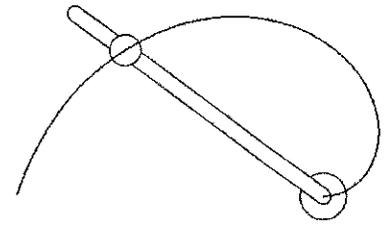


Section 1.2

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

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

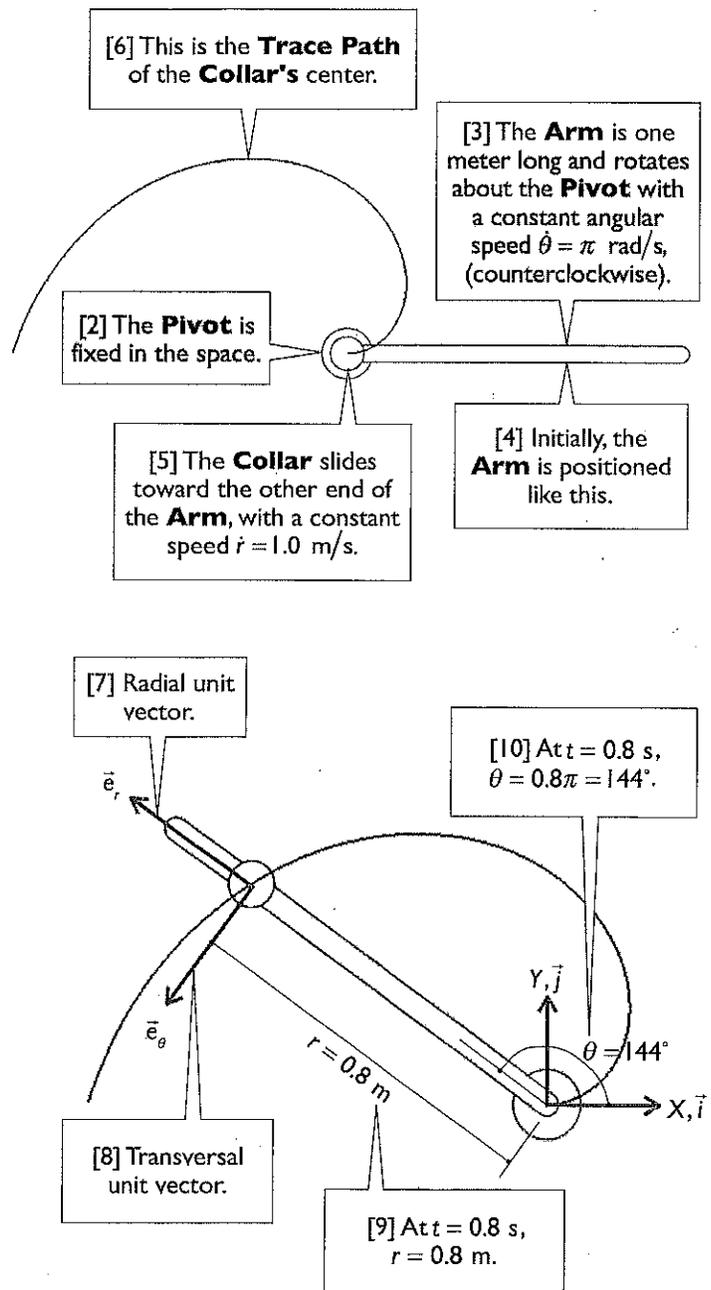
Let's calculate these values at an arbitrary time, say $t = 0.8$ s. At that time [9, 10],

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

Then, the position is

$$\begin{aligned} \vec{r} &= r\vec{e}_r \\ &= 0.8\vec{e}_r \\ &= 0.8(\cos 44^\circ)\vec{i} + 0.8(\sin 44^\circ)\vec{j} \\ &= -0.647\vec{i} + 0.470\vec{j} \end{aligned} \quad (2)$$

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.



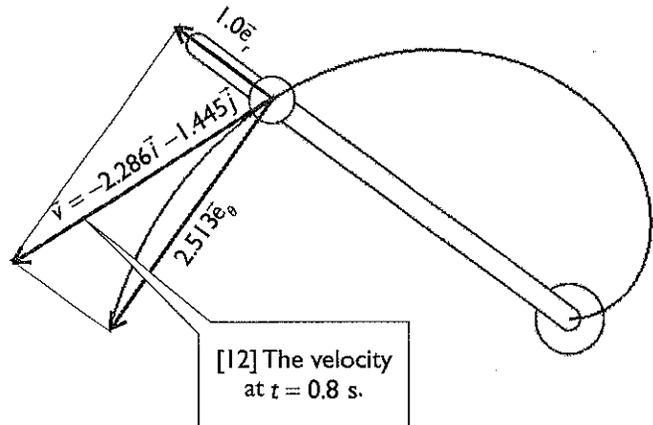
[11] The velocity is [12]

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

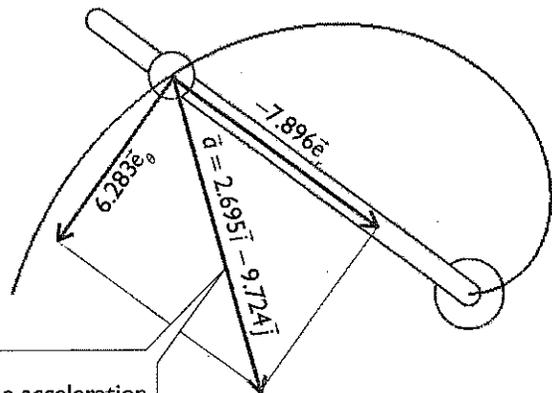
The acceleration is [13]

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

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.



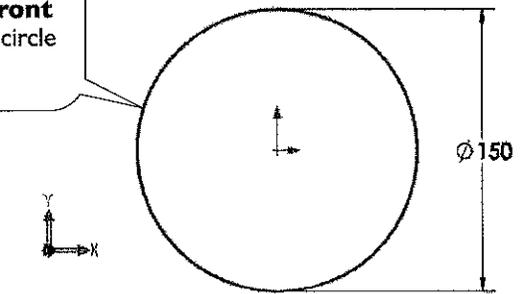
[13] The acceleration at $t = 0.8$ s. #

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.



*front

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

[5] Click **OK**.

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

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

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.

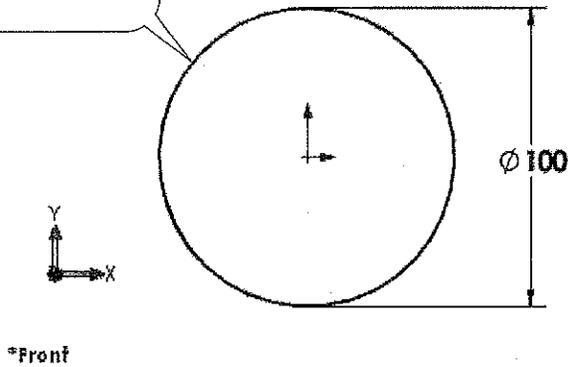
[3] Extrude 30 mm.

*Front

*Trimetric

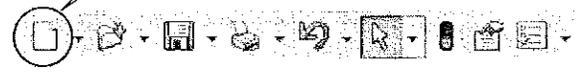
1.2-4 Create a Part: Collar

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

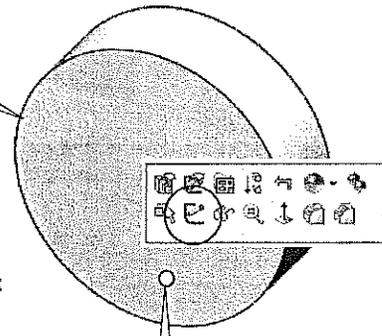


*Front

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



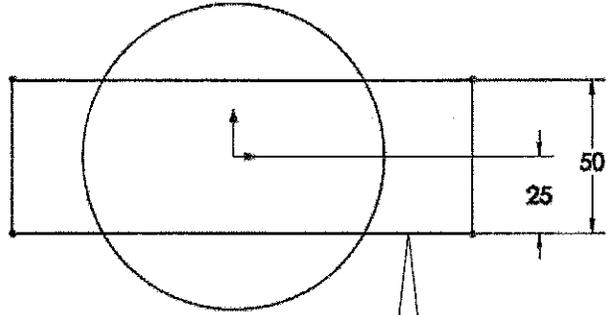
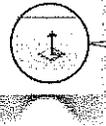
[3] Extrude 30 mm.



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

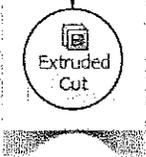
[5] In the **Standard Views Toolbar**, click **Normal To** (1.1-6[2], page 10).



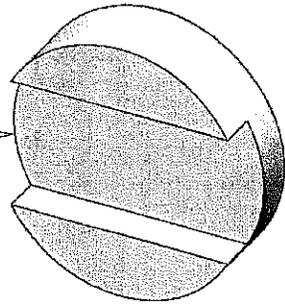
*Front

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

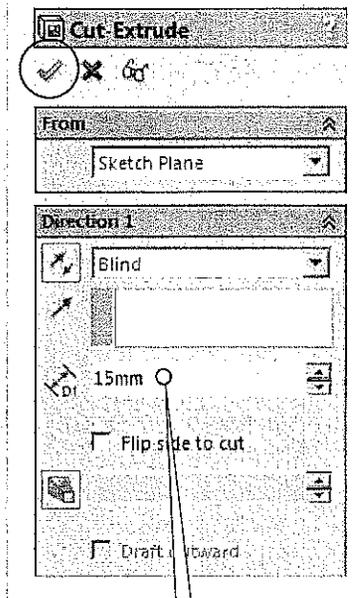
[7] In **Features Toolbar**, click **Extruded Cut**.



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



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[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.

Begin Assembly

Message

Select a component to insert, then place it in the graphics area or hit OK to locate it at the origin.

Or design top-down using a Layout with blocks. Parts may then be created from the blocks.

Create Layout

Part/Assembly to Insert

Open documents:

- Arm
- Collar
- Pivot

Browse...

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Insert Component

Message

Select a part or assembly to insert and then place the component in the graphics area. Use the push pin to insert multiple copies of the same or different components.

Hit OK button to insert a component at the origin.

Part/Assembly to Insert

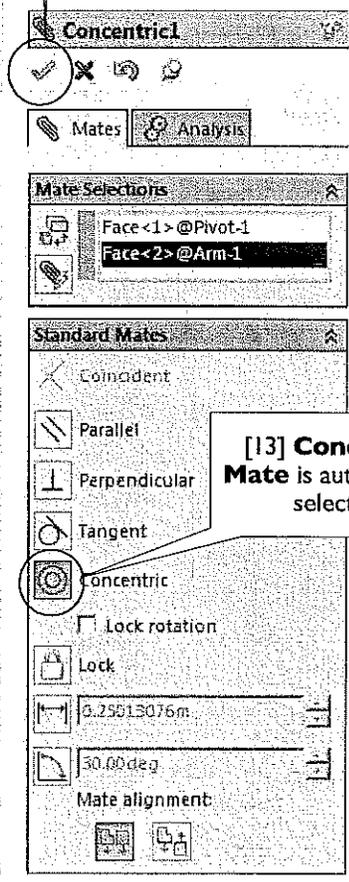
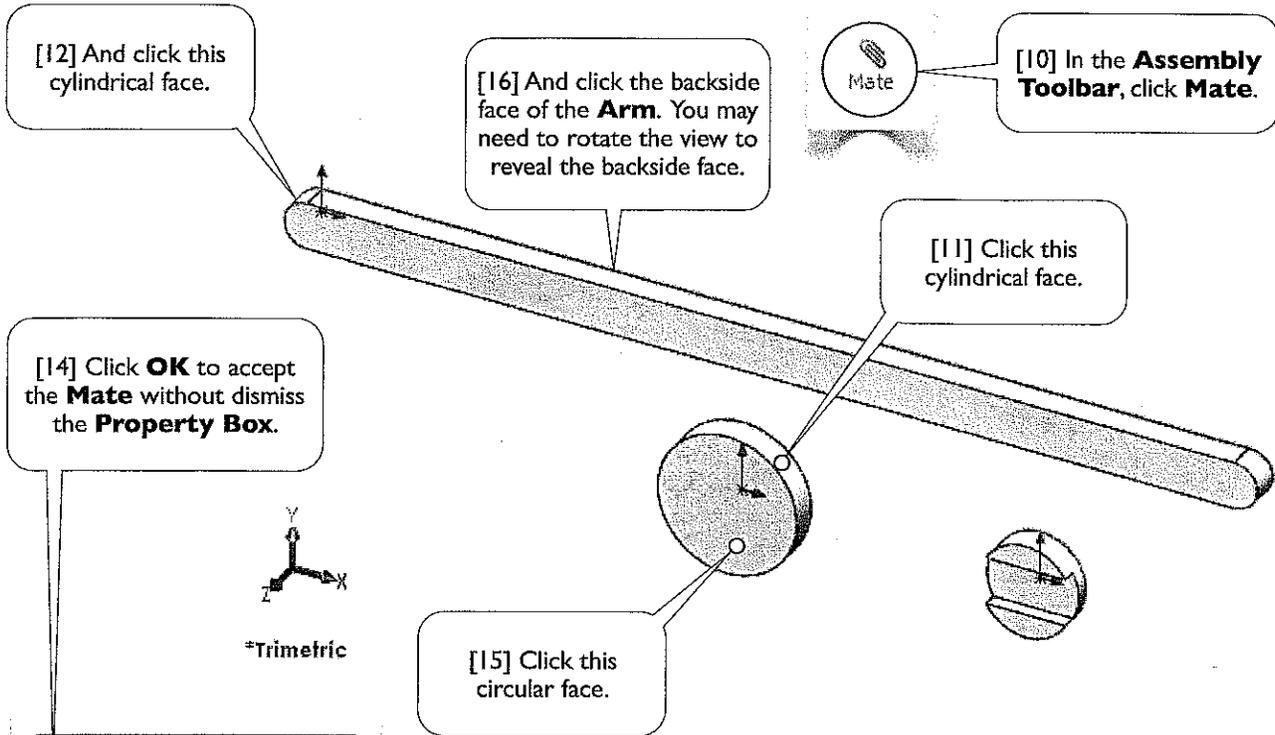
Open documents:

- Arm
- Collar
- Pivot

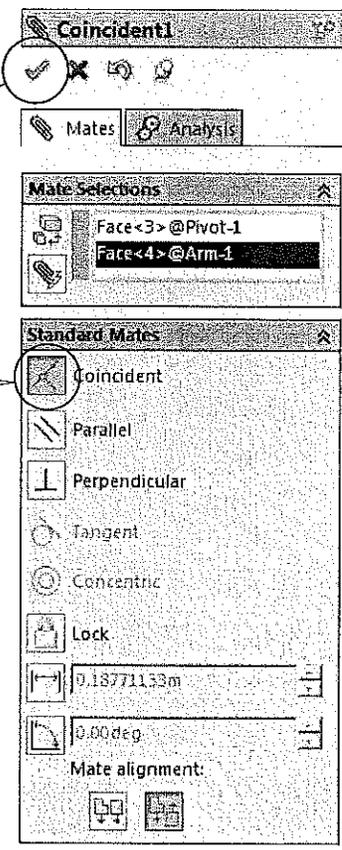
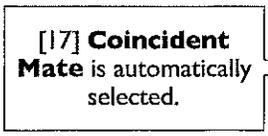
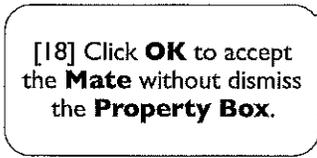
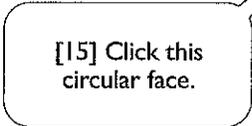
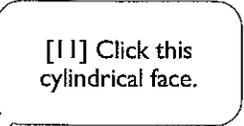
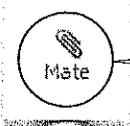
Browse...

MKS

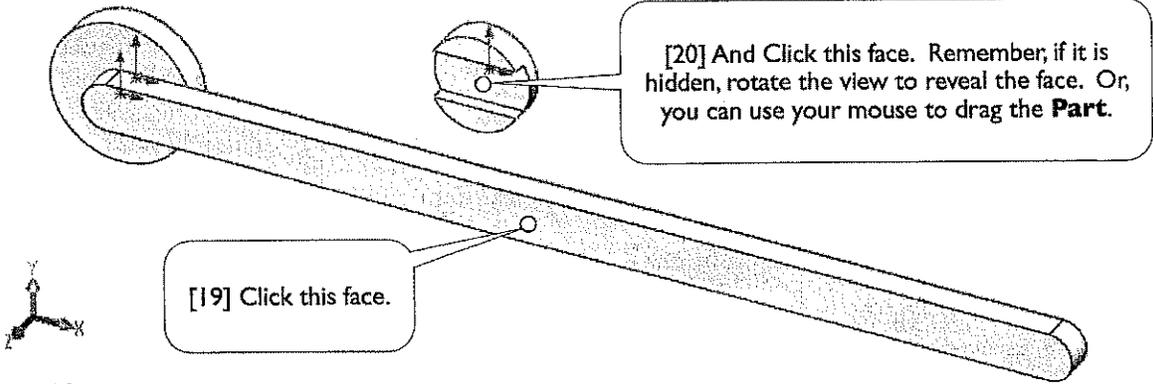
Insert Components



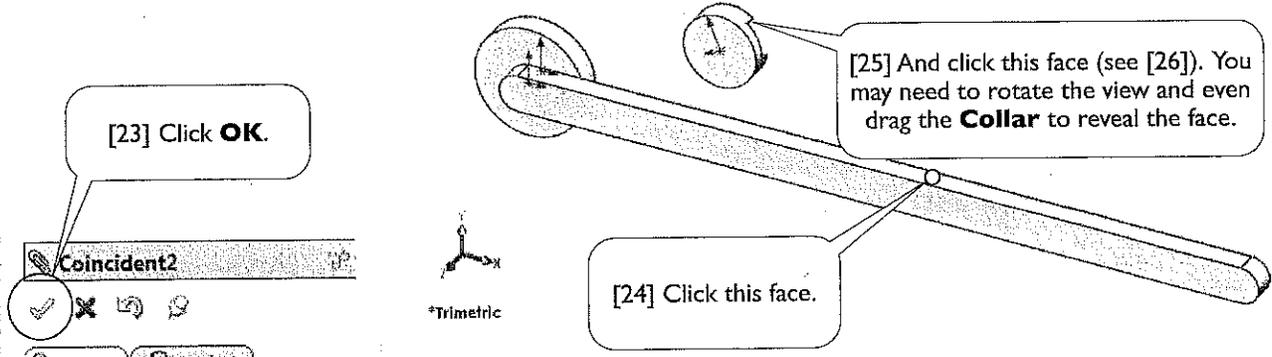
[13] **Concentric Mate** is automatically selected.



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



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Coincident2

Mates Analysis

Mate Selections

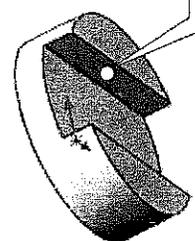
- Face<5>@Arm-1
- Face<6>@Collar-1

Standard Mates

- Coincident
- Parallel
- Perpendicular
- Tangent
- Concentric
- Lock
- 0.15706113m
- 0deg
- Mate alignment:

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

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



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

Coincident3

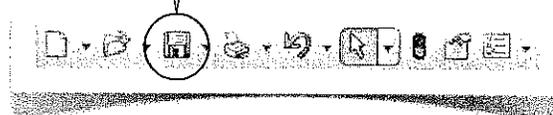
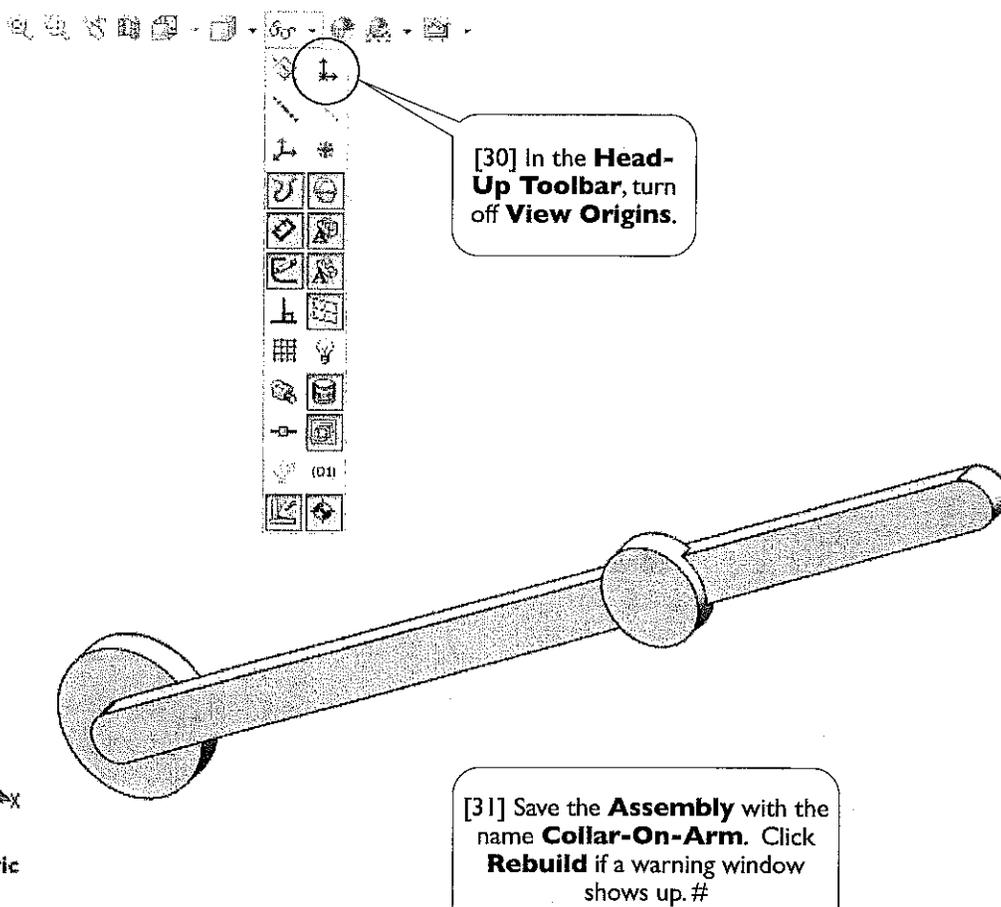
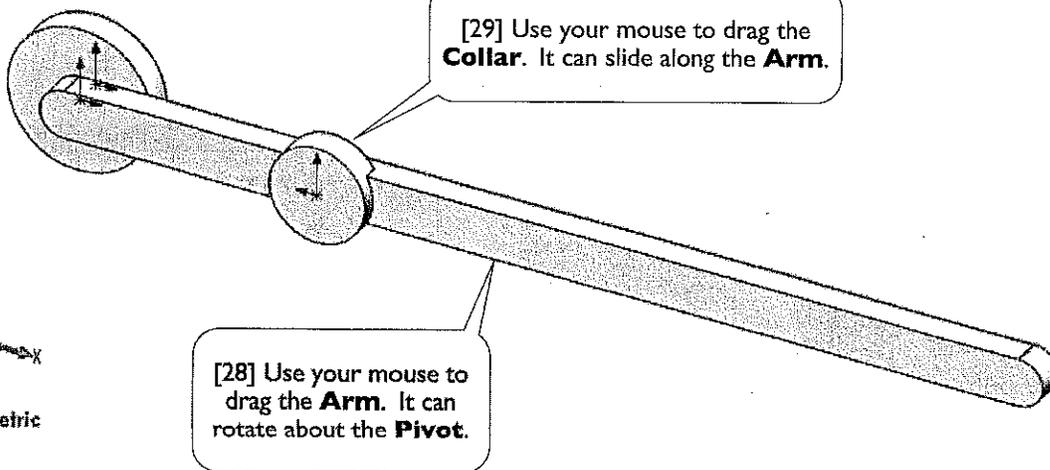
Mates Analysis

Mate Selections

- Face<7>@Arm-1
- Face<8>@Collar-1

Standard Mates

- Coincident
- Parallel
- Perpendicular
- Tangent
- Concentric
- Lock
- 0.1268594 in
- 157.47732641deg
- Mate alignment:



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. #

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

Sensors

Annotations

Front

Right

Origin

(f) Pivot<1> (Default<De...

(-) Arm<1> (Default<De...

(-) Collar<1> (Default<D...

Mates

Parallel1

Mates Analysis

Mate Selections

Face<1> @Arm-1

Top

Standard Mates

Coincident

Parallel

Perpendicular

Tangent

Concentric

Lock

0.07490536m

0.000deg

Mate alignment:

Concentric2

Mates Analysis

Mate Selections

Face<2> @Collar-1

Face<3> @Pivot-1

Standard Mates

Coincident

Parallel

Perpendicular

Tangent

Concentric

Lock rotation

Lock

0.47595536m

0.000deg

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). #

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**. #

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

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
- 1 m/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** (1.1-11 [3, 4], page 14).

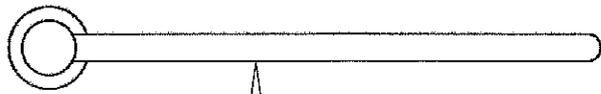
[4] Right-click this **Key Point** and select **View Orientation>Front**.

Mates

- 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>)

0 sec | 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).



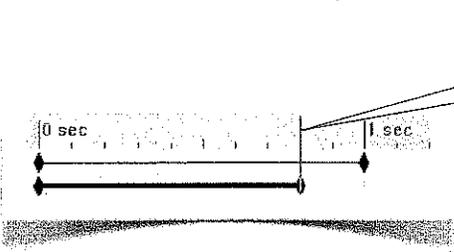
[5] For this case, a **Front** view has a better visual effect.



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

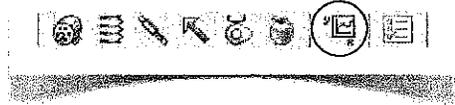
[7] Select **0.1x** for **Playback Speed**.

1.2-11 Results: Trace Path

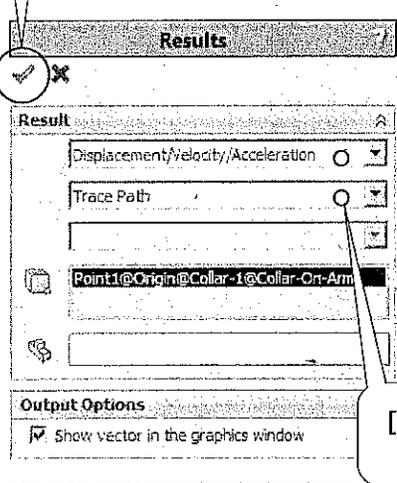


[1] In the **Timeline**, click at **0.8 sec**.

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

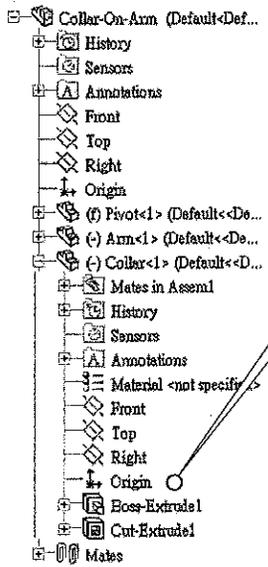


[5] Click **OK**.

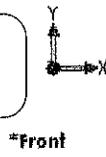
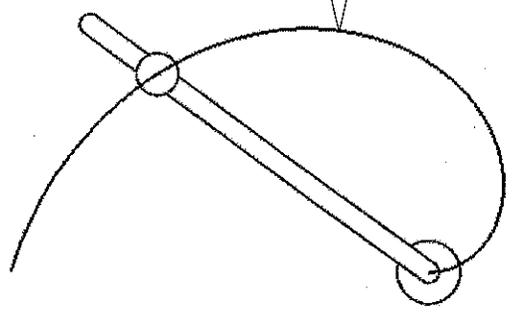


[3] Select **Trace Path**.

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



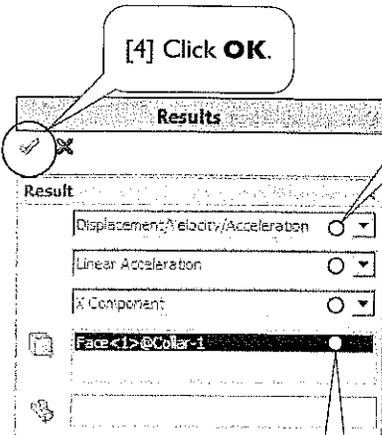
[6] Click **Play from start** (1.2-10[8], this page) to view the animation again. #



1.2-12 Results: Acceleration

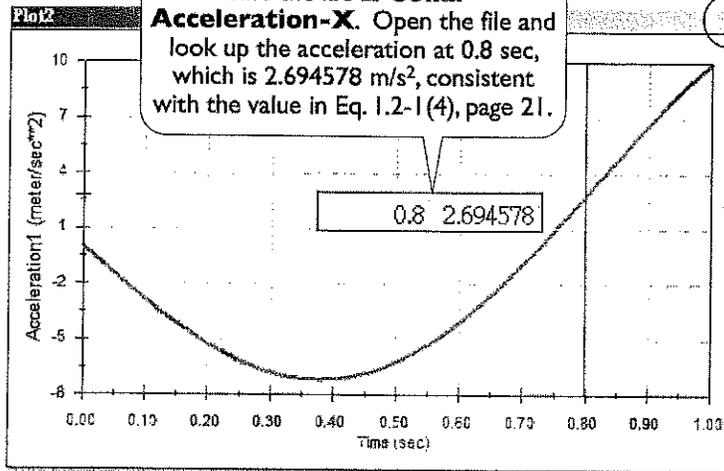


[1] In **Motion Toolbar**, click **Results and Plots**.



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

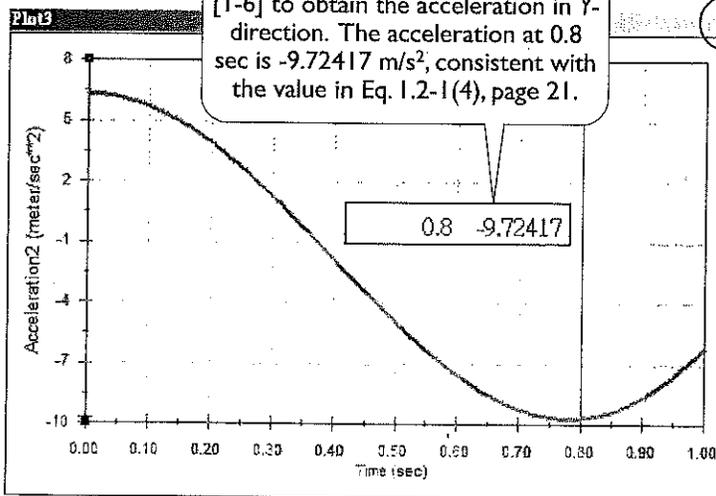
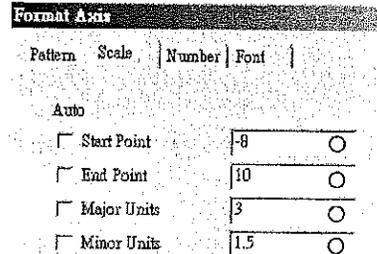
[4] Click **OK**.



[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.

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

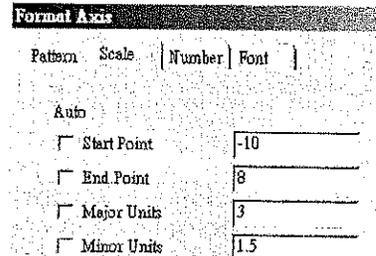
[7] Close the window.



[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.

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

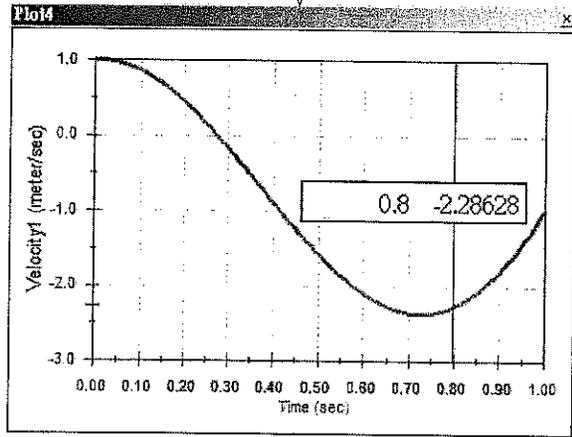
[9] Close the window. #



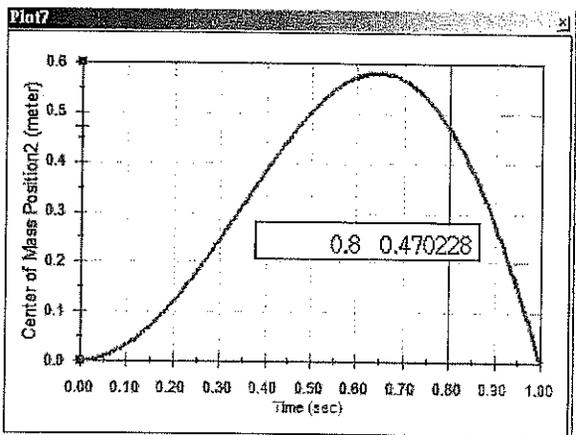
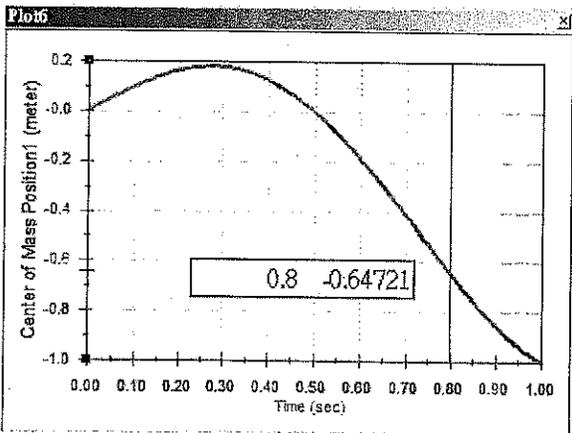
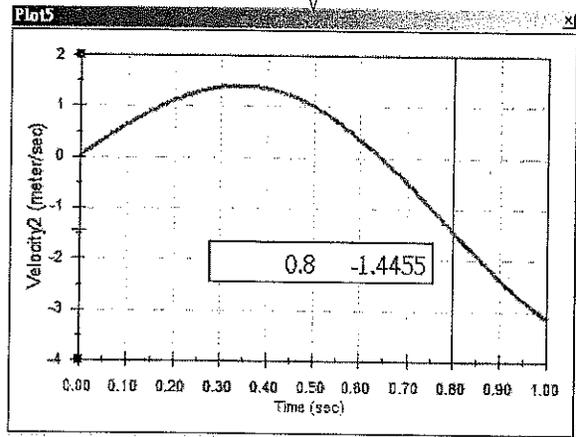
1.2-13 Do It Yourself

[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). #