Accelerating objects - car

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 a 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 car-ride. Input for example 5. On request you then enter the number of data-points, for example 100. In this example data will be collected for 500 seconds, ie, a little more than six minutes. Now the screen says ENTER, which means that the program is waiting for you to press ENTER to start collecting data.
Attach the accelerometer horizontally so that it measures the acceleration in the forward direction of the car. Start the experiment by pressing ENTER and start driving.
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).

A car ride

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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 car during the experiment. If you use previous collected data you must know that during this experiment the arrow on the accelerometer pointed forward during data collection. Now try to explain the graph.

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 meaning of the plateaus? Where do you find the greatest acceleration? Why? What does a negative slope mean? Which is the highest speed?

Analysis 3: Investigating the distance as a function of time

Now it is time to find out how far the car have travelled. Again you can try to sketch a distance – time – graph using the velocity – plot in analysis 2.

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 question above.

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

A car ride

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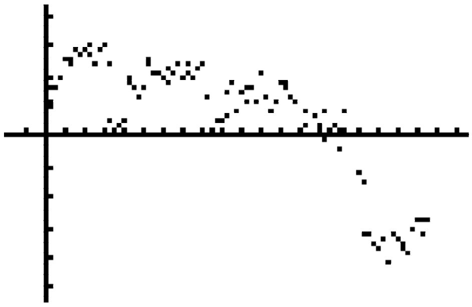
Complete analysis (TI83/TI84)

The graph of the acceleration data from the car ride that is available on the internet is shown below.

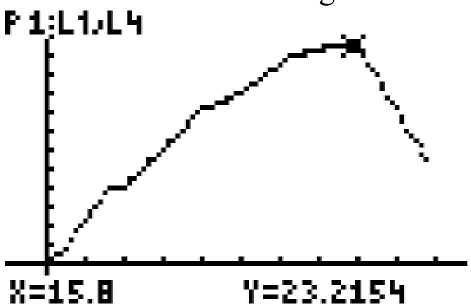


Analysis 1

The first thing we notice is that the data points are somewhat scattered. This is mainly caused by vibrations in the car. Although there seem to be three different levels. Between them the acceleration is close to zero. In the end the acceleration drops below zero to a fairly large negative value.
The different levels represent the acceleration in the different gears, first, second second and third gear. We see that every level is getting smaller, indicating that the acceleration is largest in first gear and then drops. The small parts in between with almost 0 acceleration is when we are changing gears and the clutch has "disconnected" the engine from the wheels. No forward force of course give no acceleration
The last, negative, part of the graph is when the driver brakes to reduce the speed of the car.

Analysis 2

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

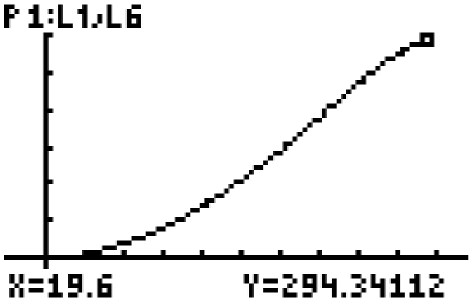


In this graph we see that the errors caused by vibrations in the first graph has almost disappeared when we calculated the cumulated sum. This is because they are randomized and when we add them we get a sum of 0.

In this graph it is very clear that the acceleration is greatest in the beginning, the slope being the steepest. This steep change in velocity is followed by a plateau when the driver is changing gears. Then follows the acceleration in second gear. This is repeated once more before the driver reduces speed and starts breaking. Data collection stops before the car comes to a complete stop.
In the graph above we have used TRACE to find the highest speed. In this car ride it was 23 m/s or 84 km/h

Analysis 3

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



This graph might look a bit surprising. We see almost no signs at all of the different accelerations in first, second and third gears an none at all of the parts where the driver is changing gears. This is because the changing of gears makes the graph go from a 2:nd degree curve to a linear, but only for a very short time. Then it continues, but with a slightly smaller acceleration.
Another surprise is the end of the curve. The part where he brakes is not very pronounced. That is because the car is still going forward and with a rather high speed. It is not until the very last points that we see the change.
Finally it might be surprising to see that a rather relaxed 20 s car-ride took the car almost 300 meters!