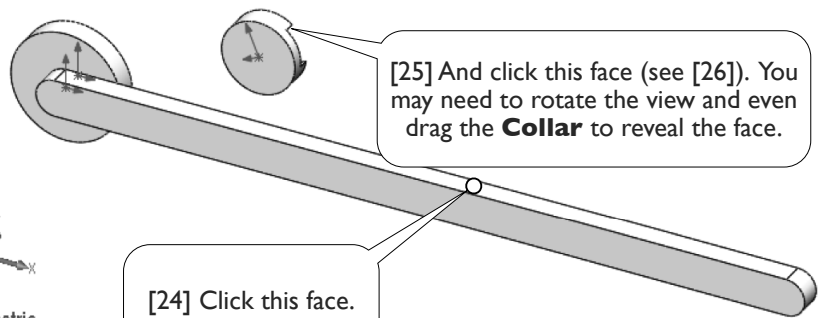
[7] In the **Property Box**, select **Arm** and click anywhere in the **Graphics Window** to temporarily park the part.

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

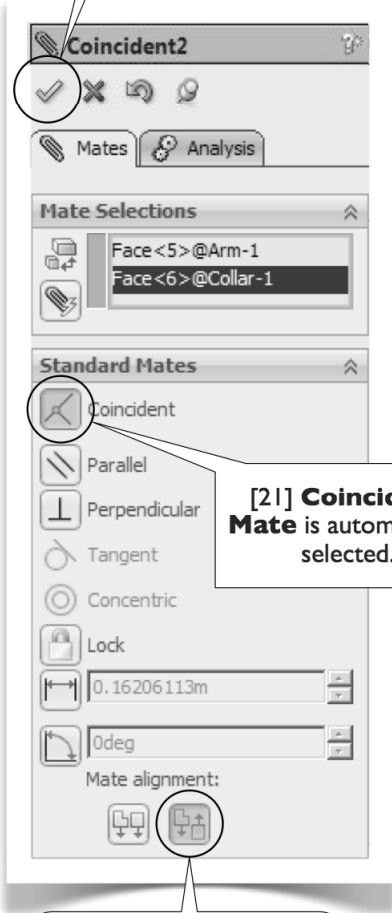




*Trimetric

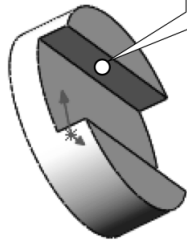


*Trimetric



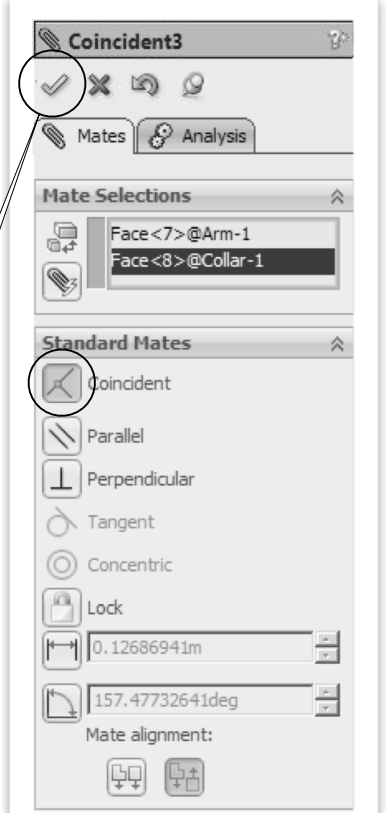
[21] **Coincident Mate** is automatically selected.

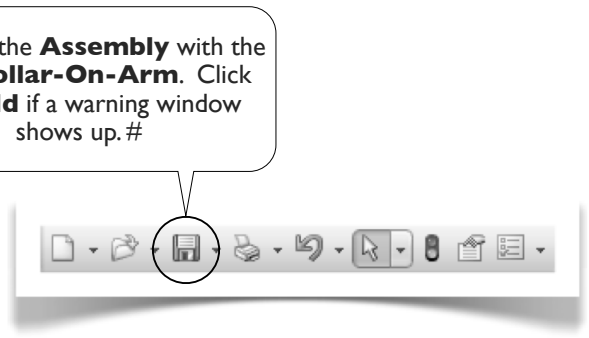
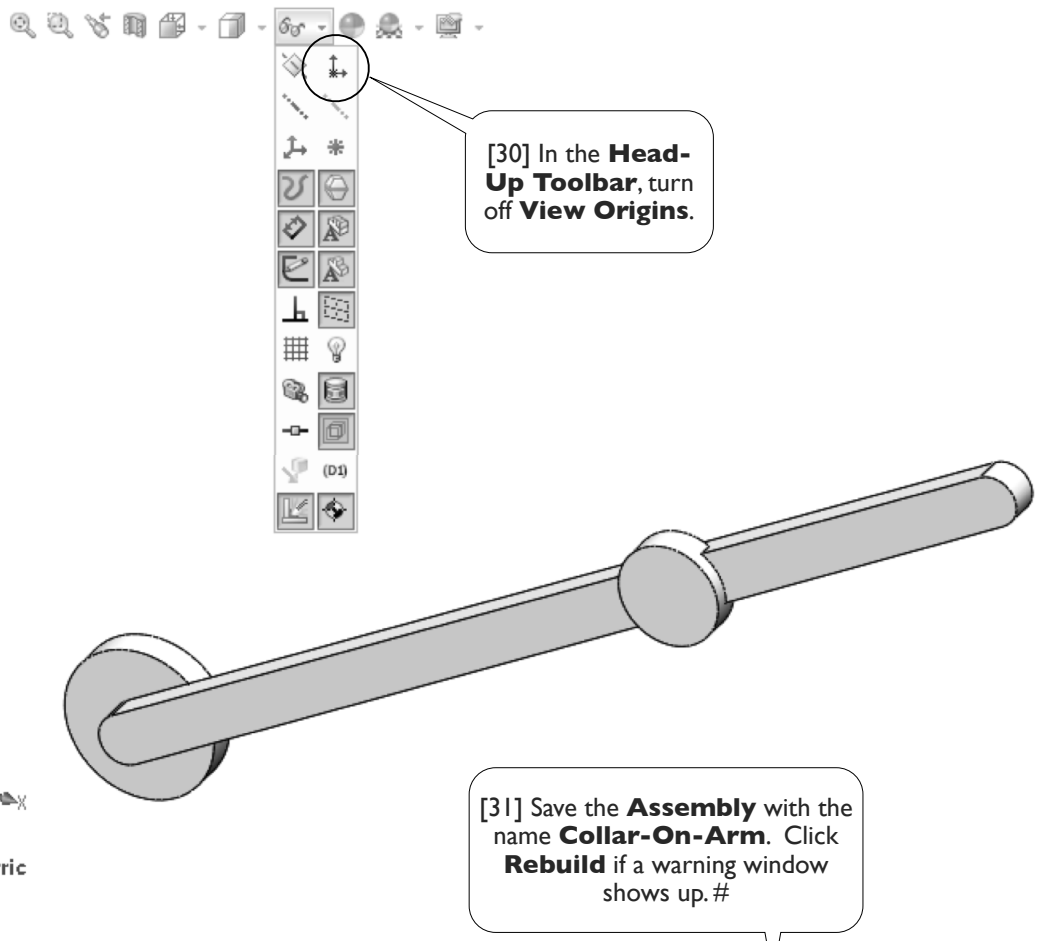
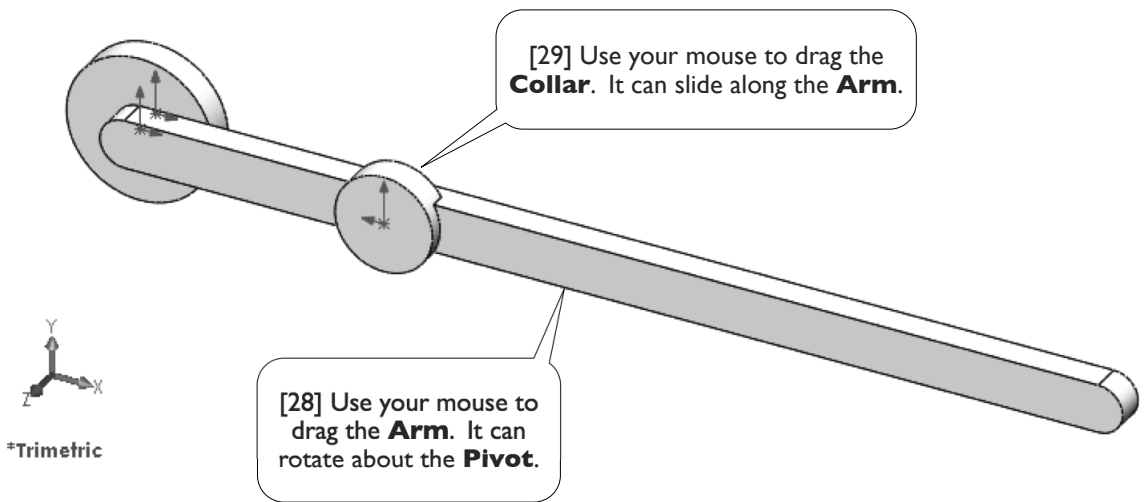
[22] Click **Anti-Aligned**.



[26] Face<8>.

[27] Click **OK**. Click **OK** again to dismiss the **Property Box**.





1.2-6 Set Up Initial Positions

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

[2] Click **Parallel**.

[3] Click this face.

[4] And click the assembly's **Top** plane .

[5] Click **OK**.

[6] Click this cylindrical face.

[7] And click this cylindrical face.

[8] Click **OK**. Click **OK** again to dismiss the **Property Box**.

[9] Now the **Arm** and the **Collar** are fixed in their initial positions. We'll release the last two **Mates** later, so the **Arm** can rotate and the **Collar** can slide. #

*Trimetric

Collar-On-Arm (Default<Def...

- Sensors
- Annotations
- Front
- Top
- Right
- Origin
- (f) Pivot<1> (Default<De...
- (-) Arm<1> (Default<De...
- (-) Collar<1> (Default<D...
- Mates

Concentric2

Mates Analysis

Mate Selections

- Face<2>@Collar-1
- Face<3>@Pivot-1

Standard Mates

- Coincident
- Parallel
- Perpendicular
- Tangent
- Concentric
- Lock rotation
- Lock
- 0.47595856m
- 0.00deg
- Mate alignment:

Parallel1

Mates Analysis

Mate Selections

- Face<1>@Arm-1
- Top

Standard Mates

- Coincident
- Parallel
- Perpendicular
- Tangent
- Concentric
- Lock
- 0.02490586m
- 4.97381208deg
- Mate alignment:

1.2-7 Create a **Motion Study**

[1] Click **Motion Study 1** tab. Double-click it and change the name to **Collar On Arm**.

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

The screenshot shows the software interface with the 'Motion Study 1' tab selected. A callout points to this tab with instruction [1]. Another callout points to the 'Motion Analysis' button in the top toolbar with instruction [2]. Below, a larger screenshot shows the 'Motion Analysis' window with a tree view containing 'Collar-On-Arm', 'Orientation and Camera Views', 'Lights, Cameras and Scene', '(f) Pivot<1>', '(-) Arm<1>', '(-) Collar<1>', and 'Mates'. The bottom tab is now labeled 'Collar On Arm'.

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

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

[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.

[5] Click **OK**.#

The image shows a 3D model of a cylindrical arm with a motor location indicated by a small circle on its side. A callout [3] points to this location. To the right, the 'Motor' dialog box is shown with 'Rotary Motor' selected as the 'Motor Type'. The 'Component/Direction' section shows 'Face<1> @Arm-1' selected. The 'Motion' section shows 'Constant Speed' and '30 RPM'. Callouts [1] through [5] point to the 'Motor' button in the toolbar, the 'Rotary Motor' option, the '30 RPM' input field, the 'OK' button, and the 'OK' button respectively.

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

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

[2] Click **Linear Motor**.

[3] Click the **Collar** as **Motor Location**.

[4] Click this edge of the **Arm** as **Motor Direction**.

[5] If the direction is not toward the free end of the **Arm**, click **Reverse Direction**.

[6] Type 1 (m/s) for **Speed**.

[7] Click **OK**.#

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Motor dialog box details:
Motor Type: Rotary Motor, Linear Motor (Actuator), Path Mate Motor
Component/Direction: Face<1> @Collar-1, Edge<1> @Arm-1, Arm-1 @Collar-On-Arm
Motion: Constant Speed, 1m/s

1.2-10 Calculate and Animate **Results**

[1] In the **Assembly Tree**, under **Mates**, select the last two **Mates** (**Parallel1** and **Concentric2**) and right-click-select **Suppress**.

[2] Drag this **Key Point** to 1.0 sec.

[3] In the **Motion Toolbar**, click **Motion Study Properties**, and type 300 for **Frames per second** (1.1-1 | [3, 4], page 14).

[4] Right-click this **Key Point** and select **View Orientation>Front**.

Mates list:
 Concentric1 (Pivot<1>,Arm<1>)
 Coincident1 (Pivot<1>,Arm<1>)
 Coincident2 (Arm<1>,Collar<1>)
 Coincident3 (Arm<1>,Collar<1>)
 Parallel1 (Arm<1>,Top) ○
 Concentric2 (Pivot<1>,Collar<1>)

Motion Study Properties timeline: 0 sec to 1 sec

[6] In the **Motion Toolbar**, Click **Calculate**. If a **Motion Analysis Messages** window appears, close it (1.1-11 [13, 14], page 15).

[5] For this case, a **Front** view has a better visual effect.

[7] Select **0.1x** for **Playback Speed**.

[8] Click **Play from Start**. #

1.2-11 Results: Trace Path

[1] In the **Timeline**, click at **0.8 sec.**

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

[4] From the **Assembly Tree** (in the **Graphics Window**), select the **Origin** of the **Collar<1>**.


[3] Select **Trace Path**.

[5] Click **OK**.

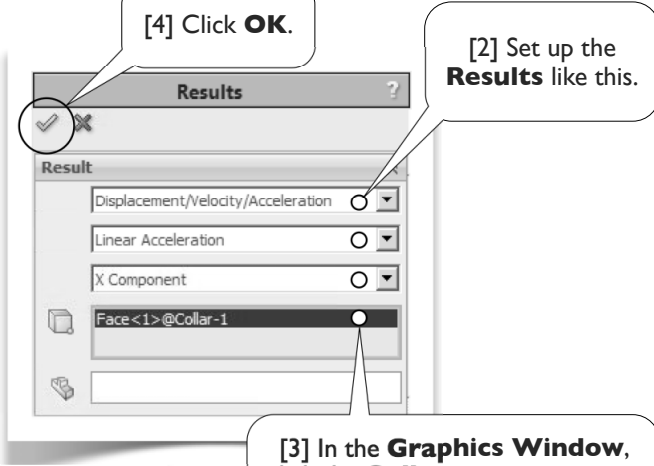
[6] Click **Play from start** (1.2-10 [8], this page) to view the animation again. #

1.2-12 Results: Acceleration

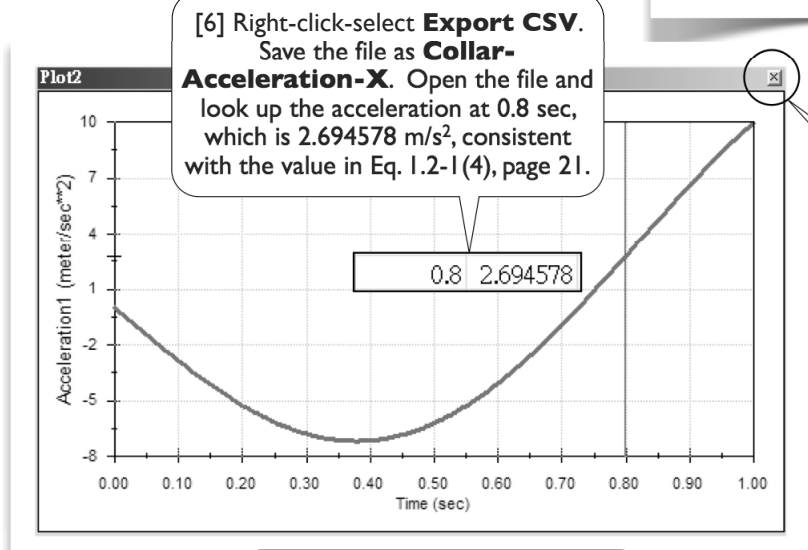
[1] In **Motion Toolbar**, click **Results and Plots**.



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

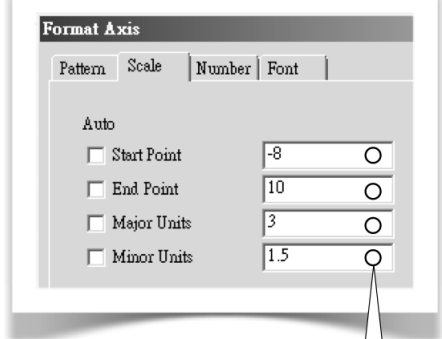


[3] In the **Graphics Window**, click the **Collar**. The acceleration will be reported at the mass center of the **Collar**.



[4] Click **OK**.

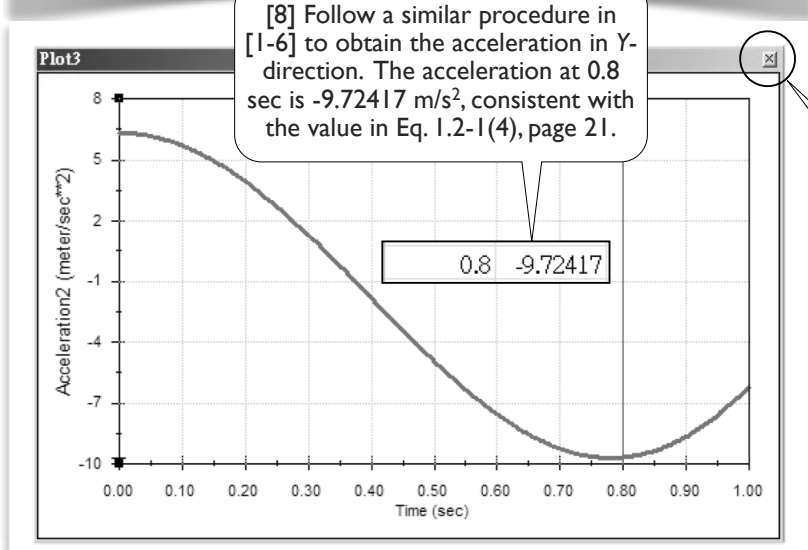
[5] Set the scale for the vertical axis like this.



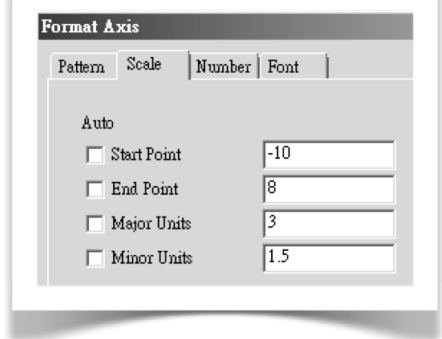
[6] Right-click-select **Export CSV**. Save the file as **Collar-Acceleration-X**. Open the file and look up the acceleration at 0.8 sec, which is 2.694578 m/s², consistent with the value in Eq. 1.2-1 (4), page 21.

[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/s², consistent with the value in Eq. 1.2-1 (4), page 21.



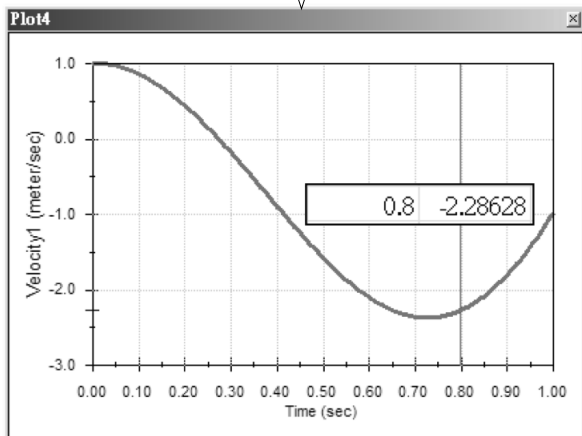
[9] Close the window. #



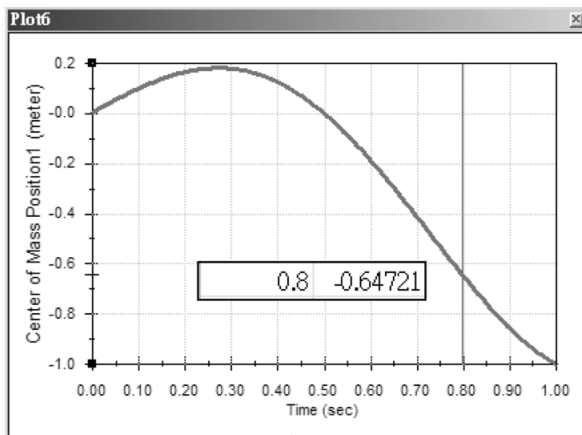
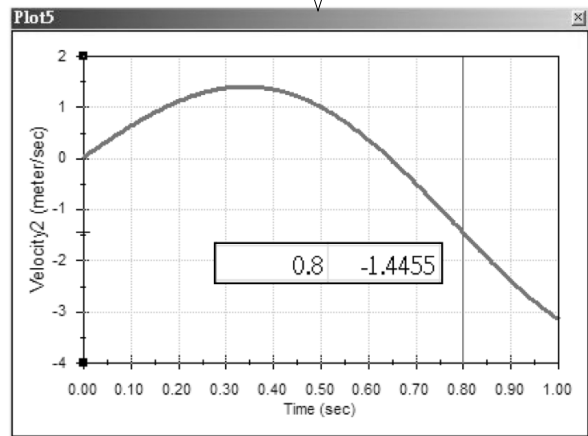
1.2-13 Do It Yourself

[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].

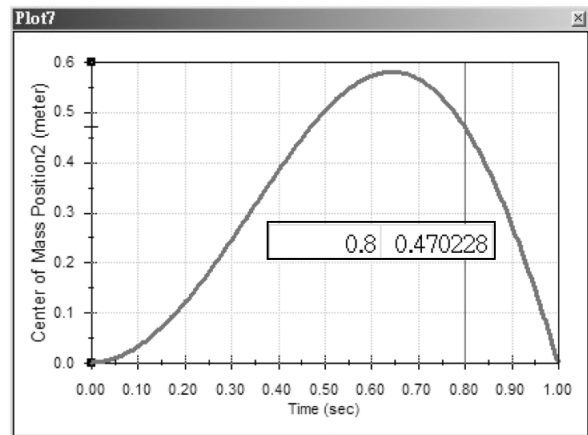
[2] Velocity in X-direction.



[3] Velocity in Y-direction.



[4] Position in X-direction.



[5] Position in Y-direction.

Wrap Up

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