An elevator ride

SOCRATES MINERVA Programme 99843-CP-1-2002-1-PL

Data acquisition (TI 83/TI84)

Objective:
In this experiment the objective is to study the motion of an elevator car measuring its acceleration. The probe is an accelerometer connected to a CBL or a LabPro.

Before setting up the experiment make sure that you have the program ACCCAR and ACCCAL in your TI-83 or TI-84 calculator. If not, download them. Short instruction on how to download here. And now download ACCCAR and ACCCAL.
Start the program ACCCAR. First you get the question whether the accelerometer needs to be calibrated or not. You have to calibrate in every new experiment. Therefore the answer is Y. After this follow the instructions on the screen of the calculator. As zero-position you use the direction of the movement of the car. It is important that the accelerometer is kept absolutely still during the calibration
The next question asks for the number of data-points per second. The answer depends on the length of the ride. Input for example 10. On request you then enter the number of data-points, for example 300. In this example data will be collected for 30 seconds. Now the screen says ENTER, which means that the program is waiting for you to press ENTER to start collecting data.
Attach the accelerometer vertically, arrow up, so that it measures the acceleration in the vertical direction. Start the experiment by pressing ENTER and press a button in the elevator. When the experiment is done the calculator screen shows a graph of the acceleration (m/s^2) versus time (s). The acceleration is stored in list L_2 and the time in list L_1. (If the experiment is repeated you can skip the calibration).
If you are unable to conduct the experiment there are files set up so that you can study the experiment and analyse previously collected data. Your options are shown below:
Get data to your TI83 or TI83 Plus. (Short instruction how to download).
You can find the files that no you need to analyse the data in the appropriate folder. If you have a TI83 Plus calculator download the group ELEVDATA. If you have a standard TI83 the lists L1 and L2 must be downloaded to your calculator.

An elevator ride

SOCRATES MINERVA Programme 99843-CP-1-2002-1-PL

Data analysis (TI 83/TI84)

If you have any problems handling the graphing calculator help is available using the links that are underlined and highlighted in blue.
Start with graphing the acceleration versus time in a Scatter plot.

Analysis 1: Discussion of the acceleration data

Study the graph and try to figure out what happens with the elevator during the experiment. If you use previous collected data you must know that during this experiment the arrow on the accelerometer pointed upwards during data collection. Now try to explain the graph. For example what is the direction of the travel? Doing this, remember that it is acceleration that is measured. What does the "peaks" mean? Defend your answer.

Analysis 2: Investigating the velocity as a function of time

The first object is to graph velocity versus time, but before you do that try to sketch it using the acceleration – time – plot above

Acceleration is defined as $a = \frac{\Delta v}{\Delta t}$, which can be written as $\Delta v = a \cdot \Delta t$. To the left of the equals sign we have the velocity change and to the right the acceleration times the length of the time interval.
Calculate the change in velocity in each time interval assuming that the acceleration is constant in that small time interval. Use list L_3 to calculate the change in velocity.
To get the velocity as a function of time we need to sum the changes in velocity, assuming it starts from 0. To do this we use the command CumSum (cumulated sum), which is found under LIST, Ops or, easiest, in the catalog. Use list L_4 to calculate the cumulated sum of list L_3.
Graph velocity data versus time in a scatter plot. Does it look as you had expected?
Look at the graph and try to explain it. For example, what is the direction of the ride? What does the two separated peaks mean? Is the elevator car travelling in the same direction all the time?

Analysis 3: Investigating the distance as a function of time

Can you make any statements concerning how many storeys the elevator car travels during the study? Does it stop somewhere? On which storeys? To answer these and similar questions we graph the distance versus time.

Velocity is defined as $v = \frac{\Delta s}{\Delta t}$, which can be written as $\Delta s = v \cdot \Delta t$. To the left of the equals sign we have the distance change and to the right the velocity times the length of the time interval.
Now you recognise the actions from the previous section. So go on in the same way using lists L_5 and L_6 to store your new values.
Explain the graph and answer the questions above.

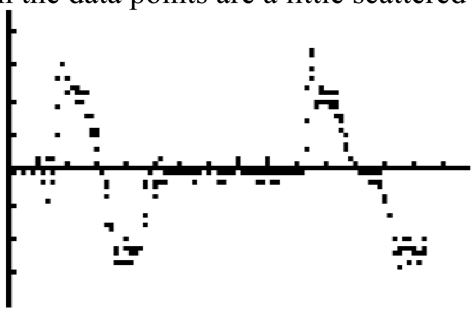
When you have finished your work, **but not before**, you can compare your conclusions with this completed analysis.

An elevator ride

SOCRATES MINERVA
Programme
99843-CP-1-2002-1-PL

Completed analysis (TI83/TI84)

The graph of the acceleration data from the elevator ride that is available on the internet is shown below. As can be seen the data points are a little scattered due to vibrations.

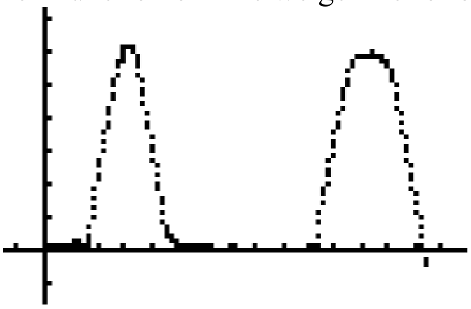


Analysis 1

After a short while there is a positive acceleration, meaning that the elevator car accelerates upwards. At about 6 s the elevator car reduces its speed until about 10 s. The areas between the graph and the x-axis in the positive and negative pulses seems to be equal, indicating that the elevator car is at rest a few storeys above the start level.
The elevator car is at rest for 10 s. After this it continues upwards. First accelerating, then after a while with zero acceleration until it brakes again. The experiment ends somewhat before the elevator car is at rest.

Analysis 2

When we graph the velocity as a function of time we get the following graph:



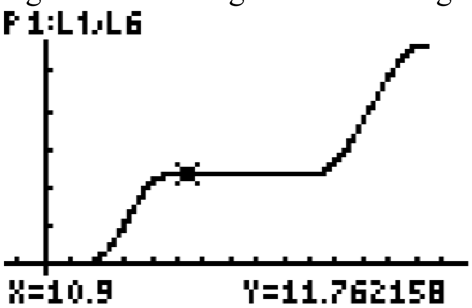
In this graph we see that the errors caused by vibrations in the first graph has almost disappeared when we calculated the cumulated sum. This is because they are randomized and when we add them we get a sum of 0.

In the graph we see that the velocity is positive meaning that the elevator car is moving in the direction of positive acceleration, that is upwards. The first peak is a result of the acceleration followed by a deceleration in the upward direction. The elevator car stops between 10 s and 20 s, when it again continues upwards. This time the elevator moves at constant speed for a few seconds before decelerating to another stop.

As can be seen the velocity at the end is negative. According to the acceleration graph above the experiment was ended before the elevator car came to a complete stop, meaning that the velocity should have been positive at the end. This is a result of summing small systematic errors which are due to difficulties calibrating the accelerometer. A small error in each data point adds up to a large error if they are systematic.

Analysis 3

Doing it all one more time we get the following distance-time-graph.



We can see that the elevator indeed has travelled upwards and using TRACE we find that is has stopped 12 m and 28 m above the start level. The stops might have occurred at the 4:th and 10:th floor, counting 3 m per floor.