Introduction to Coach 6 Oscillations
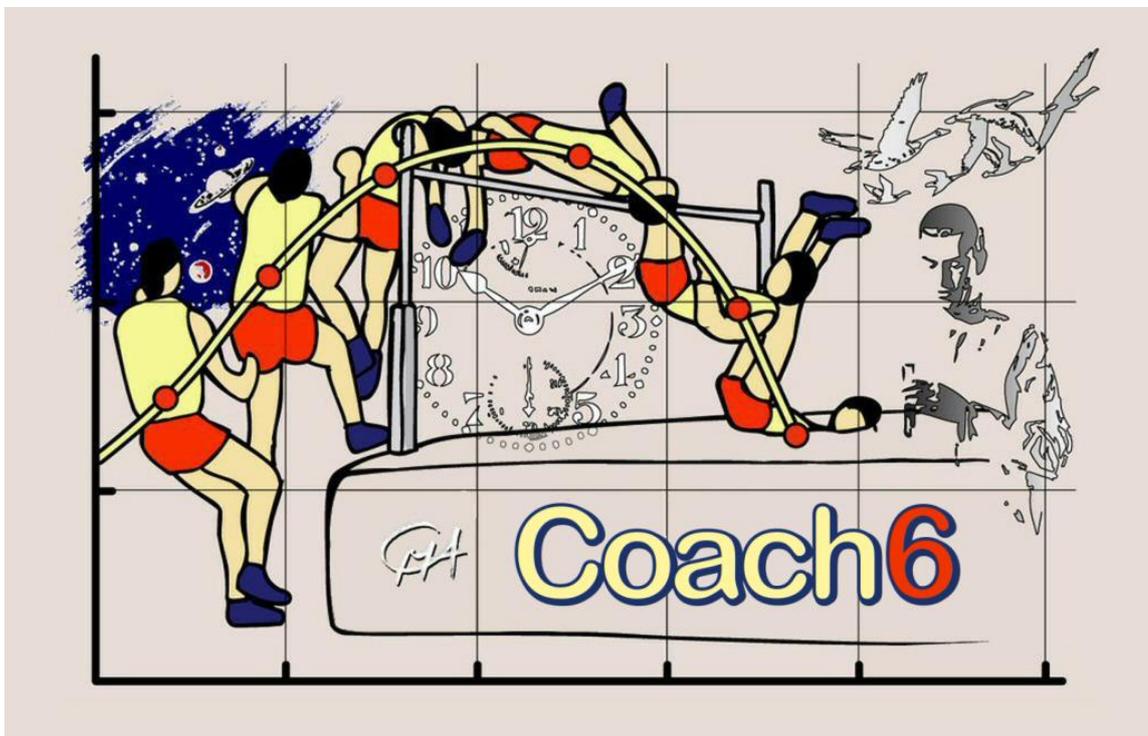
A. Coach 6 ●..

> This introductory module presents short descriptions of the software package Coach 6 and activities for learning basic features of the program.
>
> The simple step-by-step tutorials are meant for teachers and are related to the topic of **oscillations**.

Coach 6 is a versatile Learning and Authoring software for Science and Technology Education developed by Foundation **C**entre for **M**icrocomputer **A**pplications. The software is designed according to the concept of an open learning environment and integrates tools for data logging, control, video measurement, modelling and data processing and offers a multimedia environment with text, pictures, video clips, animations and internet links. It supports inquiry-led approach to learning.

Coach 6 is organized in projects filled with activities. An activity is an individual exercise that a student can perform. It can be data-logging measurement, video measurement, control or modelling activity (see detailed description further).

In an activity, information is displayed in windowpanes. Panes are used to display text, pictures, graphs, tables, values, meters, notes, video clips, models and programs. The tool button available in every pane provides context sensitive tools that match the pane type and the task, which is currently performed (i.e., taking measurements, reviewing data).

Coach as an authoring environment gives opportunities to create multimedia activities, labs, or curriculum materials for students using the authoring features. An author can:

- insert instructions, notes and text along with images, animations and video clips
- add links to relevant Internet pages
- predefine experiments
- set the movies to collect video data
- create dynamical models.

An author decides about the mode students will use in an activity. The modes range from Junior Fixed, which gives students access only to a few necessary controls, through Junior Flexible, Junior Own Lab up to Senior Student mode that allows students to use Coach as an open set of tools.

The complete description of Coach 6 functions and features can be found in the manual *Guide to Coach 6*.

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Measurement Activities

The Coach 6 Measurement Activities are used to collect data from sensors e.g. for temperature, light intensity, sound level, pH, etc. (with voltage output) and to display, analyze and process the measurement results.

The experiments in Coach are easy to set-up by dragging-and-dropping sensor icons into inputs of the interface panel on the computer screen. When a 'real' interface with sensors is connected to the computer, the sensor icons on the screen panel show the actual values measured by the sensors. Many predefined calibrated sensors are available in Coach Sensor Library. In addition user can define and calibrate own sensors by using advanced calibration program.

Coach collects measurement data according to the measurement method and measurement settings after pressing the green Start button. In most of activities the time-based measurement method is used, measurements are stored at regular time intervals according to the sampling frequency. In the event-based measurement method measurements are taken each time a pulse (event) is received on an interface counter input. In the manually triggered measurement the single measurement is taken every time a button is pressed. This method allows type-in data from keyboard.

During the measurement data can be presented in graphs, tables, meters or displayed as digital values.

Before starting a measurement, it is good practice to make a prediction based on a hypothesis of what will happen in the experiment. The option Sketch is used to predict a graph of a measurement or model. After the run, the shape of the predicted graph can be compared with the measured graph.

Coach's unique combination of measuring and control facilities (Measurement Activities with a Program) allows performing automated measurements. An example of such controlled experiment is automated titration with the CMA step motor burette in the module Strong and Weak Acids.

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Data Video Activities

The Coach 6 Data Video Activities are used to make measurements on digital video clips or digital images. In these activities it is possible to analyze motion of real objects and events which happen outside the classroom. The events can be rather ordinary, every day events such as basketball shots, soccer kicks, amusement-park rides, plant growth or more unusual ones like jumping on the Moon, car crashes or the motion of a manikin as it strikes an air bag during a car collision.

During the video measurements, the data are collected in the form of points -

● manually by clicking in successive (selected) frames on (a point of) a moving object, or

● automatically by tracking (a point of) a moving object.

From the number of frames per second with which the video clip was recorded, time information is deduced, while position information is measured on the two dimensions of the video image (picture), after calibration.
The collected data can be plotted in a graph, viewed in a table, used for further analysis and modelling and can even serve to calculate the locations of other points such as centre of mass. Graphs are synchronized with the video frames. When scanning the data in the diagram, the corresponding video frames are shown.

With the option Capture video clips can be directly recorded, edited and analyzed.

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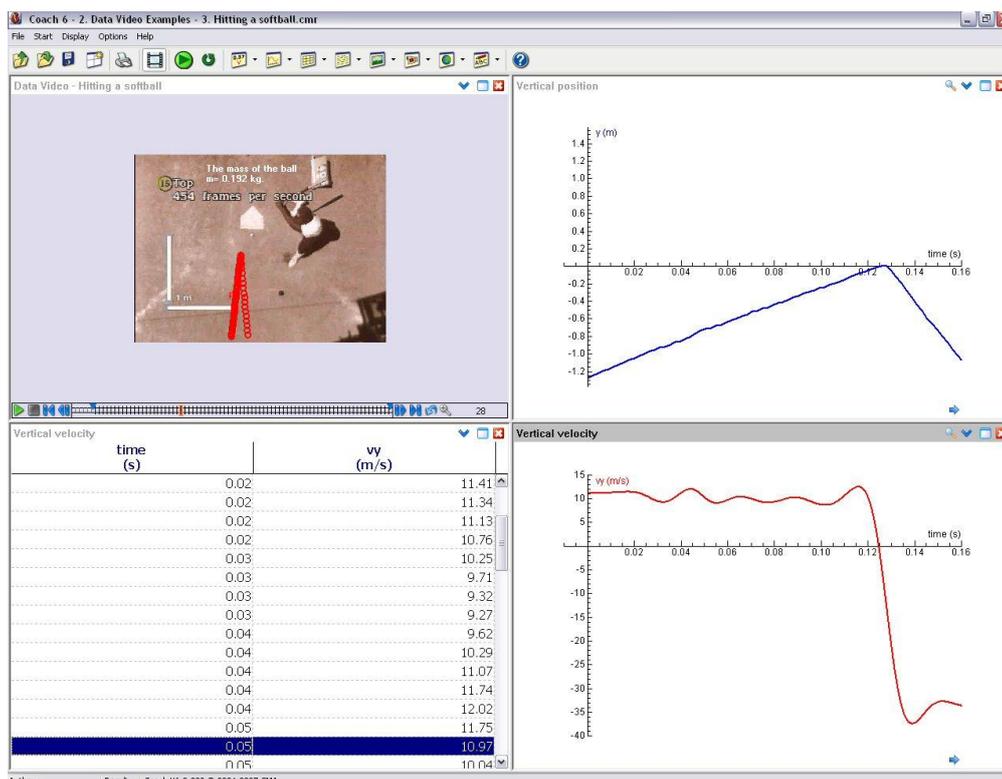
Modelling Activities

Modelling Activities enable a student to use or create numerical models of continuous changing systems. Coach offers three modes of constructing and viewing models – Graphical, Equation and Text modes.

The Graphical mode is based on the stock and flow approach[1]. The central concept of this methodology is to understand how the system changes over a time and to give an understanding of the system's structure, the interaction between its objects and the behaviour it can produce. Models are built with graphical elements: state variables (similar to the stock concept), flows, auxiliary variables and constants. Discrete changes of state variables can be provoked with events. Relationships between model variables are given by connectors.

Based on the structure and mathematical definitions from a Graphical model, Coach constructs:

● an Equations model which consists of a sequence of differential equations, formulae for the calculation of auxiliary variables, a set of initial values and constant values

● a Text model according to the rules of Coach Language[23] and consists of equations from which the model variables are calculated according to the selected iteration method.

It is also possible to create and modify models directly in Equations and Text modes. In Equations mode, the model equations are constructed by using icons for variables. In Text mode, a model is built by entering equations which have to be structured according to the rules of Coach Language.

Based on the given numerical model and the selected numerical method, iterative calculations are performed. The results of the calculations can be displayed as numbers, in graphs or tables.

The model results can be then compared with experimental data (from measurement or video measurement). The model can be easily modified or a parameter can be changed so students can test their hypothesis and make links between the real experiment and the theoretical model.
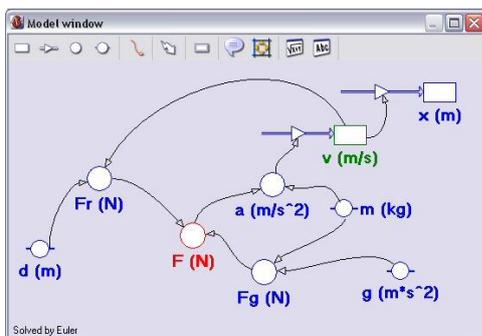
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[1] Approach developed by Prof. Jay. W. Forrester at MIT in the early 1960s.

[2] Coach Language is the programming language of Coach 6 used in Control and Modelling activities.

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B. Student Activities ●●●

ACTIVITY 1. INTRODUCTION TO DATA VIDEO – SWINGING PENDULUM

Learning Objectives:

1. To learn how to make video measurements in Coach 6

2. Analyse the pendulum's motion

Activity method:

In this activity you will analyze the motion of a simple gravity pendulum. Such pendulum is one of the simplest mechanical oscillating systems (and consists of a mass attached to a rope, which, when given an initial push, will swing back and forth under the influence of gravity).

This example is used to teach you how to make measurements in the Data Video Activity of Coach 6.

Starting Coach 6 and opening an activity:

1. Start Coach 6 by clicking on the Windows **Start** button, move to **Programs,** then to **CMA Coach 6** and next click on one of the Coach 6 program icons (for the Author mode, an Author key is required[3]) Coach shows the Main Toolbar (and in Author mode the Main Menu).

2. Use the Open button to open activity **Oscillations > Swinging pendulum**.

Opening video:

1. To open the video, right click the Data-Video Window and select Open… > Video.

2. Select *Swinging pendulum* video.

3. A video screen showing the first frame of the video appears on the screen.

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[3] See Guide to Coach 6

Playing video:

1. The video clip shows the pendulum motion. Play the video by clicking on the *Play* button on the video control bar.

2. To browse through frames, use the frame controller.

3. By clicking frame on the frame controller, a selected frame appears on the screen. At the right side of the frame controller you can find the Zoom button which allows zooming a part of the frame controller. First you have to select the frames you would like to zoom: click the first frame, while keeping the <Shift>-key pressed, click the last frame of the selection. Now click the Zoom button to zoom the frame selection.

Video calibration:

Distance

To perform the measurement you need to scale the video - you have to tell which distance on the screen corresponds to which actual distance. The "real" ruler is shown on the screen. You have to also define your coordinate system is.

1. Open the Tool menu by right clicking the Data-Video window and select the *Change scale...* option.

2. Select *Same scale on all directions*.

3. The horizontal ruler (default red) and the coordinate system (default yellow) appear on the video screen.

4. Move and match the red ruler with the vertical ruler shown on the video screen (match the first 0.5 m of the ruler)

5. Specify in the *Scale Settings* dialog the scale length of 0.5 m.

6. Position the coordinate system by dragging its origin (drag the small circle).

7. Click *OK* when you are ready.

Time

This option is used to specify how fast the video was taken.

8. Right click the Data-Video window and select the *Time calibration...* option.

9. This video clip was recorded with 25 frames per second (it can be red from '*Properties*' of the video file). This information is used to

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connect the frame number with the time t (in seconds), as soon as you have decided which frame corresponds with $t=0$. Select the choice of $t=0$ *at first selected frame*.

10. Click *OK* when you are ready.

Coordinate system settings

11. Right click the Data-Video window and select the *Co-ordinate system...* option.

12. Since the camera didn't move during recording of this movie choose *Same at all frames*.

13. Click *OK* when you are ready.

Video Points:

Video points are points collected during the video measurement.

1. From the Tool menu select the *Video Points...* option.

2. You are going to measure only one video point so choose 1 measured point per frame.

3. Go to the *Markers and colors* part of the dialog window and choose your favourite colour and marker for the video points (a white circle works fine).

Frames:

You still have to tell how you want take a video measurement. Usually the manual video measurement is performed only on a number of selected frames and the point tracking measurement on all frames of the video..

1. From the Tool menu select the *Frames…* option.

2. For manual measurement select *From 1 to 127 step size 5*. In this case it means you will measure circa every 5th frame. If you use the Point tracking use all frames
All selected frames on the frame controller are black, not selected frames are grey.

Displaying data:

1. To graph the data, select the Tool menu *Display as a Diagram* option and click the lower, left empty pane.

2. This will plot positions PX and PY versus time. The advantage of preparing the graph before the measurement is that you will see data appears on the graph during the measurements.

3. To see data in a table select the Tool menu option *Display as a Table* and click the lower, left pane. If you need to create more panes you can do it by dragging borders from the borders of main Coach window.

Collecting data:

Data can be collected manually or automatically by using Point tracking. First perform manual measurement then do the same measurement with the Point tracking.

Manually

1. Start the measurement by clicking the green *Start* button.

2. Coach automatically brings the first selected video frame on the screen.

3. Move the cursor (viewfinder) over the video screen to locate the pendulum's bob.

4. Click to store the first video point.

5. The video clip automatically advances to the next frame. Click the next point.

6. Continue clicking on the bob in each selected frame until you reach the last frame of the video.

Using the point tracking

1. Via the Tool menu select *Point Tracking....*

2. Via the Tool menu click *Point Tracking Settings* and set the colours of the tracking areas to white.

3. Via the Tool menu select *Go to tracking frame*.

4. On the tracking frame drag the tracking areas - viewfinder over the pendulum's bob.

5. Start the measurement by clicking the green *Start* button.

6. Coach automatically collects the data.

Live updating:

If you are not satisfied with some of your marked video points you can come back to a frame and move a video point to another location. You do this by selecting the frame in the frame control bar and dragging the point to the desired location. The diagram/table update simultaneously. (Note the sensitivity of the velocity plot to the location of the point.)

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You can also add some extra points after your measurement is finished.

1. Select extra frames by clicking a frame on the frame controller and press the *<INS>*- key on your keyboard. The selected frame becomes black. (You can deselect frames using the *<DEL>*- key).

2. Click the green *Start* button. The video automatically brings you to the selected frame. Locate your new video point.

3. Do the same for other extra selected frames.

Replay:

One of the greatest features of the Data Video analysis is the ability to replay the situation and watch the graphs while movie plays.

1. Click on the *Replay* button.

2. Specify the Replay time or set the replay playing speed.

3. Click *OK*. Your data should now be replaying on screen. You see live update of graphs and tables during the motion of the runner.

Assignments:

The results of the measurement are graphs of the pendulum's amplitude in horizontal and vertical direction versus time.

1. Ignore the small vertical motion of the bob and create the plot of the pendulum's amplitude in vertical direction.
    *   Right click the Diagram pane and select *Create/Edit a diagram.*
    *   Go to the data range C3: P1Y and make it *Invisible*.

2. Describe the resulting graph.
    *   Use the diagram Tool menu option *Scan* to walk through the points in the diagram. Notice that when scanning in the diagram the corresponding video points are shown in the Data video window*.*
    *   You can use for example the diagram Tool menu option *Process/Analyse > Function Fit*.

3. Determine the period of the pendulum and calculate the frequency of the pendulum.
    *   Use for example the *Scan* option*.*

4. Measure the length of the pendulum rope and calculate the theoretical value of the period of the pendulum. How they compare to each other?
    *   Right click the Data-Video window and mark *Show > Ruler*. Drag the ruler to measure a distance on the video screen*.*

5. Create and analyse the velocity versus time graph. Where is the pendulum bob when its velocity is zero, and its velocity is greatest? What is the maximal velocity of the pendulum?

    ● To make a velocity versus time graph you can use the diagram Tool menu option *Process/Analyse > Derivative.*

    ● Option *Scan* helps in analyzing the graph.

6. Create and analyse the acceleration versus time graph.
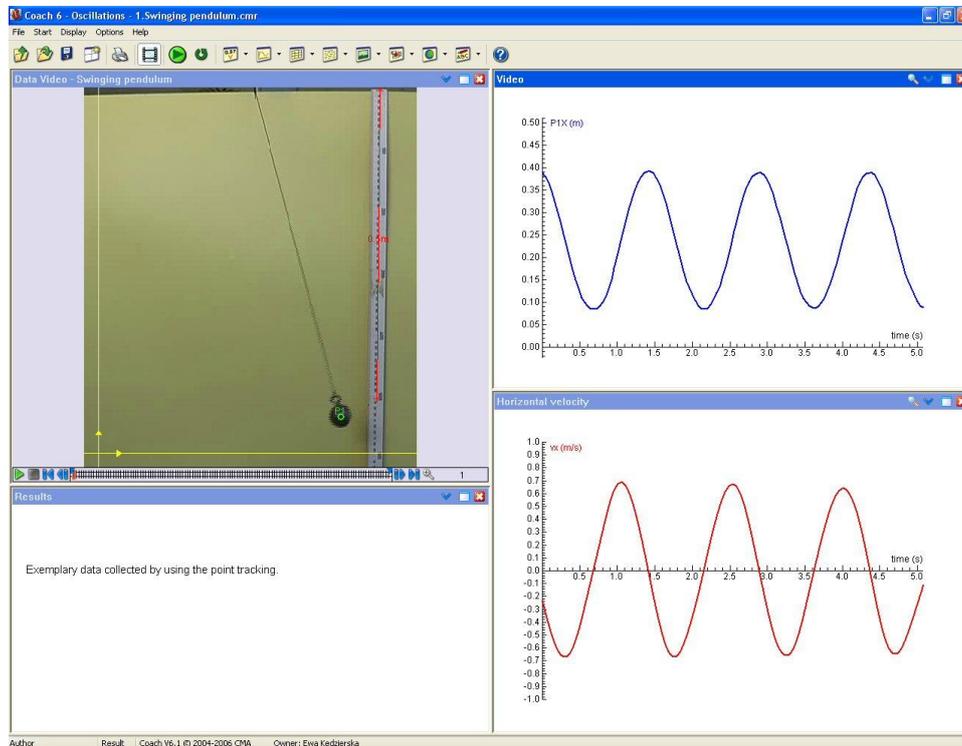
Exemplary data collected by using point tracking.

ACTIVITY 2. SPRING OSCILLATIONS

Learning Objectives:

1. To learn how to perform a measurement in Coach 6
2. To record and analyse the motion of the mass oscillating on a spring

Materials:

- Interface (CoachLab II/II$^+$)
- Ultrasonic motion detector
- Force sensor (± 50 N) (optional)
- Spring, mass, stand and clamp

Activity method:

Another example of a simple oscillating system is a mass hanging on a spring. When the mass is pulled down by a distance x from its rest position, the spring exerts a force (given by Hooke's law $F = -kx$). This force tends to restore the mass to its original equilibrium position.

In this experiment you are going to record and investigate the motion of such mass-spring system. You will record the mass position with the ultrasonic motion detector and force with the force sensor (optional). This example is used to teach you how to perform measurements with sensors in the Measurement Activity of Coach 6.Set up your experiment as shown on the photo.

Starting Coach 6 and opening an activity:

1. Start Coach 6 by clicking on the Windows **Start** button, move to **Programs,** then to **CMA Coach 6** and next click on one of the Coach 6 program icons (for the Author mode, an Author key is required[4]) Coach shows the Main Toolbar (and in Author mode the Main Menu).

2. Use the Open button to open activity *Oscillations > Spring oscillations.*

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[4] See Guide to Coach 6

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Setting up of the experiment:

1. Attach the spring to a horizontal rod connected to the stand. If you use the force sensor attach the spring to the hook of the sensor.

2. Hang the mass to the spring. The stand should not move and the mass should be able to move up and down over a 20 cm distance. Place the motion detector below the mass. (Take care that the mass does not come too close to the detector or does not fall off the spring).

3. Connect the motion detector to a sonic input of an interface.

4. If you use the force sensor connect it to input 1 of an interface.

Preparing the experiment settings:

1. Click the *Panel Window* button to display the interface panel.

2. The Motion detector icon and Force sensor icons are located on the sensor palette. Drag the sensor icons to respective interface inputs, the Motion Detector icon to a sonic input, the Force sensor icon to input 1. (This is not necessary for sensors which are automatically detected).

3. The values measured by the sensors are displayed on the sensor icons.

4. To see data on graph/table right click a sensor icon, select *Display as a Diagram/Display as a Table* and place the diagram/table in one of empty panes.

5. Click the *Settings* button and enter the measurement settings: *Measuring time = 20 seconds, Sampling frequency = 50 Hz*.

6. Click *OK* to confirm.

Measuring:

1. Lift the mass and release.

2. Start a measurement by clicking the *Start* button.

3. Save data of the motion by using the *Save as* button.

4. If you work with the force sensor you can adjust the zero point of the sensor when the mass is attached to the sensor. When the system is in equilibrium right click the sensor icon and select the *Set to zero* option. The sensor values will oscillate around the value of 0 N.

Assignments:

The results of your measurement are displayed as a graph of the mass position versus time and a graph of force versus time (if you have used the force sensor).

●   Determine the period T of the motion. Based on the period, calculate the frequency of the oscillations.

●   Is the recorded motion the simple harmonic motion? You can check this by fitting your data with sin function.

   -   Right click the diagram window and select the *Process/Analyze > Function-fit* option. Use the function $y=sin(bx+c)+d$, first press the *Estimate* button and then the *Refine* button.

   -   Does the function fit the data well?

● Investigate how changing the amplitude changes the period of the motion. Take care not to use too large an amplitude.

● Investigate how changing the mass changes the period of the motion.

● Place the velocity-time and acceleration-time diagrams in the windows on the screen.

   -   Both diagrams can be made by using the Tool menu *Process/Analyze > Derivative*.

● What are the velocity and the acceleration values when the mass is at equilibrium position?
   What are the velocity and the acceleration values when the mass is at maximum or minimum position?

   -   Use the diagram Tool menu option *Scan*.

● If the force was measured, create a graph of force vs. displacement. What conclusion can be drawn?

ACTIVITY 3. MODELLING HARMONIC MOTION

Learning Objectives:

1. To learn how to create graphical model in Coach 6

2. To create graphical model of harmonic motion

Activity method:

In the previous activity you recorded the simple harmonic motion. In this activity you are going to create a graphical model which describes such motion.

This example is used to teach you how to work in the Modelling Activity of Coach 6. You are going to start with a simple (idealized) model of the mass attached to a horizontal spring. When the spring is stretched or compressed and then released it oscillates back and forth around its equilibrium position. The force exerted by the spring is proportional to the spring displacement and its direction is always opposite the direction of the mass's displacement.

The acceleration of the mass can be found from the Newton's Second Law $a=F/m$.
For the small time interval dt the motion equations describing the displacement and velocity are dx/dt=v and dv/dt = a.

Starting Coach 6 and opening an activity:

1. Start Coach 6 by clicking on the Windows **Start** button, move to **Programs,** then to **CMA Coach 6** and next click on one of the Coach 6 program icons (for the Author mode, an Author key is required[5]) Coach shows the Main Toolbar (and in Author mode the Main Menu).

2. Use the Open button to open activity ***Oscillations > Modelling harmonic motion***.

Constructing a model :

In Graphical mode the variables of a model are represented by graphical symbols. The relations between the variables are indicated by connectors drawn between the symbols.

1. To represent a position of the mass the state variable is used.

   ● Click the *State variable* icon in the toolbar of the Model window. The cursor shape changes into the symbol of the state variable*.*

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[5] See Guide to Coach 6

- Move the cursor onto the Model window, position it and click. The variable is labelled State_1.
- Rename the variable into *position*. The symbol and its name remain selected which allows easy renaming it by overtyping.

2. To represent the rate of change of the position, the flow variable is used.
   - Select the *Flow* icon by clicking on it, position the cursor at the left side of the *Position* and drag it to the right until it makes contact with the *position* variable.

3. To represent a velocity of the mass, the state variable is used.
   - Create the *velocity* variable in a similar way as the *position* variable. Place the new variable symbol below the *position* variable.

4. To represent the rate of change of the velocity, the flow variable is used.
   - Select the *Flow* icon by clicking on it, position the cursor at the left side of the *Velocity* and drag it to the right until it makes contact with the state variable.

5. To represent acceleration, the auxiliary variable is used. Why?
   - Click the *Auxiliary variable* icon in the toolbar of the Model window. The cursor shape changes into the symbol of the auxiliary variable.
   - Move the cursor onto the Model window, position it below the *velocity* variable symbol and click. The variable is labelled Aux_1.
   - Rename the variable into *acceleration*. The symbol and its name remain selected which allows easy renaming it by overtyping.

6. In the similar way as *acceleration* variable, create the *force* variable; this is also an auxiliary variable.

7. To represent the spring mass, the constant is used.
   - Select the *Constant* icon by clicking on it, position the cursor in the Model window and click.
   - Rename the variable into *mass*. The symbol and its name remain selected which allows easy renaming it by overtyping.

8. In the similar way define the spring constant *k*.

9. Once the symbols of all model variables are in place the relationship between the variables can be given. To draw a relation:
   - Select the *Connector* icon in the toolbar of the Model window. The shape of the cursor changes into a small connector icon, click a symbol from which the connector has to start, hold and drag the cursor to a symbol where it has to end. If you are worried about the arc traced by your connector, you can bend it in any way you like. To do so click the connector and use 4 given points; 2 points which stick to the variable allow sliding around the variable edges. The other 2 points allow bending the connector.

- Draw connectors between the model variables.

  Relation 1: The rate of change of position is equal to its velocity. Drag the connector from the *velocity* variable to the flow of the *position* variable.

  Relation 2: The rate of change of velocity is equal to its acceleration. Drag the connector from the *acceleration* variable to the flow of the *velocity* variable.

  Relation 3 and 4: The acceleration is determined by its mass and the force acting on the mass. Drag the first connector from the *mass* variable to the *acceleration* variable, and the second connector from the *force* to *acceleration.*

  Relation 5 and 6: Force is determined by the spring constant and the position of the mass. Drag the first connector from the *k* variable to the *force* variable, and the second connector from the *position* to *force.*

10. Now you are ready to enter formulae and initial values. The symbols with no defined initial values and formulae show a question mark *?.*

    - Double click on the *k* constant and fill its properties. A spring constant value should be typed in the Definition field*.*

    - Double click on the *mass* constant and define its properties. Define the mass.

    - Double click the *force* symbol and define it by the formula *-k*x*. You can type the formula directly in the Definition field or you can use the Formula editor.

    - Double click on the *acceleration* and define it by *force/mass*.

    - Double click the flow of the velocity. Notice that this flow is equal to the *acceleration*. This definite was made automatically because there is only one connection made to this.

    - Double click on the *velocity* and enter its initial value for example *0 (m/s)*.

    - Double click the flow of the position; it is automatically defined as equal to the *velocity*.

    - Double click on the position and enter its initial value for example *0.2 (m)*.
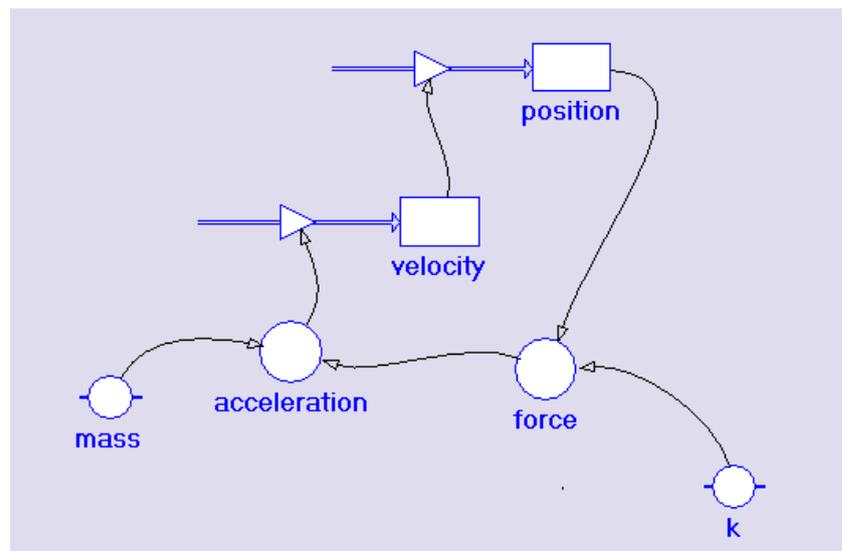
11. Select a way of presenting your model data. Right click a variable symbol (start with the *position variable)* and select a diagram, table or value. Click a pane where you want place the diagram, table or value.

12. In Graphical mode the model is defined with mathematical equations "hidden" behind the graphical symbols. In Equations mode these equations can be made visible.

    - Click the *Equations mode* button to see the mathematical equations*.*

● Click the *Graphical mode* button to return.

Model in Graphical mode.

Model in Equations mode (difference equations representation).

Model settings:

1. Press the *Settings* button on the Activity toolbar and specify the start value to *0* and stop value to *20*. Select a time step of *0.1*. This step interval is the increment of time over which the program does the calculations specified by the model.

2. Set the integration method to Runge-Kutta 2.
    Notice that simple integration method (Euler) method does not work properly for this example.

Executing a model:

1. Execute your model by clicking the green *Start* button. The computer will plot the graphs. Use the *Zoom to fit* button to adjust the scale of your diagram.

2. Right click the Model window and check the *Run controller* option. You can use the time slider to step through the time values.

3. Use the *Simulate* option to investigate effects of changing model parameters. Right click the Model window and select the *Simulate* option. Select a parameter from the drop-down-list of model variables. Specify a parameter value by typing or setting a value and click *Execute.*

Adapting the model for vertical spring :

To create a model of vertical mass-spring system (as one used the previous data-logging activity) very few changes are needed in the model.

A. The net force acting on the mass is equal to the sum of weight and the restoring force exerted by the spring

B. The initial position of the mass should be calculated taking into account the initial displacement from the rest length of the spring

1. Load as the background graph the experimental data from the *Spring oscillations* experiment result and check or your model well fit the experimental data.

2. Right click a diagram and select *Import Background Graph***.**.. Open a Result file.

3. Specify settings for the import process and click *OK.*

Further modifying the model (for example pendulum or damped oscillation):

In the model for the pendulum, the restoring force comes from the x-component of the Tension in the string. However the direction of the Tension changes as the pendulum swings. The motion can be modelled if you find the x-component of the Tension. Hence the restoring force will be equivalent to the Tension*sin(α) where α is the angle between the pendulum rope and the equilibrium position.

1. Load as the background graph the experimental data from the *Swinging pendulum* experiment result and check or your model well fit the experimental data.