What is Measured by Falling Dynamometer

We hang a bunch of keys on a dynamometer and let the dynamometer with the keys fall down from a height onto a soft surface. We let the dynamometer measure the force exerted by the keys on the dynamometer with the frequency of one hundred measurements per second. What does the graph of force vs. time look like?

What you need

- Vernier DFS-BTA dynamometer
- a bunch of keys
- a jacket, sweater or other soft pad for softening the fall
- a long ruler (at least 30 cm long, not a set square)

Tasks

Estimation of measurement results

Before conducting the measurement, read the procedure and estimate the results. Try to sketch on a piece of paper the time dependence of force acting on the hook of the dynamometer during the whole measurement. These initial concepts may differ; try to get to a solution that everybody agrees with by mutual discussion.

Preparation of measurement

1. Connect the dynamometer to your computer and run the Logger Lite programme.
2. Set Duration to 10 s and Sampling Rate to 100 Hz.
3. Place the dynamometer a table so that the hook is in a horizontal position. In this position set the sensor to zero (*Experiment* > *Zero*). **Set the sensor to zero after every fall before each measurement.**
4. Create a soft impact point on the floor with a jacket or a sweater.
5. Hang the bunch of keys on the dynamometer and place in an appropriate height.

Measurement

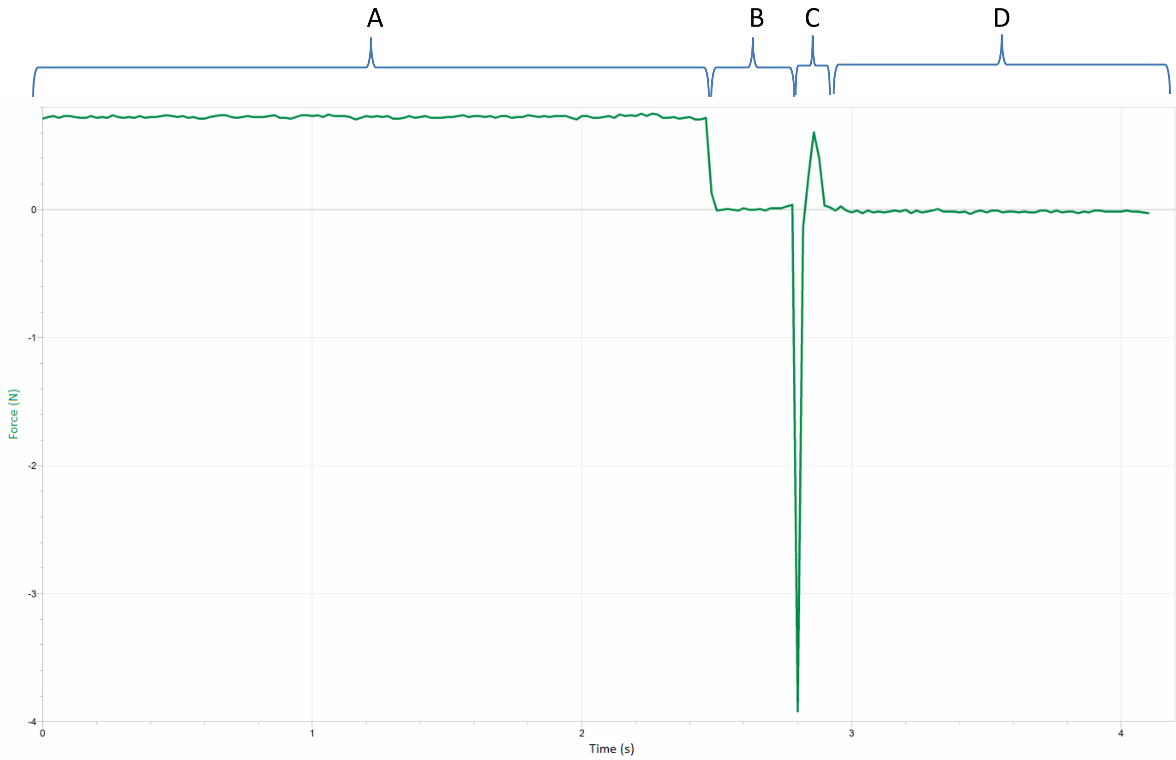
1. Start the measurement. Wait for a second or two, and then let the dynamometer with the keys fall down on the soft pad.
2. Perform the measurement for a fall from a height of knees, waist, eyes and an arm stretched out over your head.
3. Remember to put the sensor back in the horizontal position and set it to zero before each measurement (after every fall).

Analysis of measurement results

1. In particular parts of the graph, try to identify each phase of the experiment - which corresponds to holding the keys, to the fall, to the impact and to the phase when the dynamometer was put on the table after the impact.
2. What are the differences between the graphs and what are their similarities?
3. Compare the measured graphs with your estimates. If they are different, explain the differences.

Notes for teachers

Typical graph



Part A corresponds to holding the dynamometer before letting it fall. From the values of the force you can determine the mass of the keys.

Part B (zero force) corresponds to a free fall of the dynamometer and the keys. During the fall, the keys and the dynamometer are weightless. From the length of this phase, the height from which the keys were dropped can be calculated using the relationship $h = \frac{1}{2} g \cdot t^2$

Part C corresponds to the impact of the keys with the pad and a fast deceleration. While the acceleration took place on a relatively long track, the keys had to slow down on a few millimetres or centimetres (depending on the cushioning of the impact place). A shorter operating track corresponds to a significantly larger force.

Part D corresponds to the final stage of the experiment, when the dynamometer is motionless.

Possible extensions

If teachers see that students have enough time, they may have them calculate (and then measure), how long is the phase B for a randomly chosen initial height.

Students can also use the principle of calculation of the falling time to measure their reaction time. One student holds the ruler vertically; the other holds his fingers at the value 0 cm without touching the ruler. The first student drops the ruler at a random time and the second student has to catch it by clasping his fingers. They can easily deduce how many centimetres the ruler has fallen before it was caught. The falling time (and thus the reaction time) is determined form the relationship $h = \frac{1}{2} g \cdot t^2$.