

Accelerating objects - aeroplane take off



Data acquisition (TI 83/TI84)

Objective:

In this experiment the objective is to study the motion of an airplane measuring its acceleration. Since it is hard to perform this experiment nowadays, we will use data taken previous to September 11th 2001. The aircraft was a Boeing 737 and data was collected during takeoff from Stockholm-Arlanda. The probe was an accelerometer connected to a CBL and a TI83.

The acceleration data were collected mainly during the motion along the runway at the airport. The accelerations are stored in list L_2 and the corresponding times in list L_1 . The acceleration is measured in m/s^2 and time is in seconds.

Since you probably are unable to conduct the experiment there are files set up so that you can study the experiment and analyse previously collected data. If it is possible for you to perform the real experiment follow the setup procedure described in the experiment "[A car ride](#)" [Get data to your TI83 or TI83 Plus](#). (Short instruction how to download).

You can find the files that you need to analyse the data in the "Data sample" page . If you have a TI83 Plus calculator download the group [FLDATA](#). If you have a standard TI83 the lists [L1](#) and [L2](#) must be downloaded to your calculator.

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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 explain it. Try to figure out when the airplane leaves the ground. Please bear in mind that the aircraft is tilted a lot when it leaves ground. This gives the accelerometer a contribution due to a component of gravity.

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

$$a = \frac{\Delta v}{\Delta t}$$

Acceleration is defined as $\frac{\Delta v}{\Delta t}$, 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 L₃ 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 catalogue. Use list L₄ to [calculate the cumulated sum](#) of list L₃.

Graph velocity data versus time in a [scatter plot](#). Does it look as you had expected?

Look at this graph and compare with the previous one. Try to explain it. What about the takeoff speed?

Analysis 3: Investigating the distance as a function of time

How far did the airplane go during the first ten seconds? How long must the runway be? To answer these and similar questions we graph the distance versus time.

$$v = \frac{\Delta s}{\Delta t}$$

Velocity is defined as $\frac{\Delta s}{\Delta t}$, 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 L₅ and L₆ to store your new values.

Explain the graph and answer the questions above.

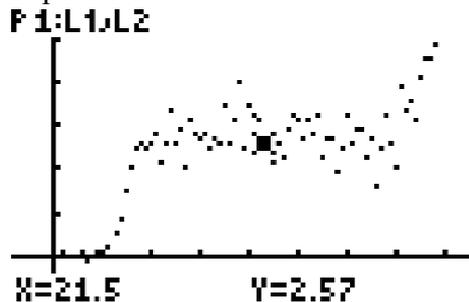
When you have finished your work, **but not before**, you can compare your conclusions with this [completed analysis](#).

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Completed analysis (TI 83/TI84)

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

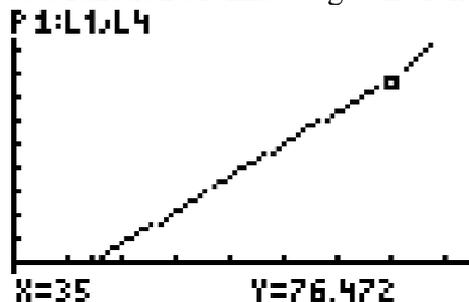


Analysis 1

At the start the acceleration increases very fast to a level of approximately $2,5 \text{ m/s}^2$. This level is rather constant until the end when it raises. This is when the airplane leaves the ground and the accelerometer which are directed forward tilts and starts to measure part of the gravity.

Analysis 2

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

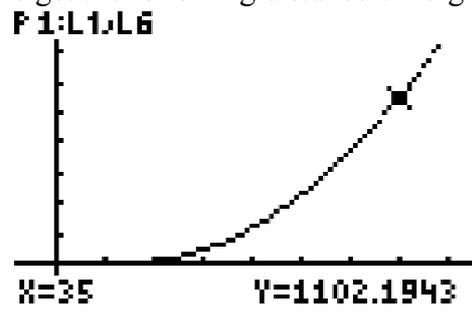


In this graph we see that the errors caused by vibrations in the first graph has almost disappeared when we calculated the cumulated sum. This is because they are randomized and when we add them we get a sum of 0.

In the graph we see that the velocity is rise in velocity is almost linear, which corresponds to acceleration data being fairly constant. Since the last part of the curve, when there is a break, depends on the plane leaving the ground we can estimate the speed at takeoff to 76 m/s or 273 km/h. A speed that the airplane reached in less than 30 s!

Analysis 3

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



If we say that takeoff was 35 s after the data collection begun, according to the previous analysis, we see that the airplane has travelled a distance of 1100 m! In only 30 s!
