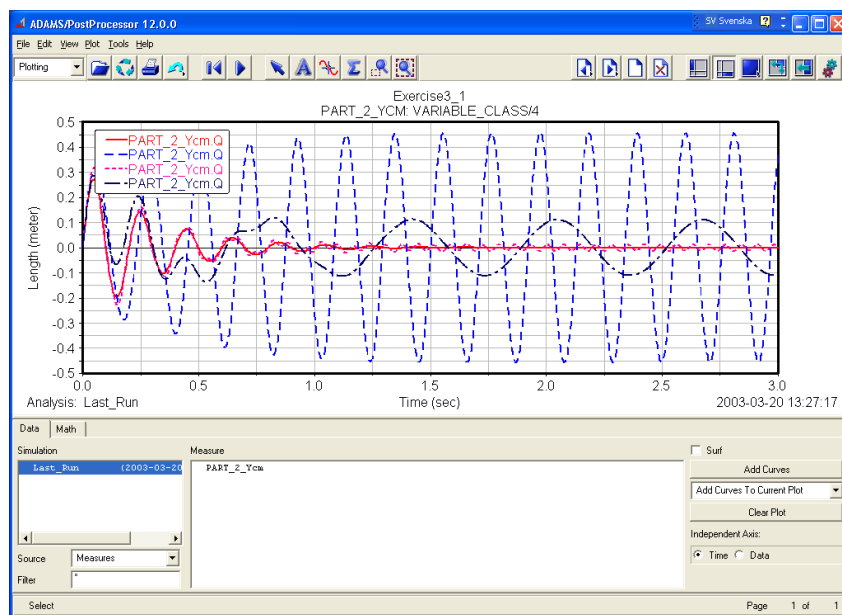


# A SHORT INTRODUCTION TO ADAMS FOR ENGINEERING PHYSICS



DIVISION OF MECHANICS

DEPARTMENT OF MECHANICAL ENGINEERING

LUND INSTITUTE OF TECHNOLOGY

2019

# FOREWORD

THESE EXERCISES SERVE THE PURPOSE OF TRAINING THE UNDERSTANDING OF SEVERAL BASIC CONCEPTS IN ELEMENTARY UNIVERSITY-LEVEL MECHANICS. THESE EXERCISES ATTEMPT TO PROVIDE KNOWLEDGE ON HOW THE BASIC THEORY WORKS, ON PRACTICAL PROBLEMS, BY USING MODERN SIMULATION COMPUTER SOFTWARE. BY SIMULATIONS, THE GENERAL PERFORMANCE OF VARIOUS MECHANICAL SYSTEMS MAY BE STUDIED, AS WELL AS THE SPECIFIC EFFECTS OF PARAMETER CHANGES LEADING, EVENTUALLY, TO A BETTER OR EVEN TO AN OPTIMAL PERFORMANCE. THE SIMULATION EXPERIENCE WILL HOPEFULLY ENHANCE THE STUDENTS INSIGHTS INTO THE PRINCIPLES OF MECHANICS AS WELL AS GIVING SOME GENERAL FEELING FOR WHAT IS POSSIBLE TO ACHIEVE WITH A MODERN MULTIBODY SIMULATION TOOL.

MARCH, 2019

DIVISION OF MECHANICS, LUND UNIVERSITY

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# COMPUTER EXERCISES

## INSTRUCTIONS

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1. Read the Introduction to each Exercise and do the **Preparation Tasks**.
2. Before you start modelling with **ADAMS**, study the questions presented in the introduction to each Exercise.
3. Open ADAMS-VIEW  
  
Adams 2017.2 /Adams-View  
  
Give your model a name and save it in a catalogue where you can find it!
4. Construct the ADAMS-model by carefully following the instructions. Test and save different versions of your model along the way. Does it work?
5. If you get into trouble with your model the easiest way out may be to start all over again creating a new model.
6. Answer the **Questions** in each Exercise. Always compare the results obtained from the ADAMS-model **simulation** with your own **hand calculations** and with the results from the **preparation tasks**!
7. **Show your results to the instructor** for approval. Make sure that both exercises are approved!
8. If you are not able to finish both Exercises during the computer-lab, you may do that later during the **Helpdesk** sessions. Do not forget to save your work and to show it to the instructors for approval.

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# COMPUTER EXERCISES

## EXERCISE 1

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The purpose of the first exercise is to study simple mechanical pendulums and to obtain some basic skill in using the commercial multi body simulation package **ADAMS**. The pendulum represents one of the most fundamental systems in dynamics and this basic concept is used in many applications.

### INTRODUCTION

In the following exercise oscillations of both a mathematical pendulum, as well as a physical pendulum, will be studied by using **ADAMS**. First, we restrict attention to oscillations of a mathematical pendulum and then we will modify the model in order to study the behaviour of a physical pendulum.

The so-called simple or mathematical pendulum consists of a point mass  $m$  swinging at the end of a mass-less inextensible cord of length  $L$ . In this exercise, the motion is restricted to a single vertical plane along a circular arc defined by the angle  $\theta$ , as shown in Figure 1.1. We are going to study how changes in the length  $L$  of the cord and the mass  $m$  affect the period time of the oscillation of the pendulum.

The physical pendulum is a rigid body that swings under its own weight about a fixed horizontal axis. The resistance to a change in rotational velocity, due to the distribution of mass over the body, is denoted the rotational inertia. The moment of inertia  $I$ , of the rigid body, is a measure of the rotational inertia. We will study how changes in the moment of inertia  $I$  will affect the oscillations. We will also study oscillations in a more realistic case, oscillation with energy loss in the form of damping.

### PREPARATION

You may have dealt with oscillation and time response problems in the mathematical courses you have studied previously. Study also chapter 12 and 14 in “*Mekanik Grundkurs*”, *Christer Nyberg* alternatively chapter 7 and 9 in “*Mekanik Partikeldynamik*”, *Christer Nyberg*, so that you can understand the concepts presented in the introduction.

#### **Preparation tasks to Exercise 1: (Continues on next page)**

- Draw a free body diagram of the pendulum in Figure 1.1.
- Introduce a cylindrical coordinate system.
- Formulate the equations of motion for the mathematical pendulum in the directions given by the cylindrical coordinate system.

- Formulate the differential equation governing the harmonic oscillation from the equation of motion in the direction of increasing  $\theta$ . Use the approximation  $\sin\theta \approx \theta$  for small  $\theta$ .
- Without solving the differential equation, determine the angular frequency  $\omega$  and the oscillation period time  $T$ . How does the period time  $T$  depend on the length  $L$  of the pendulum string and the mass  $m$ ?

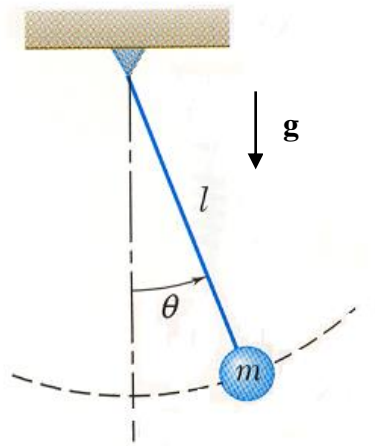


Figure 1.1 The mathematical pendulum

## COMPUTER EXERCISE

In this exercise, you will study a pendulum consisting of a bar with mass  $m_b$  and a sphere with mass  $m_s$ . Simulations with different materials (steel and wood) will be performed as well as simulations using different lengths of the bar. Damping (or friction) in the oscillation will be introduced.

Before you build your model, read through the questions below. They will be repeated later in the text.

1. In the computer simulation, what is the period time  $T$  for the following combinations of  $m_b$ ,  $m_s$  and  $L$ ?

	$m_b$ (material)	$m_s$ (material)	$L$
<b>a</b>	<b>0</b>	<b>steel</b>	<b>0.25m</b>
<b>b</b>	<b>0</b>	<b>steel</b>	<b>0.5m</b>
<b>c</b>	<b>0</b>	<b>steel</b>	<b>1.0m</b>
<b>d</b>	<b>0</b>	<b>wood</b>	<b>1.0m</b>
<b>e</b>	<b>wood</b>	<b>wood</b>	<b>1.0m</b>
<b>f</b>	<b>steel</b>	<b>wood</b>	<b>1.0m</b>
<b>g</b>	<b>steel</b>	<b>steel</b>	<b>1.0m</b>

2. Do the corresponding theoretical period times  $T$ , calculated using the expression for  $T$  found in the preparations, agree with the simulation results arrived at in a)-d)? The densities for the chosen materials are:  $\rho_{\text{steel}} = 7.8 \text{ g/cm}^3$  and  $\rho_{\text{wood}} = 4 \text{ g/cm}^3$ .
3. How does the length  $L$  of the bar affect the period time in the simulations?
4. What effect has a change of the mass  $m$  on the period time in the simulations?
5. Explain differences and similarities in the results d)-g) using concepts such as mathematical pendulum, physical pendulum and moment of inertia. What does it take for a pendulum to be considered a mathematical pendulum?

### 1-1. Start ADAMS-View.

In the following window (see Figure 1.2) select

- “New Model”

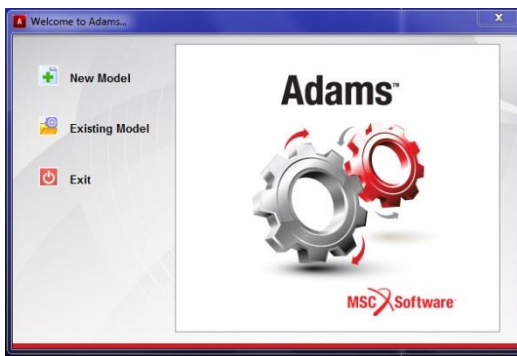


Figure 1.2

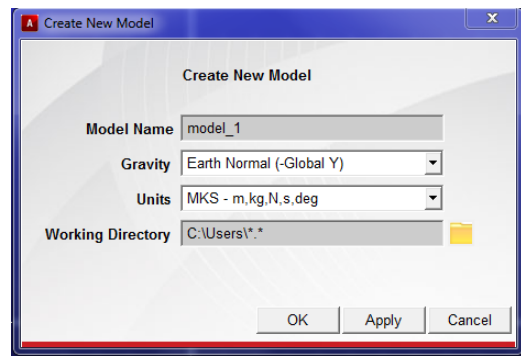


Figure 1.3

In the appearing window (see Figure 1.3) insert a suitable model name, note/choose the working directory and specify gravity and units.

- “Model Name:...”
- “Gravity: Earth Normal (-Global Y)”
- “Units: MKS”
- “Working Directory:...”

Click the OK button.

## 1-2. Define the coordinate system

From the "Settings"-menu (at the top of ADAMS/View window) choose

- "Coordinate system...."

The following window appears (Figure1.4).

Choose

- "Cartesian"
- "Space fixed"

Click the OK button.

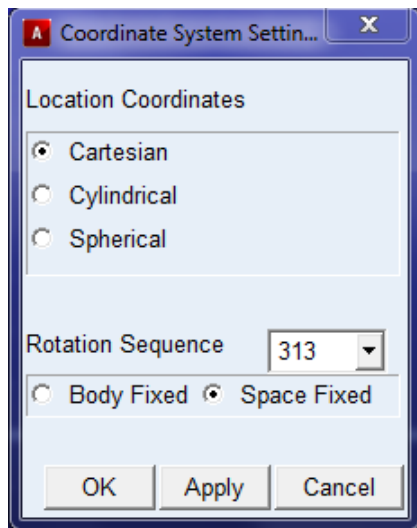


Figure 1.4

## 1-3. Define gravity

From the "Settings"-menu choose

- "Gravity..."

The following window appears (Figure1.5).

Insert

- "X =0.0, Y = -9.81, Z = 0.0"

Click the OK button.

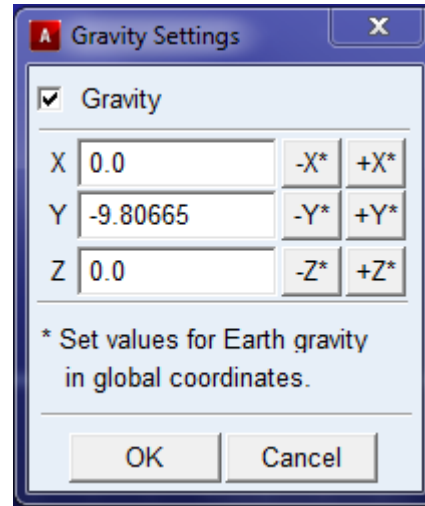


Figure 1.5

## 1-4. Define a suitable working area.

From the "Settings"-menu choose

- "Working grid..."

The following window appears (Figure1.6)

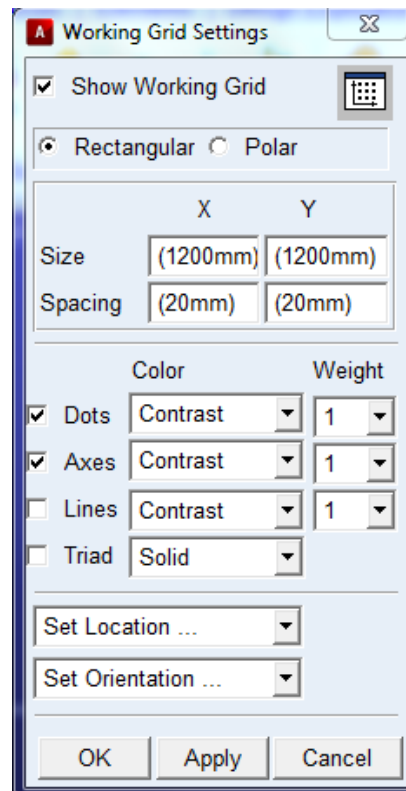


Figure 1.6

Insert

- “Size” and “Spacing” values (according to Figure 1.6)

Click OK.

To be able to see the coordinate values

- From the “View”-menu select “Coordinate Window”.

Coordinates for the cursor position will now be visible in a separate coordinate window!

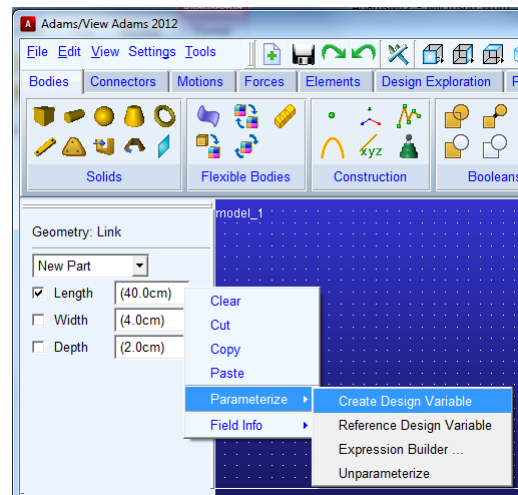


Figure 1.7

**Click(rmb) = Click with right mouse button**

### 1-5. Create model: pendulum cord **(Be careful!)**

To define the cord of the pendulum, go to the "Bodies"-menu and create a “link” (second row, first column)

- Click on the “Rigid Body: link”



- Mark "Length" by inserting “✓”. Point on the length window and click right mouse button (rmb).

Choose "Parameterize" and then "Create Design Variable". See Figure 1.7. **(Important!)**

This enables variation of the cord length.

- Now create a link by clicking in the main window first at the origin (0, 0, 0) and then **(important)** at (0.3, -0.3, 0) resulting in a 45° deflection angle.

### 1-6. Create model: pendulum sphere

To define the initial mass point of the pendulum, go to the "Bodies"-menu and create a sphere (first row, third column).

- Click on "Rigid Body: sphere"



- Select "New Part" and set the radius to 10 cm as shown in Figure 1.8 on the next page. (Do not forget to mark “Radius” with a “✓”)
- Place the centre of the sphere at the Marker at the end of the link close to (0.3,-0.3,0). (The coordinate window says: x = 0.28284, y = -0.28284, z = 0.)





Figure 1.8

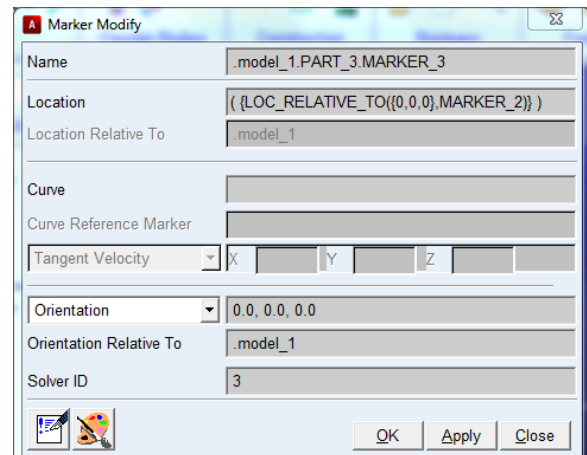



Figure 1.9

### 1-7. Create model: cord/sphere connection **(Be careful!)**

In order to connect the sphere to the cord (“link”) go to the “Connectors”-menu and create a “Fixed Joint” (first row, first column).

- Click on “Fixed Joint” 
- Select “Construction: 2 Bodies-1 Location” and “Normal to grid”.
- Click first on the link, then on the sphere and last on the marker (the tiny coordinate system) at the end of the link close to (0.3,-0.3,0). Make sure that you select the correct body by consulting the small name tag that appears close to the cursor arrow.

The joint should then be created.

- Click (rmb) on the centre of the sphere and select “Marker\_3”, “Modify”

A new dialog box will appear (see Figure 1.9).

- Insert “Location: (LOC\_RELATIVE\_TO({0,0,0}, MARKER\_2))”
- Click OK.
- Click (rmb) on the centre of the sphere and select “Marker\_4”, “Modify”
- Insert “Location: (LOC\_RELATIVE\_TO({0,0,0}, MARKER\_2))”
- Click OK.
- Click (rmb) on the centre of the sphere and select “Marker\_5”, “Modify”
- Insert “Location: (LOC\_RELATIVE\_TO({0,0,0}, MARKER\_2))”

Click OK.

**Click(rmb) = Click with right mouse button**

Note the ADAMS/View **instructions** in the “Status Toolbar” **below the working area!**

### 1-8. Create model: Pendulum-ground connection

The next step is to fix the pendulum in space. In the "Connectors"-menu create a "Revolute Joint" (first row, second column).



- Click on "Revolute Joint"
- Select "Construction: 1 Location Bodies Impl." and "Normal to grid".
- Click at (0, 0, 0).

The pendulum is now connected to "ground".

### 1-9. Create model: Assign mass properties

Now we can assign mass and inertia to the pendulum. First we set the mass of the cord ("link") equal to zero. Activate "Modify Body" by

- Double clicking on the link

Select

- "Category: Mass Properties"
- "Define Mass By : User Input" and

After choosing "Define Mass by: User Input" the mass properties may be inserted in the following window (Figure 1.10)

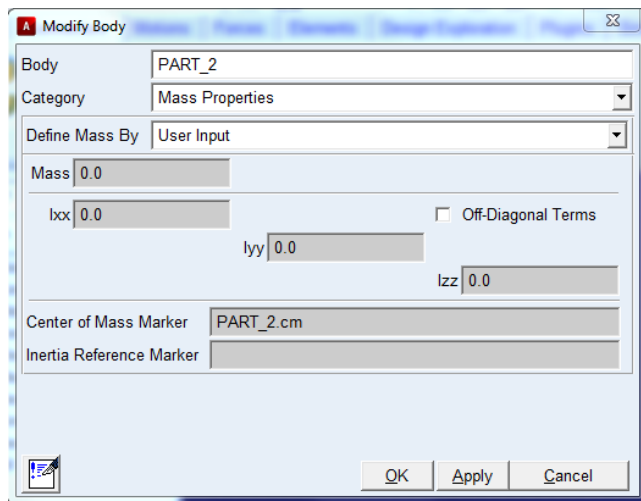


Figure 1.10

Set

- "Mass, Ixx, Iyy, Izz" to zero. (If zero is not accepted, you may try 0.000001.)

Click OK.

## 1-10. Define Design Variables

In order to choose the length of the cord (“link”) we have to modify the “Design Variable”. From “Browse” to the left of the model window choose “Design Variables”. Click (rmb) on DV\_1 and select “Modify”.

A new window appears on the screen (see Figure 1.11)

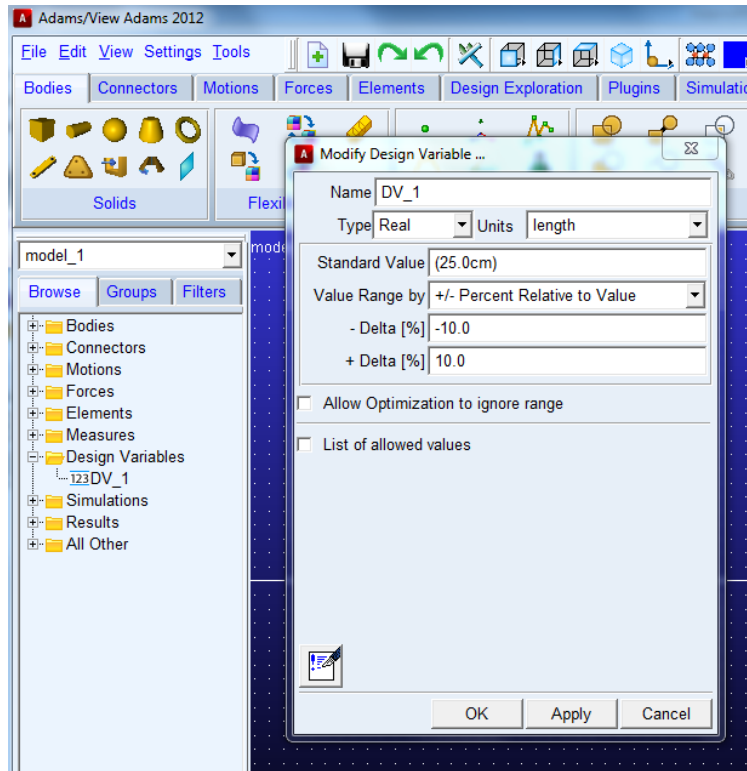


Figure 1.11

In the appearing window, select

- "Units: Length"

and change


- "Standard Value" to 25 cm.

Click OK

The model should change so that the length of the link is now 0.25m. Now we are ready to look at the motion of the pendulum by running a simulation of our model.

### 1-11. Run Simulation: Test

To define a simulation of the pendulum motion, go to the "Simulation"-menu and

- Click on "Simulate" 

See Figure 1.12

You can change duration time and number of steps in the simulation.

- Choose "End Time" and insert 5.0
- Choose "Steps" and insert 500

To run a simulation

- Click on "Start or continue simulation" (play button)



You should now be able to see the pendulum swing back and forth.

- Click on "Reset to input configuration" (rewind button)



### 1-12. Run Simulation: Create Measures

To create a measure for the position coordinates of the pendulum

- Click (rmb) on the sphere and choose "Measure" for PART\_3.

In the appearing window (see Figure 1.13 below) select

- "Characteristic: CM Position" and "Component : Y"

Choose a suitable measure name

- "Measure Name:..."

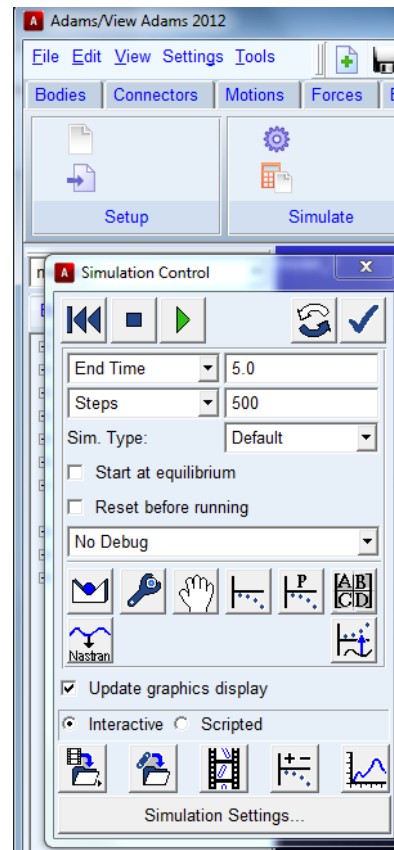
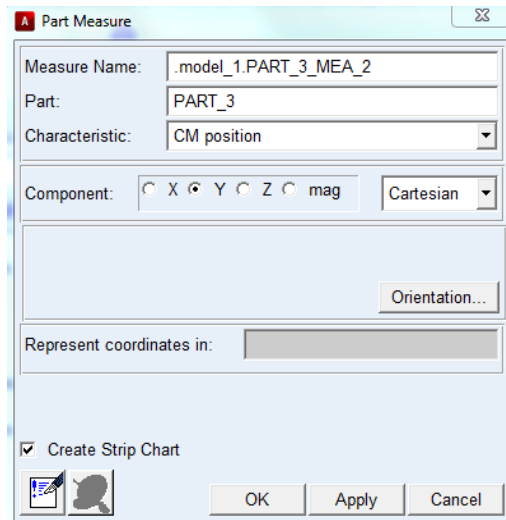


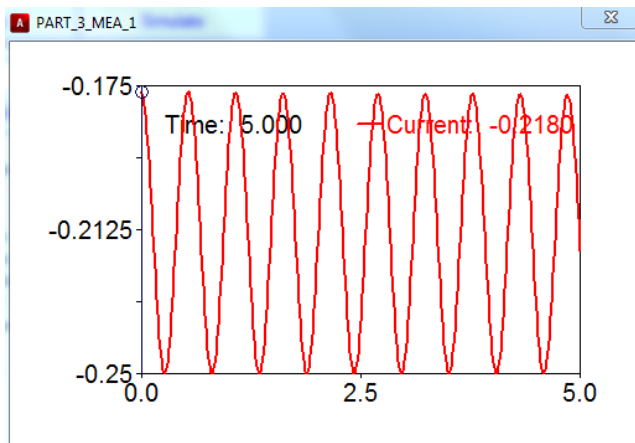
Figure 1.12



**Figure 1.13**

Click OK.

The following curve (Figure 1.14) will then appear in a window.



**Figure 1.14**

- Click (rmb) on the background of the plot window and choose “Transfer To Full Plot”. (If this does not work immediately, close the plot window and go to the “View”-menu, choose Measure and click on your chosen measure name. Then try clicking on the background of the plot window again.)
- In the plot, identify the period time  $T$  for the present “Case a:  $m_b = 0$ ,  $m_s = \text{steel}$ ,  $L = 0.25\text{m}$ ” by using “Plot tracking”, see Figure 1.15 below. (The mass of the sphere is that of steel by default.)
- Write down your results so that you can show it later to the instructors for approval.
- Return to the “ADAMS/View” window by choosing “File” (upper right corner) “Close Plot Window”.

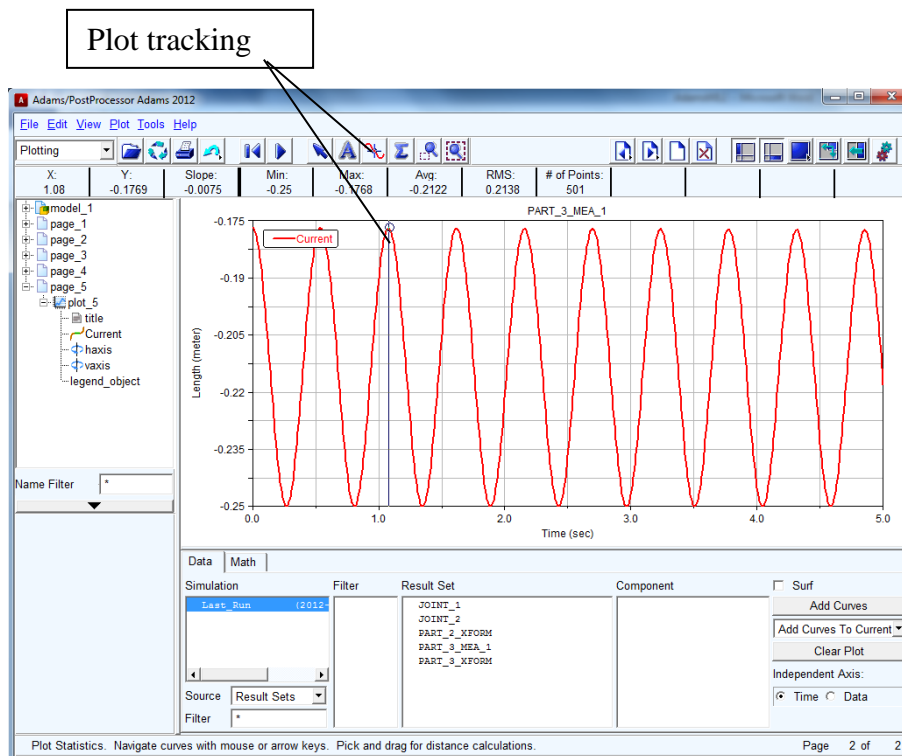


Figure 1.15

Use the **”Plot tracking”** facility to measure in the diagram! You may find coordinate values in the small windows above the graph!

### 1-13. Design study

a) To see what happens when the length and the mass of the pendulum are changed a number of different types of pendulums will now be studied.

From “Browse” choose "Design Variables" and “DV\_1”. Then click (rmb) and select “Modify”.

In the appearing window set

- "Standard Value" to 50cm.

Click OK.

Now the cord of the pendulum has a length of 0.5m.

b) Re-run the simulation

- Click on Play button
- Click (rmb) on the background of the plot window and choose “Transfer To Full Plot”.
- In the plot, identify the period time  $T$  for the present “Case b:  $m_b=0$ ,  $m_s=\text{steel}$ ,  $L=0.5\text{m}$ ”.

- Write down your results so that you can show it later to the instructors for approval.
- Return to the “ADAMS/View” window by choosing “File” (upper right corner) “Close Plot Window”.

Reset the simulation

- Click on “Reset to input configuration” (rewind button)



Repeat **1-13** for the length  $L=1.0\text{m}$  (“Case c:  $m_b=0$ ,  $m_s=\text{steel}$ ,  $L=1.0\text{m}$ ”). Note that zoom out is found by clicking (rmb) on the background. Follow the instructions in the grey instructions field at the bottom of the main window.

#### 1-14. Create model: Change material

We want to change material (and mass) of the sphere to see how the motion is affected.

- Double click on the sphere to activate the dialog box “Modify Body”
- Choose “Define Mass By”: Geometry and Material Type.
- Click (rmb) on the “Material Type” field. Select “Material” then “Browse...” and finally choose wood from the list. Click OK twice.

Repeat step **1-13 b)** above for “Case d:  $m_b=0$ ,  $m_s=\text{wood}$ ,  $L=1.0\text{m}$ ”.

We now want to change material (and mass) of the bar to see how the motion is affected.

- Double click on the bar to activate the dialog box “Modify Body”
- Choose “Define Mass By”: Geometry and Material Type.
- Click (rmb) on the “Material Type” field. Select “Material” then “Browse...” and finally choose wood from the list. Click OK twice.

Repeat step **1-13 b)** above and in the plot identify the period time  $T$  for the present “Case e:  $m_b=\text{wood}$ ,  $m_s=\text{wood}$ ,  $L=1.0\text{m}$ ”.

Now we want to change the material of the bar to steel.

- Double click on the bar to activate the dialog box “Modify Body”
- Click (rmb) on the “Material Type” field. Select “Material” then “Browse...” and finally choose steel from the list. Click OK twice.

Repeat step **1-13 b)** above and in the plot identify the period time  $T$  for the present “Case f:  $m_b=\text{steel}$ ,  $m_s=\text{wood}$ ,  $L=1.0\text{m}$ ”.

Finally, the material of the sphere should be changed back to steel.

- Double click on the sphere to activate the dialog box “Modify Body”
- Click (rmb) on the “Material Type” field. Select “Material” then “Browse...” and finally choose steel from the list. Click OK twice.

Repeat step **1-13 b)** above and in the plot identify the period time  $T$  for the present “Case g:  $m_b$ =steel,  $m_s$ =steel,  $L=1.0\text{m}$ ”.

### Questions to Exercise 1:

1. In the computer simulation, what is the period time  $T$  for cases a-g?
2. Do the corresponding theoretical period times  $T$ , calculated using the expression for  $T$  found in the preparations, agree with the simulation results arrived at in a)-d)? The densities for the chosen materials are:  $\rho_{\text{steel}} = 7.8 \text{ g/cm}^3$  and  $\rho_{\text{wood}} = 4 \text{ g/cm}^3$ .
3. How does the length  $L$  of the bar affect the period time in the simulations?
4. What effect has a change of the mass  $m$  on the period time in the simulations?
5. Explain differences and similarities in the results d)-g) using concepts such as mathematical pendulum, physical pendulum and moment of inertia. What does it take for a pendulum to be considered a mathematical pendulum?

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## COMPUTER EXERCISES

### EXERCISE 2

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In this exercise a mechanical problem relating to projectile motion will be considered. Basic concepts of particle kinematics will be used and a parameter study will be included to investigate the problem. The theory of particle kinematics is described in Chapter 6 “*Mekanik Grundkurs*”, *Christer Nyberg*, alternatively in Chapter 1 “*Mekanik Partikeldynamik*”, *Christer Nyberg*.

#### INTRODUCTION

The event to investigate here is a shot putters attempt. First we develop a mathematical model of the shot. In this mathematical model air resistance is excluded and the motion of the ball is modelled as that of a particle. In the computer simulation the ball will be modelled as a sphere for visibility reasons. We will also perform a parameter design study of the system and try to find a maximum value of a specific chosen quantity.



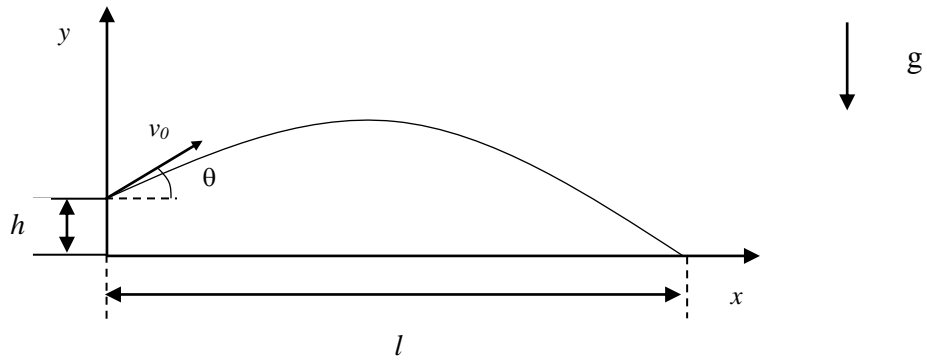


Figure 2.1: The shot put attempt

## PREPARATION

- Formulate the equations for the projectile motion; acceleration, velocity and distance as functions of time  $t$  for the  $x$ - and  $y$ -direction, respectively, see the list below. Make sure to include initial values ( $t=0$ ) in the equations. Let the initial values in the equations for the particle motion be consistent with Figure 2.1. The magnitude of the initial velocity is denoted  $v_0$ . The gravitational acceleration is denoted  $g$  and defined in the direction according to Figure 2.1.

$\ddot{x}(t) = \dots$
$\ddot{y}(t) = \dots$
$\dot{x}(t) = \dots$
$\dot{y}(t) = \dots$
$x(t) = \dots$
$y(t) = \dots$

- Combine the equations above to formulate an expression for the length  $l$  as a function of the elevation angle  $\theta$  (see Figure 2.1). The expression for the length  $l(\theta)$  may include the quantities  $\theta$ ,  $v_0$ ,  $h$  and  $g$ , *please observe – not time  $t$* .
- Calculate the angle  $\theta_{max}$  for which the length  $l$  is maximized in the case  $h=0$  and  $v_0=15\text{m/s}$ .
- Use the angle  $\theta_{max}$  to calculate the maximum length  $l_{max}$  corresponding to this angle.

## COMPUTER EXERCISE

This exercise consists of simulations of the problem given above to find a relation between the length  $l$  and the launch angle  $\theta$  for:

- $h = 0\text{m}$  (the same as in the analytical assignment above) and
- $h = 1.93\text{m}$  simulating a person throwing the ball.

Before you build your model, read through the questions below. They will be repeated later in the text.

- 1) What elevation angle  $\theta$  gives the maximum shot length for  $h=0$ ?
- 2) What is the maximum shot length for  $h=0$ ?
- 3) Does this result agree with the analytical result found using the expressions formulated in the preparation task?
- 4) If they do not agree, formulate suggestions to why this behaviour appears.
- 5) What elevation angle  $\theta$  gives the maximum shot length for  $h=1.93\text{m}$ ?
- 6) What is the maximum shot length for  $h=1.93\text{m}$ ?
- 7) Insert the maximum angle for  $h=1.93\text{m}$  found in the simulation to calculate analytically the corresponding maximum length. Do you find the same results for the maximum length in the simulation as you do in the analytical solution?
- 8) If the lengths are not the same, formulate suggestions to why this behaviour appears.
- 9) Compare the results using  $h=0$  with those found for  $h=1.93\text{m}$ . Where the differences/similarities in the results for the length and the angle respectively expected?

### **2-1. Start ADAMS-View.**

- Select “New Model”.
- To be able to find your model and results easily, pick a suitable location for “Working Directory”.
- Give the model a suitable name in “Model Name...”.
- Pick “Gravity: Earth Normal(-Global Y)” and “Units: MKS”

Click OK.

### **2-2. Define gravity**

From the "Settings" menu choose

- “Gravity... “
- Insert “X = 0.0, Y = -9.81, Z = 0.0”

Click OK.

### **2-3. Create coordinate system and suitable working area**

From the “Settings” menu choose

- “Coordinate system...” and then “Space fixed”

Click OK.

- “Working grid...” and then insert “Size” and “Spacing” values according

	X	Y
Size	(25m)	(5m)
Spacing	(1m)	(1m)

**Click(rmb) = Click with right mouse button**

Click OK.

To be able to see the coordinate values

- From the “View” menu select “Coordinate Window”.

#### **2-4. Create model: Shot**

- Build a sphere with “Radius: 50cm” at (0, 0, 0)

The radius of the sphere now appears very large relative to the screen.

#### **2-5. Zoom in the first quadrant of the working area**

Zoom in the first quadrant of the coordinate system, (the positive X and Y axis) by

- Click(rmb) on the background of the screen, select “Zoom In/Out” and follow the instructions in the grey field below.
- Click(rmb) on the background of the screen, select “Translate” and follow the instructions in the grey field below.

#### **2-6. Define a design variable**

Define the elevation angle  $\theta$  as a design variable. Go to the “Design Exploration” menu and choose

- “Design Variable”

A new dialog box “Create Design Variable...” appears.

- Choose “Name: Elevation”, “Units: angle” and then insert “Standard Value: 45”. Choose “Value Range by: Percent Relative to Value” and insert “-Delta[%]: -50” and “+Delta[%]: +50”

Click OK.

#### **2-7. Create model: Define particle weight and initial conditions for the velocity.**

Modify the particle weight and define initial velocities as a function of the angle  $\theta$ .

Mark the sphere by clicking on the sphere, then

- Click(rmb) on the sphere and select “Part” and “Modify”

- In dialog box “Modify Body” choose “Category: Mass Properties” and “Define Mass By: User Input”. Insert “Mass: 7.257kg”, “ $I_{xx} = 0.01$ ”, “ $I_{yy} = 0.01$ ”, “ $I_{zz} = 0.01$ ”.

Click Apply.

In the same dialog box

- Choose “Category: Velocity Initial Conditions”, mark “Ground” and insert for the translational velocity  
“X axis:  $(15*\cos(\text{Elevation}))$ ” and “Y axis:  $(15*\sin(\text{Elevation}))$ ”

Click OK.

## 2-8. Run Simulation: Test

Test your model by

- Click on the “Run an Interactive Simulation” button under the “Simulation” menu, insert “End Time: 5.0” and “Steps: 1000”.
- Click on the play button
- Check so that your model behaves as expected.
- Click on the rewind button

## 2-9. Create measure

Create measures for the translational displacements of the centre of mass (cm).

Mark the sphere by clicking on the sphere, then

- Click(rmb) close to the centre of the sphere, select “Marker: cm” and then “Measure”

In the appearing dialog box “Point Measure”

- Insert “Measure Name: Xdisplacement” and then Select “Characteristic: Translational displacement”, mark “Component: X” and “From/At: Ground”

Click Apply, but do not close the dialog box.

In the same dialog box

- Insert “Measure Name: Ydisplacement” and then Select “Characteristic: Translational Displacement”, mark “Component: Y” and “From/At: Ground”

Click OK.

## 2-10. Create sensor

Create a sensor which stops the simulation when the sphere hits the ground ( $Y = 0$ )

In the “Design Exploration” menu, under “Instrumentation”

- Select “Create a new Sensor”

In the “Create sensor...” dialog box

- Insert “Name: Hitground”
- Select “Event Definition: Run-Time expression”, “Expression: Ydisplacement”, replace “equal” by “less than or equal” and insert “Value: -0.001”. Mark “Standard actions: Generate additional output step at event” and “Terminate current simulation step and...Stop”

Click OK.

## 2-11. Create and run design study

Make a design study on how the length  $l$  (see Figure 2.1) depends on the elevation angle  $\theta$ .

In the “Simulation” menu under “Setup”

- Select “Create a new Simulation Script”
- In the dialog box “Create simulation script...” insert “End Time: 5.0” and “Steps: 50”

Click OK.

In the “Design Exploration” menu under “Design Evaluation” choose “Design Evaluation Tools”

In the dialog box “Design Evaluation Tools...”

- Mark “Study a: measure”, select “Maximum of” and insert “Xdisplacement”, mark “Design study” and insert “Design Variable: Elevation” and “Default Levels: 31”

Click Start.

## 2-12. Plot the first simulation result

In the “Results” menu under “Postprocessor” choose “Opens Adams/Postprocessor”.

- In the post processor window select “Source: Result Sets” (down in the left corner of the screen), “Simulation: Last Multi” (above) and “Result Set: Design\_Study\_Results” (to the right), “Component: Xdisplacement” (further to the right).
- Mark “Independent Axis: Data” (down in the right corner) and in the dialog box “Independent Axis Browser” “Component: Elevation”.

Click OK.

- Finally click on “Add Curves”.

Use the “plot tracking” device to evaluate the curve.

### Questions:

- 1) What elevation angle  $\theta$  gives the maximum shot length for  $h=0$ ?
- 2) What is the maximum shot length for  $h=0$ ?
- 3) Does this result agree with the analytical result found using the expressions formulated in the preparation task?
- 4) If they do not agree, formulate suggestions to why this behaviour appears.

### 2-13. Save the plot in a separate file.

- In the top menu select “File: Print”
- In the dialog box “Print” select “Print to: File”
- In “File Name” give the file a suitable name.
- You could replace “Postscript” with for example JPG or TIFF.

### 2-14. Create model: Shot putter's attempt

Simulate a shot putter's (height  $h = 1.93\text{m}$ ) attempt and make a study of how the length depends on the initial elevation angle.

Return to the model view.

Click on the sphere (lmb).

- In the top tool box, to the right of “File Edit View Settings Tools” select “Position: Reposition objects relative to view coordinates (x to right, y up and z out of the view)”. (Yellow square with a blue arrow.)
- Select “Rotate: Angle 0”, “Translate: Distance 193cm” and then click on the upwards arrow button for translating upwards.

### 2-15. Run the design study as before

Click “Start” in the “Design Evaluation tools” window. Then repeat **2-12** and **2-13**.

### Questions:

- 5) What elevation angle  $\theta$  gives the maximum shot length for  $h=1.93\text{m}$ ?

- 6) What is the maximum shot length for  $h=1.93\text{m}$ ?
- 7) Insert the maximum angle for  $h=1.93\text{m}$  found in the simulation to calculate analytically the corresponding maximum length. Do you find the same results for the maximum length in the simulation as you do in the analytical solution?
- 8) If the lengths are not the same, formulate suggestions to why this behaviour appears.
- 9) Compare the results using  $h=0$  with those found for  $h=1.93\text{m}$ . Where the differences/similarities in the results for the length and the angle respectively expected?