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Freie Universität Berlin

- Institut of Physics –

Linear Motion

Protocol to the attempt of the physical internship I

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Physical bases

Theory + literature values

Linear motions are normally on dimension motions that are characterised by three formulas. Uniform motions happen without external forces. A constant force powers uniformly accelerated motions. By using Newton's laws of motion the mathematical description of the above is $F = m * a$ bzw. $F = m * \dot{v}$. There will be a linear increase of the velocity over the time in the graphical analysis because of the constant acceleration. Another possibility for a motion is a acceleration or power depending on the time. But that is not what we have right here.

In our experiment is beside of the forcing power F a velocity depending braking force, which has to be considered into the motion equation.

$$F - d\vartheta = m * \frac{dv}{dt}$$

Equation 1

This differential equation can be easily transformed into the well-known equation:

$$\dot{\vartheta} + \frac{\delta}{m} v = \frac{F}{m}$$

Equation 2

The homogeneous equation is needed, to get it, a generic exponential approach is used

$$v(t) = A * e^{\lambda t}$$

Equation 3

Which results by inserting into

$$A\lambda e^{\lambda t} + \frac{d}{m} A e^{\lambda t} = 0$$
$$\Longrightarrow \lambda + \frac{d}{m} = 0;\ \Rightarrow \lambda = -\frac{d}{m}$$

Equation 4

A special solve of the inhomogeneous equation is given by

$$v = \frac{F}{\delta}$$

Equation 5

The still “free” parameter A will be replaced by the starting condition $v_0 = A + \frac{F}{\delta} = 0 \Longrightarrow A = -\frac{F}{\delta}$ so the complete solve can be seen by

$$v(t) = -\frac{F}{\delta}e^{-\frac{\delta}{m}t} + \frac{F}{\delta}$$

$$= \frac{F}{\delta}(1 - e^{-\frac{\delta}{m}t})$$

Equation 6

This results in a “constant limit velocity” for a permanent accelerated movement on the limit case $v_\infty = \frac{F}{\delta}$ which is individually setting by the dependency on the friction power or the braking power. The time in which that effect can be observed is highly depending on the friction and the mass. Where the general correlation exists; the shortest time will be with a little mass and a high friction.

Experimental setup + device list

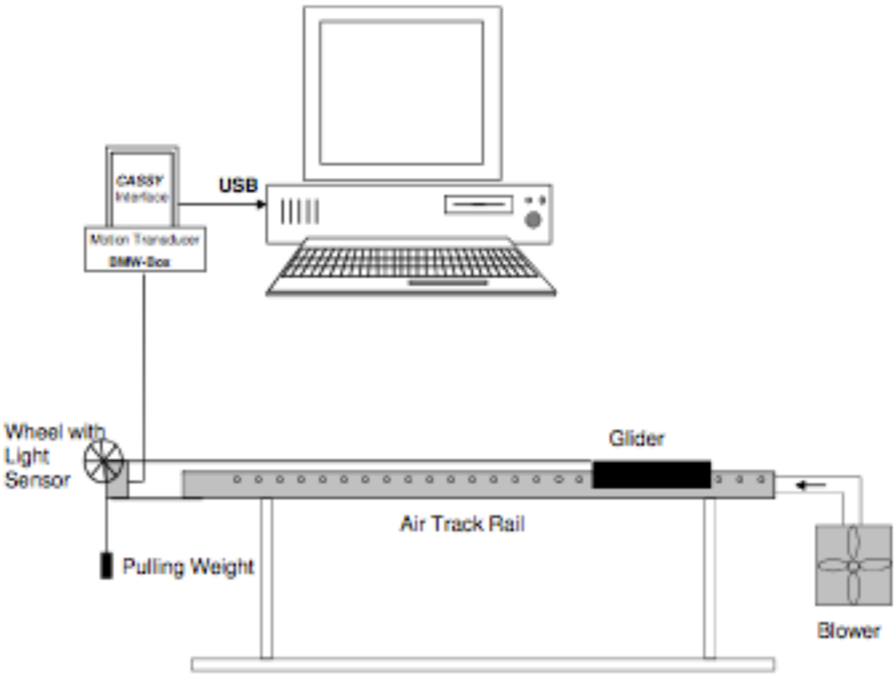


Illustration 1

Measurement protocol

Excercises

Adjusting the air track and the measuring system. (1)

The air track has to be levelled so that the glider has no forces resulting by an elevation. On this point we have a problem. Our track had a (very tiny) parabolic form. We managed to level the track as perfect as we can. So that we can see that the glider is holding still on the “parabolic” ends.

The “CASSY-System” also has to be nulled, because the way is measured by a wire running over a wheel – the friction between wire and wheel is not perfect. There can be measurement errors if the wire was slipping over the wheel so that it was not running.

Investigating motions with constant force and under the influence of a velocity proportional damping force (2+3)

Table 1 shows the values of the extra weight for this exercise. All the other values of the measurement were taken by the “CASSY-Lab System” and are attached to this protocol.

Description	Name	Value in g	Error
Paperclip	M_b	0,4	±0,1
Mass 1	M_a1	5,0	±0,1
Mass 2	M_a2	11,2	±0,1
Mass 3	M_a3	2,3	±0,1
Weight 1	M_g1	87,9	±0,1
Weight 2	M_g2	187,5	±0,1
Weight 3	M_g3	120,3	±0,1
Weight 4	M_g4	142,8	±0,1
Extra Weight 1	M_z1	99,6	±0,1
Extra Weight 1	M_z2	32,4	±0,1
Extra Weight 3	M_z3	54,9	±0,1

Table 1

Evaluation and discussion

Plots

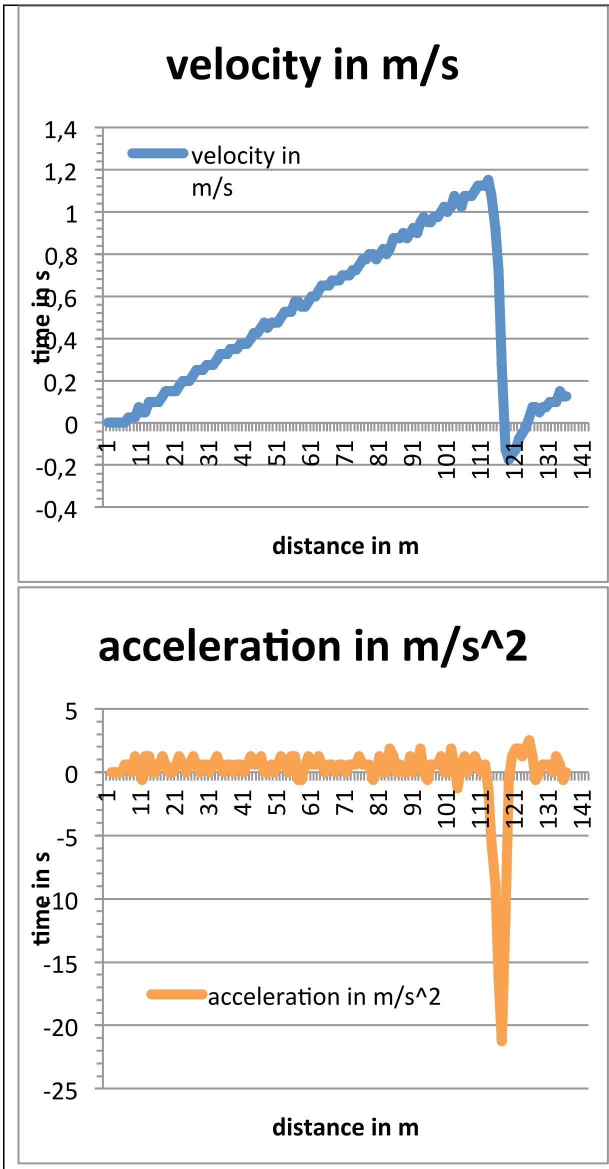


Illustration 2 Excercise 2 Measurement 1

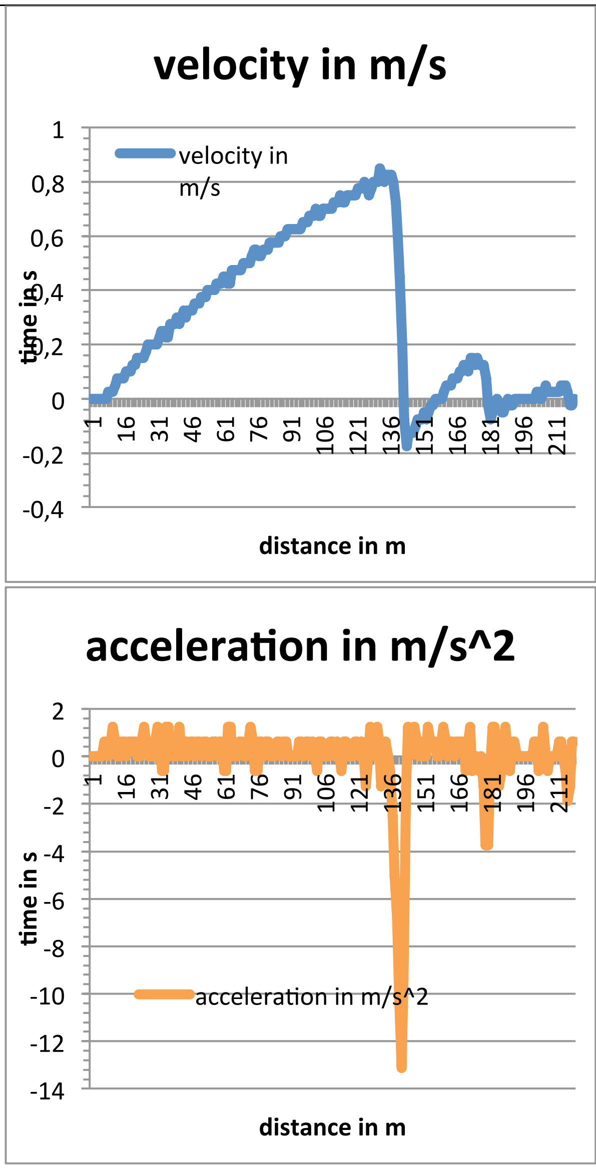


Illustration 3 Excercise 3 Measurement 1

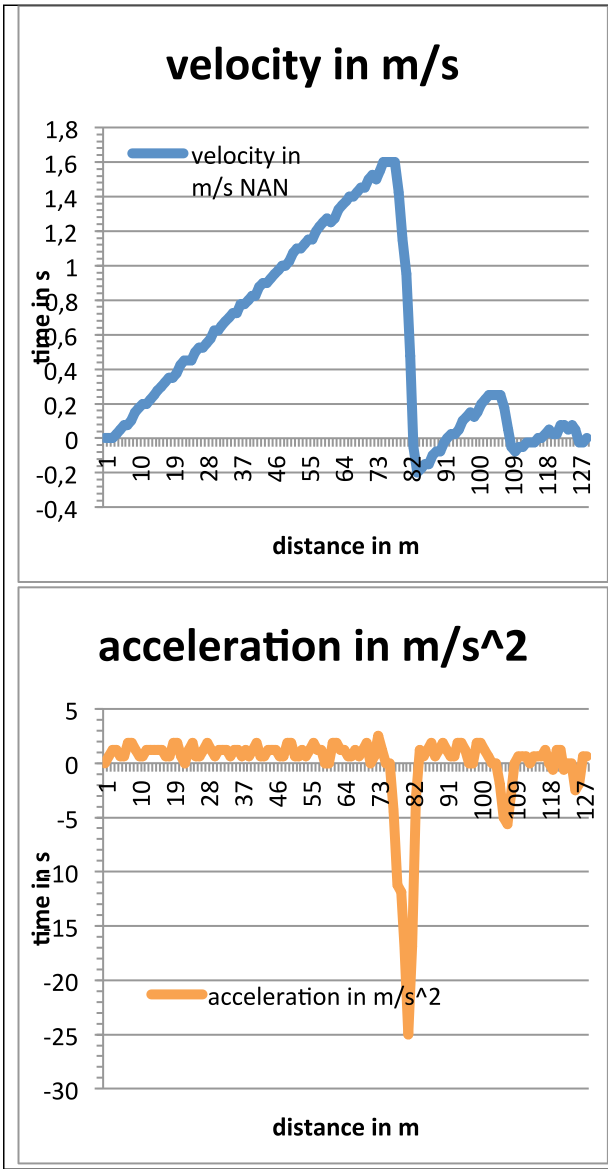


Illustration 4 Excercise 2 Measurement 2

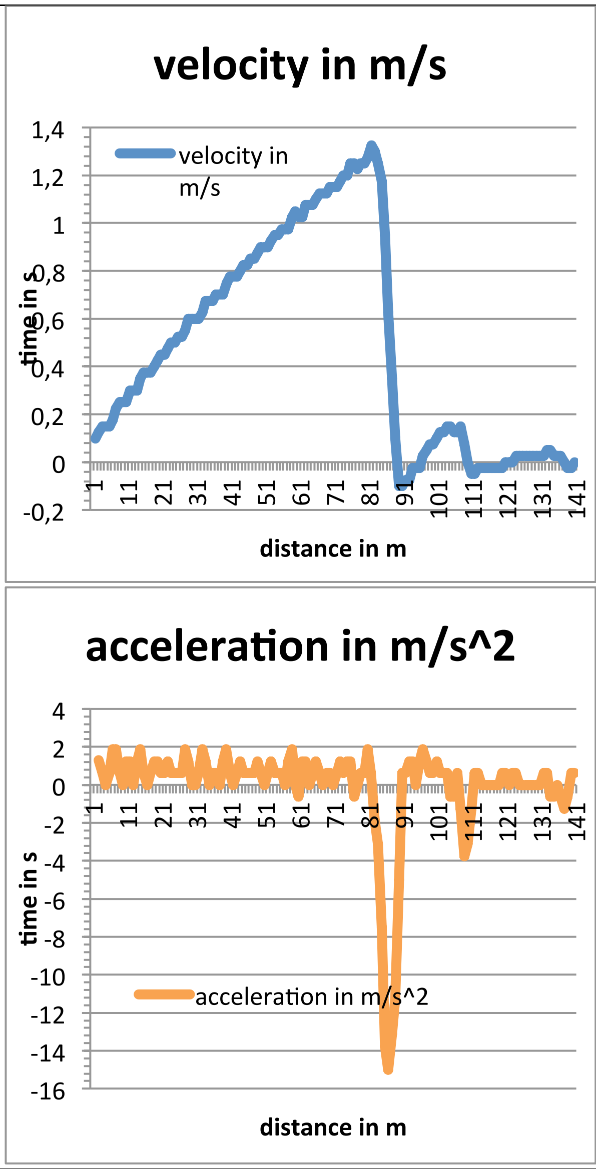
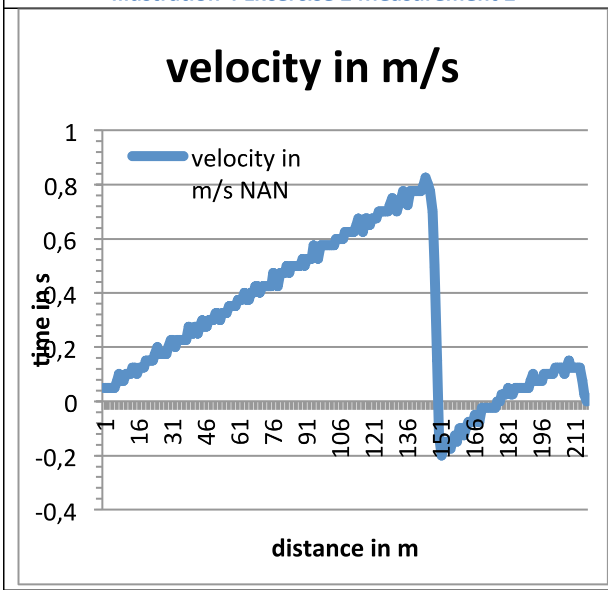
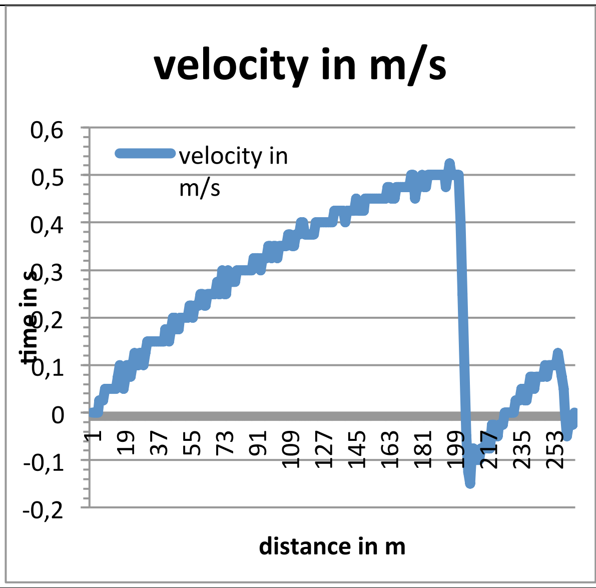
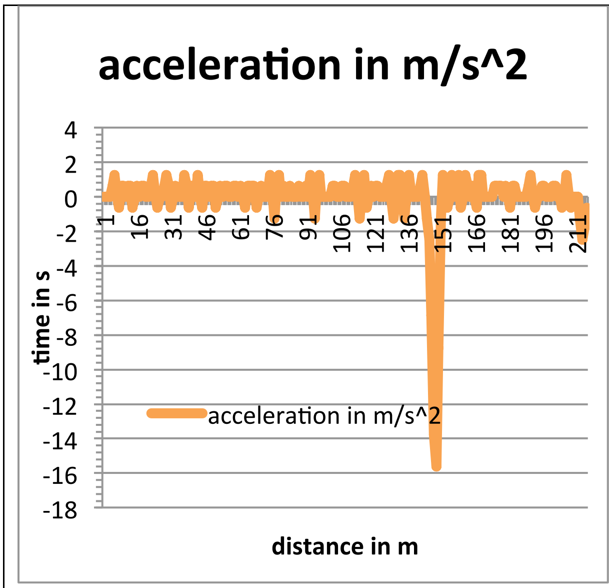


Illustration 5 Excercise 3 Measurement 2







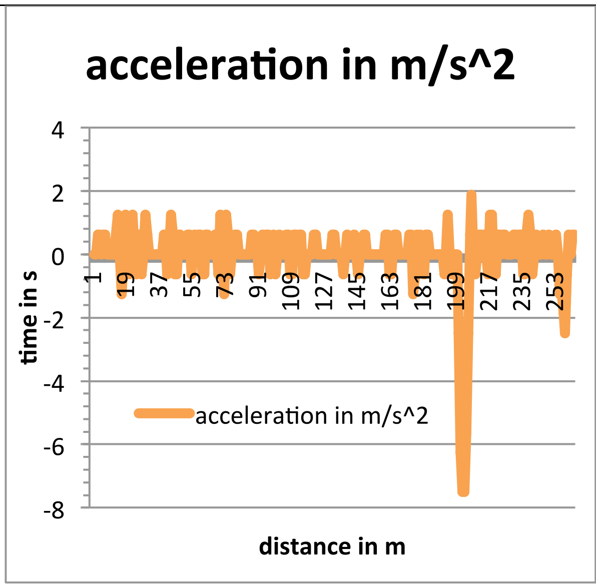
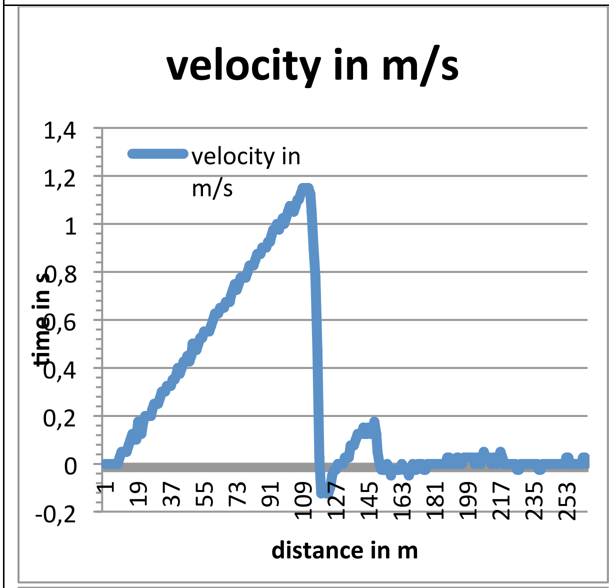
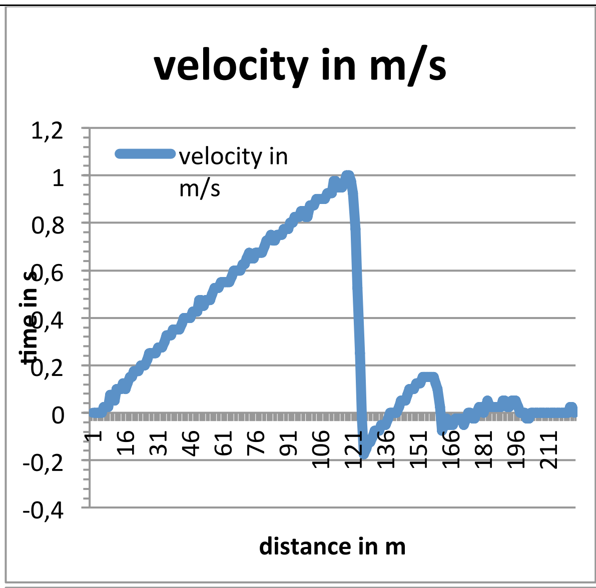
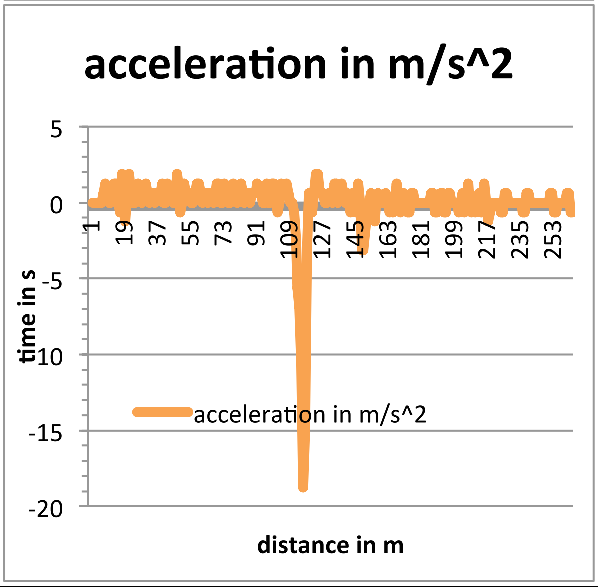


Illustration 6 Excercise 2 Measurement 3

Illustration 7 Excercise 3 Measurement 3







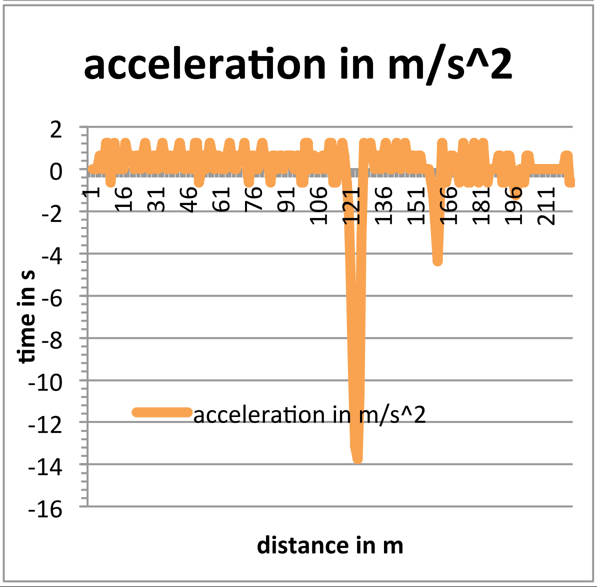
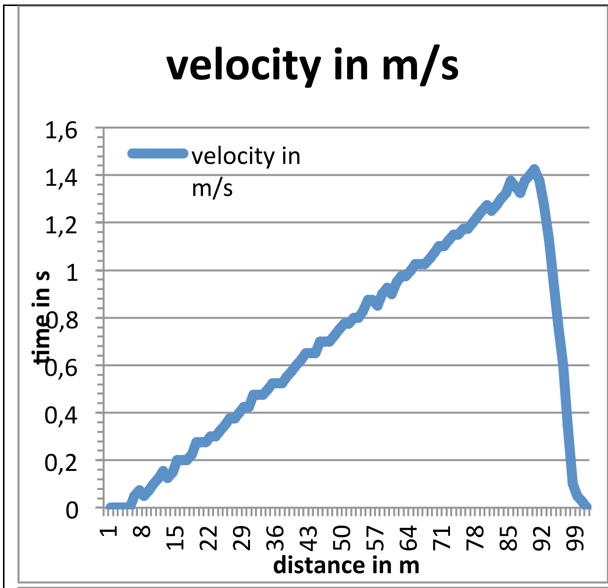
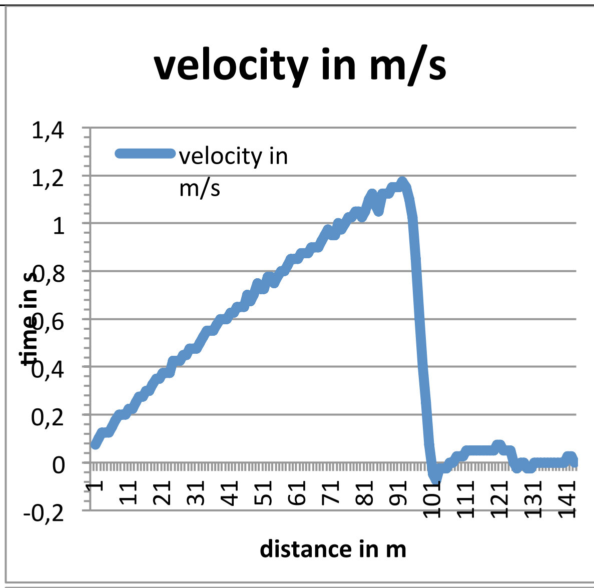
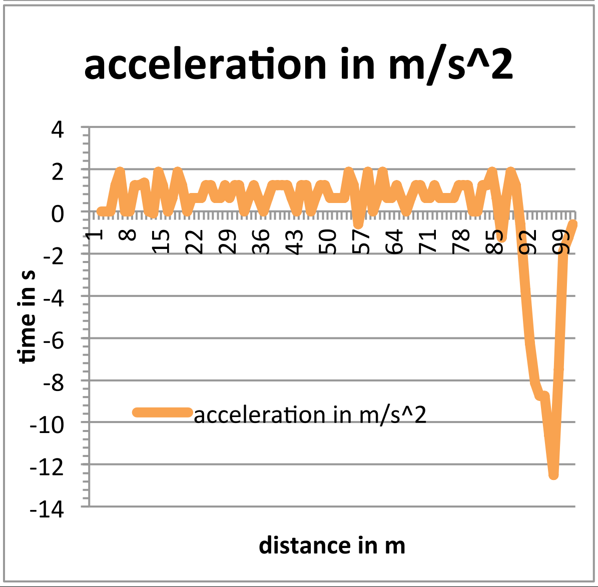


Illustration 8 Excercise 2 Measurement 4

Illustration 9 Excercise 3 Measurement 4







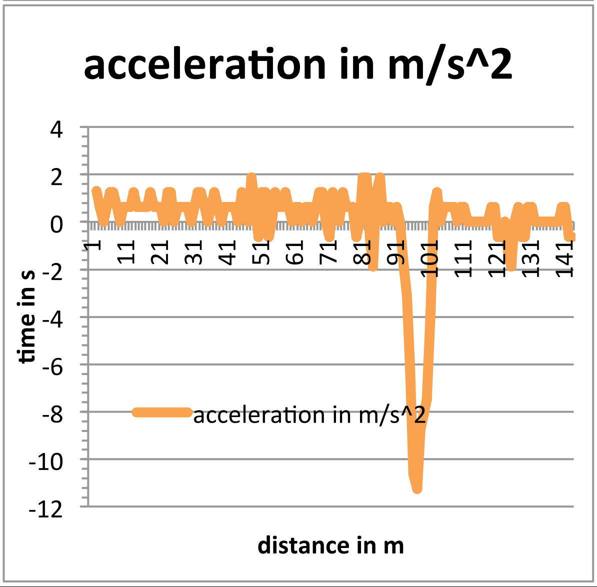
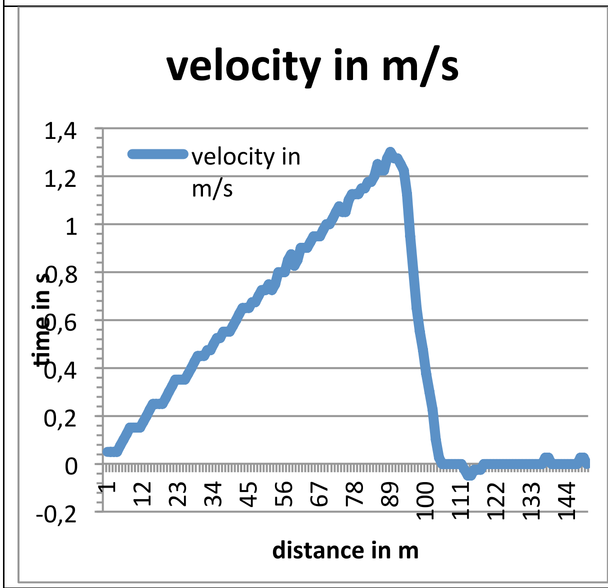
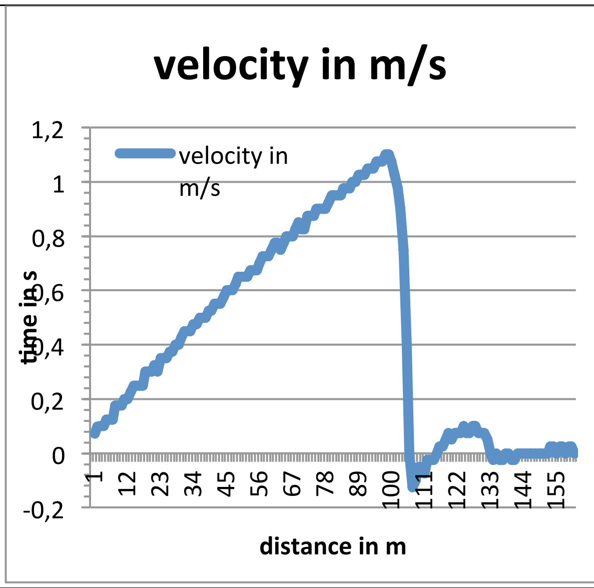


Illustration 10 Excercise 2 Measurement 5

Illustration 11 Excercise 3 Measurement 5





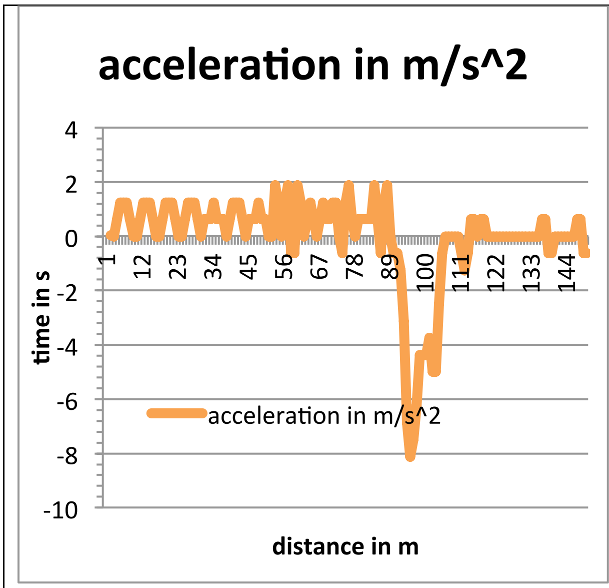


Illustration 12 Excercise 2 Measurement 6

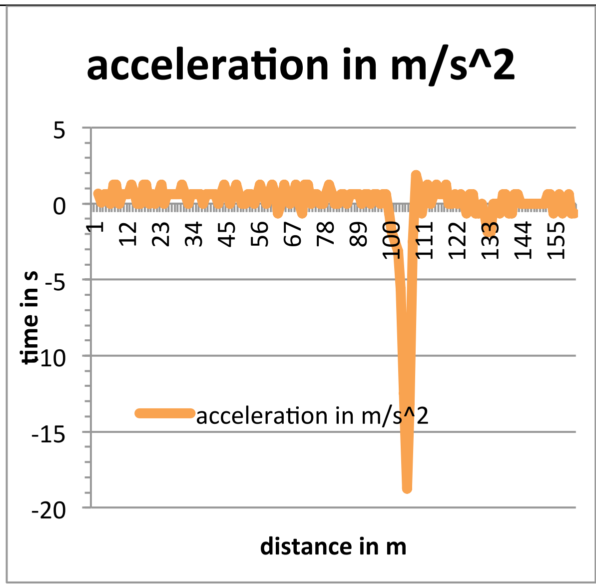


Illustration 13 Excercise 3 Measurement 6

Comparison of experimental and literature values

Exercise 2

Investigating motions with constant force: Recording and plotting distance/ velocity/ acceleration- time measurements for different combinations of mass (glider) and traction force (pulling weight) and checking the law of motion as a function of these parameters.

In this exercise the uniformly acceleration for the (nearly) free falling mentioned in the introduction is examined. From theory the simple motion equation results $F = m * a = m * \ddot{s}$ which has the (for this case) simple solution $s(t) = \frac{1}{2}at^2 + v_0 t + s_0$. Where the Parameters s_0 and v_0 are set as null by the construction of the experiment. By that the motion equation can be simplified to $s(t) = \frac{1}{2}at^2$. The acceleration results by the driving force a by

$$\begin{aligned} & F_a = F_g \\ & \Leftrightarrow m_w * a = m_g * g \\ & \Leftrightarrow a = \frac{m_g * g}{m_w} \end{aligned}$$

Where m_g is the mass of the glider and m_w is the mass of the extra weight. In the measurement were different extra weights measured by a constant glider weight. In the quantitative contemplation the expected parable can be seen.

Excercise	weight	accele-ration ø	acceleration calculated	acc. ∂
a2m1	93,3	0,046296296	0,031543408	0,014752888
a2m2	99,5	4,74298E-12	0,029577889	0,029577889
a2m3	90,6	-0,011574074	0,032483444	0,044057518
a2m4	199,1	1,02768E-12	0,014781517	0,014781517
a2m5	131,9	-7,78243E-12	0,022312358	0,022312358
a2m6	154,4	-0,016573907	0,019060881	0,035634788
a3m1	154,4	1,28117E-13	0,019060881	0,019060881
a3m2	131,9	-0,040028952	0,022312358	0,06234131
a3m3	199,1	-4,1443E-14	0,014781517	0,014781517
a3m4	99,5	1,61036E-12	0,029577889	0,029577889
a3m5	90,6	-0,030487805	0,032483444	0,062971249
a3m6	93,3	-0,026779075	0,031543408	0,058322483

Tabelle 2 weights of glider calculated comparing to Measurment

Exercise 3

Investigating motions under the influence of a velocity proportional damping force (magnetic eddy current damping). Calculating the damping constant from the time constant of the motion and from the limiting velocity.

In this Experiment the experiment construction was changed with magnet on the glider to build a eddy-current-brake. Under the air track were metal pieces so that the magnets on the glider can influence those metal pieces to have a eddy-current-brake. Except the magnets nothing changed, all the plots have the same combination of weights. We expected a not so linear and more parabolic raise of the velocity, which can be seen in the plots.

Summary

There were several sources of errors. We mentioned the not straight air track above. This is a big error that cannot be well calculated. Also the wheel which tracks the wire between the weight and the glider is a unpredictable error source. The wire has no perfect friction, so that it slips on the wheel which makes a precise measurement impossible.