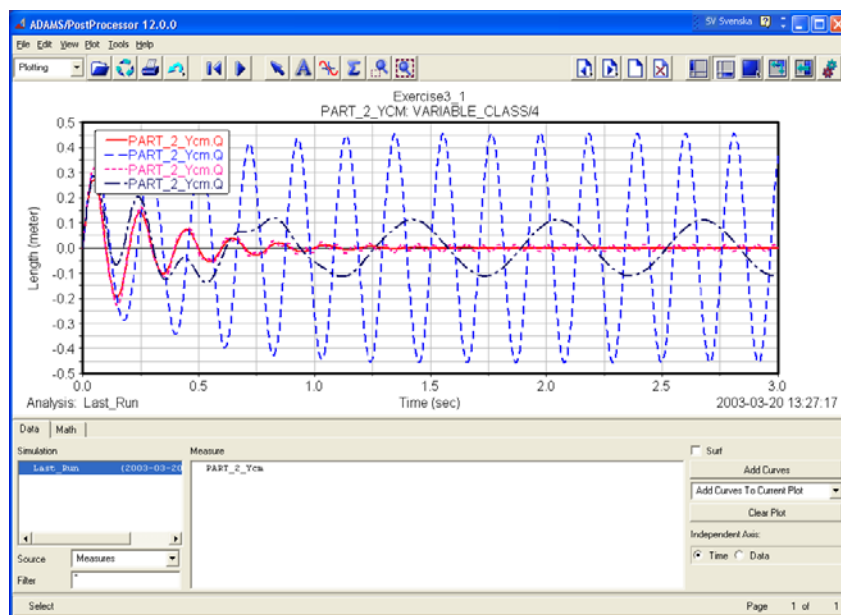A. AHADI, P. LIDSTRÖM, K. NILSSON

A SHORT INTRODUCTION TO

ADAMS

FOR MECHANICAL ENGINEERS

DIVISION OF MECHANICS

DEPARTMENT OF MECHANICAL ENGINEERING

LUND INSTITUTE OF TECHNOLOGY

2018

FOREWORD

THESE EXERCISES SERVE THE PURPOSE OF TRAINING THE UNDERSTANDING OF SEVERAL BASIC CONCEPTS IN ELEMENTARY UNIVERSITY-LEVEL MECHANICS. WHEREAS MECHANICS IS OFTEN TAUGHT AS A COURSE WHERE "PEN AND PAPER" ARE THE ONLY TOOLS, 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.

OCTOBER, 2018

DIVISION OF MECHANICS, LUND UNIVERSITY

COMPUTER EXERCISES

INSTRUCTIONS

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

    Program/Adams/Adams-View

    Name and save your model in a catalogue where you can find it!

4. Construct the ADAMS-model by carefully following the instructions. Test your model along the way. Does it work?

5. If you get into trouble with your model the easiest way out may often 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 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 have been approved before you leave!

8. If you are not able to finish both Exercises during the computer-lab, you may do that later during the week. Don't forget to **save your work** and to show it to the instructors for approval. This could be done during the **help-desk sessions.**

COMPUTER EXERCISES

EXERCISE 1

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 a mathematical and a physical pendulum, respectively, 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 θ, as shown in Figure 1.1 below. 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 (see the course book *"Analys i en variabel"*). Study also Chapter 8 in *"Engineering Mechanics DYNAMICS"*, *Meriam & Kraige* (and the Lecture Notes) so that you can understand the concepts presented in the introduction.

Preparation tasks to Exercise 1:

- Draw a free body diagram of the pendulum in Figure 1.1.

- Introduce a polar coordinate system.

- Formulate the equations of motion for the mathematical pendulum.

- Formulate the differential equation governing the harmonic oscillation from the equation of motion in the direction of increasing θ. Use the approximation $\sin\theta \approx \theta$ for small θ.

- Without solving the differential equation, determine the angular frequency ω 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?
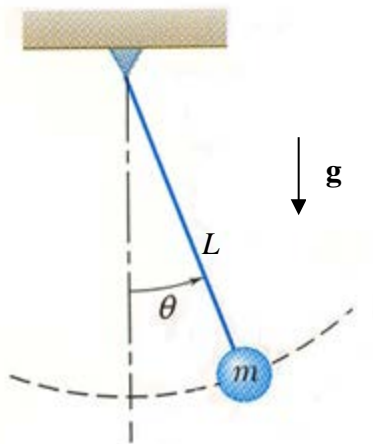

Figure 1.1 The mathematical pendulum

COMPUTER EXERCISE

In this exercise, you will build 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. The following questions will be answered.

1. What is the period time T for the following combinations of m_b, m_s and L?

	m_b (material)	m_s (material)	L
a	0	steel	0.25m
b	0	steel	1.0m
c	0	wood	1.0m
d	wood	wood	1.0m
e	steel	wood	1.0m
f	steel	steel	1.0m

2. Do the theoretical period times *T*, calculated in the preparations agree with the simulation results arrived at in a)-c)?

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. Try to explain differences and similarities in the results d)-f). Is the *mathematical pendulum* a good model for the pendulums in a)-c)? What about the pendulums d)-f)?

6. For case f) add damping to the simulation model. What is the effect of damping on the period time and the amplitude of the motion?

1-1. Start ADAMS-View.

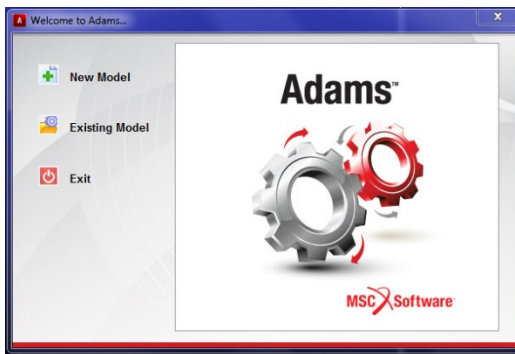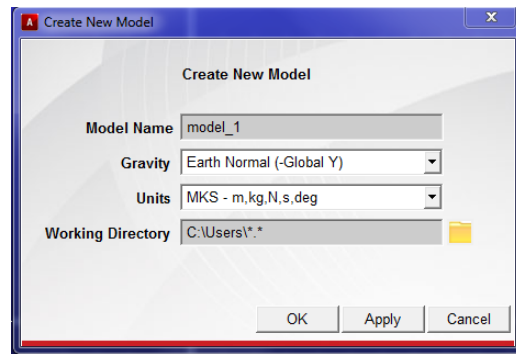In the following window (see Fig. 1.2) select

- "New Model"

| **Figure 1.2** | **Figure 1.3** |

In the appearing window (see Fig. 1.3) insert

- "Model Name:…"
- "Gravity: Earth Normal (-Global Y)"
- "Units: MKS"

Click the OK button.

1-2. Define the coordinate system

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

- "Coordinate system…."

The following window appears (Fig.1.4).

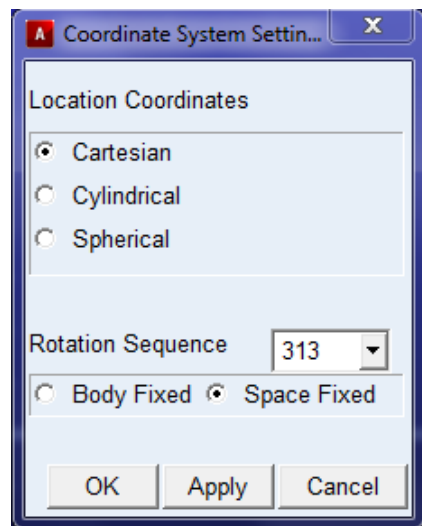Choose

- "Cartesian"
- "Space fixed"

Click the OK button.

Figure 1.4

1-3. Define gravity

From "Settings"-menu choose

- "Gravity…"

The following window appears (Fig.1.5).

Insert

- "X =0.0, Y = -9.80665, Z = 0.0"

Click the OK button.
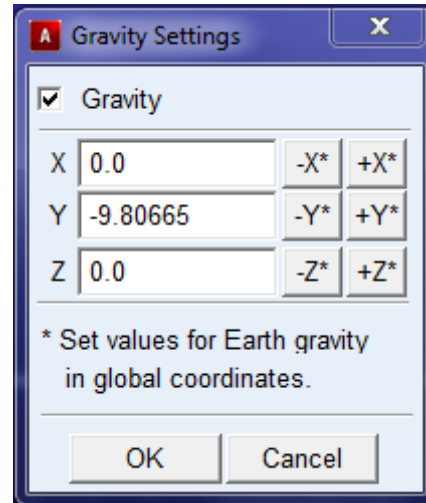
Figure 1.5

1-4. Define a suitable working area.

From "Settings"-menu choose
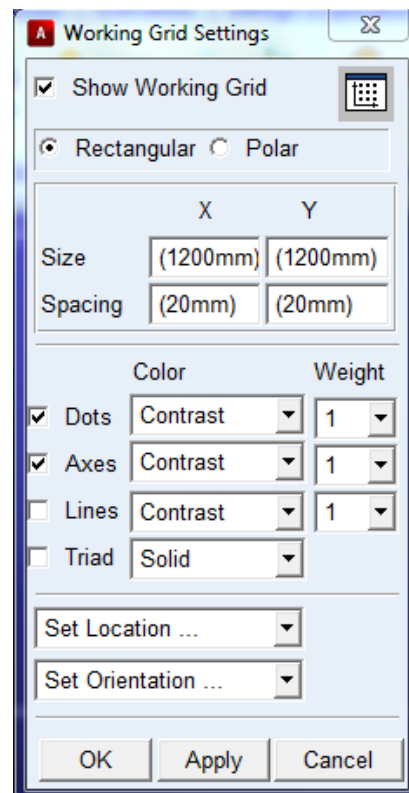
- "Working grid…"

The following window appears (Fig.1.6)

Figure 1.6

7

Insert

- "Size" and "Spacing" values (according to Fig.1.6)

Click OK.

To be able to see the coordinate values

- From "View"-menu select

"Coordinate Window".

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

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

1-5. Create model: pendulum bar

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 Fig 1.7.
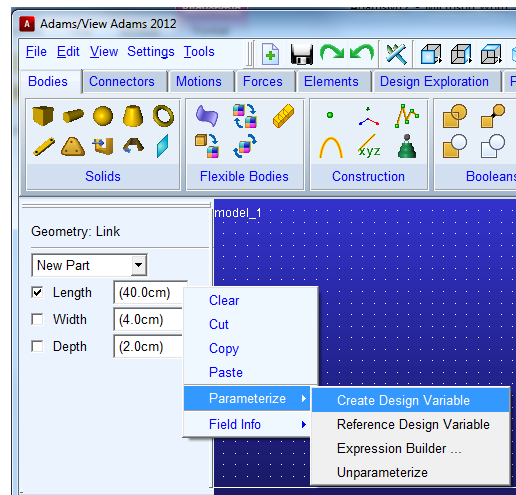

Figure 1.7

- Now create a link by clicking in the main window first at the origin (0, 0, 0) and then at (0.3, -0.3, 0).

- **1-6. Create model: Pendulum mass**

- To define the 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 100 mm as shown in Fig. 1.8. (Do not forget to mark "Radius" with a "✓")
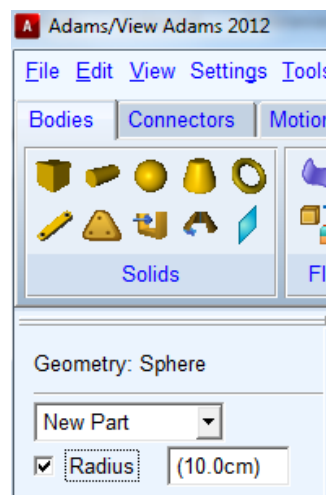

Figure 1.8

- Place the centre of the sphere at the Marker at the end of the link (0.3,-0.3,0).

1-7. Create model: cord/mass connection

- In order to connect the mass 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. 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 Fig. 1.9 below)

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**!

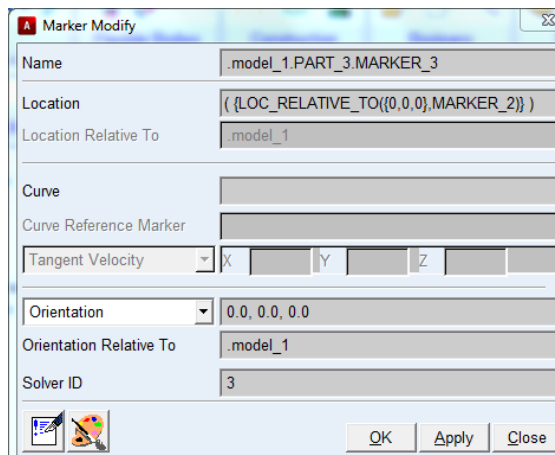|	
Marker Modify	
Name	.model_1.PART_3.MARKER_3
Location	({LOC_RELATIVE_TO({0,0,0},MARKER_2)})
Location Relative To	.model_1
Curve	
Curve Reference Marker	
Tangent Velocity	X Y Z
Orientation	0.0, 0.0, 0.0
Orientation Relative To	.model_1
Solver ID	3

OK   Apply   Close

Figure 1.9

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

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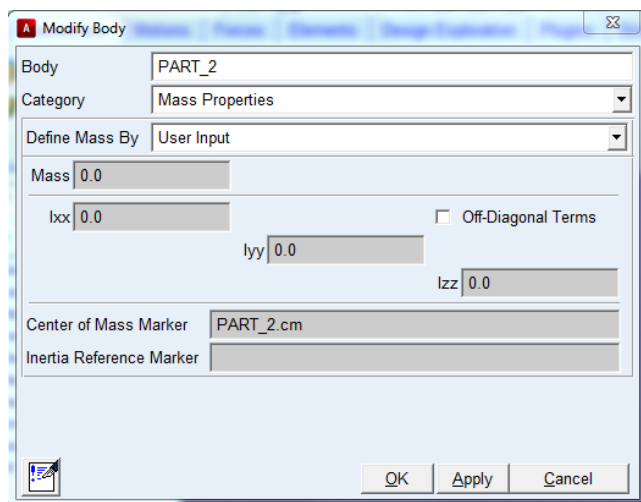

Figure 1.10

Select

- "Category: Mass Properties"

- "Define Mass By : User Input" and

and then set

- "Mass, Ixx, Iyy, Izz" to zero.

Click OK.

1-10. Define Design Variables

In order to be able to vary the length of the cord ("link") we have to modify the "Design Variable". From "Browse" choose "Design Variables" and click (rmb). Select "Modify".

In the appearing window select

- DV_1

Click OK.

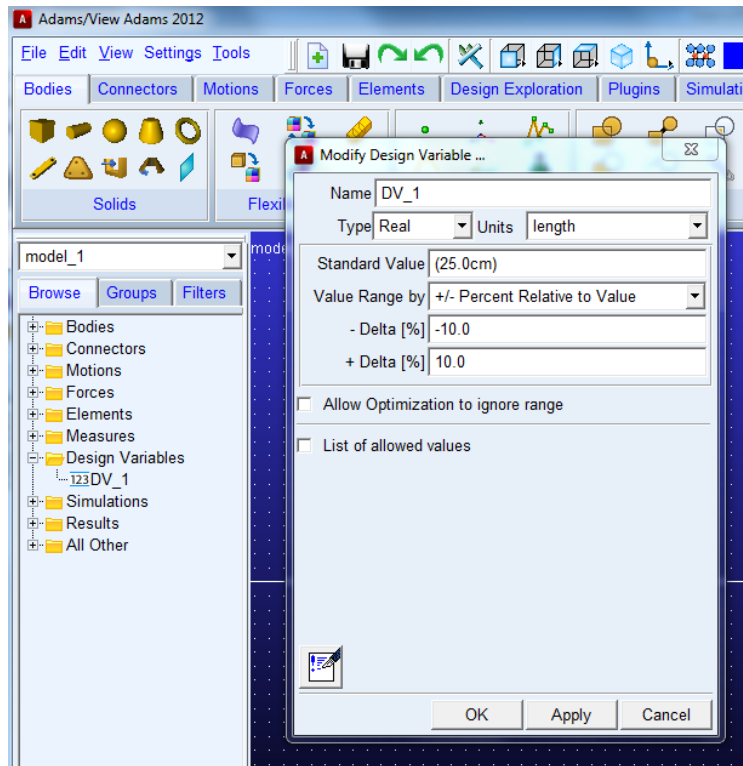A new window appears on the screen (see Fig. 1.11)

Figure 1.11

Select

- "Units: Length"

and change

- "Standard Value" to 0.25 m.

Click OK

The model should now 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

11

"Simulation"-menu and

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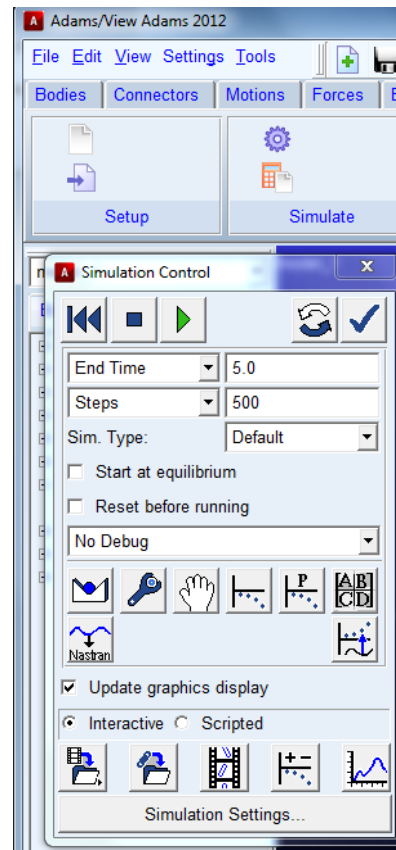
- Click on "Start or continue simulation" (play button)

  ▶️

Figure 1.12

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".

 In the appearing window (see Fig. 1.13 below) select

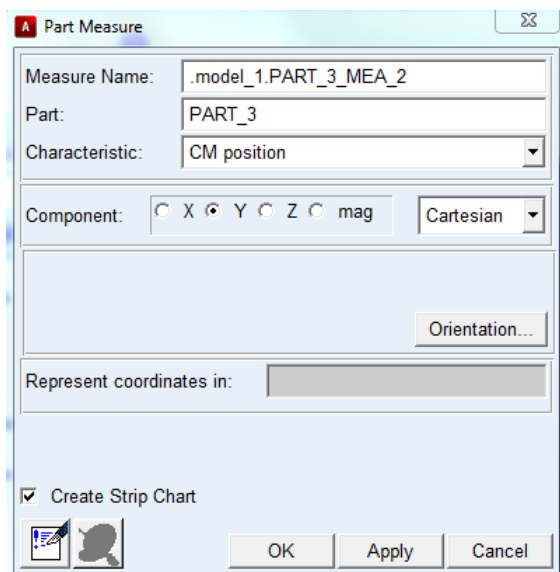- "Characteristic: CM Position" and "Component : Y"

Click OK.

Figure 1.13

The following curve (Fig. 1.14) will then appear on the window.

- Click (rmb) on the background of the plot window and choose "Transfer To Full Plot".

- Read off the period time T for the present "Case a: $m_b = 0$, m_s =steel, $L=$ 0.25m".

- Return to the "ADAMS/View" window by choosing "File" (upper right corner) "Close Plot Window".
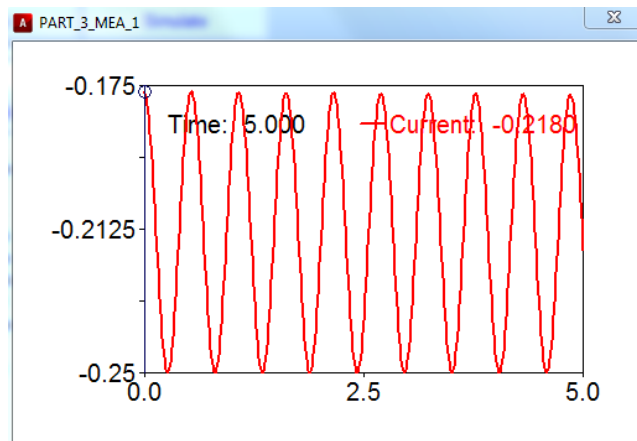

Figure 1.14

1-13. Design study

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

From "Browse" choose "Design Variables" and "DV_1". Then click (rmb) and select "Modify".

In the appearing window set

- "Standard Value" to 1.0m.

Click OK.

Now the cord of the pendulum has a length of 1.0m.

b) Reset the simulation

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

Re-run the simulation

- Click on Play button

- Click (rmb) on the background of the plot window and choose "Transfer To Full Plot".

- Read off the period time T for the present "Case b: m_b=0, m_s=steel, L=1.0m".

- Return to the "ADAMS/View" window by choosing "File" (upper right corner) "Close Plot 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"
- Click (rmb) on the "Material Type" field. Select "Material" then "Browse…" and finally choose "wood" from the list.

Repeat step **1-13 b)** above and name the curve "Case c: m_b=0, m_s=wood, L=1.0m".

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"
- Click (rmb) on the "Material Type" field. Select "Material" then "Browse…" and finally choose wood from the list.

Repeat step **1-13 b)** above and read off the period time T for the present "Case d: m_b=wood, m_s=wood, L=1.0m".

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.

Repeat step **1-13 b)** above and read off the period time T for the present "Case e: m_b=steel, m_s=wood, L=1.0m".

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.

Repeat step **1-13 b)** above and read off the period time T for the present "Case f: m_b=steel, m_s=steel, L=1.0m".

Use the **"Plot tracking"** facility to measure in the diagram! You may read off coordinate values in the small windows above the graph! See figure below!
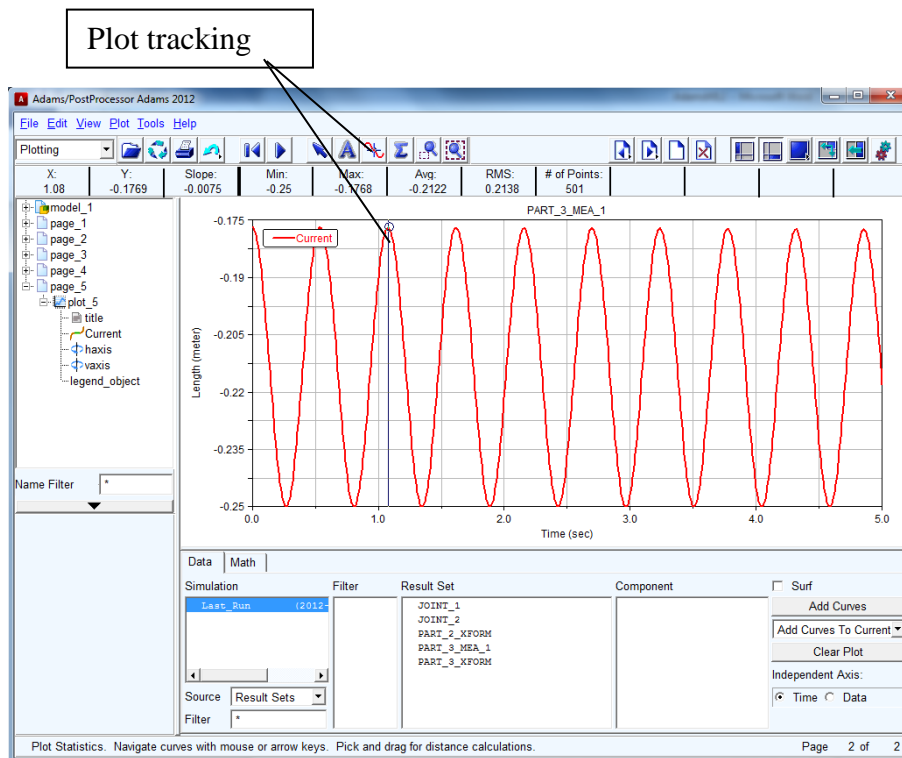
Figure 1.15

Questions to Exercise 1:

1. What is the period time T for the cases a)-f)?

2. Do the theoretical period times T, calculated in the Preparation Task agree with the simulation results arrived at in a)-d)?

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)-f) using concepts such as centre of mass, mathematical pendulum, physical pendulum. What does it take for a pendulum to be considered mathematical?

1-15. Create Model: Introduce damping

Now we are going to study a physical pendulum with damping. Use the model created in f) above. Introduce a damping mechanism in the Revolute joint by adding a Torsion spring.

- From the "Forces"-menu and "Flexible Connector" create "Rotational Spring-Damper" (first row, second column). See Figure 1.16.

    Select "Construction: 1 Location" and "Normal to Grid". Change the damping coefficient CT to "(0.01(newton-meter-sec/deg))" and set KT to zero. Select the location of the Spring-Damper by clicking on (0, 0, 0).
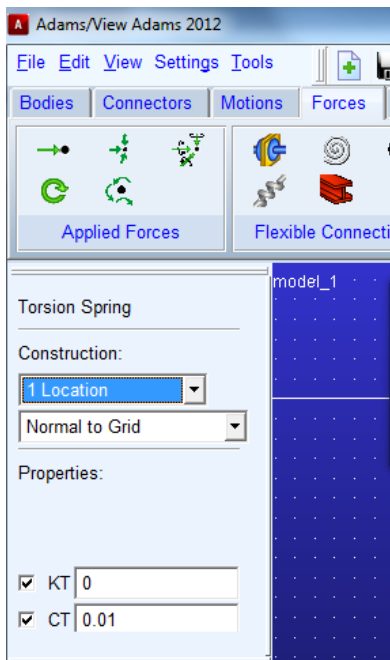
Figure 1.16

- Click on "Reset to input configuration" in the "Simulation control" window (rewind button).

Re-run the simulation.

- Click on the Play button.

- Click (rmb) on the new curve in the plot window and choose "Save Curve".

Repeat the simulation with damping coefficients 0.5, 1.0 and 10 by clicking (rmb) on the Spring-Damper and select "Modify".

- Click (rmb) on the background of the plot window and choose "Transfer To Full Plot".

Questions to Exercise 1:

6. What is the effect of damping on the period time and amplitude? Compare your findings with the theory in Meriam & Kraige *"DYNAMICS"*, *Chapter 8*!

COMPUTER EXERCISE

EXERCISE 2

In the second exercise a simple mass-spring-damper system and the effect of mechanical damping and forced oscillations will be investigated. We are studying concepts like *un-damped free vibrations, damped free vibrations and forced vibrations.*

INTRODUCTION

In this exercise, we build a simple mass-spring-damper system with an externally applied force. The theory of vibration and time response of a single degree of freedom system is presented in Chapter 8 in *"DYNAMICS"*. We will use the theory to study a simple mass-spring-damper system according to Figure 2.1 below. The system consists of a rigid body with mass m, with the possibility of a translational motion in the vertical direction

$$x = x(t)$$

where x is a coordinate measuring the vertical position of the body relative to the foundation. The body is connected by a spring-damper system to the foundation. This is modelled by using a linear spring and linear viscous damper. The force on the body from the spring-damper system may then be written

$$F_{sd} = -k(x - x_0) - c\dot{x}$$

where k is the spring constant, x_0 is the position of the housing when the spring is unloaded and c is the viscous damping coefficient. The system is subjected to an external harmonic force

$$F = F(t) = F_0 \sin \omega t$$
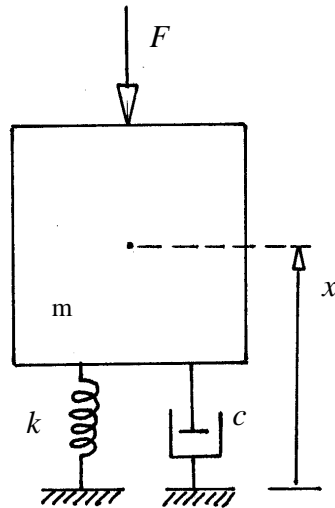
according to Figure 2.1 below. F_0 and ω are constants.

Figure 2.1: The mass-spring-damper system

PREPARATION

Preparation Tasks to Exercise 2:

With the following data: $m = 1000$kg, $k = 1.0 \cdot 10^6$N/m, $c = 6500$Ns/m and $F_0 = 100000$N, $\omega = 30$rad/s.

- Draw a free body diagram of the mechanical system.

- Derive the equation of motion in the vertical direction.

- Find the damping ratio ς and the damped natural frequency ω_d for the free vibrations of the system ($F_0 = 0$). Consult chapter 8/2 in *"DYNAMICS"* (and the Lecture Notes).

- Find the amplitude of steady-state forced vibrations of the system. Consult chapter 8/3 *"DYNAMICS"* (and the Lecture Notes).

COMPUTER EXERCISE

A simple mass-spring-damper system according to Figure 2.1 is to be simulated. The system consists of a rigid body with the possibility of a translational motion in the vertical direction. The body is connected by a spring-damper system to the foundation. This is modelled by using a linear spring and linear viscous damper. The system is given the following data: $m = 1000$kg, $k = 1.0 \cdot 10^6$N/m, $c = 6500$Ns/m and $F_0 = 1 \cdot 10^5$N, which are the same as those given in the preparations ($F_0 = 0$).

Initially, the system is given an **initial translational velocity** and no outer force is applied to the system. We will answer the following questions.

- What is the frequency of the simulated free damped vibration? Calculate it by using the ADAMS plot of the motion!

- What is the *damping ratio* ς of this vibration? Calculate it by using the ADAMS plot of the motion and the so-called *logarithmic decrement* (see *"DYNAMICS", chapter 8/2* and the Lecture Notes)!

Furthermore a **constant force** applied in the translational direction then replaces the initial velocity.

- What is the frequency of the simulated vibration?
- What is the final displacement of the body?

Finally, the system will be subjected to an external **harmonic force** $F(t) = F_0\ sin\omega t$, with ω =10rad/s.

- What is the frequency of the forced damped vibration?
- What is the amplitude of this vibration?

The external force F is then changed so that ω =10rad/s is replaced by ω = 30rad/s.

- What happens to the amplitude? Explain the reason for this behaviour.
- What is the frequency of the forced damped vibration?

Another change from ω = 30rad/s to ω = 90rad/s is performed.

- What happens to the amplitude? Explain the reason for this behaviour.
- What is the frequency of the forced damped vibration?

2-1. Start ADAMS-View.

Select

- "New model"

and insert

- "Model "Name…."
- "Gravity: Earth Normal(-Global Y)"
- "Units: MKS"

Click OK.

2-2. Define gravity

We neglect gravity in this exercise.

From the "Settings"- menu choose

- "Gravity… "
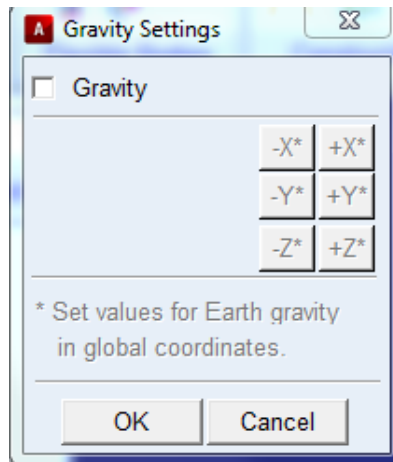- Unmark the gravity box according to Figure 2.2.

Click OK.

Figure 2.2

2-3. Create coordinate system and suitable working area

From the "Settings"-menu choose

- "Coordinate system…" and then "Space fixed"
- "Working grid…" and then insert "Size" and "Spacing" values according to

	X	Y
Size	(2m)	(2m)
Spacing	(100mm)	(100mm)

Click OK.

To be able to see the coordinate values

- From "View"-menu select "Coordinate Window"

2-4. Zoom in the working area

Zoom in the full coordinate grid by

- Click (rmb) on the background of the ADAMS/View window, select "Zoom In/Out" and follow the instructions in the "Status Toolbar" below the working area.

2-5. Create model: Body as a cubic box

Build a cubic box with side 100cm.

- In the "Bodies"-menu select "Rigid body box" (first row, first column). Insert "Length: 100cm", "Height: 100cm", "Depth: 100cm". Mark "Length", "Height" and "Depth" using "✓", see Figure 2.3 below.
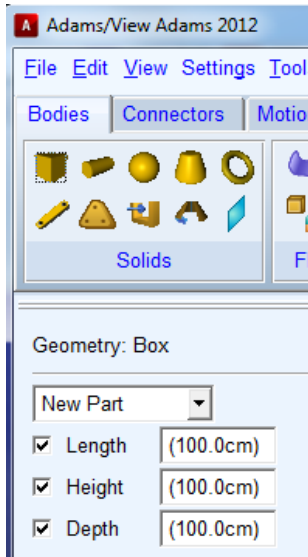- Place the box on the working area according to Figure 2.4 below.
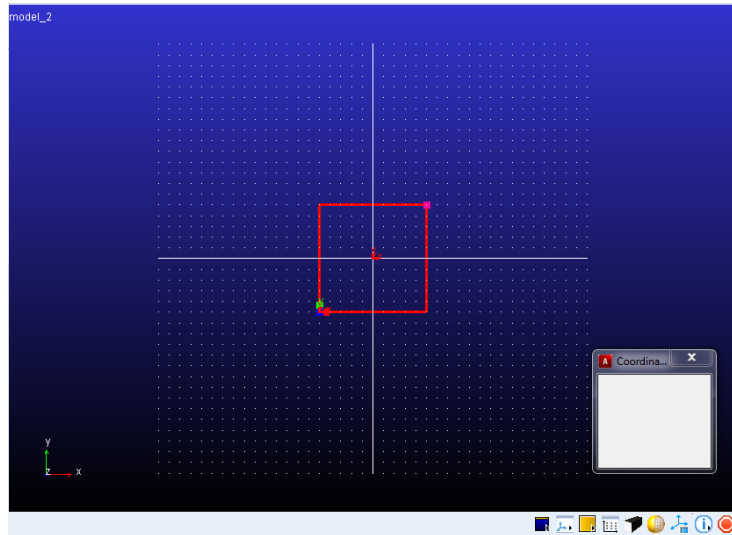
Figure 2.3

Figure 2.4

The box should now be centred at the origin.

- In the "Set the view orientation"-menu (Figure 2.5)

Figure 2.5

Choose "Set the view orientation to Right" and then click on the box. The box is now highlighted.

Selects "Position: reposition objects relative to view coordinates"

and use the "Translate" buttons (Figure 2.6, below) to move the box until the center coincides with the origin (0, 0, 0).
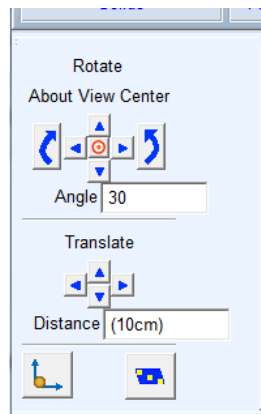

Figure 2.6

- In the "Set the view orientation"-menu (Figure 2.5) choose "Set the view orientation to Front".

2-6. Create model: Body mass

Modify the body mass (and moments of inertia). Mark the body by clicking on the box, then

- Click(rmb) on the box and select "Part" and "Modify"

- In dialog box "Modify Body" choose "Category: Mass Properties" and "Define Mass By: User Input". Insert "Mass: 1000kg", "$I_{xx} = 0$", "$I_{yy} = 0$", "$I_{zz} = 0$" and click OK.

2-7. Create model: Translational joint

We want the body to move in the vertical (y) direction only and to achieve this we introduce a translational joint connecting the body to ground.

- In the "Connectors"-menu select "Create a translational joint" (first row, third column). Select "1 Location - bodies impl." and "Pick Geometry Feature".

- Place the translational joint at the centre of mass of the body (the origin) and select the direction vector in the y-direction.

2-8. Create model: Markers for spring-damper system

We want to connect the body to ground with a spring-damper system. First we have to create a marker on the box and a marker on ground where we want to connect the spring.

- In the "Bodies"-menu select "construction" and click on "Construction geometry: Marker" (first row second column), choose "Add to Part" and "Orientation: Global XY". Select the box as the body to which the marker should be connected. Place the marker at the bottom of the box (at the point with coordinates (0,-0.5,0). We call this marker "Marker B".

- In the "Bodies"-menu select "construction" and click on "Construction geometry: Marker" (first row second column), choose "Add to Ground" and "Orientation: Global XY". Place the marker on ground at the bottom of the grid (at the point with coordinates (0,-2,0). We call this marker "Marker G".

2-9. Create model: Spring-damper system

- In the "Forces"-menu, select "Flexible Connections" and choose "Create a Translational Spring-Damper" (second row, first column). Insert "Properties: K=1000000, C = 6500 (Default units are N/m and Ns/m respectively).

- Place the spring with one end on the box ("Marker B") and the other on ground ("Marker G")

We now have the mass-spring-damper system according to Figure 2.7. Use "Set the view orientation"-menu to check that the box and the spring are centred.
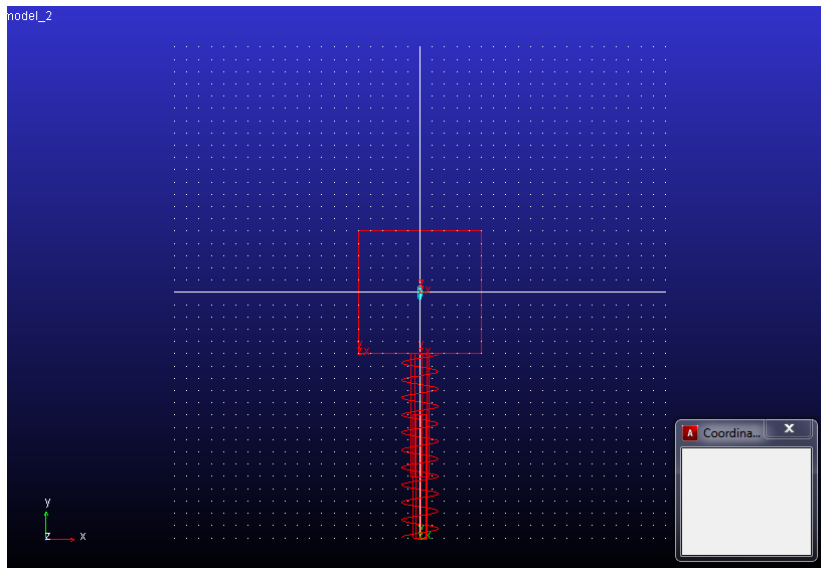

Figure 2.7

2-10. Create model: Measure of body motion

To create a measure for the position coordinates of the box

- Click (rmb) on the box and choose "Measure".

 In the appearing window select

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

Click OK.

2-11. Run simulation: Define initial conditions

We now give the body an initial velocity (10m/s in the y-direction) in order to study the free vibrations.

Mark the body by clicking on the box, then

- Click (rmb) on the box and select "Part" and "Modify"

- In the dialog box "Modify Body" choose "Category: Velocity Initial Conditions", mark "Ground" and insert

"Y axis:10.0"

Click OK.

2-12. Run simulation: Study the free vibrations

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

- Click on the "Simulate"

You can change duration time and number of steps in the simulation.
- Choose "End Time" and insert 3.0
- Choose "Steps" and insert 500

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

- Click (rmb) on the background of the plot window and choose "Transfer To Full Plot".
- Name the plot "Free damped vibrations".
- Return to the "ADAMS/View" window by choosing "File" (upper right corner) "Close Plot Window".
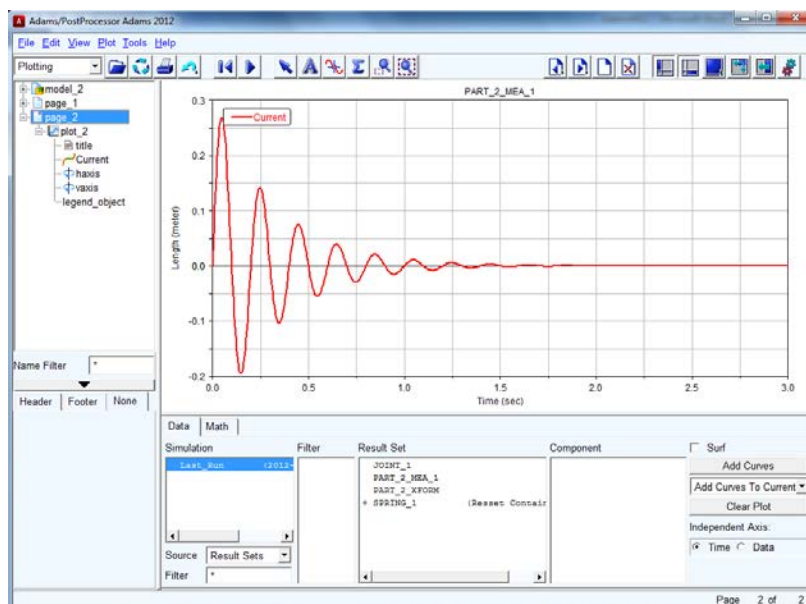
Use the **"Plot tracking"** facility to measure in the diagram! You may read off coordinate values in the small windows above the graph!

Figure 2.8

1. What is the frequency of the simulated free damped vibration? Calculate it by using the ADAMS plot of the motion!

2. What is the damping ratio ς of this vibration? Calculate it by using the ADAMS plot of the motion and the so-called *logarithmic decrement* (see *"DYNAMICS", chapter 8/2* and the Lecture Notes)!

2-13. Create model: Introduce an external force

We now want to apply an external force on the body and study the forced vibrations. First we have to create a marker on the box where we want to apply the force.

- In the "Bodies"-menu select "construction" and click on "Construction geometry: Marker" (first row second column), choose "Add to Part" and "Orientation: Global XY". Select the box as the body to which the marker should be connected. Place the marker at the top of the box (at the point with coordinates (0,0.5,0)). We call this marker "Marker F".

We now select the force.

- In the "Forces"-menu select "Applied Forces: Create a Force (Single-Component) Applied Force" (first row, first column). Select "Body moving", "Pick Feature" and "Custom".

- Select the box as the body to which the force should be connected.

- Apply the force on the box at "Marker F". Direct the force in the negative y-direction.

A new dialog box will appear

- Select "Define Using: Function" and insert "Function: 100000".

Click OK.

This means that we are now applying a constant force of 100000N. We restore the velocity initial condition to zero:

- Click(rmb) on the box and select "Part" and "Modify"

- In dialog box "Modify Body" choose "Category: Velocity Initial Conditions", mark "Ground" and insert

  "Y axis:0.0"

Click OK.

2-14. Run simulation: Force step response

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

- Click on the "Simulate"
- Choose "End Time" and insert 3.0
- Choose "Steps" and insert 500
- Click on "Start or continue simulation" (play button)

- Play and plot the result.
- Click (rmb) on the background of the plot window and choose "Transfer To Full Plot".
- Name the plot "Force step response".
- Return to the "ADAMS/View" window by choosing "File" (upper right corner) "Close Plot Window".

   3. What is the frequency of the simulated vibration?
   4. What is the final displacement of the body?

2-15. Run simulation: Harmonic force response, ω = 10 rad/s

We will now change to a harmonic external force, $F = F(t) = F_0 \sin \omega t$ where ω is measured in *radians per second*. We take $F_0 = 100000N$ and ω = *10* rad/s.

- From "Browse" choose "Force". Click (rmb) on FORCE_2. Select "Modify".
- In the dialog box change to "Function: 100000*SIN(10*time)".
- Click OK.
- Go to the "Simulation"-menu and insert End Time: 2" and "Steps: 500". Play and plot the result.
- Click (rmb) on the background of the plot window and choose "Transfer To Full Plot".
- Name the plot "Forced damped vibrations, ω = 10 rad/s ".
- Return to the "ADAMS/View" window by choosing "File" (upper right corner) "Close Plot Window".

    5. What is the frequency of the forced damped vibration?

    6. What is the amplitude of this vibration? Measure it!

2-16. Run simulation: Harmonic force response, ω = 30 rad/s

We will now change to a harmonic external force, $F_e = F_0 \sin\omega t$, where $\omega = 30$ rad/s.

- From "Browse" choose "Force". Click (rmb) on FORCE_2. Select "Modify".

- In the dialog box change to "Function: 100000*SIN(30*time)".

- Click OK.

- Go to the "Simulation"-menu and insert End Time: 2" and "Steps: 500". Play and plot the result.

- Click (rmb) on the background of the plot window and choose "Transfer To Full Plot".

- Name the plot "Forced damped vibrations, ω = 30 rad/s ".

- Return to the "ADAMS/View" window by choosing "File" (upper right corner) "Close Plot Window".

    7. What happens to the amplitude? Measure it! Explain the reason for this behaviour.

    8. What is the frequency of the forced damped vibration?

2-17. Run simulation: Harmonic force response, ω = 90 rad/s

We will now change to a harmonic external force, $F_e = F_0 \sin\omega t$, where $\omega = 90$ rad/s.

- From "Browse" choose "Force". Click (rmb) on FORCE_2. Select "Modify".

- In the dialog box change to "Function: 100000*SIN(90*time)".

- Click OK.

- Go to the "Simulation"-menu and insert "End Time: 2" and "Steps: 500". Play and plot the result.

- Click (rmb) on the background of the plot window and choose "Transfer To Full Plot".

- Name the plot "Forced damped vibrations, ω = 90 rad/s ".

- Return to the "ADAMS/View" window by choosing "File" (upper right corner) "Close Plot Window".

Questions to Exercise 2:

9. What happens to the amplitude? Measure it! Explain the reason for this behaviour.

10. What is the frequency of the forced damped vibration?