The European TI-Nspire™ Science Pilot 2010-2013

The TI-LabStation™
A solution to investigative work in science.
Supporting student understanding through the use of technology.

T³ EUROPE

Contents:

The Project

T-cubed (T^3) operates world wide and is a professional development organisation committed to using Texas Instruments technology to improve teaching and learning in the school classroom. Within Europe, different countries work at different levels of activity but come together as T^3 Europe. The most recent T^3 Europe Symposium was held in 2012 at the University of Ostende. Delegates from more than ten different countries took part. The remit of T^3 members is to:

- increase teacher confidence in using hand-held technology,
- raise teacher awareness of its potential,
- identify examples of good practice in use,
- provide a framework to raise standards of teaching,
- enable teachers to enhance student understanding.

In the European TI-Nspire Science Pilot 2010-2013 a group of teachers have come together with the express intention of exploring this remit more closely. The group is composed of very experienced T^3 trainers with many years of experience in running sessions at national and international level as well as teachers using the technology for the first time. This group is now actively collaborating having come together on four separate occasions and having been visited by the project organisers at their schools. The group is largely representative of:

- Europe, coming from 8 different countries
- Science subjects with physics, chemistry and biology teachers taking part. Many of the teachers also teach mathematics.
- Type of school with junior high (11-16 years old) senior high (11-18 years old) college (17-19 years old). All are state schools.

The principal output of the group is content. The group felt that what was needed as a minimum for a piece of work was two word (or pdf) documents, one for the student and one for the teacher. In principle neither document should have any references to key presses as they can all be accessed within the manual. The manual itself is so constructed that students can refer to just one page for a particular process, for example "selecting a subset of your measurements". As the TI-Nspire platform is updated then so can the instructions within the manual. This therefore obviates the need to update prepared content and reduces the length of documents making it easier for students to assimilate. Such a document has potential for use in all countries across Europe where TI-Nspire is used.

Some small scale research was undertaken through a collaborative approach to designing a questionnaire for students. This questionnaire(about 250 respondents) formed the basis of a communication document which will be used to disseminate the findings across Europe.

Teachers taking part in the Pilot

Participants	School	Country
Abdel Yazi	Lycée Jean Macé, Metz	France
Armando Severino	Secundária Eng. Acácio Calazans Duarte, Marinha Grande	Portugal
Cathy Baars	Martinuscollege, Grootebroek	The Netherlands
Fernanda Neri	Escola Secundária of Amares	Portugal
Fiona Dickens	Shawlands Academy, Glasgow	Scotland
Frank Liebner	Geschwister-Scholl Gymnasium,Löbau	Germany
James Afolayan	Bacon's College, London	England
Jean-Louis Balas	Lycée Maryse Bastié, Limoges	France
Lee Fox	Bacon's College, London	England
Mirco Tewes	Primo-Levi-Schule, Berlin	Germany
Olivier Douvere	Sint Jozef Humaniora, Bruges	Belgium
Petra Ryrstedt	Allvar Gullstrandgymnasiet, Landskrona Now at Polhemskolan, Lund	Sweden
Sanja Herrström	Allvar Gullstrandgymnasiet, Landskrona	Sweden
Ian Galloway	Copernican Revolutions, Southampton	England
Carlos Coelho	Texas Instruments, Boulogne-Billancourt, Paris	France
Raffaella Fiz	Texas Instruments International Trade Corporation, Vimercate. Monza e Brianza	Italy

Abdelilah YAZI

Lycée Jean MACE- Fameck - France

Education:

Bachelors in Physics	University Hassan II, Casablanca, 1991
Masters in solid state physics	University of Nancy, France, 1992
PhD in Physics	University of Metz, France, 1997

PhD dissertation title: contribution to the study of the electronic properties of metallic alloys.

Current Role : I am an academic trainer at Nancy-Metz academy (regional education authority). My duty concerns are essentially dynamic mathematical software, calculators and also interactive whiteboards.

T^3 Biography:

I have been using TI calculators (Ti-82, 83) with pupils, since the year 2000. I had a working relation with the educational representative of Texas Instruments for two years, who then invited me to their annual meeting at Cannes in June 2011. I met a dynamic and pleasant team. Then I joined their sciences team which was created in 2011. Afterwards in November 2011, I joined the T3 Europe team (sciences pilot), where I had chance to meet up for the first time at the Chicago meeting. I found another dynamic team, creative and pleasant!
The TI-nspire technology has a huge future in the education. The Labcradle with the calculator TI-nspire is really a revolution especially in sciences, because of its mobility and its simplicity.

Personal Information:
Married with three children, Nesrine, Saloua and Imane. I have a high ranking in the martial arts (Tae kwon do) and was a trainer for several years.

Armando Pires Severino

Secundária Eng. Acácio Calazans Duarte – Marinha Grande , Portugal

Education:
Degree in Chemical Engineering 1991
Catalysis with Zeolites Investigation 1991-1995
Professionalization in service as teacher of Physics and Chemistry 2002

Teaching Experience:
Physics and Chemistry Teacher at a Public School 1995-2005
Teacher at Eng. Acácio Calazans Duarte High School 2005-2012

T^3 Biography:
Since the begining of my teaching career I have always done experimental activities with my students. I was introduced in 2002 to the data collection technology (Vernier probes and TI-83,84) and this was the tool that I had been looking for to help students better understand physics and chemistry concepts. In 2004 I was invited to participate in the T^3 project in Portugal as a physics and chemistry teacher. Since then, as an instructor, I have done many workshops for Biology, Maths, Physics and Chemistry teachers to learn how to use the TI graphics calculators and Vernier probes in experimental activities in order to impact the teaching of science.
Since 2004 I have actively participated in the annual seminars of the T^3 team of Portugal, where we do a collective analysis of these new technologies and their potential exploitation as a didactic resource in teaching students.
Since 2011, I and my school have been part of the European Science Pilot Project with the goal to evaluate and validate TI science (physics, chemistry and biology) product solution in classroom. The project has been fantastic, and in the meetings we have had, all the teachers involved were able to share ideas, activities and experiences in their work with students. I'm excited with this project and I will enjoy teaching educators how to use this new data collection technology.

Personal Information:
I'm married to Tina and I have three children. I enjoy reading, to play rugby and running. I always listen to world and classical music.

Cathy Baars-de Boer

Martinuscollege, Grootebroek, Netherlands

Education: Ms. in experimental physics, specialization biophysics (University of Amsterdam,1985-1989)
Research employee (Physical oceanography NIOZ, topic: Deep sea currents South of Iceland), 1989-1994
Ms. in physics education (University of Amsterdam, 1994-1995)

Teaching Experience: 1994 - 1995 : Nieuwer Amstel (high school)
1995- now: Martinuscollege (high school)
2012: writing and presenting physics lessons for highly gifted primary school students

T³ Biography:
My first introduction to TI was the "*Little professor*" (at the age of 8 years). I enjoyed that very much. About 15 years ago, the graphical calculator was allowed in the high schools in the Netherlands. At that time I wrote a booklet for the HP38G with physics experiments. At our school we are using TI-84, but next year the students with physics will start to use TI-Nspire calculators.

In May 2010 I started to write lessons for the Nspire calculator and became involved in the T³ community. In January 2011 I joined the European Science Pilot and in November 2011 I went to Saudi Arabia to teach at two female high schools about the use of TI-Nspire calculators. I have given several workshops about the use of TI-Nspire calculators for physics education in the Netherlands. In March and April of 2012 I used the Navigator system in my classroom to prepare my students for their final exams with great success. Besides writing lessons for theTI- Nspire calculator, I also write programs for the calculator (also in Lua script). My latest programs are the Fast Fourier Transform, the Little professor and (with one of my students) a word rehearsal program to train your vocabulary.

The T³ community is a very inspiring community because it is not only physics related but much broader. This gives new ideas to enrich your lessons (for example applied physics in forensic science and earth science). I have joined TI conferences in San Antonio, Berlin, Chicago and Metz.

Personal Information:
I am married to Rik, and we have two daughters at the age of 8 and 10.
Besides being a mother, I enjoy figure and speed-skating and playing bassoon in an orchestra in Amsterdam.

Maria Fernanda Bessa Carvalho Neri

Escola Secundária of Amares, Portugal

Education
Licentiate Degree in Physics and Chemistry Education - Minho University - 1991
Post Graduate student of Supervision in Science Education

Past and Current Activities:
In the years 1999 and 2000 was Supervisor of Under-Graduated Students of Physics and Chemistry
In 2005 was nominated for “Prémio Rómulo de Carvalho”, premium established by the Portuguese Society of Physics to distinguish excellent secondary school Physics Teachers
In 2010 I attended a training course in Particle Physics at CERN.
I have been the co-ordinator of the Physics and Chemistry disciplinary group since 2003.
In the year 2009 was nominated by the Headmaster to coordinate the school evaluation team.
In addition to teaching, I have had multiple roles and have been Head of Group and Laboratory Director.

TI Biography
Since 2006 I trained secondary school teachers in the use of calculating machines and sensors in the areas of physics and chemistry, biology and mathematics, using TI technology.
In 2011 I joined the "European Science Pilots" project and in the present year I participated in the International Conference, T3 – Teachers Teaching with Technology which was held in Chicago.

Personal Information
Married to João Neri who also has a Licentiate in Physics and Chemistry Education, but is currently working in the area of information technology. His knowledge of foreign languages is a great help to me.
I am proud of my daughters aged 12 and 17 years. They love the study of Sciences and Mathematics but they are very talented in other areas. The elder paints very well, especially abstract painting. The younger is an actress at a local amateur theatre company where her work has been greatly appreciated.

Fiona Dickens

Shawlands Academy, Glasgow, Scotland

Education:	B.Sc (Genetics)	University of Glasgow, 2000
	M.Res (Integrated biomedical science)	Imperial College, London, 2002
	Ph.D	Imperial College, London, 2007
	P.G.C.E (Science)	Roehampton University, 2007

Current Role:
I am a teacher of Biology and Science at Shawlands Academy. In addition to regular classroom duties, I developed the first and second year science curriculum in school and with the Biology department am implementing the new Scottish curriculum in the upper years of secondary.

T^3 Biography:
Other than a TI calculator at school (and playing with 'Speak & Spell' and 'Speak & Maths' at home as a child) I had not used any of the previous TI data-logging systems. I have now been using the Nspire technology for 2.5 years and love it. It allows pupils to visualise data in real time and significantly helps in linking Maths with Science which has become very difficult for pupils in recent years.

The T^3 community and the collaboration with other science teachers from around the world is a fantastic resource and allows discussion and sharing. I especially enjoyed the T^3 conference in Chicago where I picked peoples brains and brought back lots of resources and activities that are now in use in my school.

Personal Information:
I have always been interested in Science and in particular Science Communication, which is why I moved from research Science into Teaching after my Ph.D. I always felt that STEM subjects need to be taught by inspiring people and aim to inspire my pupils into STEM careers. Other than science, I enjoy spending time with my husband cooking, travelling, several sports and watching TV and films.

Frank Liebner

Löbau – Grammar School
Dresden, Germany

Education: BA in Mathematics and Chemistry – 1986
MA in Mathematics and Chemistry - 1990

Teaching Experience: Mathematics and Chemistry at
- Wittgendorf - Middle School 1990- 92
- Herrnhut - Grammar School 1992 – 2005
- Löbau – Grammar School 2005 – until now

since September 1999 Supervisor for Chemistry for the local school district (East Saxony)

T^3 Biography:

In October 1999 I used a pH- sensor in combination with CBL 1 for the intake of measurement data in chemistry lessons for the first time.
After that I was asked to discuss my experiences in various workshops.
In April 2000, I introduced the first workshop for measurement data in Chemistry lessons. Since then I have been working actively in capacity of a lecturer for Mathematics and Sciences.
In recent years numerous workshops have been performed to these given topics under my guidance.
As the teachers´ demand for detailed information on these matters has been steadily growing I decided to found the special group "Chemistry" with T^3 Germany.
Since then chemistry teachers from all over Germany have been gathering in order to work on mutual projects and publications.

Meanwhile topic groups in Biology and Physics are also existing.
T^3 Germany has strongly developed in the field of natural sciences.
In March 2008 I have started coordinating and coaching the natural sciences group of T3 Germany.
This special task has through the years aroused a deeper interest on behalf of me in particular as a first analysis of the implementation of new forms of media within the ordinary lessons has been shown.

Personal Information:

I have been married since 1997 and my wife is a grammar school teacher too. We have two children, a son (15) and a daughter (13).
As a family we enjoy travelling with our caravan through Europe.

Jean-Louis Balas

Lycée Maryse Bastié, Limoges, France

Education: DUT University Institute of Technology 1981
DEUG (Maths and Physics) University of Limoges
1984 License and Masters in electronics and telecommunications
University of Limoges,
Diploma of superior specialized studies (DESS) 1985

Current Role: Mathematics teacher and physical sciences at the high school Maryse Bastié in Limoges (France). I have taught this discipline for 25 years.
At the same time as my work as a teacher, I am an instructor for IREM in Limoges (Research Institute for Education in Mathematics) and am also developing myself as an academic.

T^3 Biography:

I began to use the TI technology in 1989, after my success in winning a place as a teacher. Previously I was already interested in calculators during my years of studies in high school.

When I became a T3 instructor in December, 97, I received the first interface for collecting data with calculators, the CBL. It was then necessary to make our own programs for collecting data. This interface amazed me because at the time the corresponding equipment for computers was extremely expensive for (often) lower technical performance. But one of the most fascinating points in the TI technology is the constant research serving a single objective, all the mathematical and scientific disciplines, physics, chemistry, biology. It facilitates a natural way of teaching and represents in a sense, the cement binding the stones in the wall of knowledge.

My participation to the group T3 has given me unthinkable opportunities in the life of a of high school teacher. I was particularly impressed by the objectives of the project LEPLA (http: // www.lepla.edu.pl/), which provided a way of accessing experimental resources in physical sciences remotely. I particularly appreciate the exchanges with teachers of the T3 group. All have as a common denominator the passion for their discipline, an original spirit tinged with artistic taste.

The highlight of the year has to be the T^3 International conference where I am fortunate to have been invited to deliver at Columbus, Dallas, San Antonio, Seattle, Atlanta and Chicago…and the highlight of these meeting is surely the Gallery Walk!

Personal Information:

I share my days with my wife Brigitte, a mathematics teacher, our two daughters Clémence and Juliette and Maksym, a young Ukrainian boy whom we have sponsored since he was a child and who gets fresh ideas every summer with us. One of my biggest pleasures is music with a classical guitar which I practise surrounded by my cats.

Mirco Tewes

Primo-Levi-School
Berlin , Germany

Education:

Abitur: Educational college of Halle / Germany, 1990
Final university examination: University of Halle / Germany, 1995

Teaching Experience (physics, mathematics):

Georg-Cantor-School Halle / Germany, 1996 - 1998
Comprehensive school Kandel / Germany, 1998 - 2000
Primo-Levi-School Berlin / Germany, 2000 - present

T^3 Certifications:

T^3 Physics Germany (coordinator)
Voyage 200
TI-Nspire CAS

T^3 Biography:

I have had the first contact with the Voyage 200 in 2004. In 2005 my friend Dr. Karl-Heinz Keunecke from Kiel invited me to a meeting of the T^3 Physics-Group. I learnt there a lot about how one uses Voyage 200, CBL2 and CBR2 in the Physics lessons. I was and am enthusiastically about the possibilities. For some years I carry out advanced trainings for teachers and am involved in the development of workshops and training aids. I coordinate the work of the T^3 physics-group since 2008.

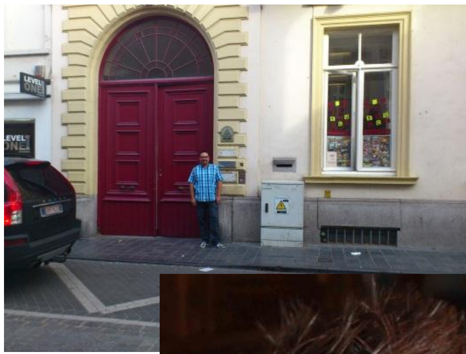
Personal Information:

I was born in 1973, am married and have two sons.

Links

www.mrtewes.de
www.t3deutschland.de
www.t3-trainingcenter-berlin.de
http://www.gymnasium-weissensee.cidsnet.de

Olivier Douvere



Sint Jozef Humaniora, Bruges Belgium

Education: Master in chemistry (University of Ghent; Belgium)

Current Role:

I am currently a science teacher at the Sint-Jozef Humaniora. I teach chemistry and physics at students of 16-18 years old. Besides being an teacher I am also a member of the steering committee chemistry of my region. We provide training to colleagues on various chemistry topics.
Recently I started writing chemistry textbooks for students in Belgium.

T^3 Biography:

I am a strong proponent of ICT integration in chemistry lessons. In my classroom I often use an ActivBoard and TI technology like the TI 84+ and TI Nspire. I also started several years ago with automated data collection. The students use their TI84+ calculator and the Vernier sensors with an EasyLink interface. Since the European science pilot I've started in my classroom to use data collection with the TI Nspire with the Lab Cradle interface. I think it is a good and fun way to understand better the chemistry lessons. In collaboration with T3 Belgium I wrote several booklets on the use of the TI84 + and TI Nspire in science lessons. As a T3 instructor I gave some training about the use of TI Nspire technology in the science classroom.

Personal Information:

I live together with Wendy in Bruges. She is also a science teacher. We have a son called Nathan. In our free time we like to travel. I also like cooking and I enjoy good food and drink.

Petra Ryrstedt

Allvar Gullstrand School
Landskrona, Sweden

Education: Math and physics at Lund University-1999
Teaching education at Malmoe University-1999

Current role:
Teacher in mathematics and physics at a school called Allvar Gullstrand where I teach students between 16 to 19 years old. The school is located in Landskrona which is in the south of Sweden.

T³ Biography:
I started working as a T3 instructor in December 2009.
I have been using graphing calculators and CBL2 since I started teaching. My first graphing calculator was TI-83. One of my teachers, Lars Jakobsson, has inspired me a lot and showed many ways to use graphing calculators in class in order to help students understand mathematics and physics. Since 2008 I have been using TI Nspire CAS in my classroom. In the beginning of 2009 I started a pilot class exploring TI Navigator for TI Nspire CAS. It was a very interesting time and I met many interesting people. It also opened up different ways of teaching. I think that if you use TI Nspire in your classroom you should also get TI Navigator since it opens up new possibilities to visualize mathematics and physics, it also makes the teaching more effective. I am very grateful to have been chosen to participate in this project.

Right now I am involved in another project where I am using TI Nspire CAS CX together with a labcradle and different probes in my physics classes. You have a special application for this in your software/handheld called DataQuest. I must say that it is very easy to use and you can do a lot of different measurements with these tools! This project has given me many new ideas about how the students can explore real time data in the physics classroom.

Personal Information: I am 38 years old, married and have two daughters, Siri and Tyra. We live in the south of Sweden close to Denmark. We have three horses, eight cats and one dog. I love animals and have competed with my horses in both dressage and show jumping, but for the moment it is just a hobby. On holidays our family travels to the south of Spain where my parents have an apartment by the ocean.

Sanja Herrström

Allvar Gullstrand high school
Landskrona, Sweden

Education:
Math and physics including teaching at Växjö university -1994 - 1998
Chemistry and Biology at Malmö university 2008 – 2009

Teaching Experience:
Mathematics, physics and natural science at Alvesta high school and Allvar Gullstrand high school in Landskrona since 1998.

T^3 Certifications:
I have no certifications but I have used TI Nspire CAS in my work since 2010.

T^3 Biography:
I have been using graphing calculators since I started teaching.
My first graphing calculator was TI-83.
I have used TI-83 and TI-84 with CBL in physics education.
I have used LabPro a few times.
I have used TI Navigator, the old version with cables.

Now I am involved in this project where I am going to use TI Nspire with different probes in my physics classes. I hope that this project gives me many new ideas about how to make the students understand physics and how to make them love it!

Personal Information: I am 36 years old, married and have two boys, Moltas 9 and Malte 6. We live in the south of Sweden close to Denmark. We have a small boat I which we make trips to Denmark and Ven, an island near the coast of Sweden. I am also training my boys in handball together with my husband, Joakim. So we will follow the Swedish team with great joy now when the World Championship is taking place in Sweden. I am also participating in a musical show at the theater in Landskrona in the end of January. It is very stimulating to do different things on your free time.

Lee Fox

Bacon's College, London, England

Education

PGCE	Manchester University 1991
BSc (Hons) Applied Physics with Electronics	Salford University 1990

Current Role: I am currently second in charge in the science department (with additional responsibility of IT coordinator) at Bacons College. This is an 11-18 state school near central London. I am currently involved in the Texas Instruments' European Science Pilot Project.

T^3 Biography: Having had no previous experience of using the Nspire or any other TI data logging equipment I became involved in the Texas Instruments' European Science Pilot Project in the summer of 2010. I began using the equipment in my school in September 2010 and immediately became a convert ! I found the Nspire data logging system to be the best I have ever used when compared to the many other data logging systems I have used in the past. I have attended T^3 conferences in San Antonio and Chicago in the US and Edinburgh in Scotland. I have found the opportunity to meet teaching colleagues from around the world highly valuable. Attending the conferences has greatly increased my knowledge of the practical applications of the Nspire system. I have also attended a European Science Pilot conference in Berlin. Again the opportunity to share ideas and have input into how the Nspire can be improved has further enhanced my skills. As a group we presented examples of practical experiments we had devised in the T^3 conference in Chicago. I have applied to become a T^3 instructor. As part of this I will be taking MA modules in information Technology at Canterbury University in the UK. I have attended STEM meetings at London South Bank University and feel that the Npsire system offers a great way to develop links between Physics and Maths teaching.

Personal Information: My greatest life experience was teaching Physics and Mathematics at the British Aerospace Training Facility in Riyadh in Saudi Arabia. I greatly enjoyed experiencing the Arabic culture and the beauty of the desert landscapes outside Riyadh. I also had the opportunity to travel to many parts of the world I may never have otherwise visited from the UK. I am single living in Richmond Surrey. I enjoy most sports and also have interests in Astronomy and Politics.

The Investigations

The following activities have been designed and carried out by the participants of the European Science Pilot. To a very large extent they all follow a similar philosophy. That is they tend to be investigative tasks in keeping with the general trend across the European continent towards practical work of a more investigative nature.

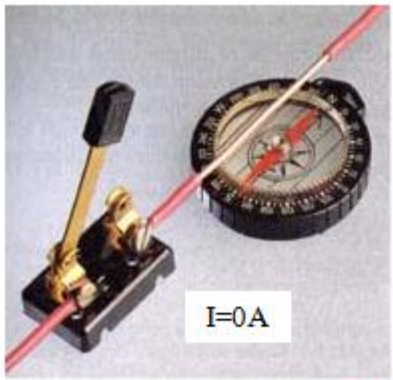
There are two documents for each experiment. A student sheet and a set of notes for the teacher. The student sheet is not intended to be a work sheet and does not contain all the instructions for carrying out a task. In particular the key presses for the TI-Nspire are to a great extent missing. The teacher notes may refer to a tns file which can be used in addition to the student sheet. The teacher notes contain exemplar results and any tips for ensuring the success of the activity if necessary. The apparatus required and the DataQuest set-up needed will be found here. Additionally any science which was felt might be useful to the teacher has been included.

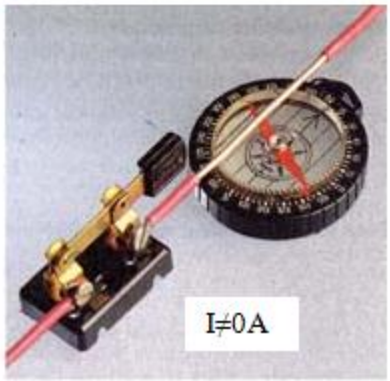
Support in using the LabStation™ (Handheld plus Lab Cradle™) and DataQuest™ to carry out tasks can be found in the Guidance Manual prepared by T^3 Germany. The instructions have been set out on single sheets for ease of use.

The Magnetic field of a solenoid   Student notes

Context

The Danish physicist Christian Œrsted (1777-1851) was the first who noticed the link between the electric current and the magnetic field.





The passage of an electric current, intensity I in a solenoid causes the appearance of a magnetic field of value B.

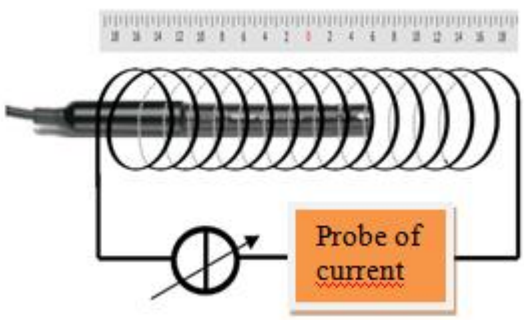
The magnetic field is measured by means of a magnetic field detector, which uses a Hall effect transducer. This magnetic field detector produces a voltage which is proportional to the magnetic field. This voltage is amplified by an electronic system. The Hall probe is situated at the end of the magnetic field sensor which is used to insert it inside the solenoid.

We propose to :

- Demonstrate the uniformity of the magnetic field inside the solenoid
- Verify the relation giving the value of the magnetic field inside the solenoid:

$$\boldsymbol{B} = \mu_0 \times \frac{N}{L} \times I = \mu_0 \times n \times I$$

Experiment notes, Observations and Questions



Uniformity of the field inside the solenoid

- Connect the circuit as shown in the diagram
- The dimensions of the solenoid are :
  length L = 40 cm; diameter D = 5 cm.
- The current I is set to 1.5A
- Place the extremity of the magnetic field sensor in the centre of the solenoid.

We suggest conducting a series of magnetic field measurements by displacing the probe various distances from the solenoid centre.

1. *From what distance from the centre of the solenoid can we consider that the magnetic field is about uniform ?*

………
………

2. *When the current is zero, what is the value of the magnetic field?*

………
………

3. *With a current flowing through the solenoid, what other source (other than the field due to the current) of magnetic field is being measured?*

………
………

4. *The back-ground magnetic field is of the order of 2×10^{-5} Tesla. Can we neglect the back-ground field in favour of the solenoid field?.*

………
………

Influence of the current.

- Set up the experiment as described above. Then place the probe in the centre of the solenoid.
- Setup DataQuest to measure the magnetic field created by the solenoid while varying the current.

5. *How does the intensity of the magnetic field B vary with electric current I ?*

………

We know that the magnetic field in the centre of a solenoid is given by the following formula:

$$B = \mu_0 \times \frac{N}{L} \times I = \mu_0 \times n \times I \,.$$

The value of the magnetic field created by an electric current is proportional to the size of this current.

Where, $\mathbf{k} = \mu_0 \times n$

6. *Show that the theoretical value of the coefficient of proportionality is given by* k_{calcul} = *0.628*$\times 10^{-3}$mT/A

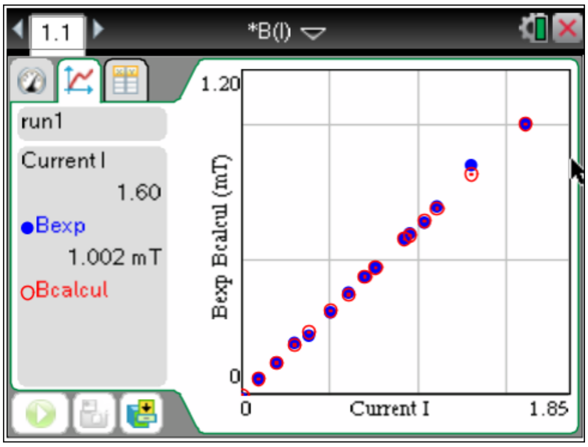
($\mu_0 = 4\pi \times 10^{-7} = 1.26 \times 10^{-6}$ SI ; N = 200 turns ; L = 40 cm = 0.40 m)

………

………

Then $\boldsymbol{B_{calcul}}$ **= ………**$\times$ ***I***. (mT)

We will compare the experimental results for B wand the theoretical field given by the formula above. Construct a new calculated column for B.

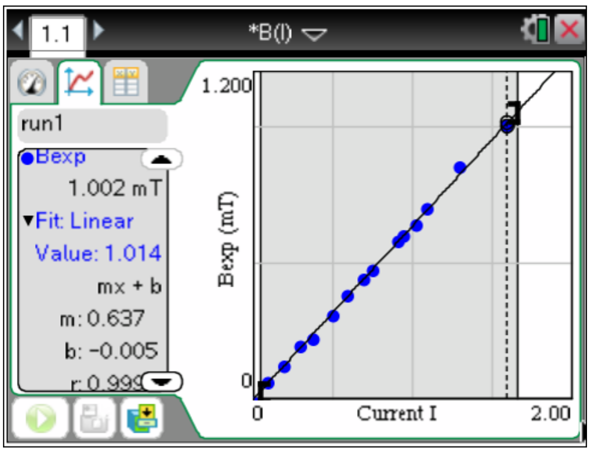


Then plot Bcalcul and Bexp against I on the same graph.

Plot Bexp against I and then fit a linear regression to the data.

This straight line suggests B is function of I so that

B*(*I*) = ……….** $\times$ ***I. (mT)



7. To calculate the percentage difference between both coefficients of proportionality

***B* = *k* × *I*,** (k_{exp} = ……………. **et** k_{cal} **= 0.628**)

$$E(\%) = \frac{|k_{cal} - k_{\exp}|}{k_{cal}} \times 100 = \frac{|\text{..........} - \text{.........}|}{\text{.......}} \times 100 = \text{.......}\%.$$

8. Is this result satisfactory?

……

……

9. Complete the following sentence. Use these words: proportional, uniform, number of coils per unit length, current I

In a long solenoid, the magnetic field is …………………. except for the neighborhood of the extremities.

The magnetic field inside a solenoid is …………………………………. to both the applied ……………………….. and the …………………………………… $\frac{N}{L}$ **.**

The Magnetic field of a solenoid   Teacher notes

Key words

magnetic field, solenoid, Ampere law, probe with effect Hall.

Complementary files

B(d).tns; B(I).tns

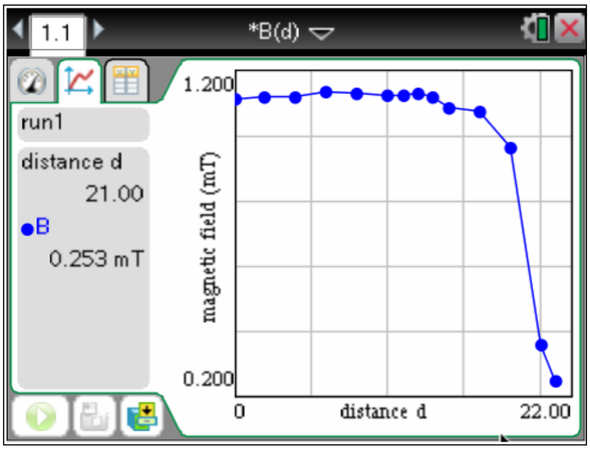
Equipment needed

- Solenoid,
- DC generator.
- Sensors: *magnetic field* (Hall probe)*; current*

Set up

Data with Entry

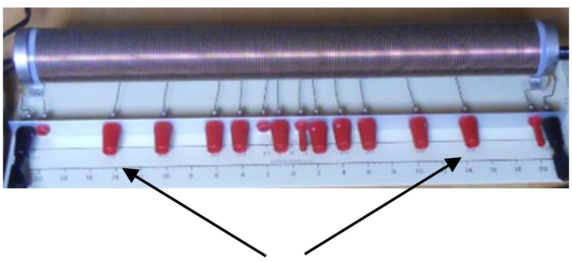
B(d), uniformity of the field inside the solenoid



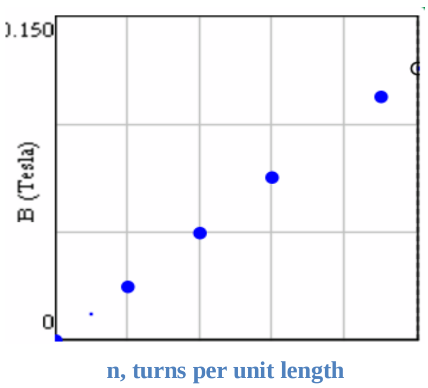
- When I=0 the magnetic field is almost zero (B ~ 0.128 10^{-3} mT).
- When a current flows through the solenoid, a magnetic field is created.
- We notice for a fixed value of current I, the magnetic field remains constant to a distance approximately 13 cm on both sides from the centre of the solenoid.
- ***In a long solenoid, the magnetic field is uniform except for the neighbourhood of the extremities.***

Extension work

In the same way, we can show that, for a fixed value of the current, the magnetic field is proportional to n, the number of coils per unit length.



Choice of the number of turns per unit length $\frac{N}{L}$



To estimate the Earth's *albedo* Student notes

Context of the activity:

Light is reflected differently from different surfaces or colours. In this activity, we measure the percentage of reflected light from sheets of paper with colours similar to those that dominate the surface of our planet, taking as a standard the shiny side of a sheet of aluminum (good reflector).

If the Earth were a disc ($area = \pi R_T^2$), the solar radiation incident perpendicular to the atmosphere at all wavelengths is about **1370** W/m^2. This value is called the solar constant, and was measured by satellites placed above the atmosphere.

Some of the incoming solar radiation is reflected by the atmosphere, clouds and the Earth's surface, constituting the Earth's **ALBEDO**.

The ***albedo*** of a planet is the % of incident radiation reflected by the planet.

Learning Outcomes:

- Able to use a light sensor to measure the reflectivity of light
- Able to determine the percentage reflectance for different colours
- Able to estimate the Earth's *albedo* from the results obtained

Experiment notes and instructions:

1. Position the light sensor **5** *cm* above the sheet (see fig **1**). The existing light in a classroom will be sufficient for this activity.
Note: If using the Vernier light sensor, select the range 0-6000 lux

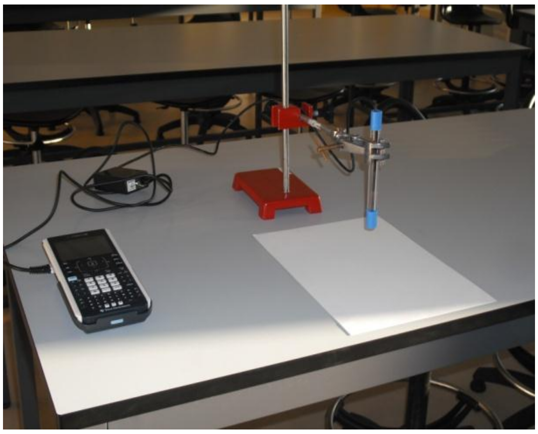


Fig. 1

2. Set up DatQuest to collect using Events with Entry. Enter the name "*colour*" and enable the average over 10 *s*

3 Start collecting data using the foil first and remembering that a sample is averaged over 10 seconds.

4 Repeat the same process for all sheets.

5 To do the calculations, open a new Lists & Spreadsheet application and enter the data obtained in DataQuest.

Results

Colour	Aluminum	White	Green	Blue	Sand colour	Black
Reflection value (Lux)						

Questions

1. Since the earth is roughly a sphere, determine the value of the solar constant at the top of the atmosphere.

2. Calculate the percentage of light reflectivity of each of the colours, and filling in the table.

Colour	Aluminum	White	Green	Blue	Sand colour	Black
% of reflectivity	**100%**					

3. What type of surface will give a planet a high reflectivity? Explain.

4. Does planet Earth have a high reflectivity? Explain.

5. The distribution of surface area of earth is approximately: **water**-70%, **deserts** - 9%, **forests and plantations** - 14%, **ice and snow** - 7% and **Asphalt** - 0.05%. Based on this information and with the results obtained, make an estimate of the ***albedo*** of the Earth. (*Do the calculations in a Lists & Spreadsheet application*)

6. Find out what the current value for the Earth's ***albedo*** is and compare with the value obtained in this activity (suggestion - determine the relative error)

7. Based on the results, determine the energy absorbed (in W/m^2) by the earth's surface.

8. Is the so-called “global warming” affected by the ***albedo*** of our planet? Explain.

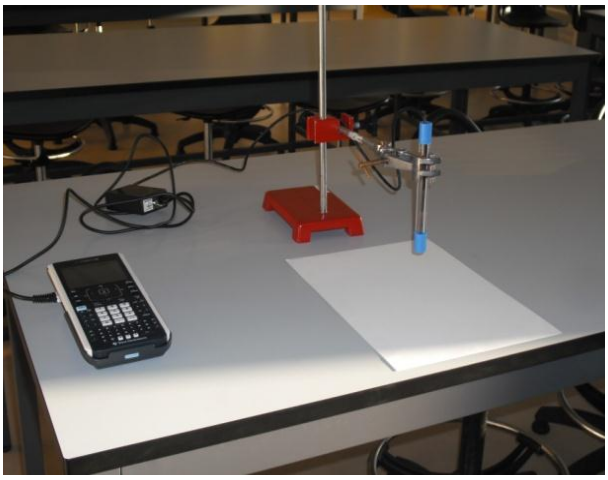
To estimate the Earth’s *albedo* Teacher notes

Key words

radiation, absorption and reflection of light, albedo, global warming

Apparatus needed:

- *TI-Nspire Handheld with OS 3.1*
- *Lab Cradle*
- *Light Sensor (Vernier)*
- *Aluminum foil*
- *Ring stand and utility clamp*
- *Five sheets of colored paper: white, black, blue, green and sand color*



Overview of the science:

When solar radiation reaches the Earth's atmosphere, three processes occur: **reflection, absorption and transmission.**

The solar radiation incident perpendicular to the top of the atmosphere at all wavelengths is about **1370** J per square meter per second, ie, **1370** W/m^2. This value is called the **solar constant** and its measurement is made by satellites placed above the atmosphere. It is an average value adopted by the World Meteorological Organization.

Let's see what happens to this energy:

- About 30% of incident radiation is reflected into the atmosphere by clouds and the Earth's surface. This is the albedo of the planet.
- The rest of the incident radiation, 70%, is distributed approximately as follows:
  - 19% is absorbed by the atmosphere and clouds; ultraviolet radiation of high energy is absorbed in the thermosphere and other radiation with lower energy in the

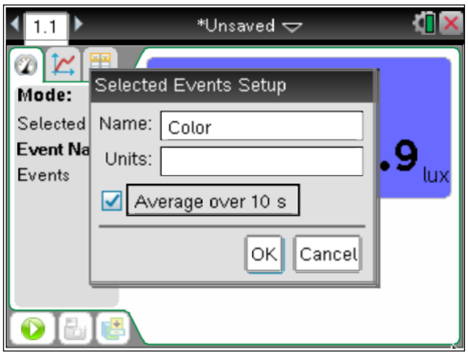
stratosphere, most of the infrared radiation is absorbed in the lower troposphere and stratosphere;
- 51% is transmitted to the surface, but only 25% of that radiation is direct sunlight, the remaining 26% is reflected and scattered to the earth's surface by clouds and atmosphere. The radiation that arrives at a point on the earth's surface will depend on factors such as the latitude, time of day, season and atmospheric transparency.

Experiment set-up and collection mode:

1. Position the light sensor **5** *cm* above the sheet (see figure). The existing light in a classroom will be sufficient for this activity.

2. Data collection mode: Selected Events, averaging over 10 seconds

3. Calculations in a Lists & Spreradsheet application



Experiment activity and tips:

- Use sheets of A4 paper of different colours
- Although undetectable to your eyes, artificial lights flicker. The light sensor picks up this flicker, and variation in light intensity can be seen when you view the values displayed. The selected events mode average provides a single illumination value for each run.

Exemplar results:

1. The surface area of a sphere is $A = 4 \times \pi \times R_{earth}^2 \quad \Rightarrow \quad I = \frac{1370}{4} = 342\ W/m^2$

2.

Color	Aluminum	White	Green	Blue	Sand color	Black
Reflection value (Lux)	575.14	394.72	131.40	143.39	184.13	35.42
% of reflectivity	**100 %**	**68.63 %**	**22.85 %**	**24.93 %**	**32.01 %**	**6.16 %**

3. Surfaces such as snow, ice and water would be expected to give a planet high reflectivity. The results of this activity suggest that light-colored and shiny surfaces reflect light best.

4. Planet Earth has some reflectivity because much of it is covered by snow, ice, sand and water. The dark-colored parts of the earth, such as forests and green-crop land, would have lower reflectivity.

5.

$$Earth_{albedo} = \frac{(6,16\times5\times10^{-4}) + (68,63\times0,07) + (22,85\times0,14) + (24,93\times0,7) + (32,01\times0,09)}{1} = 28,34\%$$

6. $E_r = \frac{|30-28,34|}{30}\times100 = 5,5\%$

7. $I_{absorbed} = 342,5\times(1-0,283) = 245,6 \quad W/m^2$

8. If the Earth's average temperature increases due to the greenhouse effect the surface covered by snow and ice will fall and the earth's surface will reflect less radiation. As a result, its albedo will decrease and the earth will absorb more energy.

Specific Heat of Aluminium   Student Notes

Context

Heating a substance leads to a temperature rise. To investigate the relationship between applied heat and temperature rise, most experiments are conducted in calorimeters. This is to prevent heat loss to the surroundings. But this is not necessary. If the heat loss to the surroundings is taken into account the specific heat can be determined.

Learning Outcomes

Be able to account for heat loss in calorimetry
Be able to determine the specific heat of aluminium without using a calorimeter.

Experiment notes

An aluminium cylinder is placed on a wooden plate. A hole is drilled in the top part to take a temperature probe. A 4,7 Ω resistor is placed in a horizontal cavity. You will use the LabStation to measure the temperature change with time. The aluminium cylinder must be heated for 5 minutes. Then you let the cylinder cool down for 5 minutes. The LabStation measures at the same time the voltage across the resistor inside the cylinder, the current through the resistor and the temperature in the cylinder. DataQuest must be setup first. If no am probe is available, it is possible to add a small resistor into the circuit, and measure the voltage over this extra resistor. The resistance of this extra resistor must be known. The current can be calculated.

Instructions and Questions

1. Which quantities do you need to calculate the specific heat of aluminium?
2. Draw the electrical circuit. Make a note of all relevant information
3. Open the file aluminium1.tns in the Nspire. Setup DataQuest to measure every 4 seconds during 10 minutes. Let your teacher check the setup.
4. Measure for 10 minutes. Don't forget to switch off the power supply after 5 minutes.

5. *If an extra resistor is added to calculate the current:*
   Add a calculated column to calculate the current from the voltage of the voltage probe. Which formula do you use, and which values do you use?

6. Add a calculated column to calculate the power in the resistor inside the cylinder. Which columns do you use, and which formula(s)?

From the gradient of the graph, right after switching off the power supply, partly on the basis of theoretical considerations, one or more conclusions can be drawn. Four students formulate the following conclusions:

A. During heating the temperature is the same in the whole cylinder.
B. It takes some time before heat from the resistor is spread over the cylinder.
C. The added electrical energy is also, after switching off the power supply, converted to heat.

D. The temperature of the resistor is higher (when there is a current) than the temperature of the temperature sensor.

7. Which conclusions are valid?
8. During which time interval can the heat loss to the surrounding be calculated
9. During which time interval is heat lost to the surroundings?
10. Determine the total electric energy supplied from the graph of power against time. Determine the average power delivered. Explain clearly how you calculated the average power. Use the third page for calculations.

On the second page in your calculator you can see the temperature gradient. There are also four points A, B, C and D. These points can be used to manipulate the lines. You can use these lines to calculate the gradient of the graph. The values are listed on the right side of the page. H1 is the slope of the line segment AB and H2 is the slope of line segment CD. These variables can be used for your calculations.

11. Determine from the graph the average temperature increase per second over the interval t = 1.0 min to 5.0 min. Use points A and B.
12. Determine from the graph the average temperature decrease per second . Use points C and D
13. Calculate the temperature increase per second if all the electrical energy was used for heating the cylinder. Use the third page on the Nspire for calculations.

The height of the cylinder is 7.0 cm and the diameter is 3.0 cm. The volume of the cylinder is calculated by $V = \pi \cdot r^2 \cdot h$.

14. Calculate the mass of the cylinder (use the third page in the Nspire). Neglect the holes in the cylinder. Give the results of your calculations on your answering paper. Look for the density of aluminium in a table book with chemical and physical properties..
15. Show that the specific heat can be calculated from the following formula:

$$c = \frac{P_{in}}{m \cdot \frac{\Delta T}{\Delta t}}$$

16. Calculate the specific heat using the answers from the previous questions.
17. Explain the influence of the neglected holes in the aluminium cylinder on the calculated value of the specific heat.
18. Imagine that the cylinder is painted black. Would the calculated specific heat be greater, smaller or stay the same? Explain your answer.

Specific Heat of Aluminium   Teacher Notes

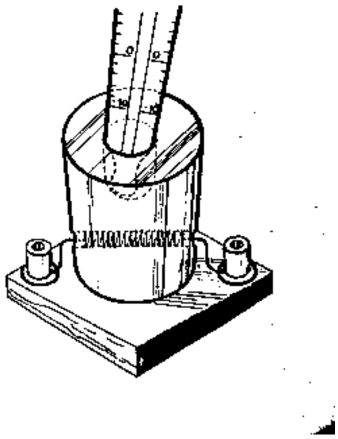
Keywords and other files

Specific heat, temperature, power, electrical energy, current, voltage

Equipment needed

To execute the experiment the following equipment is needed:

- Voltage probe
- Am probe or second voltage probe with an extra (small) resistor with known resistance
- Temperature probe
- Lab cradle
- TI-Nspire
- Aluminium cylinder
- Power supply with at least 5 V output
- Cables



The Aluminium cylinder
The construction of the aluminium cylinder:

- height: 7.0 cm
- diameter: 3.0 cm
- Cavity at the top: depth : 1.5 cm and diameter 7.0 mm
- Horizontal cavity: diameter 9.0mm.

A 4.7 Ω resistor is placed in the cavity with heat conductive paste and sealed with resin. Working method and equipment

Overview

Using an aluminium cylinder in which a heater is placed students measure the specific heat of aluminium. The cylinder is not insulated; this forces the students take into account the heat loss to the environment. Over 5 minutes, the cylinder is heated, and measurements are taken for a further 5 minutes to measure the heat loss to the environment. From the measurements of the last five minutes, the students can correct for the heat loss to the surroundings. The specific heat can be calculated from the total electric energy added, the temperature increase and the temperature decrease. It is based on a practical exam from CITO 1979. This material consists of an experimental description, student sheet, response sheet for students, expected answers, score form and two tns files.

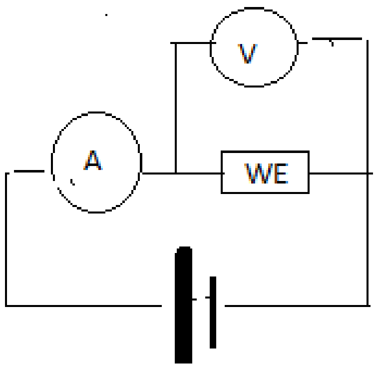
Set up

- Time Based for 10 minutes
- Data rate 0.25 Hz, (Interval 4 seconds)

Experiment Activity and Tips

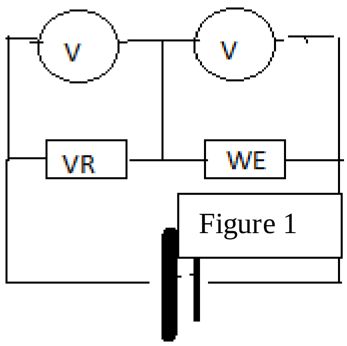
The experiment uses the circuit of Figure 1 or figure 2. The first circuit is used when a current probe is available. The second circuit can be used if no current probe is available. The current is measured by adding an extra (small) resistor with a known resistance and measuring the voltage across this extra resistance. The negative poles of the two voltage sensors are connected to the same point. In the setup of the tns file it is ensured that the voltage across the resistor in the cylinder appears as positive. The current can be calculated using Ohm's law . The voltage supply is set up to ensure a voltage of 5 V across the resistor in the cylinder. A temperature sensor is connected to the second or third channel of the labcradle. After 5 minutes the heating must be turned off. Afterwards, students have to take measurements for five more minutes. Students must save their measurements in the Nspire for inspection by the teacher.
Using a current probe the student has to add one new calculated column for the
power supplied, if two voltages probes are used the student has to add two
new columns, one for the current and one for the power.

To calculate the specific heat of aluminium the student has to determine the area under the P(t) graph and the slope of the T(t) line. With these values the student has to calculate the specific heat of aluminium



WE = resistor in cylinder

Figure 1

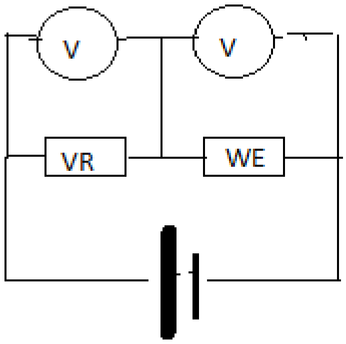
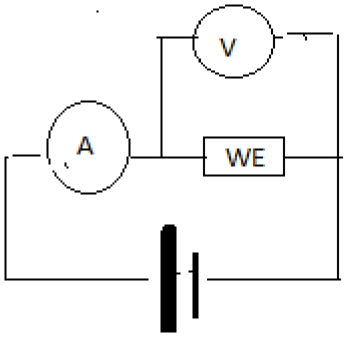
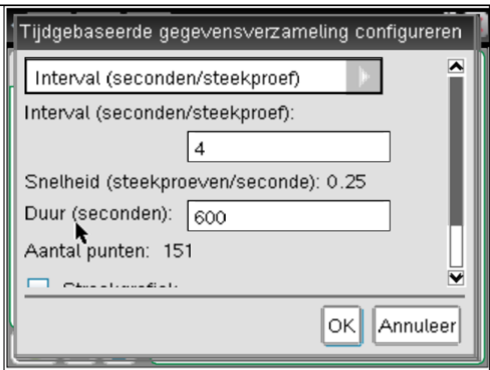
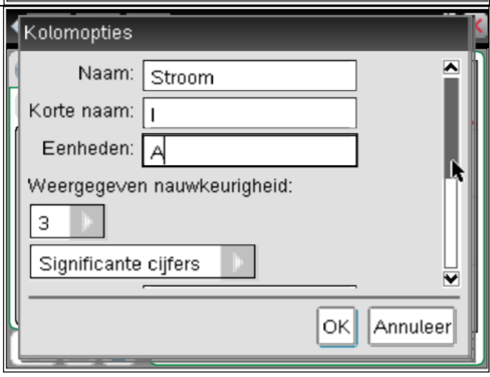
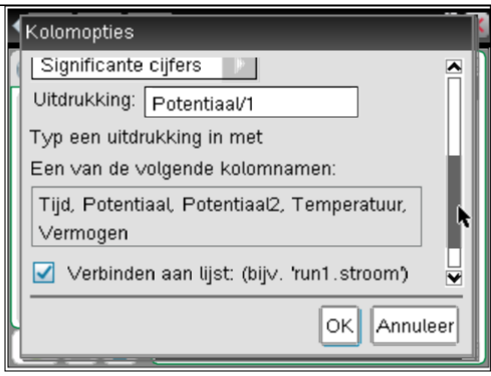
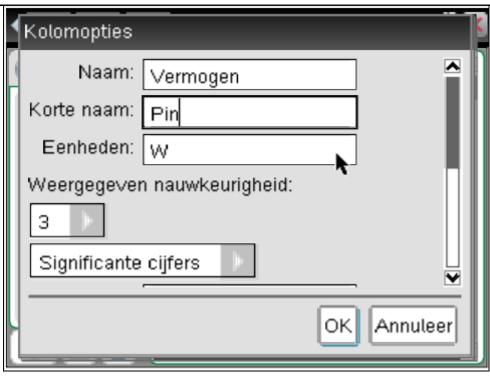
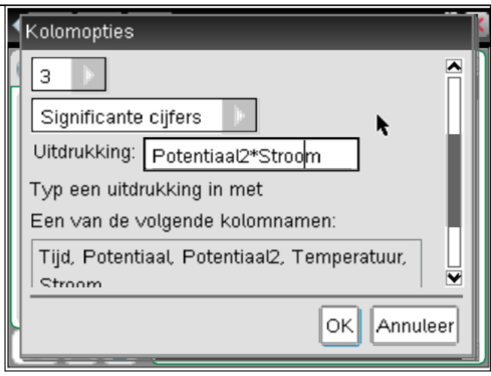


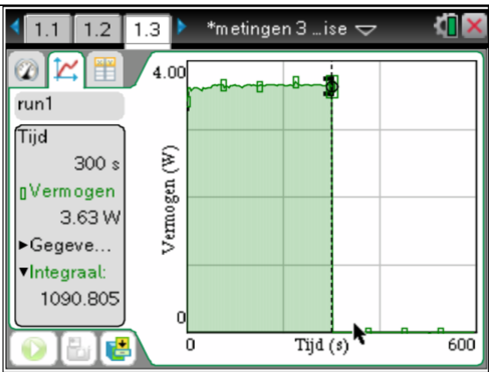
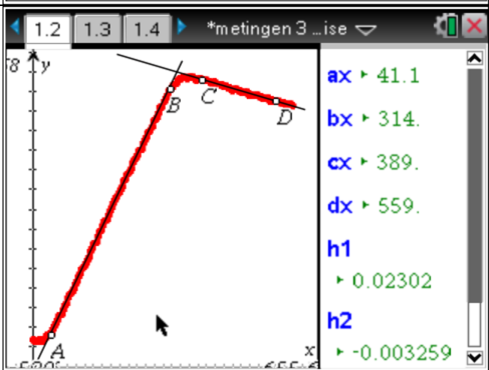
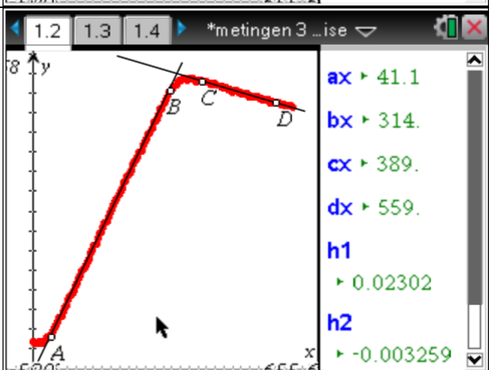
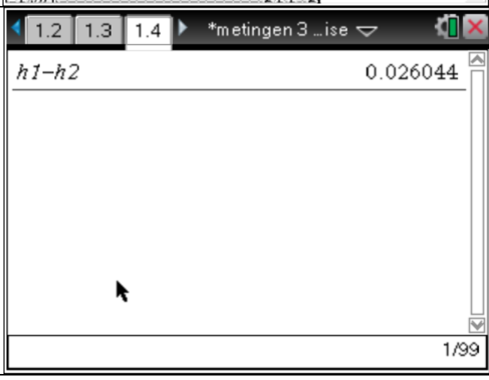
VR = Extra resistor
WE = resistor in cylinder

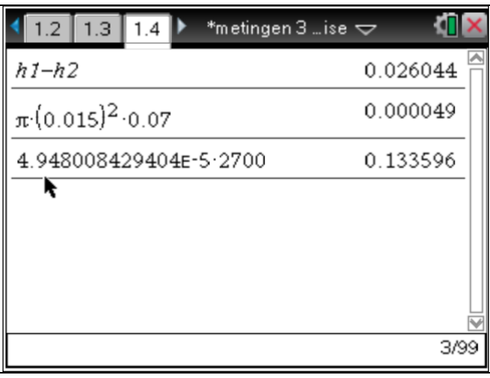
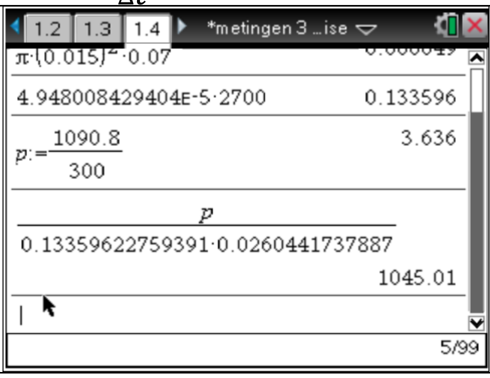
Figure 2

Exemplar Results

Question	Answers
1	Mass, temperature increase and added heat.

2	 VR = Extra resistor WE = resistor in cylinder  WE = resistor in cylinder
3 + 4	
5	 I=U/R with R the value of the extra resistor. Left column is not nessecarily when an am probe is used.
6	 P=V*I with V= Potential2 and I = Current.

7	B and D.
8	From the moment that the temperature starts to decrease. t > 390s (Look in graph)
9	From the moment that the temperature is higher than the temperature of the surrounding, from t > 34s (look in graph).
10	 E_{el} area under P(t) graph= 1090,8 J in 300 seconds P = 1090.8/300 = 3.6 W
11	 The value h1 := 0.023 °C/s. ±0.001 °C/s
12	 The value h1 := -0.003 °C/s. ±0.001 °C/s
13	 h1 – h2 = 0.026 °C/s ± 0.002 °C/s

14		$V = 4.9\cdot10^{-5}$ m^3 Density is $2.7\cdot10^3$ kg/m^3 $M = \rho\cdot V = 0.13$ kg.
15	Q=P·t = m·c·ΔT→ P = m·c· ΔT/t, $c = \frac{P_{in}}{m\cdot\frac{\Delta T}{\Delta t}}$	
16		$c = 1.1\cdot10^3$ J/kg·°C
17	By neglecting the holes the calculated mass is too high. Therefore the calculated specific heat is too low. . But the holes are filled with paste and resin which have a higher specific heat then aluminium. They also absorb heat. Therefore it is difficult to predict the influence of neglecting the holes	
18	With a black cylinder the heat loss to the surrounding is higher , due to the correction this is no problem . Therefore the calculated specific heat will not change.	

Analysis of light intensity **student notes**

Context of the activity:

In electromagnetic wave propagation the signal is attenuated. The intensity of light from a lamp decreases as it moves away. The light intensity (I) is a function of the distance (d) from the light source.

$$I = \frac{E}{d^2}$$

This relationship is called the inverse square law of distance.

The value of the constant E, depends on the lamp used, you will need this later.

Learning Outcomes:

Learn that the intensity of light striking a surface is inversely proportional to the square of the distance from the source.

Experiment notes and instructions:

Prepare the activity (see the figure).

Place the light sensor near the lamp inside the tube at a point where the intensity is a maximum. The lamp should be at one end of the tube.

You will need Data with Entry.

Collect 9 or 10 points by moving the lamp and sensor away from each other.

Analysis of your results

Fit a power curve to your data and note the value of "b".

Now open a data and statistics application and re-plot your data. Again fit a regression curve.

What is the value of "y" when x is "1", we will call it "a".

Now plot the theoretical curve for the attenuation of the lamp given by

$$\boldsymbol{y = a/x^2}$$

Questions

Why is it necessary to place antennas at a certain distance from each other?

Why is it necessary to put microwave antennas on high tower?

Analysis of light intensity **teacher notes**

Key words:

Reflection, refraction, diffraction, attenuation and absorption of light

Complementary files;

Student sheet (word doc), teacher sheet (word doc), Intensity.tns

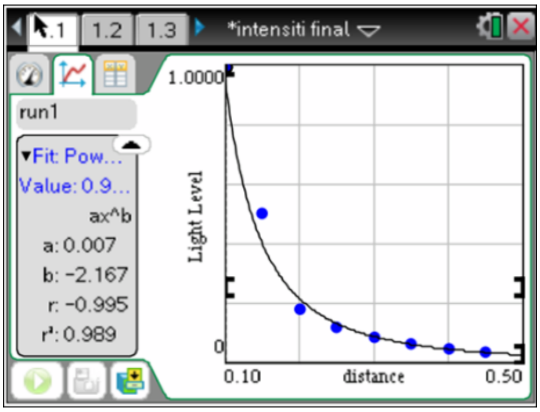
Apparatus needed:

TI-*nspire* Handheld with OS 3.2
A light sensor Lab Cradle
Tube about 0.5 -1 *m* long
Tape measure
Lamp to fit in one end of tube

Experiment set-up and collection mode:
Events with entry.

Ensure that a sensible number of results can be obtained starting from the maximum value for the intensity.

Students will need to find a way to measure “d”.



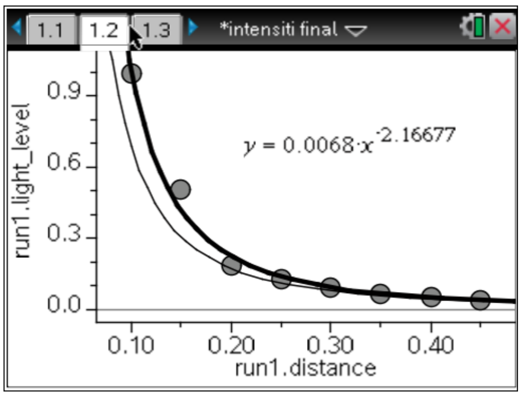
Tips

When fitting the power regression note that the value of the coefficient, “a”, is likley to be truncated in the details box. This coefficiemnt is needed for fitting a theoretical curve in the Data and Statistics application. It is also easy to use the DataQuest application to model the data.

Exemplar results

Here you can see that the value of a is 0.0068 rather than 0.007. There are an infinite number of inverse square functions which could be drawn but by taking the value of y when x is 1 we ensure that the theoretical curve passes through the regression curve. The lighter curve here is

$$y = \frac{0.0068}{x^2}$$



In mobile and satellite communications microwave radiation are used in different frequency bands. In large cities tall towers are built supporting a set of parabolic antennae to enable signal propagation.

The microwaves propagate practically in a straight line but are easily absorbed by molecules of water from the atmosphere. This significantly increases attenuation . The existence of multiple antennas allows reception and amplification of the received signal for retransmitting.

The antennas are placed at reasonable heights to avoid diffraction by buildings and to place a security distance between them and humans.

Mineral water – acid water student notes

Context

Mineral water with gas – a lot of people don´t like it. Why not? Is it the gas in the water? Is it because the pH is smaller than 7. What can they do?
Why is the pH of mineral water less than 7?
The following experiment may help.

Experiment

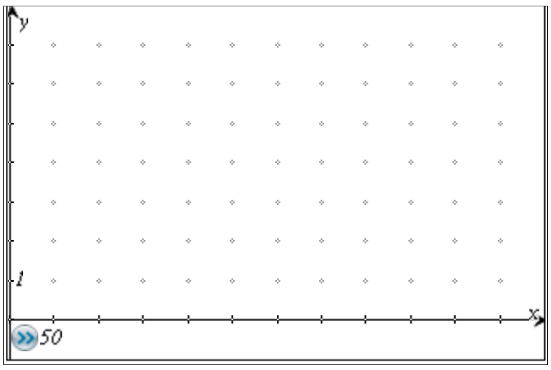
Put about 50 ml mineral water in a beaker. Place the beaker with the mineral water and the stirring bar on the magnetic stirrer.
Prepare to take measurements with the pH-sensor.
Measure the pH over a period of 10 minutes every 5 seconds.
Switch the magnetic stirrer on (high speed) and after about 20 seconds start the measurements.

Evaluation

1
Write down your observations.

____

2
Sketch the graph and interpret it.



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3
Explain the change in pH during the experiment.

____

4*
What happens to the pH, if the magnetic stirrer turns slowly?
Develop an experiment to verify your Prediction.

Mineral water – acid water teacher notes

Equipment

Chemicals

- magnetic with stir bar
- beaker (V = 80 mL)
- support material

- pH - sensor
- mineral water

Settings for measuring

- Time Based
- Interval (seconds/samples): 5   Duration (seconds): 600

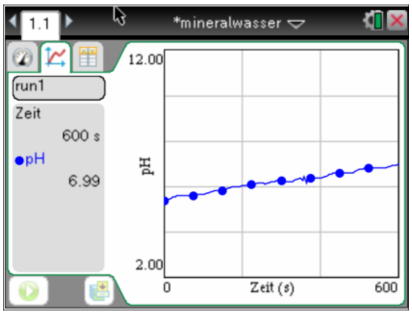
Tips for the experiment

You can also do this experiment with a conductivity sensor. The conductivity goes down. It is not possible to do this experiment with conductivity and pH sensor together as they affect each other.

Results and notes

1 At first you can see a strong gas evolution. During the experiment the gas evolution decreases.

2 The pH rises from about 5,0 to 6,3.



3 Carbon dioxide evolves with vigorous stirring.
Carbon dioxide is removed and so affects the equilibrium. The following reaction will shift to the left. After a few minutes there are fewer hydronium ions in the mineral water therefore the pH rises.

$$CO_2 + 2\,H_2O \rightleftharpoons H_2CO_3 + H_2O \rightleftharpoons H_3O^+ + HCO_3^-$$

4* If the magnetic stirrer works slowly the Carbon dioxide escapes slowly too.
The pH rises less quickly.

How do we protect ourselves from sounds? Student notes

Context of the activity:

For Anis's birthday, his friend Loïc wishes to offer him a high quality headset. Very worried about choosing a quality device, he looks on the Internet for some technical information, in particular concerning the audio quality of the headset.

Among the characteristics for all audio headsets, what is the one which seems to you to measure the quality of the audio headset?

Frequency response

sensitivity

	Panasonic RP-HTX7	Sony MDR-570LP	AKG K 518LE	Monster Beats Solo	JBL Roxy Reference 430	Philips SHL 8800	Coloud Star Wars Darth Vader
e en ce	7 - 22 000 Hz	12 - 22 000 Hz	16 - 24 000 Hz	N.C.	20 - 20 000 Hz (- 10 dB)	15 - 24 000 Hz	20 - 20 001 Hz
	Fermé	Fermé	Fermé	Fermé	Fermé	Fermé	Fermé
té	99 dB	105 dB	115 dB	N.C.	91 dB	107 dB	120 dB
ce	40 Ohm	24 Ohm	32 Ohm	N.C.	32 Ohm	32 Ohm	32 Ohm
e le	1 000 mW	1 000 mW	2 000 mW	N.C.	50 mW	100 mW	100 mW
e des cteurs	40 mm	30 mm	N.C.	N.C.	N.C.	40 mm	40 mm
	Non	Pivot écouteurs	Oui	Oui	Oui	Pivot écouteurs	Non

Learning Outcomes:

- Able to examine a sheet of technical characteristics.
- Able to calculate an acoustic level
- Know what is meant by decibels and a dangerous level of sound.
- Know that frequency is expressed in hertz.

Experiment notes and instructions:

Prove so that these reasons we do not have to confuse both types of information.

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Propose the implementation of a simple experiment (protocol-plan) allowing by means of a microphone to verify if the listening of your walkman presents a danger for your health.

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Sound Sources (Noise) Examples with distance	Sound Pressure Level L_p dB SPL
Jet aircraft, 50 m away	140
Threshold of pain	130
Threshold of discomfort	120
Chainsaw, 1 m distance	110
Disco, 1 m from speaker	100
Diesel truck, 10 m away	90
Kerbside of busy road, 5 m	80
Vacuum cleaner, distance 1 m	70
Conversational speech, 1 m	60
Average home	50
Quiet library	40
Quiet bedroom at night	30
Background in TV studio	20
Rustling leaves in the distance	10
Threshold of hearing	0

- Place the microphone against the earphone of your walkman's headset.
- Adjust the sound volume of your walkman at his usual level of listening.
- Record the data.
- Examine the appearance of the signal.

……………………………………………………

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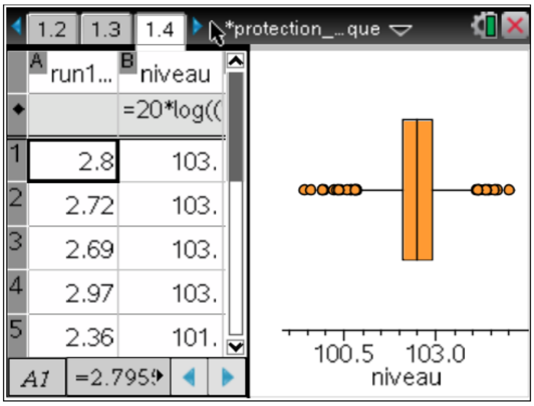
Instructions for analysis of results:



• A box plot is shown here. Analyze this representation of the data and write down the values of

- Average acoustic level
- Acoustic median level

……………………………………………………

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• What difference is there between the median and average (mean) acoustic levels?

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Instructions for observations and/or questions:

- Ask your teacher how acoustic levels are measured in decibels.
- The sensitivity of an audio headset is expressed in decibels. Dangerous sound levels are also expressed in decibels. Are the two confused?

How do we protect ourselves from sound? Teacher notes

Key words: acoustic intensity, acoustics, decibels, protection, sensitivity, Fletcher's diagram, logarithm

Complementary files:

protection_acoustique.tns

Apparatus needed:

- Microphone
- Audio headset
- TI-Nspire Cas
- Labcradle
- Walkman mp3

Overview of the science:

Acoustic intensity is expressed in decibels. Sensitivity is more correctly expressed in dB/mW or dB/mV. Sensitivity here is more closely connected to efficiency particularly when measured in dB/mW.

General question: «do certain sounds seem to you to be dangerous for your health ?»

The following is in the student notes:

For Anis's birthday, his friend Loïc wishes to offer him a high quality headset. Very worried about offering a quality device, he looks on the Internet for some technical information, in particular concerning the audio quality of the headset.

Among the characteristics for all audio headsets, what is the one which seems to you to measure the quality of the audio headset?

Frequency response →

sensitivity →

	Panasonic RP-HTX7	Sony MDR-570LP	AKG K 518LE	Monster Beats Solo	JBL Roxy Reference 430	Philips SHL 8800	Coloud Star Wars Darth Vader
Réponse en fréquence	7 - 22 000 Hz	12 - 22 000 Hz	16 - 24 000 Hz	N.C.	20 - 20 000 Hz (- 10 dB)	15 - 24 000 Hz	20 - 20 001 Hz
Type	Fermé	Fermé	Fermé	Fermé	Fermé	Fermé	Fermé
Sensibilité	99 dB	105 dB	115 dB	N.C.	91 dB	107 dB	120 dB
Impédance	40 Ohm	24 Ohm	32 Ohm	N.C.	32 Ohm	32 Ohm	32 Ohm
Puissance admissible	1 000 mW	1 000 mW	2 000 mW	N.C.	50 mW	100 mW	100 mW
Diamètre des transducteurs	40 mm	30 mm	N.C.	N.C.	N.C.	40 mm	40 mm
Pliable	Non	Pivot écouteurs	Oui	Oui	Oui	Pivot écouteurs	Non

But the information used to estimate the quality of the product, namely the sensitivity, is also associated with the level of danger of a sound.

The students have to contrast the information read in the table of the characteristics of the audio headset with that of the acoustic intensities.

Indeed, in the first table, 100 dB corresponds to an audio headset of good sensitivity, while in the second table, it is about the threshold of dangerous acoustic intensity.

The experiment is thus going to consist of recording the acoustic pressure of an audio headset from a walkman, then to analyze the data obtained to:

- Determine the median and average acoustic intensities, using a box plot.
- Revise lessons learned in maths class.

Sound Sources (Noise) Examples with distance	Sound Pressure Level L_p dB SPL
Jet aircraft, 50 m away	140
Threshold of pain	130
Threshold of discomfort	120
Chainsaw, 1 m distance	110
Disco, 1 m from speaker	100
Diesel truck, 10 m away	90
Kerbside of busy road, 5 m	80
Vacuum cleaner, distance 1 m	70
Conversational speech, 1 m	60
Average home	50
Quiet library	40
Quiet bedroom at night	30
Background in TV studio	20
Rustling leaves in the distance	10
Threshold of hearing	0

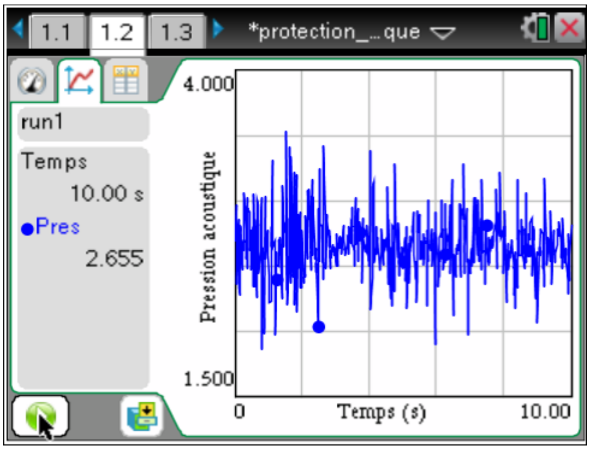
Experiment set-up and collection mode:

Set up DataQuest to record for 10 seconds at 100 samples per second.

Experiment activity and tips:

Insert a Lists and Spreadsheet application.

Insert in column A the acoustic pressure (in pascals). In column B students will be calculating the acoustic intensity(in decibels).

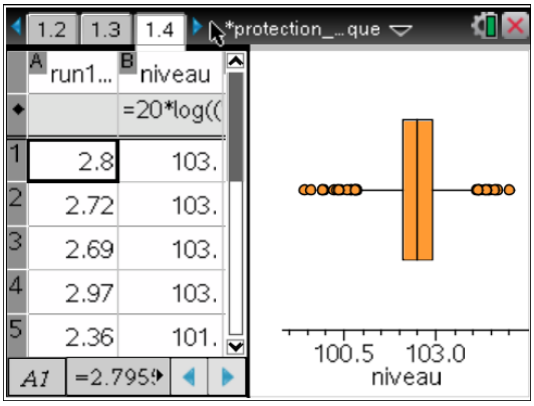


Exemplar results:

In column B, calculate the acoustic intensity, by using the formula :

$$L = 20\log\left(\frac{run1.acoustic\_pressure}{2\times10^{-5}}\right)$$

We so obtain, the acoustic intensity in dB, the acoustic pressure being expressed in Pa.



The students will have to examine and compare the various samples obtained in the class, analyze the box plot and finally draw conclusions about the danger level for listening with their walkman.

Finally the teacher will have to explain what the sensitivity of an audio headset represents to help the students conclude that a high sensitivity may represent high security. Headphones with a higher sound pressure level (sensitivity) will generally be louder when supplied with any given audio source.

The government of France has imposed a limit on all music players sold in the country. They must not be capable of producing more than 100dBA (the threshold of hearing damage during extended listening is 80dB, and the threshold of pain, or theoretically of immediate hearing loss, is 130dB).

Newton's second law   Student notes

A Fundamental Law of Mechanics

Setting up the experiment

Experiment with force and acceleration sensor

Settings

- Mode: Time Based
- Duration: 3 s
- Rate: 5 samples/second
- Ch1: low-g accelerometer
- Ch2: Force sensor (range: 50 N)

Notes

The arrow on the acceleration sensor should be facing up. The acceleration and forced sensors are zeroed with the object standing on the surface and hanging motionless on the sensor, respectively. The acceleration of free fall is not being measured. The force sensor must be zeroed in this way in order to measure the accelerating force only.

Procedure and Analysis

(A) Attach the accelerometer using the tape in an exactly vertical position(upward arrow) on the first object. Connect the sensors to the handheld computer.

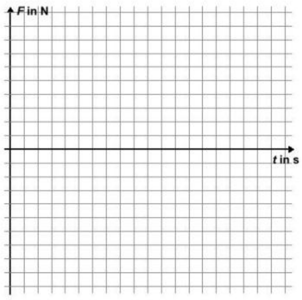
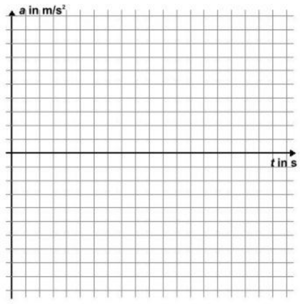
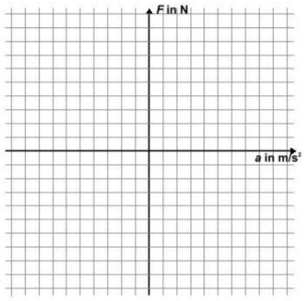
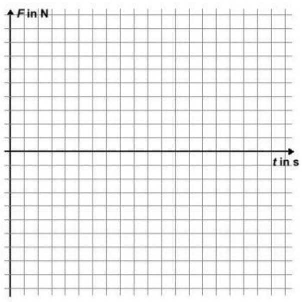
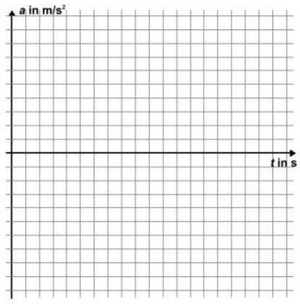
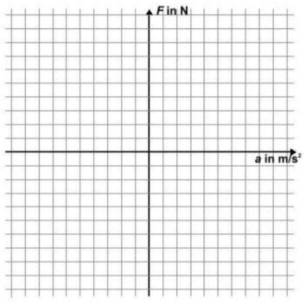
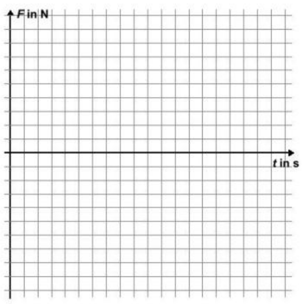
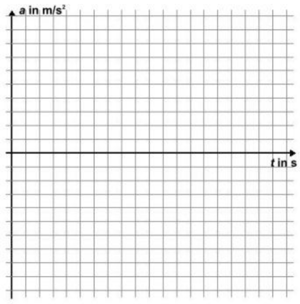
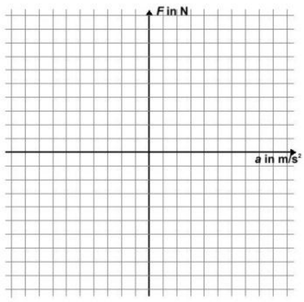
(B) Zero the acceleration sensor while the weight is still standing on the surface. Now lift the weight hanging on the force sensor and zero the force sensor (keep very still!). Make all other settings.

(C) Start the measurement. The object is raised several times during the measurement period. During this short time it is being accelerated, then it is lowered again.

(D) Observe the graphs of force and acceleration as a function of time and construct the graph of force as a function of the acceleration. (You may want to select the graphical representation for this). Sketch the curves of the graphs on the worksheet.

(E) The graph of force against acceleration is a straight line passing through the origin. Determine the equation of such a line.
(F) Repeat instructions (A) through (E) with the other masses.

Accelerated mass 1 m_1 =

<table>
<tr><td colspan="3">Accelerated mass 1 m_1 =</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="2">Equation of the line:</td><td></td></tr>
<tr><td colspan="3">Accelerated mass 2 m_2 =</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="2">Equation of the line:</td><td></td></tr>
<tr><td colspan="3">Accelerated mass 3 m_3 =</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="2">Equation of the line:</td><td></td></tr>
</table>

Conclusion

What is the relationship between the accelerating force F and the acceleration a? What is the physical significance of the gradients of each of the lines in the F-a charts? Write a conclusion.

Newton's second law Teacher notes

A fundamental law of mechanics

This fundamental law of mechanics tells us what happens when a net force is exerted on a body. It causes the velocity to change and a change in velocity is an acceleration. For a body of constant mass, the acceleration is directly proportional to the net force applied to it.
Experimental confirmation of the law is usually carried out by applying a constant force to a mass and calculating the acceleration from position and time measurements. The force and the mass can be varied and new accelerations calculated.
Using the new TI-Nspire^{TM} LabStation, a direct measurement of a varying accelerating force during the acceleration is possible. Students can observe that the quantities are directly proportional to each other immediately without having to carry out several experiments with different sized forces.
Here a force sensor and an acceleration sensor are used. The latter resembles the acceleration sensors used in mobile phones. Sufficient experience of measuring accelerations conventionally in kinematics classes justifies the use of computer-aided measurement techniques here, even if the meter itself remains a black box.

Experimental Set-up

Experiment with force and acceleration sensor

Equipment

- Objects with different masses (for example 0.5 kg, 1 kg, 2 kg)
- Labstation; here TI-Nspire™ with TI-Nspire™ LabCradle
- Force sensor (for example dual-range-force-Sensor, DFS-BTA)
- Acceleration sensor (for example low-g accelerometer, LGA-BTA), or
- Ultrasonic motion detector (for example CBR 2™)

Carrying out the experiment

An object is raised several times, with short duration accelerations and then lowered again. The accelerating force and acceleration are measured simultaneously. The experiment is repeated with objects of different mass.
Preparation: 5 min, *Carrying out:* 25 min (with analysis)

Setting up the experiment.

- Mode: Time Based
- Duration: 3 s
- Rate: 5 samples/second
- Ch1: low-g accelerometer, LGA-BTA, arrow pointing up. Zero the sensor with the mass motionless on the surface.
- Ch2: dual-range-force-Sensor, DFS-BTA (50 N). Zero the sensor with the mass hanging motionless.

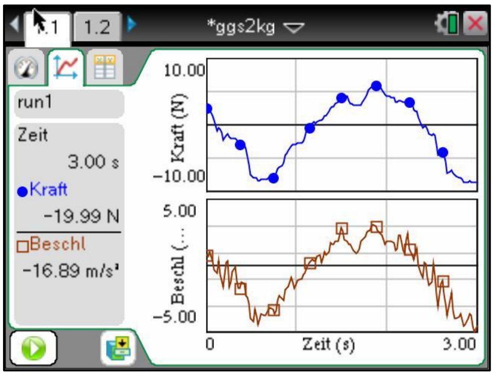
Important notes

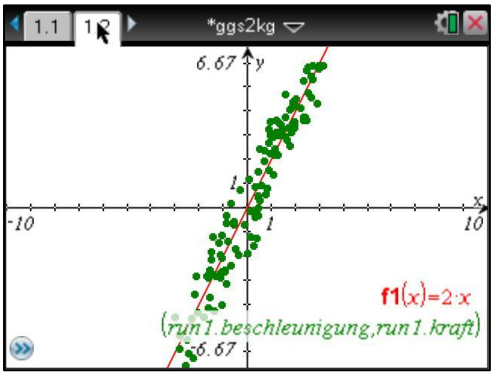
The arrow on the acceleration sensor should be facing up. The sensors are set to zero when the object is standing on the surface hanging motionless on the sensor. The acceleration of free fall is not being measured. The force sensor must be zeroed in this way in order to measure the accelerating force only.

Analysis

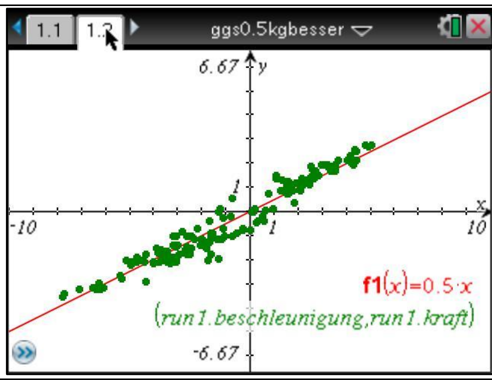
The graphs show similar trends, as would be expected. Then upper graph is force against time while the lower graph shows acceleration against time.

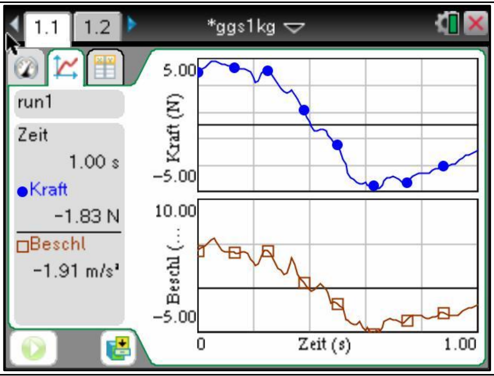
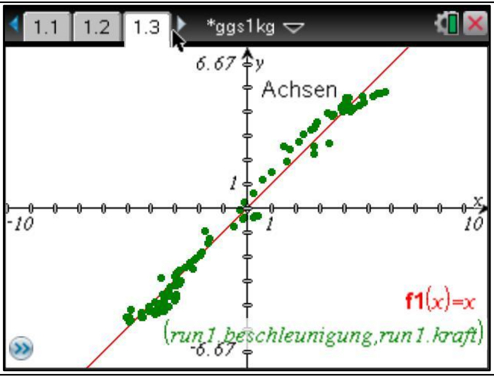
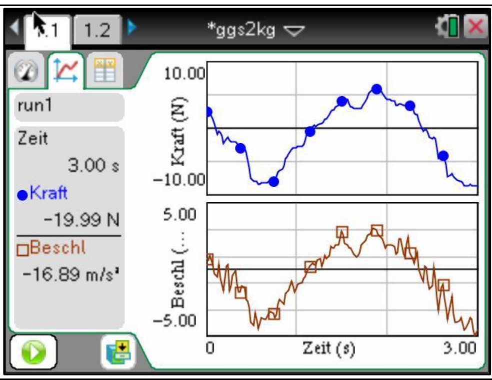
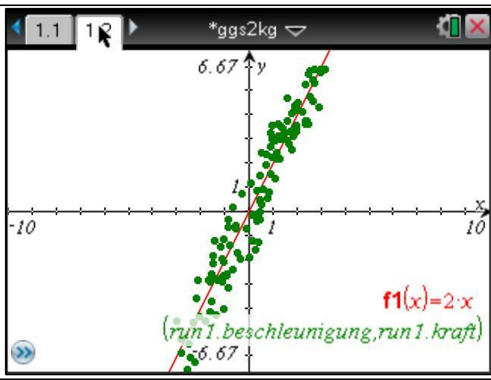
A scatter graph of force against acceleration suggests a straight line passing through the origin. Now we could determine the equation of such a line with an automatic regression. The gradient is of course the mass of the accelerated body.





Exemplar results

<table>
<tr><td colspan="2">Accelerated mass 1 m_1 = 0,5 kg</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">Accelerated mass 2 m_2 = 1 kg</td></tr>
</table>

<table>
<tr><td>
</td><td>
</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">Accelerated mass 3 $m_3 = 2$ kg</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td colspan="2">Note that the graphs in the Dataquest diagrams are similar. The proportionality between F and a is confirmed by the best fit lines in the F-a graphs. In addition the experimental uncertainty in the ratio of F and a is shown. The gradient of the line gives the mass of the accelerated body, $F = m \cdot a$</td></tr>
</table>

Acid base titration Student notes

determination of the amount of acetic acid in vinegar .

Explore

Research question
How can we determine experimentally the concentration of acetic acid in vinegar?
We apply an automatic titration using a drop counter and TI-Nspire technology.

Prepare

<u>Material</u>

Vernier Drop Counter 100 mL beaker
60 mL reagent reservoir 10 mL graduated cylinder
10 mL pipette Lab Cradle + TI-Nspire

compounds

vinegar (10 X diluted)
NaOH- solution(0,10 mol/l)
phenolphthalein: indicator

Instructions

1. Calibrate the drop counter.
2. Rinse the 10 ml pipette three times with water, three times with distilled water and twice with diluted vinegar.
3. Rinse the 250 ml beaker three times with water, then three times with distilled water
4. Connect the pH sensor to the first analogue port of the Lab Cradle. Attach the micro stirrer to the pH sensor.
5. Place the pH sensor in the large circular opening of the dropper.
6. Put 100 ml of distilled water in the 250 ml beaker.
7. Place 10 ml of the diluted vinegar with the aid of a pipette in the 250 ml beaker with the distilled water. Add a few drops of phenolphthalein.
8. Place the beaker on a stirrer plate.
9. Raise the pH sensor and lower it into the vinegar solution.
10. Fill the burette with NaOH - solution 0,1 mol / l.
11. Start the measurement. No data will be collected until the first drop through the slot of the dropper falls.

12. Open the bottom valve of the burette.
13. Stop measurement a few ml after the pH rapid change has clearly occurred.
14. Determine graphically V_{NaOH} added up to the Equivalence Point (EP).

    V_{NaOH} = ... ml

Questions

Calculate the percentage of acetic acid in vinegar.

Acid base titration Teacher notes

Determination of the amount of acetic acid in vinegar

The concentration of acetic acid in vinegar can be determined by means of a volumetric acid - base titration with sodium hydroxide according to the neutralization reaction:

$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$

Remark:

The concentration of acetic acid in vinegar is expressed in degrees (mass-volume percent). Vinegar of 8 degrees means 8 g per 100 ml acetic acid equivalent to about 1.3 moles of acetic acid per litre of vinegar. Because we titrate with a NaOH solution of 0,1 mol/l we dilute the vinegar first 10 times.

hints

Calibration drop counter

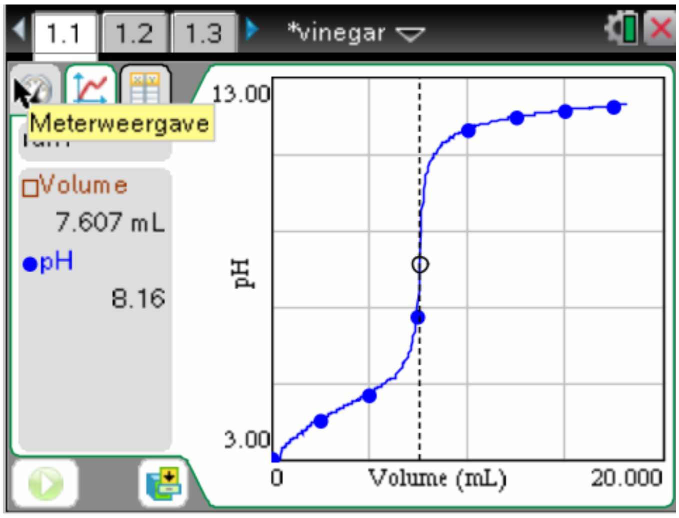
1. Press menu---experiment---sensor ----calibrate---one point
2. Place a 10 mL graduated cylinder directly below the slot on the Drop Counter, lining it up with the tip of the reagent reservoir
3. Open the bottom valve on the reagent reservoir (vertical). Keep the top valve closed (horizontal).
4. Slowly open the top valve of the reagent reservoir so that drops are released at a slow rate (~1 drop every two seconds). You should see the drops being counted on the screen.
5. When the volume of NaOH solution in the graduated cylinder is between 9 and 10 mL, close the bottom valve of the reagent reservoir.
6. Enter the precise volume of NaOH (read to the nearest 0.1 mL) in the edit box.

Equilibrium Point EP

In the expected results below a Lists and Spreadsheet application has been opened so that a manual calculation of the derivative can be carried out on the data. It is possible to use DataQuest directly: enter derivative (pH, Volume, 1, 1) to create a new calculated column in the DataQuest table (spreadsheet).

Expected results

$a_{acetic\ acid}\ V_{acetic\ acid}\ c_{acetic\ acid} = a_{NaOH}\ V_{NaOH}\ c_{NaOH}$



$a_{acetic\ acid} = 1$

$V_{acetic\ acid} = 10$ ml

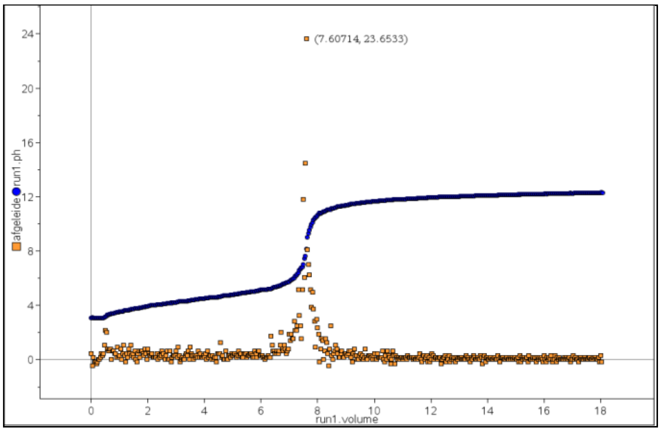
$c_{\ acetic\ acid}$ = unknown (diluted)

$a_{NaOH} = 1$

V_{NaOH} =volume NaOH – solution added up to the EP = 7,61 ml

c_{NaOH} = 0,10 mol/l

We calculate $c_{\ acetic\ acid}$: $c_{\ acetic\ acid}$ = 0,0761 mol/l
$c_{\ acetic\ acid}$ (non diluted) = 0,761 mol/l
mass acetic acid per litre of solution = 0,761 mol/l x 60 g/mol = 45,7 g/l
percentage mass acetic acid = $\frac{45,7\frac{g}{l}}{1006\frac{g}{l}}$ x 100% = 4,54 %
(density = 1006 g/l)
From the first derivative you can easily determine the EP:



Simple Harmonic Oscillations   student notes

Context of the activity

To find out what variables affect the period of a simple harmonic oscillator and carry out some investigations to discover how they depend on each other.

Learning Outcomes

- Know how to use the CBR 2 together with the LabStation to collect some real time data
- Know how to explore their data when investigating what affects the period of a simple harmonic oscillator.
- Be able to use mathematical models.

Experiment notes and instructions

You need a file called simple_harmonic_oscillation.tns. Open that file and follow the instructions. If you need help ask your teacher.

Instructions for analysis of results

Follow the instructions in the file mentioned above. You will collect a lot of data and be required to control variables which are not being investigated. For example when you investigate if the amplitude affects the period you must change the spring or the mass of the block that is oscillating.

Finally you will examine all the factors affecting the period of an oscillator and derive a single equation, the mathematical model, for the period of a simple harmonic oscillator.

Observations and/or questions

1. On what do you think the period of a simple harmonic oscillator depends?
2. Investigate all those things in the file you got from your teacher and if you find some connections write them down, both in the file and on paper.
3. Derive a formula for the period involving the variables you have investigated.
4. Can you show that the constant of proportionality is 2π?

Simple harmonic oscillations   teacher notes

Key words

simple harmonic oscillation, period, spring constant, Nspire

Complementary files

Simple_harmonic_oscillations.tns, a file for the students which they use during their experiments.
Simple_harmonic_oscillations_tv.tns, a file for the teacher providing exemplar results.

Apparatus needed

springs with different spring constants
support and clamp
blocks with different masses
rulers
CBR 2 plus LabStation or TI-Nspire.

Overview of the science

In this experiment the students are going to find the relationship for the period of a simple harmonic oscillator. The students are going to follow the instructions in the file mentioned above. They will collect rich data and be obliged to control their variables. Finally they will bring their work together by graphing different relations and find a formula for the period. The period is given by $T = 2\pi\sqrt{\frac{m}{k}}$ where m is the mass of the block that is oscillating and k is the spring constant. They are also going to try and derive this relation theoretically.

Experiment set-up and collection mode

The experiment set-up you can see in the picture to the right. The students will use a premade file and in that file they use the timebased mode.

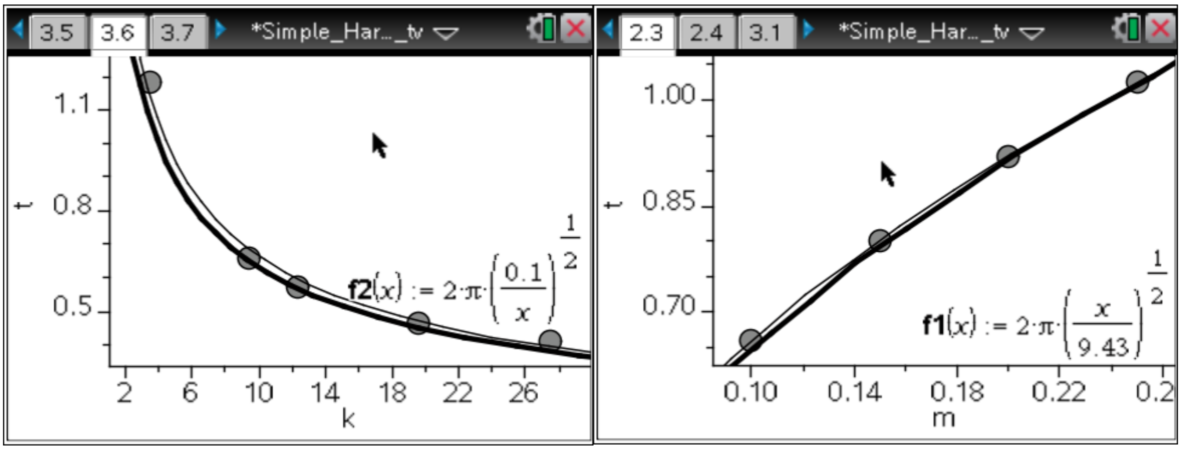
Experiment activity and tips

The students will answer the following questions.

1. On what do you think the period of a simple harmonic oscillator depends?
2. Investigate all those things in the file you got from your teacher and if you find some connections write them down, both in the file and on paper.
3. Derive a formula for the period involving the variables you have investigated.
4. Can you show that the constant of proportionality is 2π.

Exemplar results

All the results are presented in the file Simple_harmonic_oscillation_tv.tns except for plotting the time versus mass and time versus spring constant graphs. You can see these in the diagrams below, a very good fit!



When they establish the relation theoretically they use the already established equations of simple harmonic motion

position $y = A * sin\omega t$ where $\omega = 2\pi f$

to get the acceleration, $a = -A\omega^2 * sin\omega t = -\omega^2 * y$.

Use Newton's second law to get $F = m * -\omega^2 * y$.

The resultant force on the block displaced y from the equilibrium position is $F = -k * y$

Therefore $-k * y = m * -\omega^2 * y$

$$\omega = \sqrt{k/m}$$
$$T = 2\pi\sqrt{\frac{m}{k}}.$$

Measuring muscle fatigue   student notes

When you are exercising you are transforming energy in the muscles. To respire you need glucose and oxygen. If you do not have enough oxygen your muscles make lactic acid which causes muscle fatigue – usually called “the burn”. You will compare your left and right hands and investigate the effect of competition on performance.

Learning outcomes

- Know what muscle fatigue is
- Able to measure muscle fatigue in the hand

Instructions

1. Connect the Hand grip sensor to the lab cradle
2. Open a new document
3 Zero the dynamometer
3. Hold the sensor in your hand
4. Partner to press play while you grip as hard as possible for the time
   Do not watch the screen while gripping.
5. Save the data
   (In the data table you can change the data headings)
6. Repeat for the your other hand and save
   (Both hands can be tested simultaneously if two sensors are attached)
7. Partner to repeat the whole process and save in the same file
8. Show the graphs together to compare the data.

Extension

Connect two sensors and compare your hand grip
One hand not looking with the other hand looking at the screen
One hand against another in competition from another person

Questions

1. Which hand was stronger?   Why do you think that was?
2. Describe the pattern in the graph
3. How does this data show muscle fatigue?
4. What is the effect of competing with someone?

Measuring muscle fatigue   teacher notes

Materials

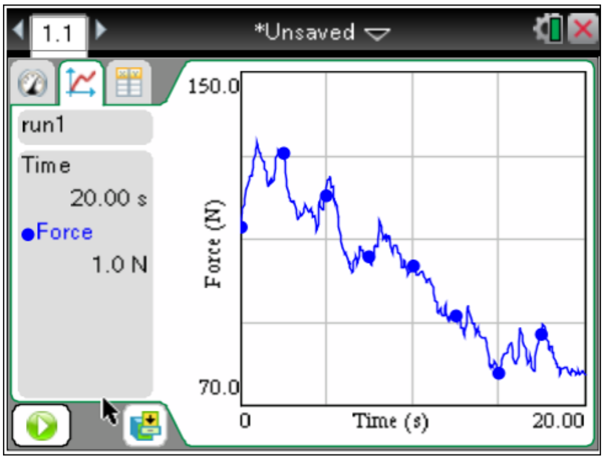
TI Nspire and lab cradle
1 or 2 hand grip dynamometers

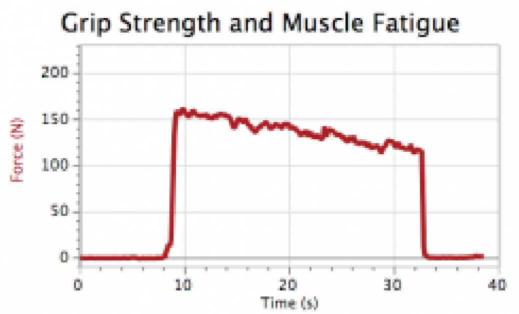
Set-up and Collection Mode

Edit settings to record 20 samples a second for 20 seconds in time based mode.

Exemplar results and notes

What students are likely to produce. This is useful for fitting a linear regression as there is no need to select data to fit the straight line.





Including the zero reading, it can be seen that the data needs to be selected to provide a suitable region as above in order to fit a linear regression.

Students could make estimates of overall fitness from the gradients of the linear fit to these graphs.
They could further explore the graphs for linearity as fatigue may not be a linear relation.

Impulse and Momentum   student notes

Context of the activity

The purpose of the session is to verify that impulse equals change in momentum.

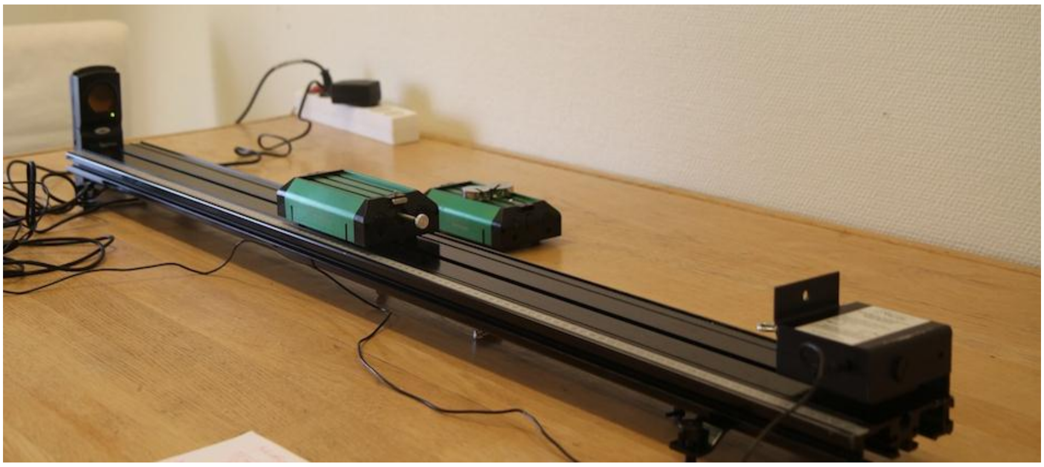
Learning Outcomes

Able to use the “position – time” graph to calculate the speed
and the “force – time” graph to calculate the impulse of an impact.

Experiment notes and instructions

You need a motion track with a carriage, CBR and a Force Sensor (Dual-Range Force Sensor or Student Force Sensor). A computer with TI-Nspire program (or a TI-Nspire handheld) and a Lab Cradle.

Switch the force sensor to the ±10 N scale and connect it to CH 1 on the lab cradle.
Make sure the track is horizontal. Attach the force sensor in one end of the track.
Place a CBR on the other side of the track and switch it to the ”car – mode”.
Connect the CBR-unit to DIG 1 on the lab cradle. The program should identify the sensors.
Do a test to make sure the equipment is working properly.



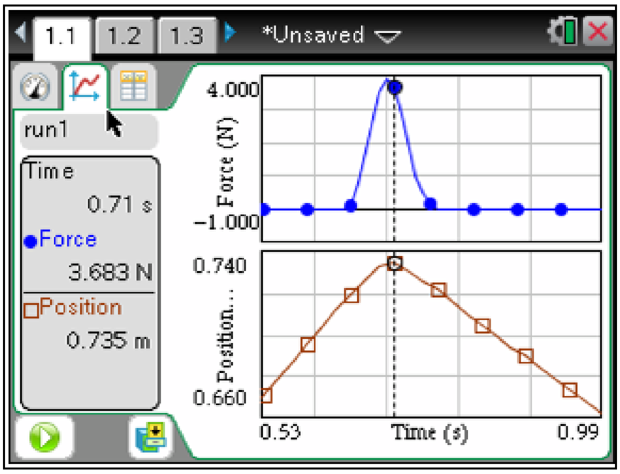
- Turn on TI-Nspire on your computer (or the handheld). Connect the labcradle to your computer.
- The force sensor measures negative force when pushed. You can change this by reversing measurements.
- Set the force sensor to zero by clicking: Experiment, Set up Sensors, Zero and Dual Range Force Sensor.

- To set up the experiment click on Experiment followed by Collection Setup since ”Timebased” is already chosen by default. Choose 100 measurements/second as rate and 2 seconds as duration.
- Place the carriage 20 cm from the CBR and start collecting data. When the CBR starts clicking faster, give the vehicle a push towards the force sensor.

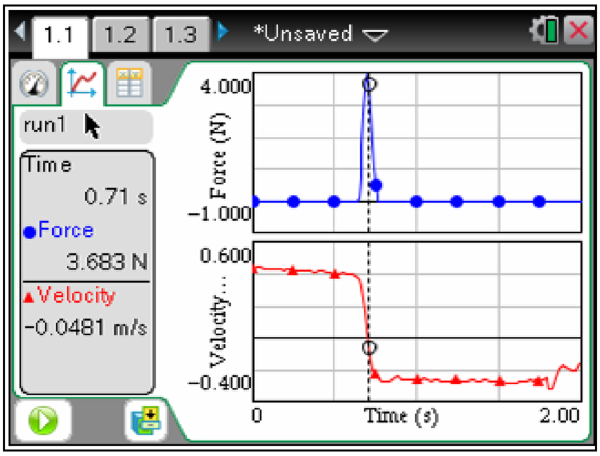
Instructions for analysis of results:

Look at the graphs “force- time” and “position- time” and try to understand why they look like this.

When you want to verify the impulse/momentum relationship you need the speed before and after impact to calculate the change in linear momentum. You can calculate them from the “position-time” graph or by changing to “velocity-time” graph. If you use the velocity graph you can estimate an average or use a tangent. Remember that the linear momentum is a vector.



To calculate the impulse you need the area under the “force - time” graph. You can use DataQuest to measure the area very easily.



Questions:

What's the unit of the area you calculated from the "force-time" graph?
What does the area represent?
Compare the change in linear momentum with the area you just calculated. What do you find?

Impulse and Momentum teacher notes

Key words:

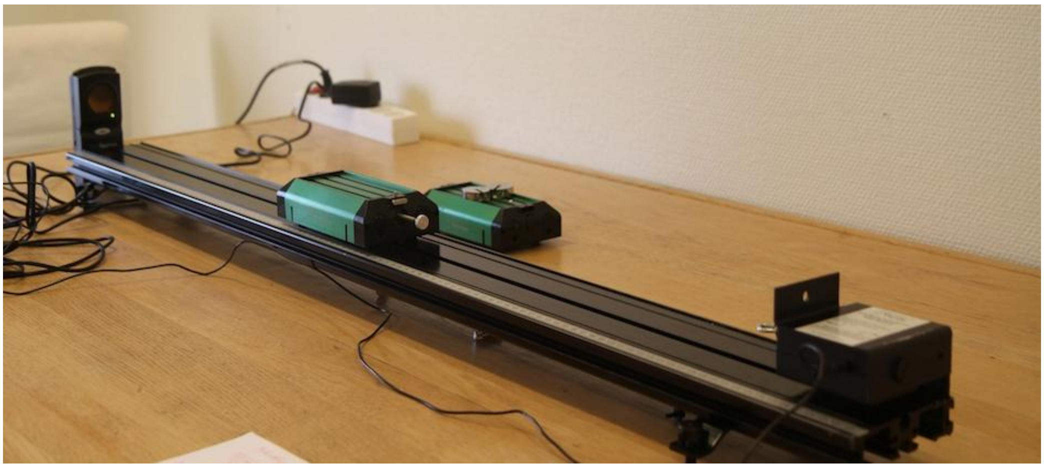
Impulse, TI Nspire, Linear Momentum

Apparatus needed:

A motion track with a carriage,
CBR and a Force Sensor (Dual-Range Force Sensor or Student Force Sensor).
A computer with TI-Nspire or a TI-Nspire LabStation

Overview of the science:

In this experiment students will measure the speed and the forces exerted during an impact. They will calculate the linear momentum before and after the impact and compare this with the impulse of the impact.



Set-up and collection mode:

Time based mode.
Choose 100 measurements/second as rate and 2 seconds as duration.

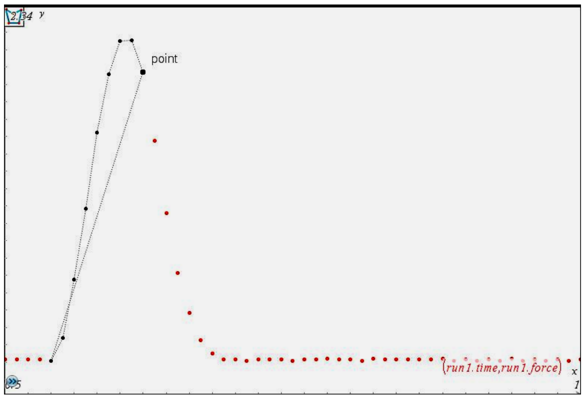
Switch the force sensor to the ±10 N scale and connect it to CH 1 on the lab cradle. Make sure the track is horizontal. Attach the force sensor in one end of the track. Place a CBR at the other end of the track and switch it to the "car – mode". Connect the CBR-unit to DIG 1 on the lab cradle. The program should identify the sensors. Test to make sure the equipment is working properly.

Activity and tips:

- The force sensor measures negative force when pushed. You can change this by reversing measurements.

- Set the force sensor to zero by clicking: Experiment, Set up Sensors, Zero and Dual Range Force Sensor

- Place the carriage 20 cm from the CBR and start collecting data. When the CBR starts clicking faster, give the vehicle a push towards the force sensor.

If your students don´t know how to integrate yet you can open a new graph page and choose the graph type scatter plot. Use the “var”-button to choose your values for time and force as x-values and y-values. If you do “zoom-data” you will get a better window. Then construct a polygon (menu-shape-polygon) and attach it to your points by clicking on each point once. When you are finished you double-click on the last point. Then you calculate the area of the polygon (menu-measurement-area). This way is a little bit tricky, but understandable.	

Exemplar results:

In this experiment we calculated the velocity before impact to approximately 0.417 m/s and after -0.262 m/s, when using the “position-time” graph. The change in velocity is $\Delta v = (0.417 - (-0.262))$ m/s = 0.679 m/s. The mass of the carriage was 0.352 kg.

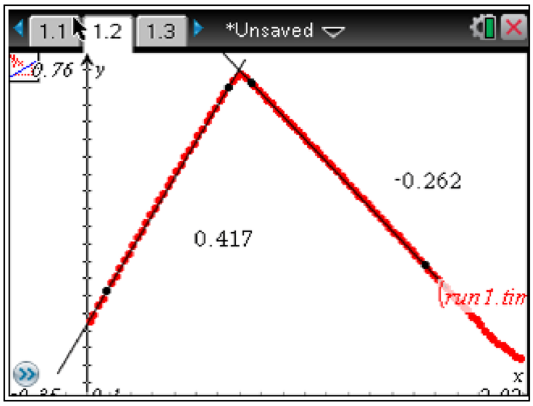
The linear momentum is: $p = m \cdot \Delta v = 0.352 \cdot 0.679$ m/s = 0.239 kgm/s.
(If we had used the “velocity-time” graph we would have gotten the value 0.233 kgm/s.)

In this experiment we calculated the area under the graph to 0.228 Ns. This represents the impulse. The unit of the area must be Ns as it is a “Force-time” graph. This represents the impulse of the impact.

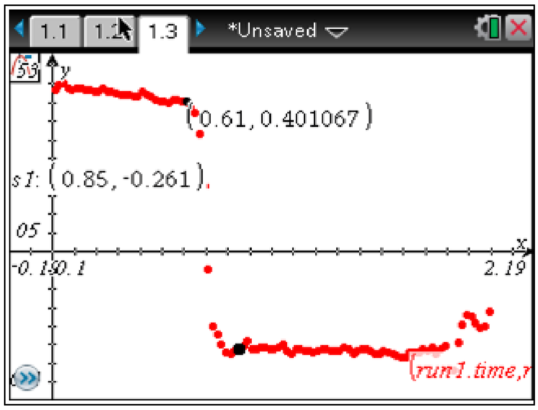
As we can see the two values (0.239 kgm/s and 0.228 Ns) are a little bit different, but the difference is less than 5%, so we can assumed they are the same.

We have now verified that the difference in linear momentum equals the impulse.

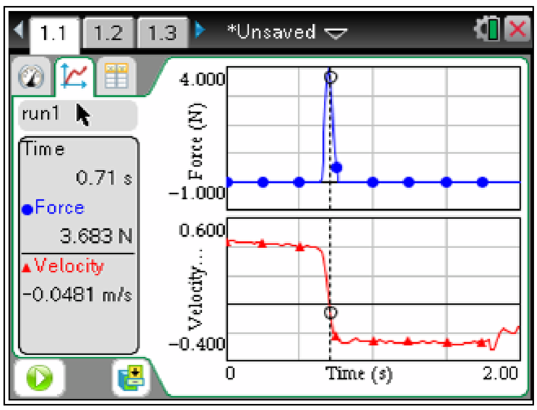
When you want to verify the impulse/momentum relationship you need the speed before and after impact to calculate the change in linear momentum. You can calculate them from the “position- time” graph or by changing to “velocity- time”. If you use the velocity graph you can estimate an average or use a tangent. Remember that the linear momentum is a vector.



The results shown here have been displayed in the Graphs application to allow analysis of the data. The upper graph shows an analysis using position time while the lower graph shows what happens when velocity time is plotted.



To calculate the impulse you need the area under the “force - time” graph. You can use DataQuest to measure the area very easily.



Conductivity of very dilute solutions   Student Notes

Context of the activity:

If an ionic solid (salt) is water-soluble, ions are released and the resulting solution will conduct electric current.

In this activity, we study the effect of concentration on the electrical conductivity of aqueous solutions of potassium chloride, calcium chloride and ferric chloride. We will measure the conductivity of the three solutions as amount of salt is increased by the addition of single drops of the respective solutions.

Learning Outcomes:

- Understand the process of dissolution in water of ionic compounds.
- Relate the conductivity of a solution with the quantity / quality of the ions present.
- Use data and graphs to draw conclusions on conductivity.

Experiment notes and instructions:

1. Place 80 ml of distilled water in a 100 ml beaker.

2. Making an assembly similar to the previous figure.

3. Connect the Lab Cradle to the handheld and plug the sensor into the Lab Cradle.

4. Open a new document with the application DataQuest.

5. Configure the data collection.

a) Select Data with Entry

b) Enter the name "Drops" and enable the "average over 10 s".

6. Sensor configuration: Select the conductivityrange0 to 2000 μS/cm

7. Making the measurements

a) completely submerge the sensor in a beaker of distilled water. Start collection.

enter "0" as the number of drops of KCl added.

c) Add a single drop of KCl solution and stir. Enter "1" as the number of drops added.

d) Repeat successively to add 10 drops of solution.

8. Do not forget to save the run.

9. Carry out two further experiments on the chlorides of calcium and iron.

Instructions for analysis of results:

View the three tests on the same graph.

Questions:

1. Explain why the conductivity is on the vertical axis.
2. Write the equations for the dissolution of the three salts.
3. Describe the change in conductivity with increasing amount of added salt.
4. Examine the trend line for each test, and write the respective expressions.
5. Explain the differences between the three lines obtained.

Conductivity of very dilute solutions   Teacher Notes

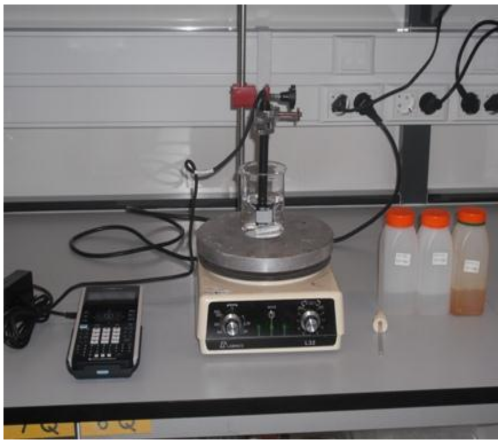
Key words:

Conductivity, water-soluble ionic compounds, dilute solutions, concentration, TI-Nspire

Complementary files:

instruction manual

Apparatus needed:



- *TI-Nspire with OS 3.1*
- *Lab Cradle*
- *Conductivity Sensor*
- *Stand and clamp*
- *Distilled water*
- *100 ml beaker*
- *Solutions of KCl, $CaCl_2$, $FeCl_3$ 0,05* mol/dm^3

Overview of the science:

The equations governing conductivity indicate that the conductivity of a solution depends on the number of charge carriers (i.e., the concentrations of the ions), the mobility of the charge carriers and their charge.
Theoretically, conductivity should increase in direct proportion to concentration. This implies that if the concentration of sodium chloride, for example, in a solution were doubled, the conductivity should also double. In practice, this does not hold true. The concentration and mobility of the ions are not independent properties. As the concentration of an ion increases, its mobility decreases. As a consequence the conductivity increases as the square root of the concentration instead of being in direct proportion.
In this activity, for dilute solutions, the conductivity is directly proportional to its concentration.

Experiment set-up and collection mode:

1. Place 80 ml of distilled water in a 100 ml beaker.

2. Set up the apparatus as shown in the previous figure.

3. Connect the conductivity sensor to the analog port CH1 on the LabSation.

4. Open a new DataQuest application.

5. Set up data collection using Events with Entry

Enter the name "Drops" and enable the average over 10 s option

6. Select the conductivity range 0 to 2000 µS/cm

7. Making the measurements

Completely submerge the sensor on the end of the probe in the beaker of distilled water.

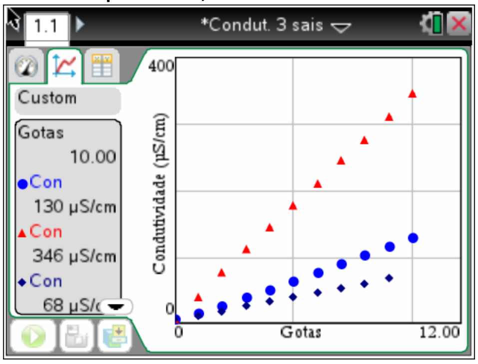
Collect data adding one drop at a time.

8 Do not forget to save the run.

9. Carry out two further experiments on the chlorides of calcium and iron.

Experiment activity and tips:

For comparison, it is better to show the three tests on the same graph.



Questions

1. **Explain why the conductivity is on the vertical axis.**
   Conductivity is graphed on the vertical axis because it is the dependent variable in this activity.

2. Write the equations of the disassociation of the three salts.

$$KCl\ (s) \rightarrow K^{+}(aq) + Cl^{-}(aq)$$

$$CaCl_2\ (s) \rightarrow Ca^{2+}(aq) + 2Cl^{-}(aq)$$

$$FeCl_3\ (s) \rightarrow Fe^{3+}(aq) + 3Cl^{-}(aq)$$

3. Describe the change in conductivity with increasing the amount of added salt.
   In the three solutions, the conductivity increases linearly with concentration

4. See the trend line for each test and write the respective expressions.

For KCl solution $\rightarrow k_{KCl} = 6,80 \times C + 6,6 \quad \mu Scm^{-1}$

For $CaCl_2$ solution $\rightarrow k_{CaCl_2} = 12,36 \times C + 4,3 \quad \mu Scm^{-1}$

For $FeCl_3$ solution $\rightarrow k_{FeCl_3} = 33,67 \times C + 9,1 \quad \mu Scm^{-1}$

5. Explain the difference between the three lines obtained.

The table shows differences between all three solutions

Solution of	Charge of the cation	Ionic radius of cation /pm	Ions given to the solution
KCl	+1	152	2
$CaCl_2$	+2	114	3
$FeCl_3$	+3	64	4

The solution of ferric chloride (III) exhibits a greater slope, because it puts more ions into the solution. The cation has a higher electrical charge and has a smaller radius so it provides greater mobility despite increased concentration.

Sound analysis: Fourier Transform Student Notes

Context of the activity:

The sounds of musical instruments and voices all differ. In this lesson you will investigate these differences. To understand the origin of sound differences, you will use a model to understand what is meant by the superposition of fundamentals and higher harmonics. The fundamental is the lowest frequency present in a sound, the higher harmonics are waves of higher frequencies, often a whole number multiple of the fundamental frequency. These are the building blocks of a sound. This superposition in which the amplitudes are summed to provide the resultant wave is called sound synthesis. With Fourier analysis you can do the opposite: sound analysis amounts to extracting from the sound its fundamental and higher harmonics. A model will illustrate the synthesis and analysis of sound. The Fourier analysis gives the spectrum of a sound meaning it shows the relative amplitude of the fundamental frequency and the higher harmonics in the resultant wave. This spectrum can be seen as the "finger print" of a sound. It is unique for every vowel, musical instrument or voice.
After this introduction the spectra of several musical instruments, or voices or vowels will be investigated.

Learning Outcomes:

- Know what is meant by the superposition of fundamental and higher harmonics
- Able to describe the analysis of a sound
- Able to recognize differences in spectra and connect them to sound differences.

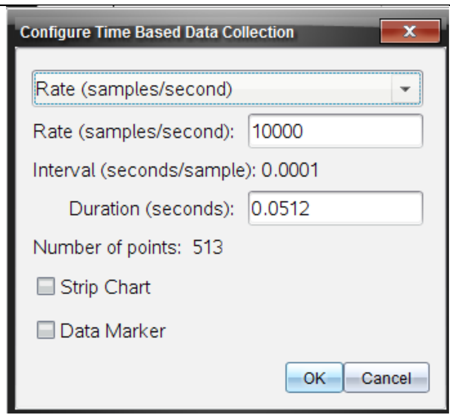
Experiment notes and instructions:

For the sound measurements you need:

- TI- Nspire handheld
- Labcradle
- Microphone
- (Musical instrument or voice, depending on the choice of the teacher)
- Introduction Fouriertransformation.tns, and FFT.tns empty.

The collection setup is shown in the table below.

When performing FFT on a handheld choose 10.000 Hz as sample frequency and 0.0512 s as sample time. (The handheld will tell you that it will take 513 samples, but it takes 512 samples). With this collection setup it will take 30 seconds to perform a FFT analysis of sound, with a resolution of 20 Hz and a highest detectable frequency (Nyquist frequency) of 5000 Hz.



Instructions for analysis of results:

a. Open the document Introduction Fouriertransformation.tns

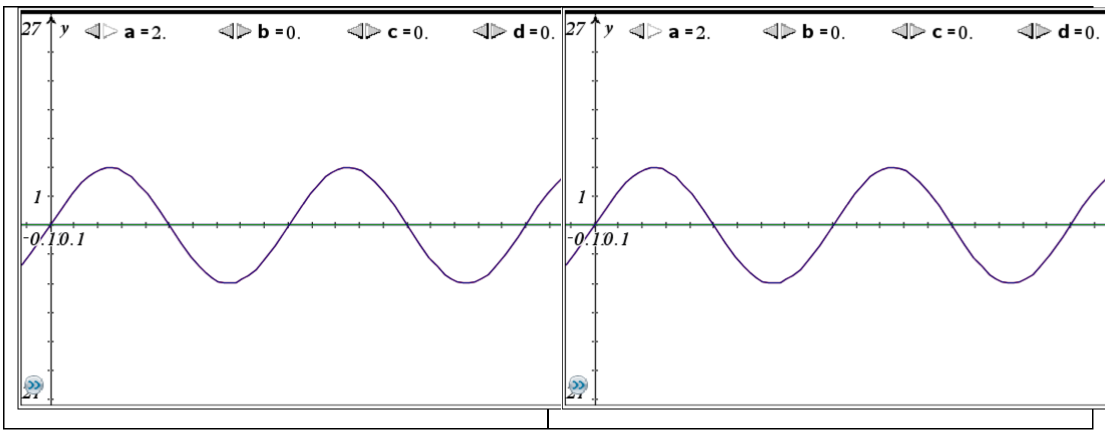
On the first page of this document you see one single wave, and four sliders called a, b, c and d. These sliders change the amplitude of the fundamental (a) and the first three higher harmonics (b, c and d).

b. Play with the values of a, b, c and d. Complete the table beside.

Color	Fundamental/ harmonic
Red	Fundamental
Green	
Blue	
Dark blue	resultant
Cyan	

c. In table two you will find different values for a, b, c and d. Draw the graphs belonging to these values in figure 1 (panel 1 to 3). Draw only the final (resultant) wave. The fundamental is drawn. To change the value of the sliders, you can use the arrows or type a number.

d. Design your own wave, draw it in figure 1 panel 4. List the values in table 2.



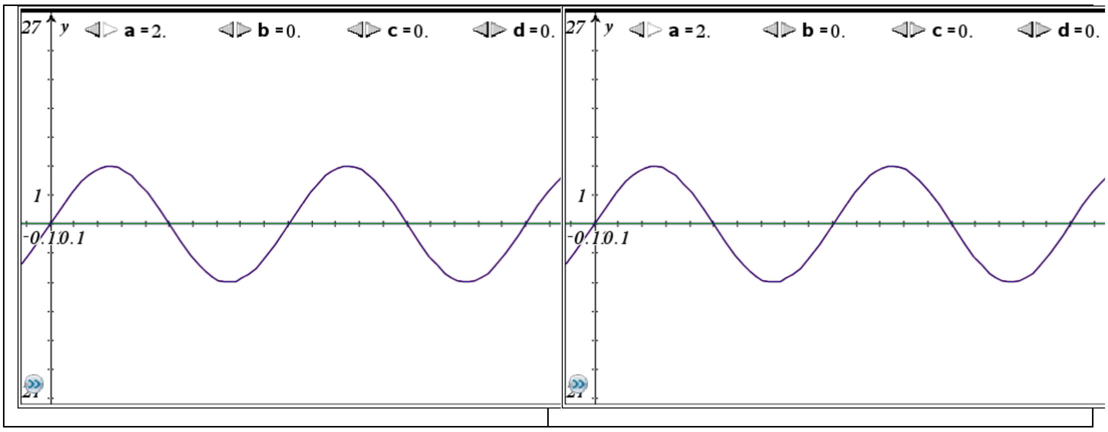


Figure 1

Table 2	A	B	C	D
1	2	1	0.67	0.5
2	2	0	0.67	0
3	2	-0.25	0.22	-0.125
Own				

e. Does the period of the resulting wave change when you add higher harmonics?

____

On the second page of this document you will find a screen divided into two parts. The left half shows the synthesis of waves (similar to the first page), the right half is the Fourier analysis of the resultant wave. The FFT analysis samples the resultant wave (the yellow dots). With this sample it calculates the importance of the higher harmonics. The Fourier spectrum is shown on the right panel of the screen. The x-axis shows the frequency and the y-axis shows the relative contribution of that frequency to the resultant wave. Play with the sliders on the left half of the page, watch what happens on the right side of the screen.

f. Make the waves from table 2, and find the corresponding values of the frequencies in the spectra (these are the maxima on the right side of the screen). Place them in table 3. The open point can be moved around the graph of the FFT spectrum. The x values give the frequency and the y values give the relative importance of the harmonic with the x-value frequency. Write the frequency values in the first column (with header f) and the importance (=amplitude) in the second column (header amp).

Table 3	A		B		C		D	
	f	**Amp**	**f**	**Amp**	**f**	**Amp**	**f**	**Amp**
1								
2								
3								
Own								

g. Give the sliders on the left side of the page the values of the amplitude divided by 100. Compare the resulting waves with the original waves from question 4c.

Comparisons:

____

Differences:

____

h. Although the Fourier analysis doesn't give negative values (which were used in wave 3), the wave form looks very similar. Look carefully and note the differences:

____

Conclusions

All kinds of wave forms can be made by adding higher harmonics to a fundamental. Fourier analysis is able to split the resultant wave form back into its fundamental and higher harmonics. The contributions of the higher harmonics are the amplitudes in the Fourier spectrum.

Observations and questions:

In this part of the lesson the Fourier analysis is used to investigate the spectrum of:

i. Musical instruments
ii. Vowels
iii. Male and female voices
iv. High and low use of voices.

The teacher will tell you which sound machine has to be investigated. All these "sound machines" will be called instruments from now on.
The questions apply to all.

a. Open the document FFT empty.tns
b. Setup the data collection in DataQuest, see paragraph 3 for experimental notes.
c. Measure the sound of your instrument. The sound must be sounding before you start your measurements.
d. Go to the next page and perform a FastFourierTransform (Fourier analysis) by copying the line on this page and pasting it into the line underneath. Make sure that you replace the Dutch variables with the variables in your version of DataQuest (run1.soundpressure, run1.time or other corresponding variables). It will take 30 seconds to calculate the analysis. If it fails to perform, check the number of sample by typing dim(run1.soundpressure). This must return 512. If not, readjust the data collection setup.
e. On page 3 and 4 the Fourier spectrum is shown. On page 3 this is done in Data and Statistics view, and on page 4 in graph view. On page 4 the red open point can be used to find the proper values. The red dot is connected to the data in ff. Fill in the next table (the first two columns of the first sound).

	First sound				Second sound			
Name	Frequency (Hz)	Ampli-tude	Freq. ratio (f/f_0)	Ampl. ratio (A/A_0)	Frequency (Hz)	Ampli-tude	Freq. ratio (f/f_0)	Ampl. ratio (A/A_0)
Fundamental			1	1			1	1
1e harmonic								
2e harmonic								
3e harmonic								
4e harmonic								
5e harmonic								

f. The frequency of the fundamental is called f_0 and the amplitude of the fundamental is called A_0. Calculate the ratio of the frequencies of the higher harmonics to the fundamental, and the ratio of the amplitudes.
g. Make another sound (for example higher note, other vowel, different voice), and measure this. Calculate the Fourier spectrum with fouriertransf2 (just add 2 to the copy of the line). Make sure you use the proper data.
h. Repeat step e and f and complete the table. The blue open dot is connected to the data in ff2.
i. Compare the table for the two different sounds. Compare the frequency ratios and the corresponding amplitude ratios.

Suggestions for further research (always use the Fourier spectrum and the table):

Investigate the difference between:

1. A nice round sound and a nasty sound
2. The vowels
3. One vowel by different people (accents/nationalities)
4. Woodwind and stringed instruments
5. Soft and loud playing on an instrument
6. Where you strike the string of a harp or guitar
7. Shapes of the resonance box of a guitar.
8. Materials of the string of a guitar.

Sound analysis: Fourier Transform   Teacher Notes

Key words: Waves, sound, frequency, spectra, music, fundamental, higher harmonics

Complementary files:

introduction fouriertransformation.tns and FFT.tns
FFT empty.tns. (FFT.tns contains real data.)

Apparatus needed:

- Nspire calculator
- Labcradle
- Microphone
- Musical instruments or voices

Overview of the science:

This lesson is an introduction to Fourier analysis of sound. The sounds of musical instruments differ. The differences in the same note or timbre are a result of the fundamental being combined with higher harmonics in varying proportions. Every musical instrument has its own "finger"print which makes the sound unique. In this lesson the synthesis of harmonic waves is illustrated with a model and is related to the analysis of waves. The relationship between the spectra (Fourier analysis) and the presence of higher harmonics is demonstrated with this model.

After the introduction of the technique the student is challenged to investigate the differences between musical instruments, male or female voices or vowels.

Experiment set-up and collection mode:

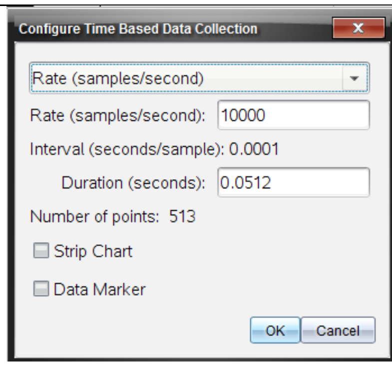
For a Fast Fourier Analysis (FFT) it is important to have 2^n samples. It must be a whole power of 2 otherwise the program will crash.

When performing FFT on a handheld choose 10.000 Hz as sample frequency and 0.0512 s as sample time. (The calculator will tell you that it will take 513 samples, but it takes 512 samples). With this collection setup it will take 30 seconds to perform a FFT analysis of sound, with a resolution of 20 Hz and a highest detectable	

frequency (Nyquist frequency) of 5000 Hz.

When using the computer the data collection setup may be changed: A higher sample frequency gives a higher Nyquist (maximum frequency detectable because of aliasing) frequency (=1/2 · sample frequency). More samples gives a better resolution.

($resolution = \frac{sample\ frequency}{number\ of\ samples}$)



The file FFT.tns consists of 2 programs and 2 functions:

- fouriertransf
- fouriertransf2
- FFT
- Frequencylist

  The first two programs use FFT and Frequencylist. The only difference is that the second program stores the analysis in the variable ff2 and the first in ff. This is done to make comparison of spectra easier. The last two items are the functions used to carry out the analysis. Frequencylist calculates the frequencies in the sample and FFT calculates the spectral values.

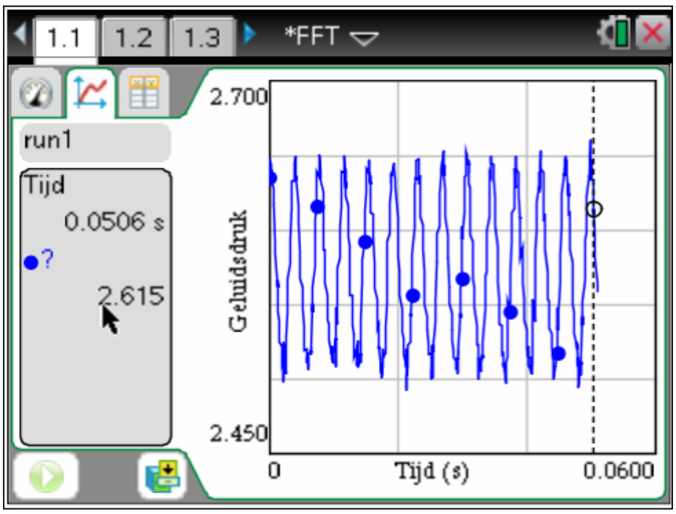
Experiment activity and tips:

<u>Further experiments</u>:

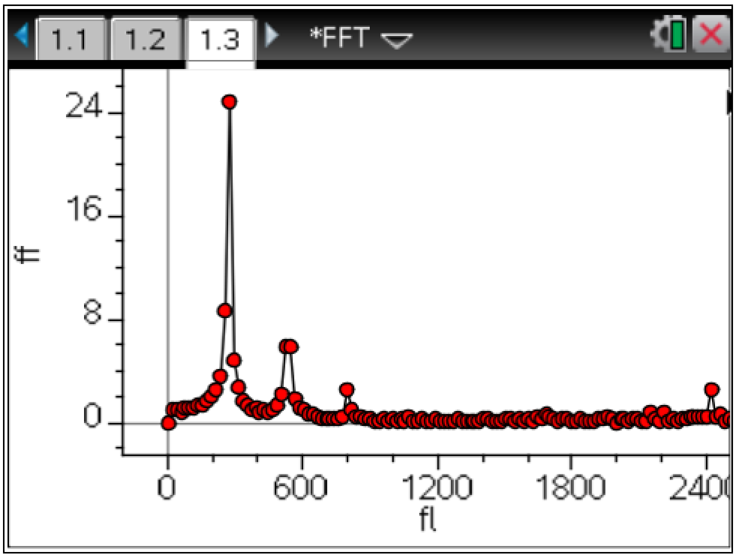
- Differences in play style of a guitar
- Differences in (self-built) resonance boxes of a guitar
- Differences in vowels
- Differences in male and female voices
- Differences in registers of wind instruments.

Exemplar results:

The first graphs show a sound wave measured with a sample frequency of
10 000 Hz and a sample time of 0.0512 s.



The second graph shows the spectrum of the sound. The value of the x-axis is the frequency, the value on the y-axis is the relative amplitude.

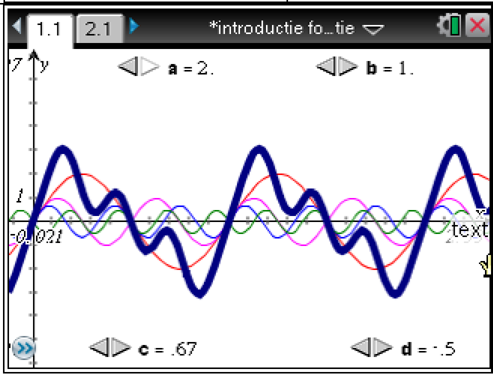


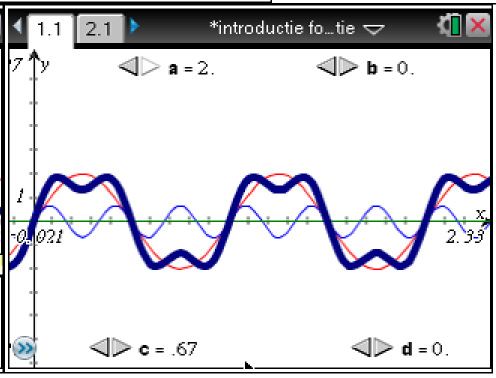
Answers

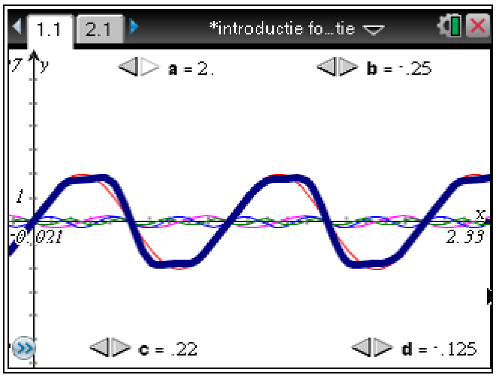
4a

Color	Fundamental/harmonic
Red	fundamental
Green	3 harmonic
Blue	2 harmonic
Dark blue	superposition
Cyan	1 harmonic

4c







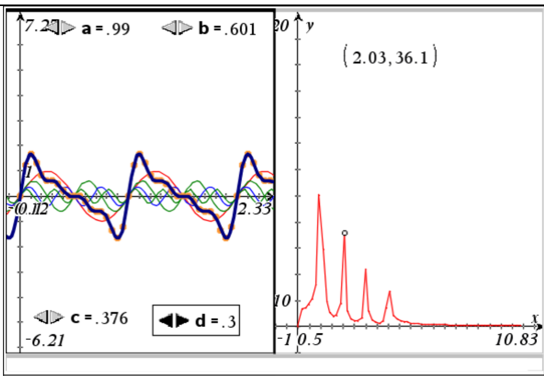
4e

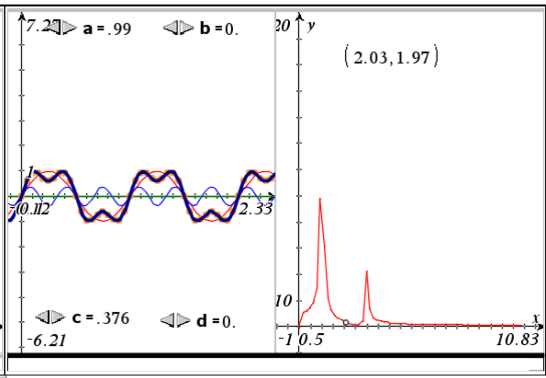
The period equals the period of the fundamental.

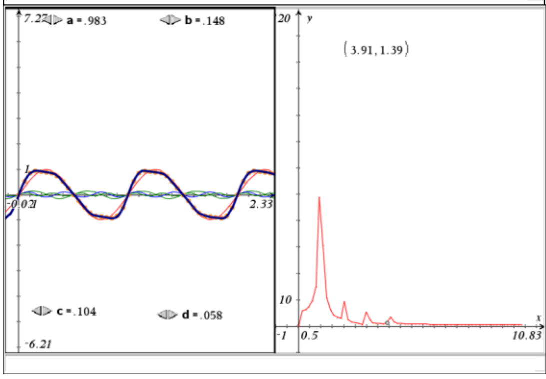
4g

Table 3	A		B		C		D	
	f	**Amp**	**f**	**Amp**	**f**	**Amp**	**f**	**Amp**
1	0.937	101	2.03	60.1	2.97	39.4	4.06	25.9
2	0.937	99			2.97	37.6		
3	0.937	98.3	2.03	14.8	2.97	10.4	3.91	5.76
Own								

4h







The form is almost the same, only less clear.

4i

The third wave is inverted.

5e
5f

	First sound			
Name	Frequency (Hz)	Amplitude	Freq. ratio (f/f_0)	Ampl. ratio (A/A_0)
Fundamental	254	13	1	1
1e harmonic	527	2	2.1	0.15
2e harmonic	781	0.5	3.1	0.038
3e harmonic				
4e harmonic				
5e harmonic				

These values are obtained from the measurements in FFT.tns

g by free fall using a light gate student notes

Context

We say that an object is in free fall when the only force acting on it is the gravitational force. Thus, the air resistance must be zero or so small that it can be neglected. When the object is in free fall near the earth's surface, the force of gravity acting on it is almost constant. Consequently, an object in free fall accelerates downward at a constant rate. This acceleration is usually represented by the symbol ***g***.

You can determine the acceleration due to gravity using a variety of methods. In this activity we will use the technology of TI-Nspire (DataQuest application, the Lab Cradle and a light-gate) to collect data. The light-gate (photo-gate) operates with a beam of infrared light that is blocked whenever an object comes between the emitter and detector. The activity consists of dropping a transparent plastic ruler covered with black bars separated uniformly. When the ruler is dropped through the light-gate, the Lab Cradle interface measures the time interval between the passage of the leading edge of a bar blocking the beam to the leading edge of the next bar (see figure) that will block the beam again. This timing continues as all eight bars pass through the light-gate.

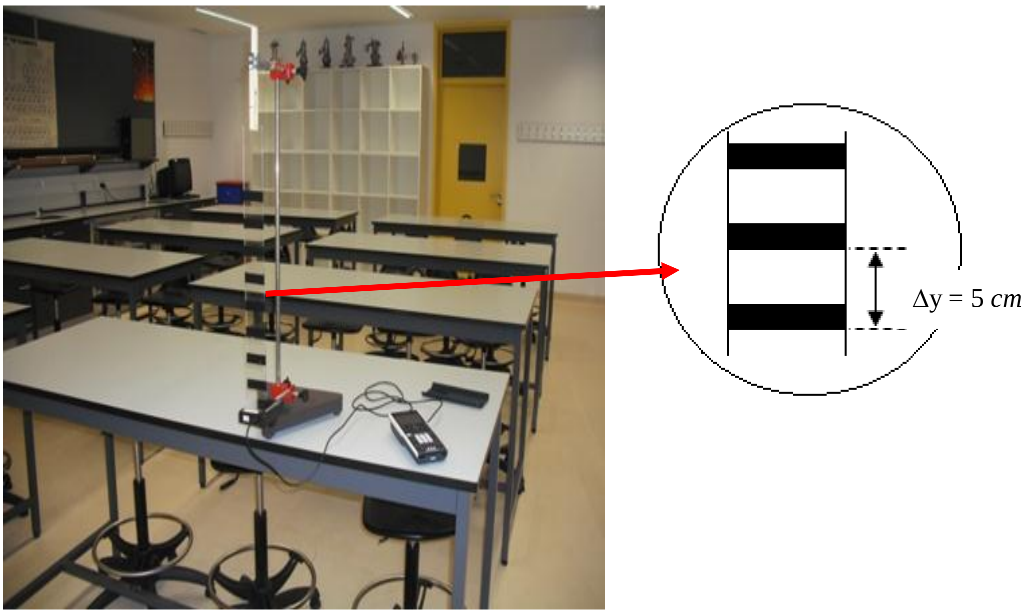
Learning Outcomes

- Measure the acceleration of a body in free fall using a plastic ruler and a light-gate.
- Compare the value obtained experimentally with the theoretical value.

Equipment

TI-Nspire handheld with OS 3.0
Light-gate (photo-gate)
Tape and one clamp
one clamp

Lab Cradle
Plastic ruler
Stand, two bosses and



Set up and Procedure

1 – Prepare the activity (see photo previous page).

a) Position the light-gate horizontally. Suspend the ruler with a clamp above the light-gate.

b) Slide Lab Cradle onto the handheld unit.

c) Connect the light-gate to **DIG / SONIC 1** input on the Lab Cradle.

2 – Open a new document with DataQuest application.

3 – Set the light-gate for the collection data.

a) In b, select **1: EXPERIMENT** → **7: COLLECTION MODE** → **4: PHOTO-GATE TIMING** (figure 1).

b) Select **MOTION TIMING**, press **OK** and then **User Defined** and press **OK** (Figure 2).

c) Type **0.05** in the distance (if applicable), select **AFTER NUM EVENTS** and enter the **NUMBER OF EVENTS** (number of bars in Figure 3).

4 – Collect the data.

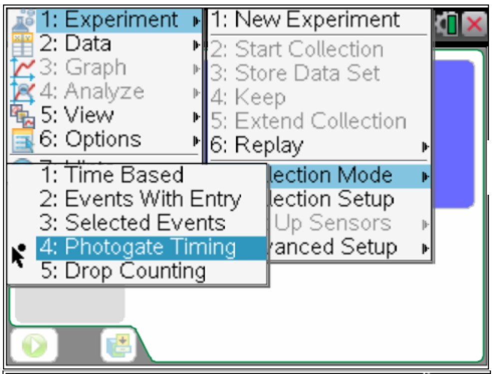
a) Press the icon at the bottom left to start collecting data (or **1: EXPERIENCE**→ **2: START COLLECTION).**

b) The message "Waiting for..." will appear.

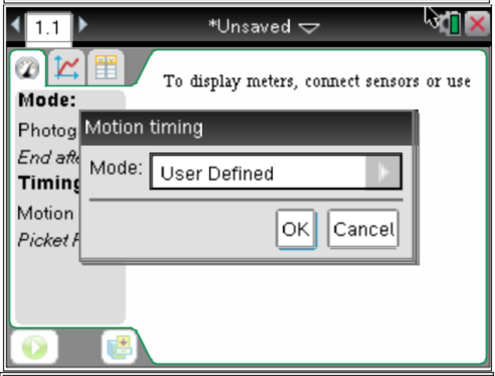
c) Free the ruler and let it fall through the light-gate. Be careful to let the ruler fall vertically.

5 - If successful, the graphs of position and velocity versus time will appear (Figure 4).

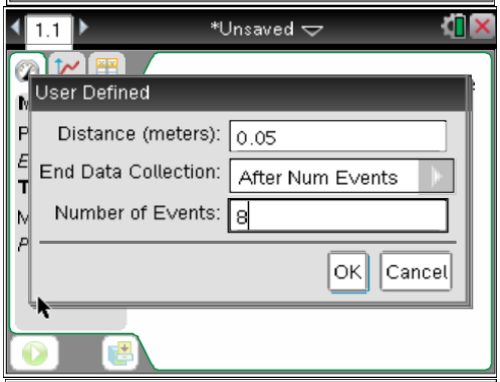
6 - Make a total of seven trials.



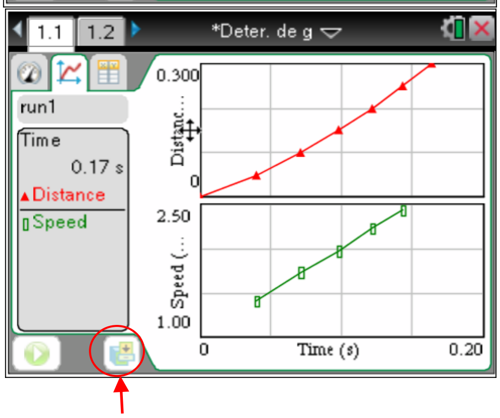
1



2



3



4

Note: *Before collecting new data (new run), do not forget to save the current data by pressing the right icon in the lower left shown here.*

Analysis

Examine the velocity -time graph. The gradient of the graph is a measure of the acceleration. If the graph of the velocity is approximately a straight line of constant gradient, the acceleration is a constant.

You can either fit your own model to the data or carry out a regression. Whichever method you choose record the gradient of the seven velocity –time graphs in the table below.

DATA RECORDING

Run	*Slope* (m/s^2)	*Absolute deviation*
1		
2		
3		
4		
5		
6		
7		

	Acceleration (m/s^2)
Minimum	
Maximum	
Mean	

$g_{obtained}$ (m/s^2)	±
uncertainty (%)	

Questions

1. Does the initial velocity of an object have anything to do with its acceleration? For example, if an object is thrown down, would the acceleration after release be different compared to simply releasing the object?

2. From the seven runs, determine the minimum, maximum and average values for the acceleration of the ruler. Register them in the data table.

3. Describe in words the shape of the graph of position-time for the free fall of the ruler.

4. Describe in words the shape of the velocity-time graph. How does this relate to the shape of the position-time graph?

5. The average acceleration obtained is the most likely value from all the measurements. The minimum and maximum values give an indication of how the measurements vary from experiment to experiment, that is, they indicate the uncertainty in repeatability of the measurements. Another method for determining the uncertainty is to calculate the absolute deviation of each measurement and use the maximum result as the measurement uncertainty. Express the final experimental result as the mean value ± uncertainty.

6. Express the uncertainty as a percentage of the acceleration. This is related to the accuracy of the experiment. Record the value in the data table.

7. Compare the result obtained with the accepted value of ***g*** (use your calculated value of the uncertainty). Does the known value fall within the range of your values?

8. Inspect the velocity graph. What will the graph of acceleration-time look like? Sketch your prediction on paper. Select acceleration-time in graph view. Discuss any differences between this graph and your prediction. Follow the acceleration values using the cursor keys. Note that the vertical scale of the graph does not include zero. Is the variation as great as it seems?

9. Find the average acceleration from the previous chart. How does this compare with the acceleration determined from the gradients of the velocity graphs?

g by free fall using a light gate teacher notes

Key words:

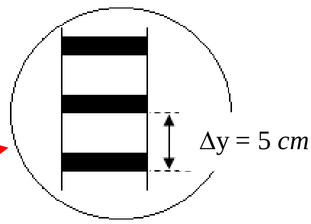
Photo-gate, acceleration, free fall, TI-Nspire…

Complementary files:

instruction manual…notes on photogate timing are included within the student notes as they are not to be found in the instruction manual.

Apparatus needed:

- TI-*Nspire handheld with OS 3.*
- *Lab Cradle*
- *Light-gate (photo-gate)*
- *Rectangular shaped plastic ruler*
- *Tape and one clamp*
- *Stand, two bosses and one clamp*



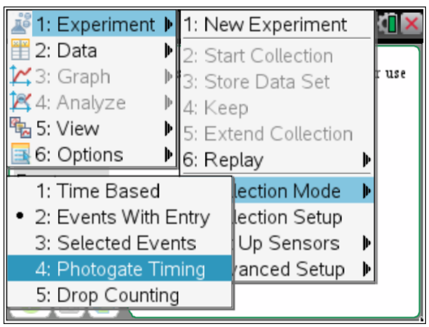
Overview of the science:

You can determine the acceleration due to gravity using a variety of methods. In this activity we will use the technology of TI-Nspire (DataQuest application, the Lab Cradle and a light-gate to collect data. The light-gate (photo-gate) is a **U** shape measuring device. A beam of infrared light emitting diode (source) and a photodiode (sensor) are placed on each side of the U-shaped frame. When something passes through the light-gate the sensor is blocked from the source and a signal is sent to Lab Cradle. The activity consists of dropping a rectangular shaped transparent plastic ruler covered with black bars separated uniformly.

When the ruler is dropped through the light-gate, the Lab Cradle interface measures the time interval between the passage of the leading edge of a bar blocking the beam to the leading edge of the next bar (see figure) that will block the beam again. This timing continues as all bars pass through the light-gate.

Experiment set-up and collection mode:

1. Prepare the activity (see photo).



d) Position the light-gate horizontally. Suspend the ruler with a clamp above the light-gate.
e) Slide Lab Cradle onto the handheld unit.
f) Connect the light-gate to DIG / SONIC 1 input on the Lab Cradle.

2. Open a new document with DataQuest application.

3. Set up Photogate timing and then Motion Timing followed by User Defined. Then type 0.05 for the Distance and the number of bars for Number of Events.

4. Collect the data.

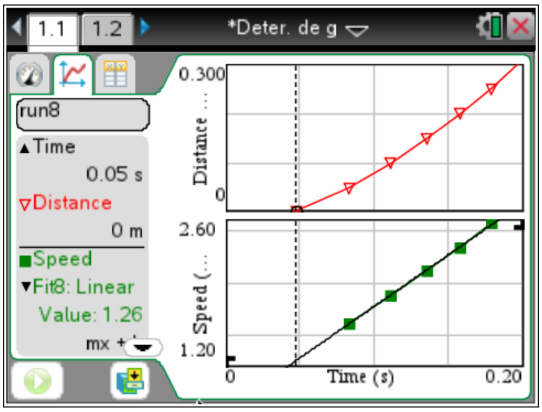
d) Press the icon at the bottom left to start collecting data (or 1: EXPERIENCE→ 2: START COLLECTION).
e) The message "Waiting for..." will appear.
f) Free the ruler and let it fall through the light-gate. Be careful to let the ruler fall vertically.

5. If successful, the graphs of position and velocity versus time will appear.

6. Make a total of seven trials.

Experiment activity and tips:

1. Examine the graph of velocity vs. time. The slope of the graph is a measure of acceleration. If the graph of the velocity is approximately a straight line of constant gradient, the acceleration is constant.



2. From the seven runs, determine the minimum, maximum and average values for the acceleration of the ruler and the absolute deviation. Register them in the data tables.

	Acceleration (m/s^2)
Minimum	9,665
Maximum	9,819
Mean	9,729

Run	*Slope* (m/s^2)	Absolute deviation
1	9.677	0.052
2	9.665	0.064
3	9.775	0.046
4	9.819	0.090
5	9.679	0.050
6	9.746	0.017
7	9.742	0.013

4. Exemplar results:

1. Does the initial velocity of an object have something to do with its acceleration? For example, compared to dropping an object, if it is throw down, would the acceleration be different after release?

The initial rate is independent of the slope of a graph, that is, the acceleration. An object that is thrown down continues to accelerate after being released at the same rate as that subject is dropped.

2. Describe in words the shape of the graph of position vs. time for the free fall of the ruler.

The graph position vs time is a parabola.

3. Describe in words the shape of the velocity vs. time graph. How does this relate to the shape of the position vs. time graph?

The velocity vs. time graph is a straight line. The slope of the position vs. time graph, at certain point is equal to the velocity in this point.

4. The average acceleration obtained is the most likely value from all the measurements. The minimum and maximum values give an indication of how the measurements vary from experiment to experiment. A method for determining the accuracy is to calculate the absolute deviation of each measurement and use the result of the maximum measurement as uncertainty. Express the final experimental result as the mean value ± uncertainty.

$$g = 9,729 \pm 0,090 \quad ms^{-2}$$

5. Express the uncertainty as a percentage uncertainty of the acceleration. This is related to the accuracy of the experiment.

$$E_r = \frac{0,090}{9,729} \times 100 = 0,93\ \%$$

6. Compare the result obtained with the known value of **g** (use your calculated value of the uncertainty). Does the known value fall within the range of your values?

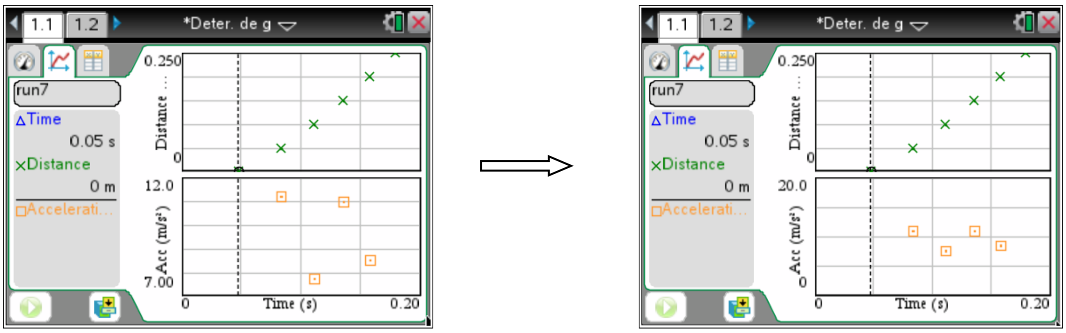
*The average theoretical value for **g** at the Earth's surface is 9.806 m/s^2. Since this value is within the range of 9.729 ± 0.090 m/s^2, the experimental result is in good agreement with the value of the textbooks. The relative error is:*

$$E_r = \frac{|9,806 - 9,729|}{9,806} \times 100 = 0,78\ \%$$

7. Inspect the velocity graph. What will the graph of acceleration vs. time look like? Then in the **graph** view, position the cursor over the dependent variable (speed) and pressing CRTL+MENU select acceleration. Discuss any differences between this graph and your prediction. Follow the acceleration values using the cursor keys. Note that the vertical scale of the graph does not include zero. Is the variation as great as it seems?

As the graph of speed is linear with a slope constant, the graph of the acceleration would be a constant function - a horizontal line above the time axis. When the graph of acceleration vs. time is selected, the data appear irregularly. This is due to small variations in the measurement of time, and the graph appears with an auto-scale, amplifying these variations.

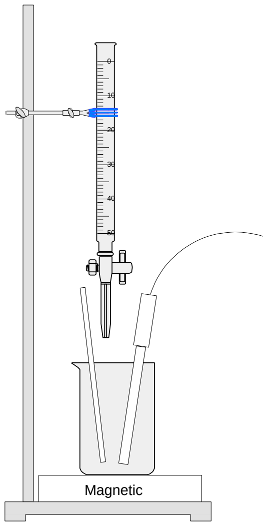
*When the source is included on the vertical axis, the data appear more consistent, as the graph below shows. The **y** axis of the accleration-time graph on the right has a range of 0-20 m/ s^2.*



8. Find the average acceleration from the previous chart. How does this compare with the acceleration value, determined from the slopes of the velocity graphs?

The values of the graph of the acceleration-time graph are dispersed around the value of the slope of the graph of speed-time.

Different Types of Titrations Student Notes



General instructions

In the lab you will find some work stations with five different titrations. Select two experiments and carry out the different titrations with the TI-Nspire CX calculator and two different sensors.
Save each result as a file on the calculator. After the experiments we will observe, check and discuss your results.
Complete the following worksheet during or after the experiments with the help of your textbook and other materials.
Prepare a short talk about your results for the other students. After the presentations compare the different titrations and discuss the main differences.

Instructions for the experiments

Do the experiments using the instructions which you will find at the work stations.

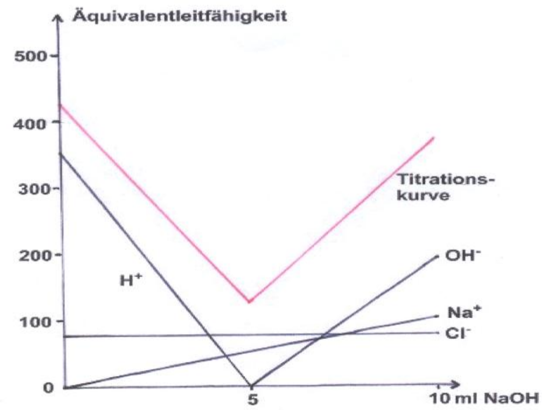
- Develop the chemical equation for all experiments.
- Sketch the graphs into the worksheet and interpret them.
- Try to explain the shapes of the graphs.

Clean all equipment (but not the burette) after your experiment.

If you have time at the end, edit another worksheet with the title “Conductivity titration for a mixture of hydrochloric and vinegar acid with a solution of sodium hydroxide”.

Information:

Ion equivalence-conductivity by infinite dilution	σ $cm \cdot \Omega^{-1} \cdot mol^{-1}$
H_3O^+	350
Cl^-	76
OH^-	198
Na^+	50
CH_3COO^-	41



Indicator for different pH values

	pH- range	color
Methyl Red	4,4 to 6,2	Red/yellow
Neutral Red	6,8 to 8,0	Red/yellow
Phenolphthalein	8,3 to 10,0	Colourless/red

$H_3O^+ + OH^- \rightleftharpoons 2\,H_2O \quad \Delta_N H = -55\ kJ \cdot mol^{-1}$

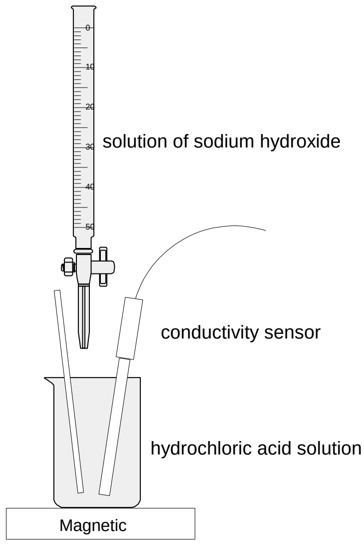
Station I

Conductivity titration of 100 ml hydrochloric acid solution (concentration c = 0,1 mol·l^{-1}) with a solution of sodium hydroxide (concentration c = 1 mol·l^{-1})

Put 100 ml hydrochloric acid solution and the conductivity sensor in a beaker.
Prepare the calculator for measuring (Events with entry).
Switch on the magnetic stirrer stirrer.

Measure the conductivity of the hydrochloric acid solution.
Put 1 ml from the sodium hydroxide solution into the hydrochloric acid solution. Measure the conductivity again.
Repeat the procedure 15 more times.
Notes:

- ❖ Events: 0 ml; 1 ml, 2 ml, …., 16 ml
  (addition sodium hydroxide)



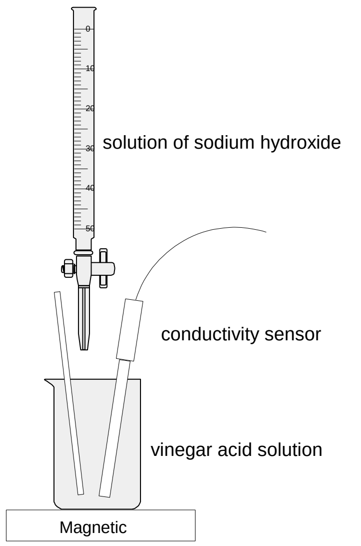
Station II

Conductivity titration of 100 ml vinegar acid solution (concentration c = 0,1 mol·l^{-1}) with a solution of sodium hydroxide (concentration c = 1 mol·l^{-1})

Put 100 ml vinegar acid solution and the conductivity sensor in a beaker.
Prepare the calculator for measuring (Events with entry).
Switch on the magnetic stirrer stirrer.

Measure the conductivity of the vinegar acid solution.
Put 1 ml from the sodium hydroxide solution into the vinegar acid solution. Measure the conductivity again.
Repeat the procedure 15 more times.
Notes:

- ❖ Events: 0 ml; 1 ml, 2 ml, …., 16 ml
  (addition sodium hydroxide)



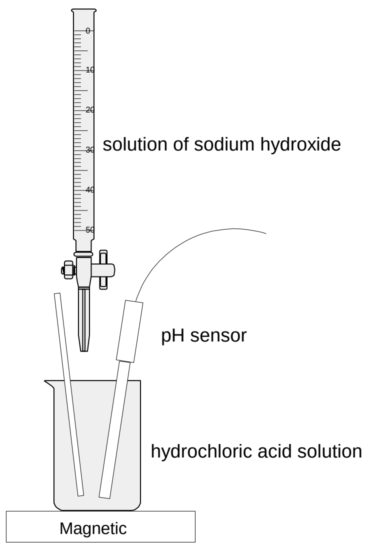
Station III

pH titration of 100 ml hydrochloric acid solution (concentration c = 0,1 mol·l^{-1}) with a solution of sodium hydroxide (concentration c = 1 mol·l^{-1})

Put 100 ml hydrochloric acid solution and the pH sensor in a beaker.
Prepare the calculator for measuring (Events with entry).
Switch on the magnetic stirrer stirrer.

Measure the pH of the hydrochloric acid solution.
Put 1 ml from the sodium hydroxide solution into the hydrochloric acid solution. Measure the pH again.
Repeat the procedure 15 more times.
Notes:

- ❖ Events: 0 ml; 1 ml, 2 ml, …., 16 ml (addition sodium hydroxide)



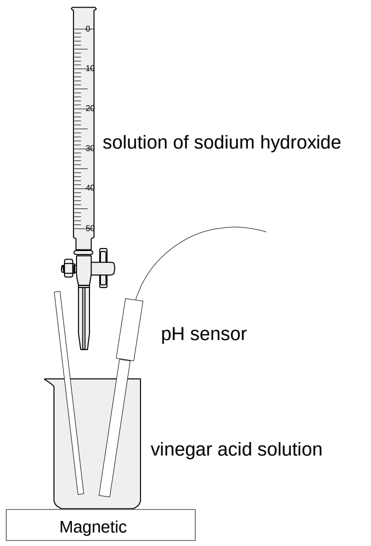
Station IV

pH titration of 100 ml vinegar acid solution (concentration c = 0,1 mol·l^{-1}) with a solution of sodium hydroxide (concentration c = 1 mol·l^{-1})

Put 100 ml vinegar acid solution and the pH sensor in a beaker.
Prepare the calculator for measuring (Events with entry).
Switch on the magnetic stirrer stirrer.

Measure the pH of the vinegar acid solution.
Put 1 ml from the sodium hydroxide solution into the vinegar acid solution. Measure the pH again.
Repeat the procedure 15 more times.
Notes:

- ❖ Events: 0 ml; 1 ml, 2 ml, …., 16 ml (addition sodium hydroxide)

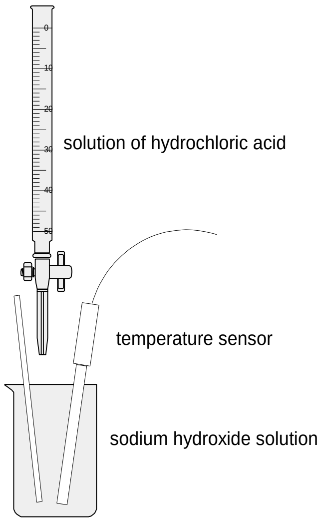


Station V

Temperature titration of 20 ml sodium hydroxide solution (concentration c = 1 mol·l^{-1}) with a solution of hydrochloric acid (concentration c = 1 mol·l^{-1})

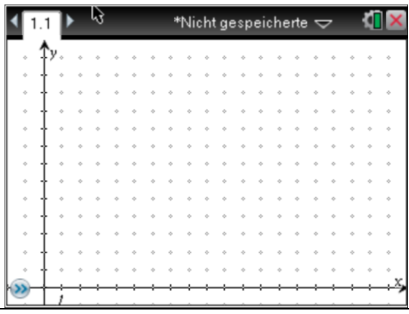
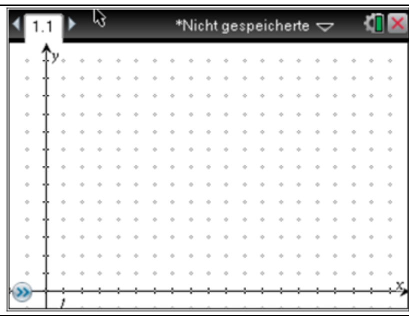
Put 20 ml sodium hydroxide solution and the temperature sensor in a beaker.
Prepare the calculator for measuring (Events with entry).

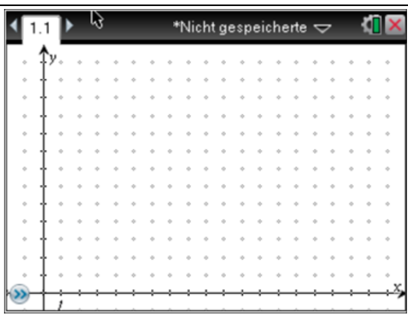
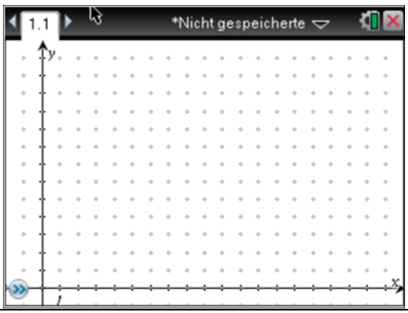
Measure the temperature of the sodium hydroxide solution.
Put 5 ml from the hydrochloric acid into the sodium hydroxide solution and stir. Measure the temperature again.
Quickly repeat the procedure 6 more times.



Notes:

- ❖ Events: 0 ml; 5 ml, 10 ml, …., 35 ml (addition hydrochloric acid)

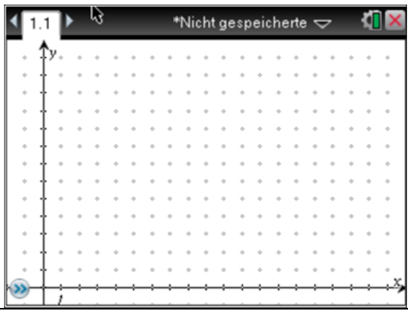
Station I Conductivity titration of 100 ml hydrochloric acid solution (concentration c = 0,1 mol·l^{-1}) with a solution of sodium hydroxide (concentration c = 1 mol·l^{-1}) (strong acid, strong hydroxide)	**Station II** Conductivity titration of 100 ml vinegar acid solution (concentration c = 0,1 mol·l^{-1}) with a solution of sodium hydroxide (concentration c = 1 mol·l^{-1}) (weak acid, strong hydroxide)
Chemical equation	**Chemical equation**
Graph 	**Graph** 
Interpretation Point of interest(How much (in ml) hydroxide solution was added up to the point of interest?):	**Interpretation** Point of interest(How much (in ml) hydroxide solution was added up to the point of interest?):

Station III pH titration of 100 ml hydrochloric acid solution (concentration c = 0,1 mol·l^{-1}) with a solution of sodium hydroxide (concentration c = 1 mol·l^{-1}) (strong acid, strong hydroxide)	**Station IV** pH titration of 100 ml vinegar acid solution (concentration c = 0,1 mol·l^{-1}) with a solution of sodium hydroxide (concentration c = 1 mol·l^{-1}) (weak acid, strong hydroxide)
Chemical equation	**Chemical equation**
Graph 	**Graph** 
Interpretation pH of the hydrochloric acid at the beginning:	**Interpretation** pH of the vinegar acid at the beginning:

Station V
Temperature titration of 20 ml sodium hydroxide solution (concentration c = 1 mol·l^{-1}) with a solution of hydrochloric acid (concentration c = 1 mol·l^{-1})

Chemical equation

Graph



Interpretation
Point of interest(How much (in ml) hydrochloric acid was added up to the point of interest?):

Different Types of Titrations   Teacher Notes

Context

A special function of the TI-Nspire CX calculator is its use as a measuring instrument in chemistry lessons. This technical device opens up new approaches to teaching and learning. No student has seen an ion but s/he can measure the properties of ion solutions in different ways.
Students can measure for example the temperature, the conductivity or the pH.
After that they can observe all measured values as graphs on the handheld device.
If they wish or if they are able to, they can analyse the graphs using mathematical tools. But this is not the primary purpose in chemistry lessons.
In chemistry the handheld is especially helpful for recording measured values which facilitate an understanding of causal relationships between variables.

The following material shows for example, the use of the calculator with different sensors and different types of titrations.
This teaching unit was tested several times with students from grade 11 in the Geschwister-Scholl-High school in Löbau.
Students got accurate measured values (graphs) through doing the experiments in an intensive manner. The results were very interesting. Students were able to interpret the different graphs from the different titrations and discussed criteria for comparison.

At the end of this material you will find some information and instructions for analysing the results from the titrations using mathematical tools.

Prior Learning

Students should

- Know about strong and weak acids
- know the Acid- Hydroxide- Theory of BRÖNSTED
- have mastered titration as an analytical method
- know the terms Equivalent point, Neutral point, Half equivalent point
- know what a buffer system is
- realize that neutralization is an exothermic reaction
- are able to operate the calculator as a measuring instrument

Recommendations for use in the classroom

Students should work as a team of two at the various work stations.
For example, every team selects two titrations with different sensors. The students do the experiments and later they present their results to the class. Therefore all students have all the results from the five different titrations.
This sequence requires 3 lessons each 45 minutes long.
Students need to prepare their little presentation using various resource materials, like for example their text books.

It is very important and it is also interesting to compare the different titrations and to find out the main differences. Before they can do this, they have to develop criteria for comparison. If there is enough time students can work on the additional material.

Special notes

The focus of this sequence is that students understand chemical relationships. It means students are able to do titrations, interpret the recorded graphs and recognize the special features.
For interested students it would be great to find out the equivalent point using mathematical tools. This is not easy and is not always possible for all titrations.

Apparatus required

Station I

Conductivity titration of 100 ml hydrochloric acid solution (concentration $c = 0{,}1\ mol \cdot l^{-1}$) with a solution of sodium hydroxide (concentration $c = 1\ mol \cdot l^{-1}$)

Equipment

- magnetic stirrer with stir bar or glass stirring rod
- beaker (V = 150 ml)
- stands
- graduated cylinder (V = 100 ml)
- burette

- conductivity sensor

Chemicals

For each titration
- sodium hydroxide $c(NaOH) = 1\ mol \cdot l^{-1}$ (V ≈ 20 ml)
- hydrochloric acid $c(HCl) = 0{,}1\ mol \cdot l^{-1}$ (V = 100 ml)

Station II

Conductivity titration of 100 ml vinegar acid solution (concentration $c = 0{,}1\ mol \cdot l^{-1}$) with a solution of sodium hydroxide (concentration $c = 1\ mol \cdot l^{-1}$)

Equipment

- magnetic stirrer with stir bar or glass stirring rod
- beaker (V = 150 ml)
- stands
- graduated cylinder (V = 100 ml)

Chemicals

For each titration
- sodium hydroxide $c(NaOH) = 1\ mol \cdot l^{-1}$ (V ≈ 20 ml)
- vinegar acid $c(HCl) = 0{,}1\ mol \cdot l^{-1}$ (V = 100 ml)

- burette

- conductivity sensor

Station III

pH titration of 100 ml hydrochloric acid solution (concentration c = 0,1 mol·l^{-1}) with a solution of sodium hydroxide (concentration c = 1 mol·l^{-1})

Equipment

- magnetic stirrer with stir bar or glass stirring rod
- beaker (V = 150 ml)
- stands
- graduated cylinder (V = 100 ml)
- burette

- pH sensor

Chemicals

For each titration
- sodium hydroxide c(NaOH) = 1 mol·l^{-1} (V ≈ 20 ml)
- hydrochloric acid c(HCl) = 0,1 mol·l^{-1} (V = 100 ml)

Station IV

pH titration of 100 ml vinegar acid solution (concentration c = 0,1 mol·l^{-1}) with a solution of sodium hydroxide (concentration c = 1 mol·l^{-1})

Equipment

- magnetic stirrer with stir bar or glass stirring rod
- beaker (V = 150 ml)
- stands
- graduated cylinder (V = 100 ml)
- burette

- pH sensor

Chemicals

For each titration
- sodium hydroxide c(NaOH) = 1 mol·l^{-1} (V ≈ 20 ml)
- vinegar acid c(HCl) = 0,1 mol·l^{-1} (V = 100 ml)

Station V

Temperature titration of 20 ml sodium hydroxide solution (concentration c = 1 mol·l^{-1}) with a solution of hydrochloric acid (concentration c = 1 mol·l^{-1})

Equipment

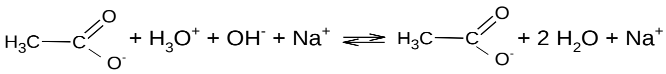
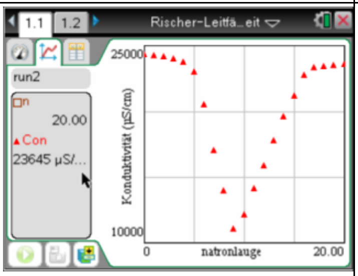
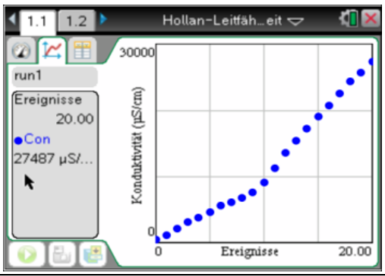
- magnetic stirrer with stir bar or glass stirring rod
- calorimeter with beaker (V = 80 ml)
- stands
- graduated cylinder (V = 50 ml)
- burette

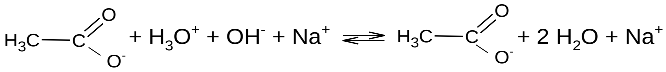
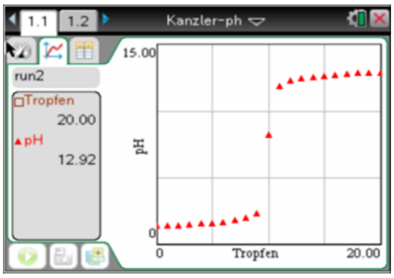
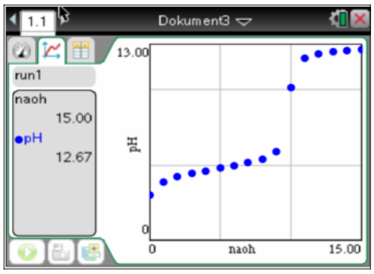
- temperature sensor

Chemicals

For each titration
- sodium hydroxide c(NaOH) = 1 mol·l^{-1} (V = 20 ml)
- hydrochloric acid c(HCl) = 1 mol·l^{-1} (V = 35 ml)

Exemplar Results

Station I	**Station II**
Conductivity titration of 100 ml hydrochloric acid solution (concentration c = 0,1 mol·l^{-1}) with a solution of sodium hydroxide (concentration c = 1 mol·l^{-1}) (strong acid, strong hydroxide)	Conductivity titration of 100 ml vinegar acid solution (concentration c = 0,1 mol·l^{-1}) with a solution of sodium hydroxide (concentration c = 1 mol·l^{-1}) (weak acid, strong hydroxide)
Chemical equation $H_3O^+ + Cl^- + Na^+ + OH^- \rightleftharpoons 2\ H_2O + Na^+ + Cl^-$	**Chemical equation** 
Graph 	**Graph** 
Interpretation Point of interest(How much (in ml) hydroxide solution was added up to the point of interest?): *10 ml* *For example:* *- At first the conductivity goes down because hydrogen ions react with hydroxide ions.* *- At the minimum point the reaction is completed.* *- After the minimum point the conductivity rises because the concentration of ions increases.* *- During the titration the concentration of sodium-ions rises but the specific conductivity of hydrogen and hydroxide ions is higher.* *- The minimum point is the equivalence point of the titration.*	**Interpretation** Point of interest(How much (in ml) hydroxide solution was added up to the point of interest?): *10 ml* *For example:* *- Vinegar acid is a weak acid which means it doesn't dissociate completely.* *- At first the conductivity rises slowly because the concentration of acetate-ions increases and hydrogen ions react with hydroxide ions.* *- Later the conductivity rises more. The reaction between hydroxide- and hydrogen ions is completed. The concentration of ions increases.* *- The intersection of the two graphs is the equivalence point.*

Station III	Station IV
Station III pH titration of 100 ml hydrochloric acid solution (concentration c = 0,1 mol·l^{-1}) with a solution of sodium hydroxide (concentration c = 1 mol·l^{-1}) (strong acid, strong hydroxide)	**Station IV** pH titration of 100 ml vinegar acid solution (concentration c = 0,1 mol·l^{-1}) with a solution of sodium hydroxide (concentration c = 1 mol·l^{-1}) (weak acid, strong hydroxide)
Chemical equation $H_3O^+ + Cl^- + Na^+ + OH^- \rightleftharpoons 2\ H_2O + Na^+ + Cl^-$	**Chemical equation** 
Graph **pH of the hydrochloric acid at the beginning:** *pH = 1* 	**Graph** **pH of the vinegar acid at the beginning**: *pH = 2,9* 
Interpretation *For example:* *- At the beginning of the titration the pH rises slowly.* *Later the pH rises sharply. This is called the pH jump. At the end of the titration the pH rises slowly again.* *- The graph has one turning point. The turning point is the equivalence point and the neutral point.* *- The pH at the beginning of the titration is lower than the titration of vinegar acid because hydrochloric acid is a strong acid.*	**Interpretation** *For example:* *- At the beginning of the titration the pH rises slowly and the following pH- jump is small* *- The graph has two turning points. The first is called half-equivalence point. The pH at this point corresponds to the* pK_S*- value. Also there is a buffer system. That´s the reason for the weak increase. It is c(HAc) = c(Ac*$^-$*).* $pH = pks + \lg\left(\frac{c(A^-)}{c(HA)}\right)$ $pH = pks + \lg(1)$ $pH = pks$ *- The second turning point is the equivalence point. The pH at this point is about pH = 8 because the acetate-ions are causing this pH-value.* *- The neutral and equivalence point are different.* *- The pH at the beginning of the titration is higher than the titration of hydrogen chloric acid because this acid is a weak acid.*

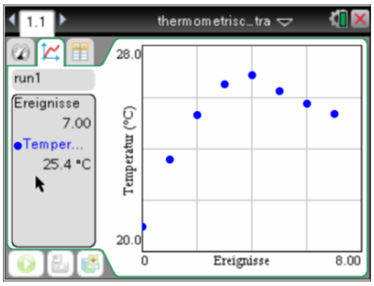
Station V

Temperature titration of 20 ml sodium hydroxide solution (concentration c = 1 mol·l^{-1}) with a solution of hydrochloric acid (concentration c = 1 mol·l^{-1})

Chemical equation

$H_3O^+ + Cl^- + Na^+ + OH^- \rightleftharpoons 2\ H_2O + Na^+ + Cl^-$

Graph



Interpretation

Point of interest(How much (in ml) hydrochloric acid was added up to the point of interest?): 20 ml

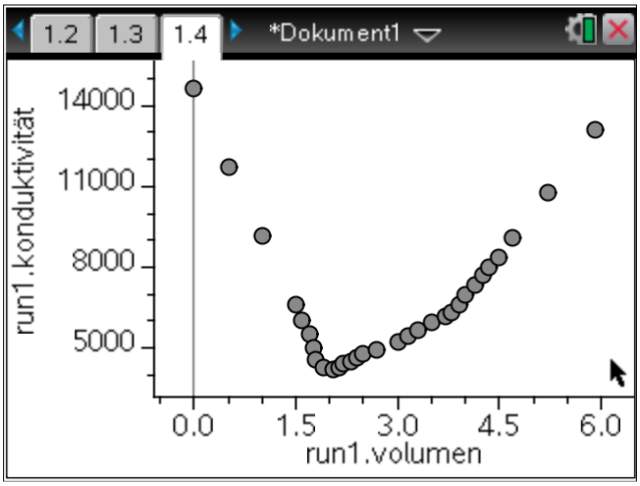
For example:
- At first the temperature rises because sodium hydroxide reacts with hydrochloric acid.
- At the maximum point the reaction is completed.
- Afterwards the temperature goes down because the cold solution of hydrochloric acid was dropped into the warm solution.
- The maximum point is the equivalent point.

Additional material

Conductivity titration for a solution of hydrochloric and vinegar acid
with a solution of sodium hydroxide

The screenshot shows the result of a conductivity titration for a solution of hydrochloric and vinegar acid with a solution of sodium hydroxide.
Interpret the graph.

Note: The titration is a special titration from two different acid solutions. One of the acid solutions is strong and the other is a weak acid solution.

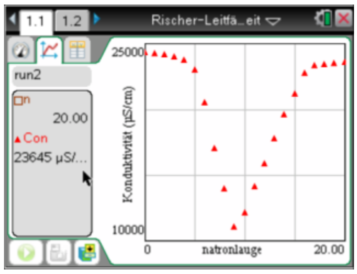


Determining the equivalence point

with the help of mathematical tools

There are many ways of determining the equivalent point. Many students use the calculator more in mathematics than in chemistry or other science, therefore they have a lot of knowledge about the various applications, for example “Lists & Spreadsheets”.
Because it is easy to transfer the measurement data from DataQuest into the other applications, the following instructions do not use DataQuest for analysing and calculating.

Conductivity titration of 100 ml hydrochloric acid solution (concentration c = 0,1 mol·l^{-1}) with a solution of sodium hydroxide (concentration c = 1 mol·l^{-1})

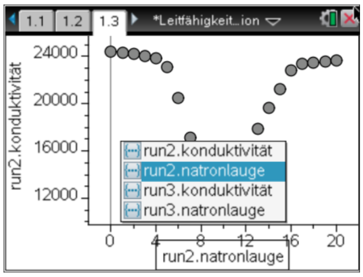


Copy the data into

Data&Statistics

plot the data

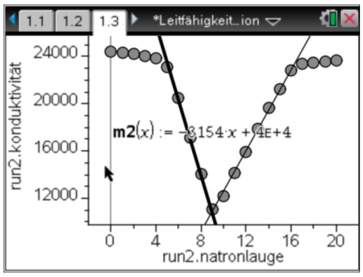
select the appropriate data



add two movable lines

menu 4:Analyze

2:add movable line

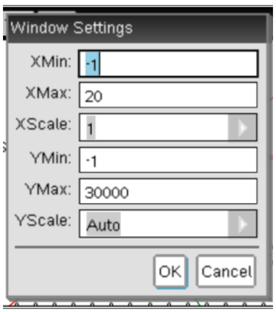


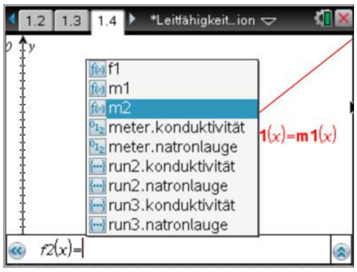
change the application

Graphs

insert graphs (lines)

var
select





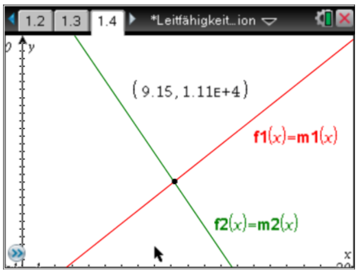
appropriate graphs

put into the right window

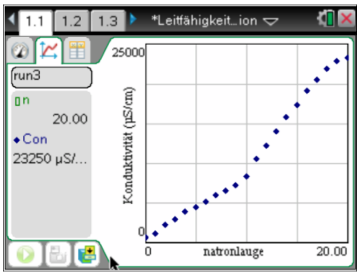
menu

4:Window/ Zoom

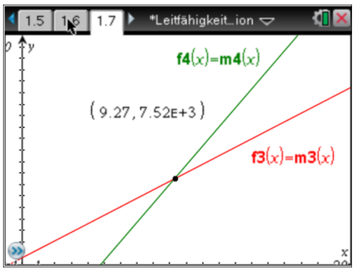
Calculate the intersection point menu 6:Analyse Graph 4:Intersection



Conductivity titration of 100 ml vinegar acid solution (concentration c = 0,1 mol·l^{-1}) with a solution of sodium hydroxide (concentration c = 1 mol·l^{-1}) (weak acid, strong hydroxide)



To determine the equivalence point use the same procedure as with the conductivity titration for hydrochloric acid.



Bungee Jumping   student notes

Context of the activity:

When bungee jumpers leap into the air their physical properties change. Energies are “converted” from one kind to another. The velocity increases and decreases. From the physical point of view the motion is very interesting and is not straight-forward. It therefore presents a challenge to understand. In this project you will investigate the motion with a mathematical model and a ball acting as the bungee jumper. The challenge is to predict with the model what the measured data will be. This needs a calibrated force sensor, elastic rope of known force constant and ball of known mass.

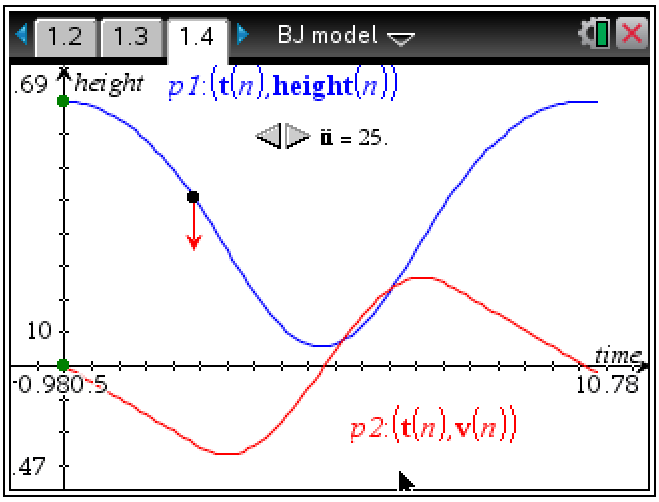
Learning Outcomes:

- You will be able to construct a mathematical model.
- You will be able carry out an investigation to confirm or refute the model.

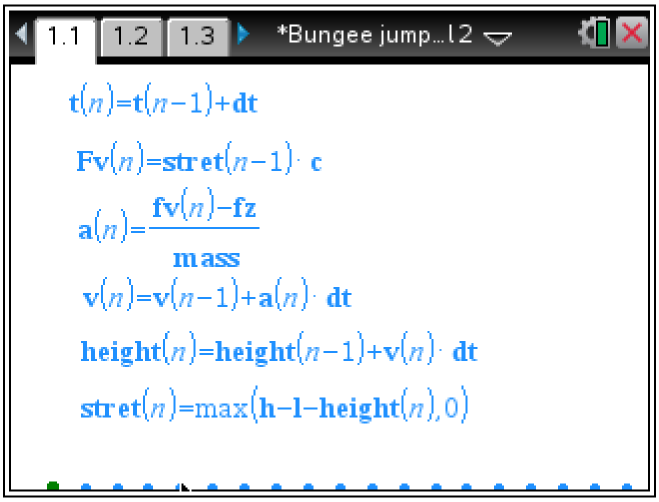
Mathematical Model of a bungee jump

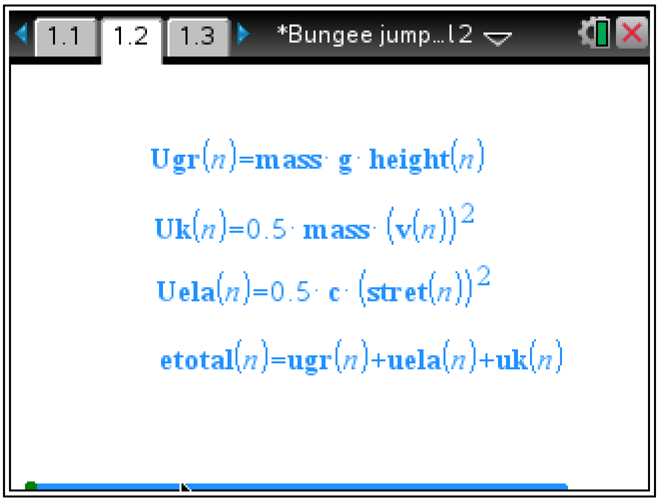
a) Open the document BJ model.tns

b) Look at page 1.1. and 1.2 (in your calculator or on the next page). You can see the model. The first page gives all the motion related rules and the second page gives all the energy related rules. On page 1.3 you can see the initial values for the model. Fill in the tables below the model. Use table 1 for the motion related rules (6 in all) and table two for the energy related rules (4 in all). Explain each line or rule of the model in your own words.



In the following pages
Ugr is gravitational potential energy
Uk is kinetic energy
Uela is elastic energy





First page

line number	Description in words of the calculation
1	
2	
3	
4	
5	
6	

Second page

line number	Description in words of the calculation
1	
2	
3	
4	

c) Why is the expression for stret(n) calculated using a max formula?

____

____

d) Op page 1.3 the initial values are shown. Fill in the next table (don't forget the units).

Question	**Answer**
Mass of Jumper ?	
Jumps from what height ?	
Length of rope	
Force constant	

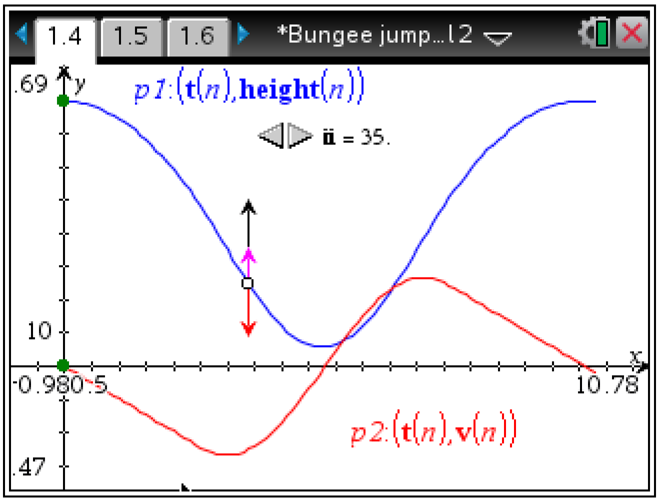
On page 1.4 you see the results of the model. In blue the position of the jumper, and in red the velocity of the jumper. There are three arrows indicating the elastic force, Fv, (black), the gravitational force, Fg, (red) and the resultant force, Fn, (magenta). With the slider you can step through the model. Make sure that n is a whole number. If necessary you can change the step size.

e) What is the minimum height of the jumper (use trace). Is this jump safe?

____

What happens if the force constant of the rope is smaller (so the rope stretches more easily)? Change the force (elastic) constant on page 1.3 and look at 1.4 to see what happens.

____



f) The first part of the bungee jump is a free fall downwards. Draw the graph of a free falling object in your model by adding a function to f1(x). What happens when the graph of the free falling object is no longer following the model? Why is the model different from a free falling body?

____

____

g) When and where is the jumper as the rope starts to stretch? Use the information on page 3 and the formula of the free falling body._____________________

____

h) Change the line f1(x) to -9.81*x. It now gives the velocity. Use trace to see at what time the velocity of the model is not equal to -9.8*x anymore. Is this the same time you calculated in question g?____

____

i) Describe what happens to the three forces that are drawn. Use the slider to move the arrows.
(gravitational) Fg =

____

(elastic) Fv =

____

(resultant) Fn=

____

At what time is the resultant force zero? What is happening then? Where is the jumper in his or her motion?____

____

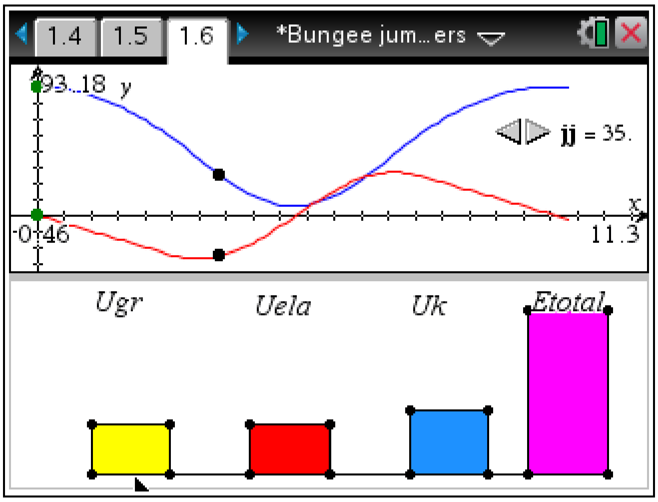
__

j) Someone stated that the time from maximum speed to zero speed equals a quarter of the period of the mass spring system. Investigate this statement. Is it true or false?

____

____

k) On page 1.5 you can step through the motion of the bungee jumper with the sliders. In the lower panel you will see the corresponding energy changes. Draw the changes in the energies in the figure below (1.8), and give an explanation for the shape of the curves.



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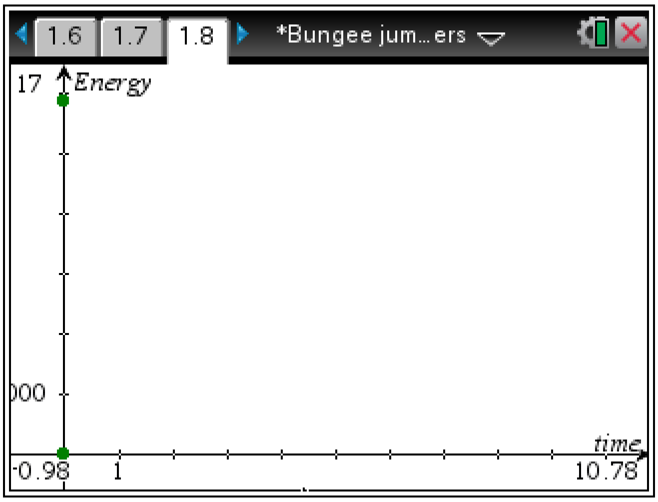


The total energy is not totally constant in the model (in real life it is!!). (This is due to the simple integration routine within the handheld that is used.)

l) Compare your graphs with the graphs on page 1.6. Use the same colour convention as in page 1.6. Why is the potential gravitational energy never zero? What happens when it is zero?

____

____

m) Fill the following table. Use the model to answer the questions. For the energies use maximum, minimum, zero etc. (↑ means moving in the upward direction). To find the answers you can use the trace function in a graph with the entity you need.

Summary

Height (m)	Velocity (m/s)	Acceleration (m/s^2)	Force of rope (N)	Resultant force (N)	Ugr (J)	Uela (J)	Uk (J)
80							
	↓			0			
	↑						maximum
	0						
					minimum		

Calibration of the force sensor

4 This experiment can be skipped if a recognized force sensor is used. Otherwise, start a new experiment.

a) Connect the cradle to the calculator and the force sensor to the cradle.
b) Make a calibration graph and determine the relationship between potential and mass. Use the collection mode: events with entry. Connect different masses to the force sensor and measure the potential.
c) Add an extra calculated data column with the formula

   mass·9,81

d) Draw the graph (Potential, Force) and calculate the best fit through the data.
e) Is the relationship between potential and force linear? What is the formula:

   Force = ……………. * potential + …………………….

Mass(kg)	Potential (V)	Force (N)

f) What is the sensitivity of the sensor …………………………………….

Experiment instructions: the constants

In this paragraph you will determine the force constant of the spring in two different ways.

a) Start a new document. Connect the cradle to the calculator and the force sensor to the cradle.
b) Use manual entry calibration to set up the force sensor (if necessarily).
c) Measure the mass using the calibrated force sensor

   Force ____________________, Mass _____________________________

First method to determine the force constant C of the spring

d) Connect the spring to the force sensor. Connect different masses to the spring, measure the stretching of the spring. Use events with entry as collection mode. Determine for at least 4 different masses the stretching. Analyze the data by fitting a curve through the data. The slope of the line gives the force constant C.

C = ______________________________ N/m

Second method to determine the force constant C of the spring

e) Connect the ball to a rope and the rope to the spring, and the spring to the force sensor. Connect the force sensor to the cradle and the calculator. Start a new experiment. Discard the data. Select time based for collection mode. Setup duration to 5 seconds. Give the ball a small pull down wards and let the ball oscillate. Measure during 5 seconds the oscillation.

f) Analyze the data with a sinusoidal curve. The value b gives the angular frequency:

$$stat.b = \omega = \frac{2 \cdot \pi}{T}$$

With this angular frequency and the formula for the period of a mass − spring system,

$$T = 2 \cdot \pi \sqrt{\frac{m}{C}}$$

the force constant C can be calculated.

____

____

____

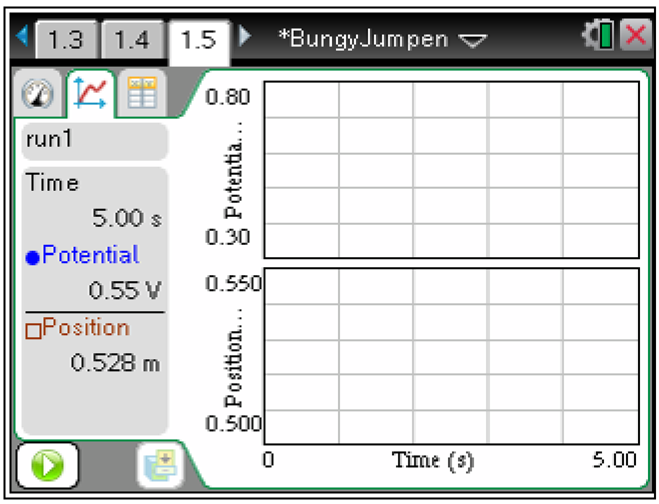
C = ________________________________ N/m

Which value is more reliable and why?

____

Experiment instructions: the Energies

Open the document *BJ measurements*



a) Connect the ball to a rope and then to a spring. Connect the spring to the force sensor, and the sensor to the cradle. Connect a CBR to the cradle. Put the CBR on the ground, measuring the ball's position.
b) Calibrate (if necessary) the force sensor.
c) Pull the ball a little bit downwards and measure for 5 seconds the force and the position. Draw the graph in the blank figure above.
d) Insert a calculator page and define mass,

gravity and ForceConstant (mass:= …, g:= 9.81 and c:= ….). You can see the formulas on the right side of the screen.

e) Insert a new DataQuest page. Add two calculated columns: one for kinetic energy K, and one for gravitational potential energy Ug. Plot both graphs in one graph. Use the variables mass and g.
What do you see

____

____

Can there be energy conservation with only kinetic and gravitational potential energy?

____

The missing link is the elastic potential energy, calculated by

$$U_{el} = \frac{1}{2} \cdot C \cdot u^2$$

With C the force constant in N/m and u the extension (stretch) in meters. The problem: how to connect the extension with the measured position?

In the equilibrium position the sum of the forces on the ball are equal to zero. The force from the spring is equal to the gravitational force. Because $F_z = F_{spring}$ we can calculate the stretching in the equilibrium position uo.

f) Calculate the stretch in the equilibrium position.
uo:=____

g) The equilibrium position can be calculated by taking the statistics of the position. The mean value is the equilibrium position:

Equilibrium position

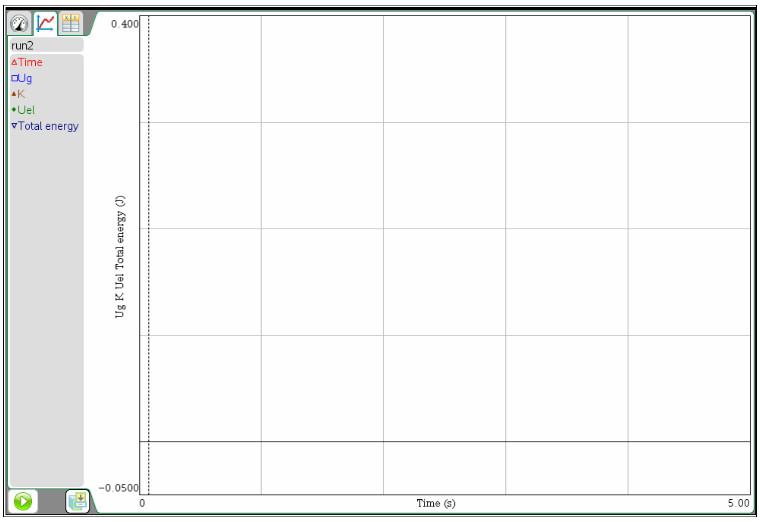
Eqp:=

____

h) The general stretching can be calculated now from these values by:

$$us = (eqp - Position) + uo$$

Add a new calculated column with the elastic potential energy Uel and Etot (total energy = K+Ug+Uel)
Draw a graph with all four energies. Copy it in the figure beside.



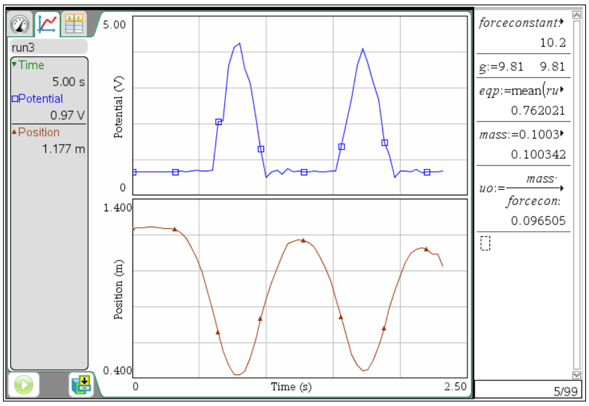
If you didn't make a mistake, the total energy is conserved. If not, find out what is wrong before continuing to the last experiment. Save your document in the calculator.

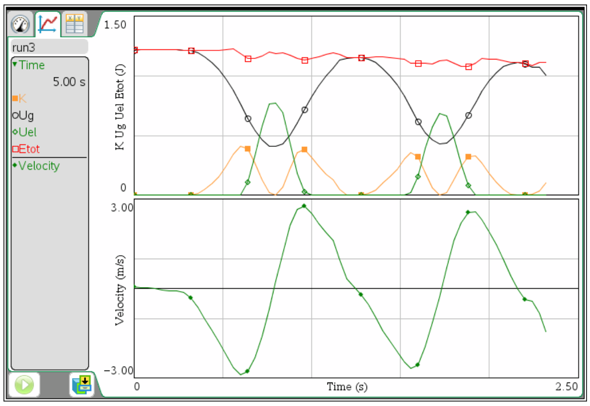
Experiment instructions: the Jump

a) Save your document again with a new name (Bungee ex.)

b) Use all the same settings and let the ball fall down. The length of the rope is the free fall part of the motion. Perform a few measurements. If the rope is too long, the ball will start moving backwards and forwards, and perhaps comes to close to the CBR. If this is the case shorten the rope. Do a new experiment to determine the new eqp. If the sample frequency is too low, make the mass larger (or use a spring with a lower force constant). If you do so, determine again the mass/force constant/uo and eqp.

If necessary strike some data out. It is possible to obtain graphs as below:





Observations and questions:

On page 1.3 and 1.4 the model is listed again. The velocity is now called vel instead of v. On page 1.5 the initial values are shown. Page 1.6 shows a graph of the model (blue line) and the measurements (red line). If your measurements are not in run3, change the settings of the scatterplot to the corresponding data set.

a) Use trace to find the exact time that the ball starts to fall. Adjust the initial time in the model by clicking on page 1.3 on the label of the t(n) sequence, and change the initial value.

b) Use trace to find the exact height form which the ball fell down. Adjust the initial height by changing h on page 1.5.

c) Look to the graph at page 1.6 and see if the model predicts your measurements. What is correct and what is wrong? Look also at the graphs of the velocity and energies.

____

____

____

____

____

d) Change the model on page 1.3 if necessary to fit the measurements. Possible considerations are:

The initial height, Length of elastic rope, Mass or force constant (?)
Add air resistance to the formula of the acceleration, Add energy loss due to stretching of the rope, ????

Bungee Jumping Teacher Notes

Key words:

Modelling, Energy conservation, kinetic energy, gravitational energy, elastic potential energy.

Complementary files:

BJ model.tns, BJ model and data.tns (containing data and model),
BJ measurements.tns (with an adjusted model without data).

Apparatus needed:

- Force sensor
- CBR
- Lab Cradle
- Spring and rope or elastic
- Ball
- Stand
- Nspire calculator
- Mass blocks
- lineal

Overview of the science:

This project contains three parts:

- a mathematical model about bungee jumping
- guide experiment to determine the force constant of the spring and the mass of the ball (optional calibration of the force sensor)
- experiment with a falling ball on a spring as a hardware model of a bungee jumper and fitting the model to the real world data.

Experiment activity and tips:

This is a quite extensive project. It contains 4 different activities. Calibrating a force sensor, determination of the mass and the force constant of the spring and real measurements on a bungee jumping ball and trying to fit the model to the real world data. The paragraph about calibrating the sensor can be skipped if a known force sensor is used, or the calibration values can be given to the student. The model in the first and last activity are the same. Only the values are already adjusted from real live jumping to a bungee jumping ball. These initial values can be changed on the page with the list of values or by double clicking on the label of the formula.
The total energy in the model is not totally constant, this is due to the simple integration scheme that is used. When the time step is decreased this behavior vanishes.
Sometimes the model doesn't respond on the changes of the initial values. Go to the page with all the model descriptions and press ctrt T. Select the first row of values and the calculator starts to recalculate the model.
The last part of the activity (measuring real data and fitting the model) works better on the computer then the calculator.

Exemplar results and answers:

<table>
<tr><td>3b</td><td>

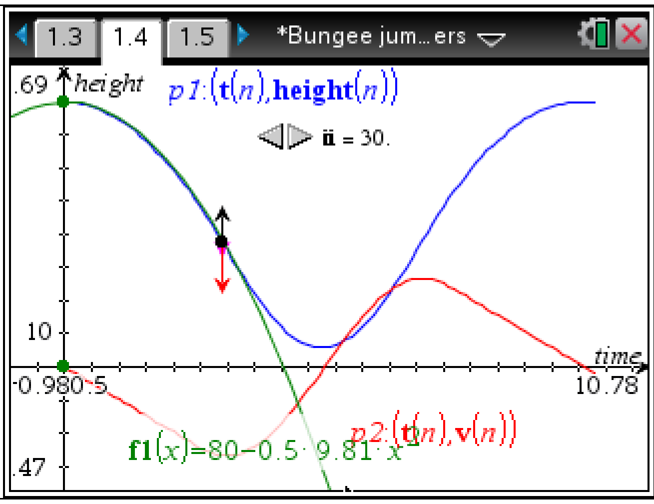
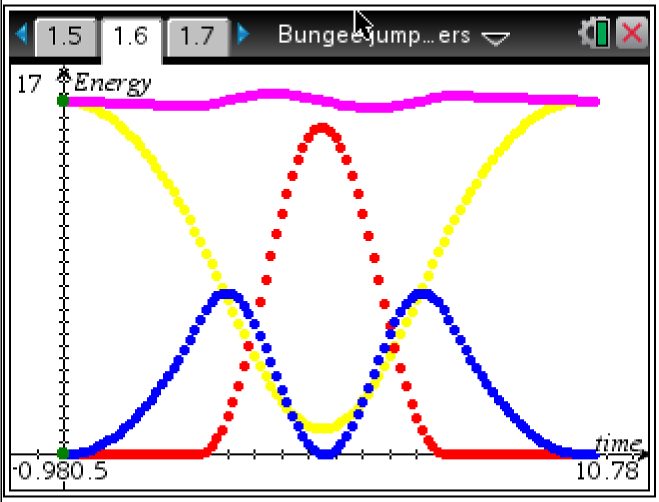
line number	Description in words of the calculation
1	New time is old time + time step dt
2	Extension uit(n) is calculated from initial jump height minus rope length and height of jumper
3	Spring force Fv = C· uit (extension)
4	The acceleration is F/mass. Including the gravitational force
5	The new velocity is the old velocity corrected with the new acceleration * dt
6	The new height is the old height corrected with velocity * dt

line number	Description in words of the calculation
1	Gravitational potential energy: Ugr = mass.gravity·height
2	Elastic potential energy: Uela = ½ · $C \cdot u^2$ with u the extension
3	Kinetic energy Uk = ½ · m· $velocity^2$
4	Total energy Etotal = $U_k + U_{ela} + U_{gr}$

</td></tr>
<tr><td>3c</td><td>If a spring is pushed (the extension is negative) the spring starts to push, but an elastic rope is unable to push. Therefore if the extension is negative, the formula responds with a zero extension, so the calculated force is zero.</td></tr>
<tr><td>3d</td><td>

Question	**Answer**
Mass of Jumper ?	75 kg
Jumps from which height ?	80 m
Length of rope	30 m
Force constant	56 N/m

</td></tr>
<tr><td>3e</td><td>Minimum height is 5.88 m, so just safe. If the force constant is lower, the rope will extend more and the jumper will eventually hit the ground.</td></tr>
</table>

3f	 The model starts to deviate from the line of the freely falling body at the moment that the elastic rope starts to stretch. Then the acceleration is no longer equal to the gravitational accelaration. Due to the incremental model steps, the moment the two lines diverge will not correspond exactly to the moment the rope starts to stretch
3g	When the height is 50 m, the rope starts to stretch (initial height – rope length). The jumper has fallen 30 m. 30 = 0.5*9.81*t^2. t = 2.5 seconds.
3h	Almost, it looks like 2.6 s.
3i	Fg stays the same for the whole movement. Not related to the height of the jumper Fv is zero until the height is less then 50 m, than it increases until maximum stretch, then decreases until the height is again 50 m. Then it becomes zero. Fn the resulting force and equals the gravity force until the rope becomes stretched. Than the resulting force decreases, changes direction, increases, decreases changes direction again and becomes equal to the gravity again. When the resulting force is zero, the velocity is at his maximum. The motion starts to slow down. In the model maximum velocity is at 35-37 m height. This can be calculated with Fz = Fv ; mass*g/C = stretch = 13 m. This means that the jumper is 37 m high.
3j	T = $2\pi(\text{mass}/C)^{1/2}$=7.3 s. So the time is 7.3/4 = 1.8 s. With the trace option the maximum velocity is at 3,0 s and zero velocity is at 4.8s. So the statement seems to be true.
3 k+l	 Yellow = U_{gr} Red = U_{ela} Blue = U_k Magenta = E_{total}. Due to the simple handheld integration routine E_{total} is not completely constant. When the time step is decreased this becomes less. U_{gr} decreases and increases because the jumper is going up and down U_{ela} increases in the middle due to stretching of the rope. U_k has two maxima, both times when the resulting force is zero. Then the jumper is moving at maximum speed and has the greatest kinetic energy. When the Ugr = 0 this means that the jumper hits the ground!!!

3m

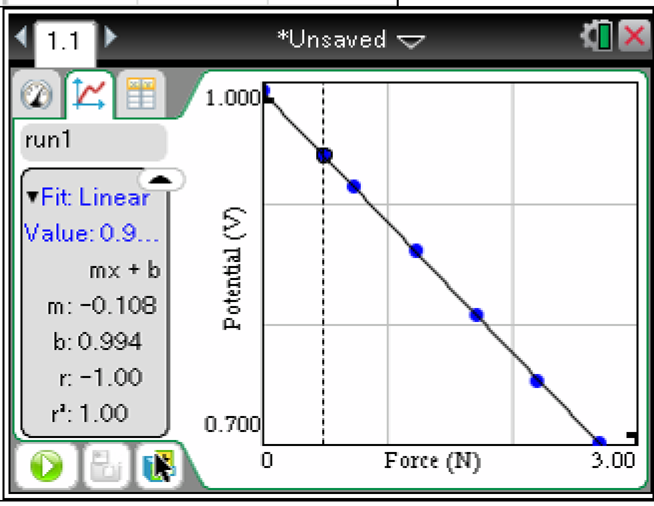
Height (m)	Velocity (m/s)	Acceleration (m/s^2)	Force of rope (N)	Resultant force (N)	Ugr (J)	Uela (J)	Uk (J)
80	0	-9.81	0	Fz= 736	max	0	0
35	↓-26.8	0	736 ↑	**0**	25 k	4.2 k	max
38	↑ 26.8	0	736 ↑	0	27 k	6.3 K	**max**
5.9	**0**	23.1	2.5 k	max	min	max	min
5.9	0	23.1	2.5 k	max	**min**	max	0

Note: due to step size in time height values 35 and 38 are not equal, as of course they should be.

4c

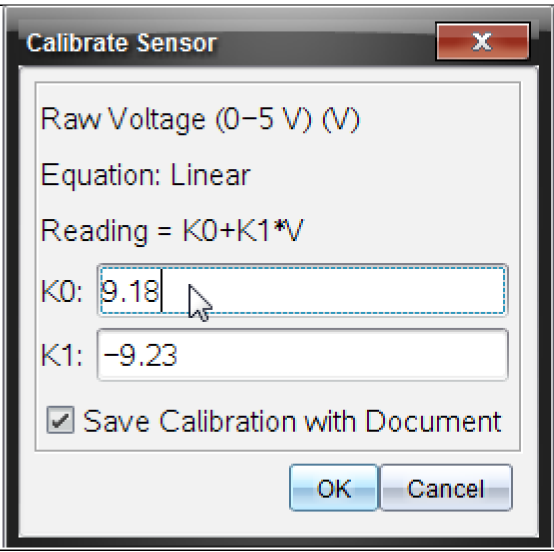
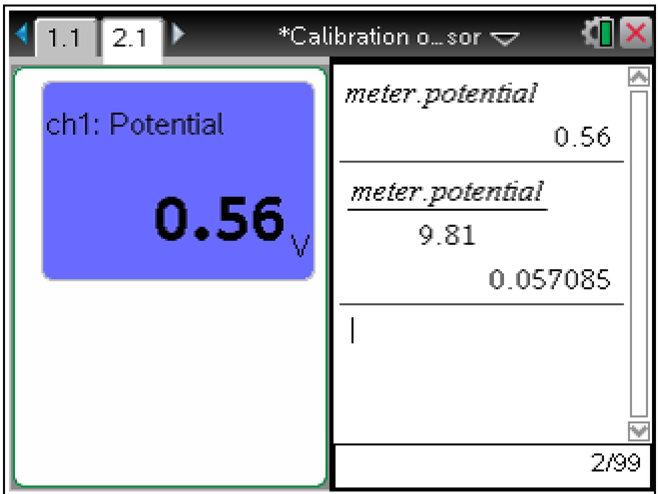
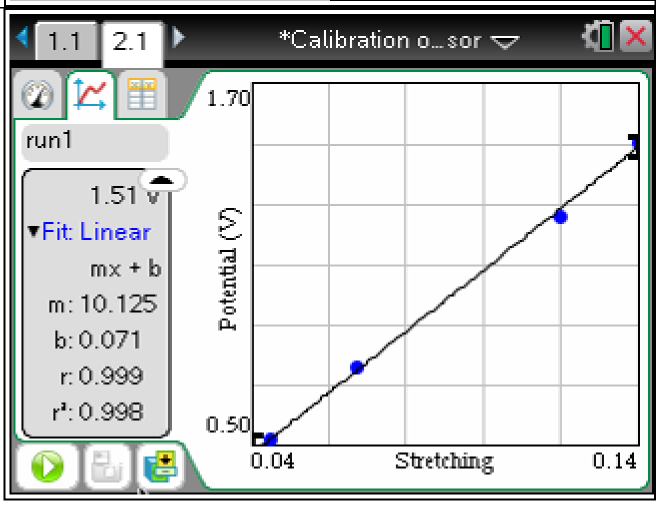
run1		
Mass	Potential	Force
0	0.994	0
0.05	0.941	0.491
0.08	0.914	0.736
0.13	0.861	1.23
0.18	0.808	1.72
0.23	0.755	2.21
0.28	0.702	2.70

4d

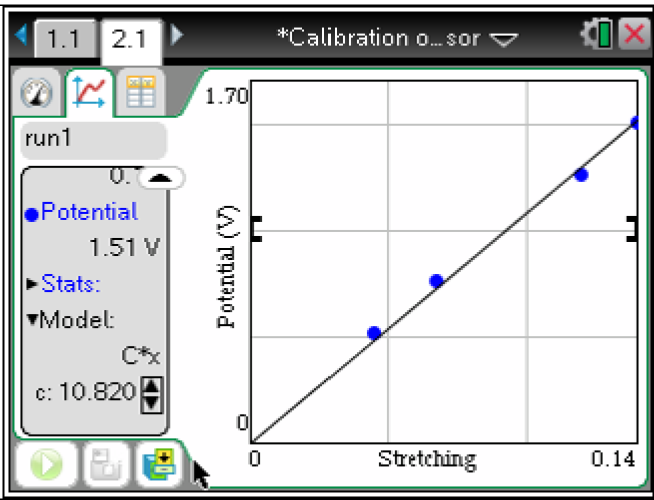


4e -9.23·Potential+9.18

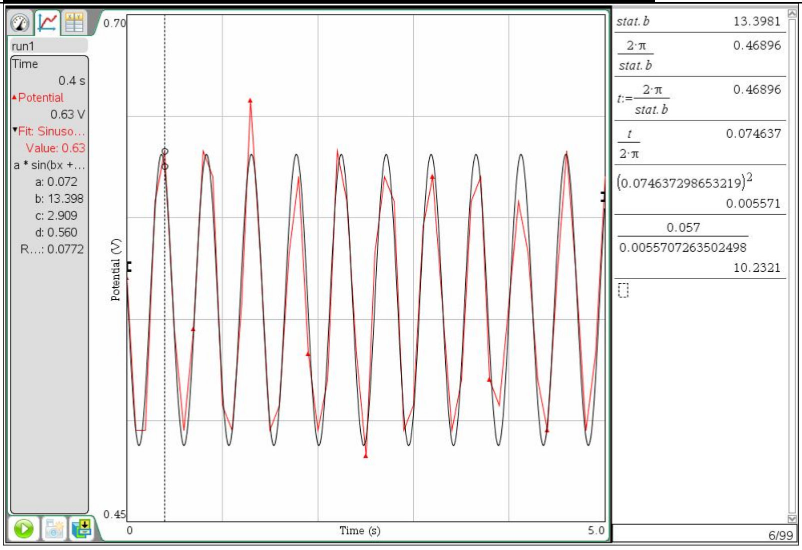
4f -0.108 V/N

<table>
<tr><td>5b</td><td>
</td></tr>
<tr><td>5c</td><td>Force: 0.56 N M = F/9.81=0.057 kg

</td></tr>
<tr><td>5d</td><td>

Although the y-axis is called potential it is in fact the force.
This gives a force constant of 10.1 N/m.
A different approach can be done by using model and choose as model C*x. With initial value of C= 10N/m and spin increment of 0.02. This gives 10.8 N/m</td></tr>
</table>



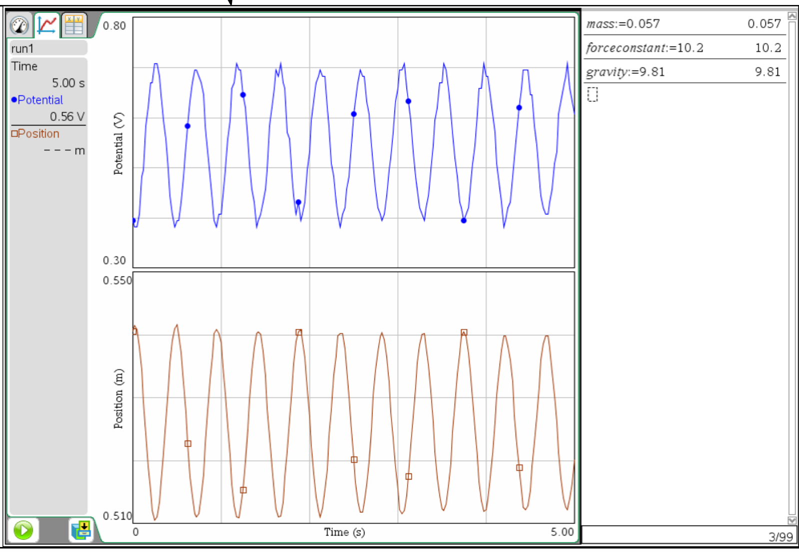
5e+f

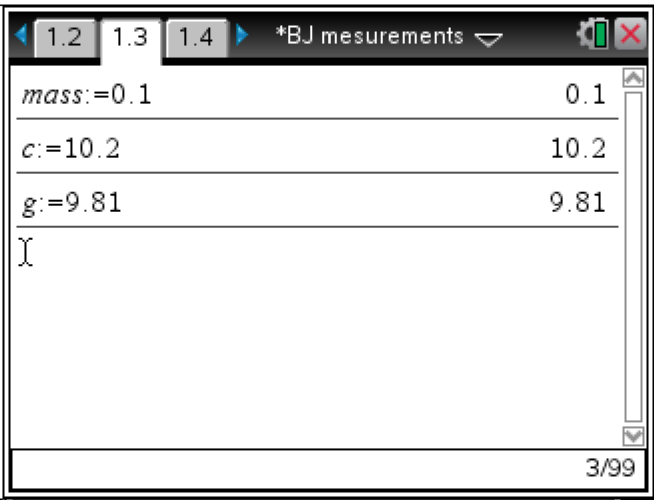
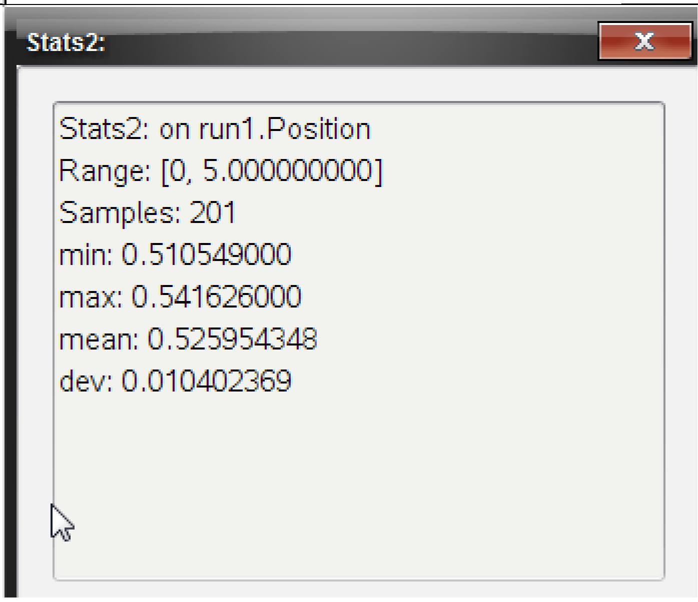
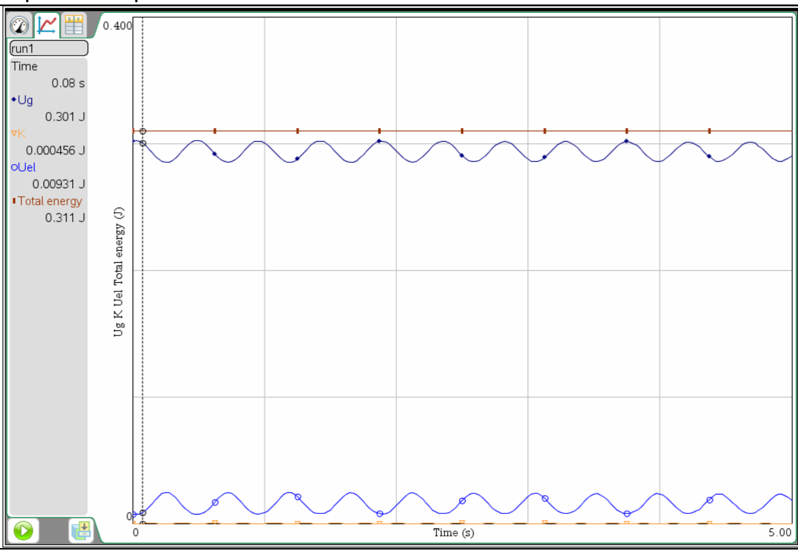


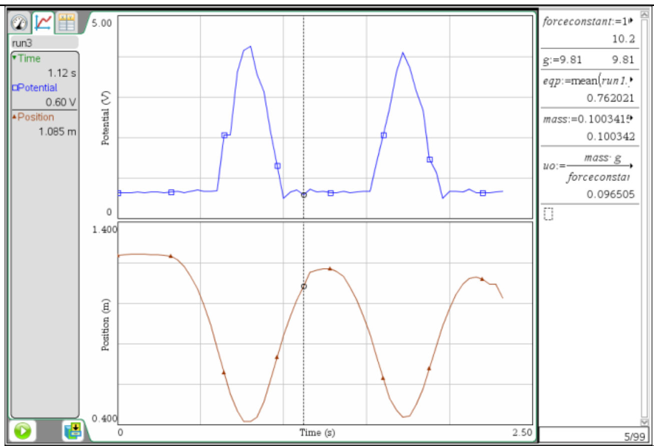
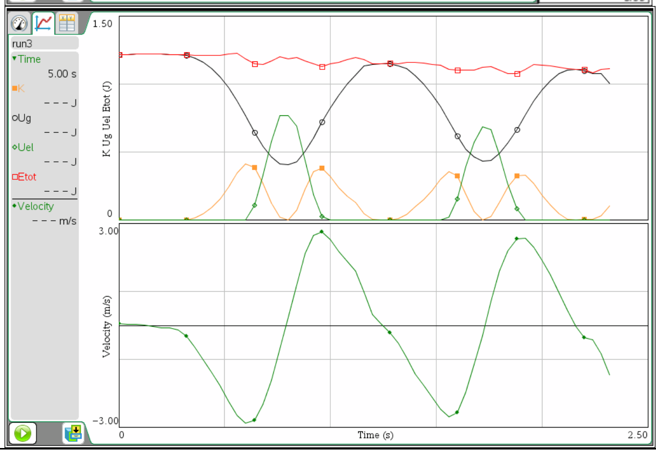
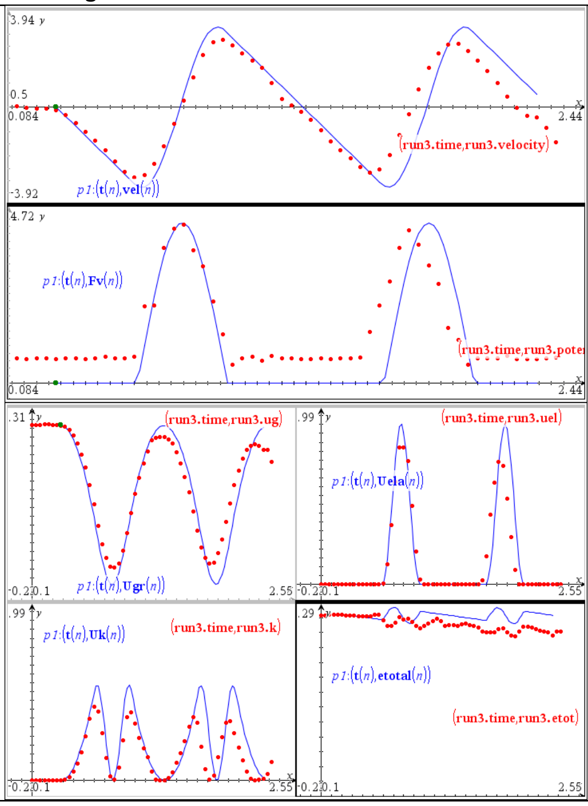
The stat.b value gives the angular frequency constant, ω.
The period is calculated by
T:= 2*π/stat.b

With $T = 2 \cdot \pi \sqrt{\frac{m}{C}}$ gives C = 10.2 N/m

6c



6d	
6f	$uo:=\frac{mass \cdot g}{c}$ 0.096176
6g	 Equilibrium postion: 0.526m
6h	
7b	The following graphs are obtainable.

	 
8a+b	On the given measurements to is 0.31 s and h = 1.24 m
8c	
8d	Mass and force constant are not likely to be the source of the non fitting of the model unless some sort of zero error has occurred.

Evaporation and intermolecular forces   Student notes

Context

How can we investigate and predict the influence of intermolecular forces on the physical properties of substances?

Preparation

In this experiment, a temperature sensor is placed in various liquids. Evaporation occurs when the sensor is removed from the fluid. Evaporation is an endothermic process, resulting in a temperature decrease. The size of the temperature decrease is, like the boiling point temperature, a measure of the strength of the intermolecular forces.

Material needed

- Lab Cradle
- TI- Nspire
- 2 temperature probes
- Four pieces of filtration paper shaped like a rectangle
- Two small bungs
- tape

Chemicals needed

- ethanol (R11, S2, S7, S16)
- 1-propanol (R11,R41,R67, S2, S7, S16, S24,S26, S39)
- 1-butanol (R10, R22, R37/38, R41, R67, S7/9, S13, S26, S37/39, S46)
- Pentane

Figure 1 Figure 2

Setting up

a. Start a new document:

b. Connect the interface to the TI-Nspire calculator.

c. Connect the two temperature probes to the Lab Cradle.

d. Always start with a new experiment:

e. Setting the collection mode: Time based

f. Set the sample rate (samples / second) to 0.3 samples per three seconds, (or I sample every 3 seconds).

g. Adjust the duration of the experiment to **240** seconds.

Instructions

Wear Safety Goggles

1. Wrap a rectangular piece of filter paper around the two temperature probes and secure it with a rubber band. Roll the filter paper around the sensors in the form of a cylinder.

2. Now insert a probe in a test tube that you have filled about 1/5th full with ethanol(see Figure 1). Ensure that the test tube does not overflow. Insert the second probe in a test tube that you have filled about 1/5th full with with 1-butanol.

3. Make pieces of tape about 10 cm long. These will be used in the next step.

4.Begin collecting temperature data if the probes are 30 seconds in the liquid. You will see a real-time graph (temperature as a function of time) on the screen of the calculator. Leave for 15 seconds the temperature probes in the test tubes with the liquid to determine the initial temperature. Then remove the probes at the SAME time from the test tubes and attach the sensors with tape to a table as shown in Figure 2.

5. During data collection you can fill in table 1 of the report. (see further in the document)

6. The data collection will stop automatically after four minutes. On the screen you get a graph on which the measurements are shown (temperature as a function of time). If you move the cursor over the graph, at the top of the screen the corresponding time (X) and temperature (Y) are displayed.

7. Determine the maximum temperature $\theta 1$ and minimum temperature $\theta 2$ and calculate the $\Delta\theta$ using statistical analysis.

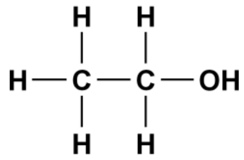
8. Save the data from the first run.

9. Predict $\Delta\theta$ for 1-propanol and pentane based on the data for ethanol and 1-propanol.

10. Repeat steps 1-7 for 1-propanol and pentane.

Report

TABLE 1

substances	Formula	Structural formula	molar mass (g/mol)	Hydrogen bonds? Yes or no
ethanol	C_2H_5OH			
1- propanol	C_3H_7OH			
1 - butanol	C_4H_9OH			
pentane	C_5H_{12}			

Data

substances	θ_1(°C)	θ_2 (°C)	$\Delta\theta$ (°C)
ethanol			
1- propanol			
1 - butanol			
pentane			

Prediction $\Delta\theta$ (°C)	Motivation

Questions

1. Sort the substances according to increasing intermolecular forces and explain!

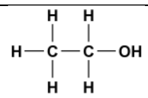
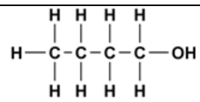
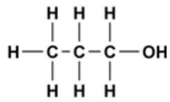
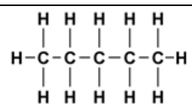
2. Identify the curves of the different substances

colour of the curve	name of substance

3. Explain why the temperature increases again after a while in the case of pentane.

Evaporation and intermolecular forces Teacher sheet:

Exemplar Results for Report

substances	Formula	Structural formula	molar mass (g/mol)	Hydrogen bonds? Yes or no
ethanol	C_2H_5OH		46,1	Yes
1-butanol	C_4H_9OH		74,1	Yes
1-propanol	C_3H_7OH		60,1	Yes
pentaan	C_5H_{12}		72,1	No

Data

substances	θ_1(°C)	θ_2 (°C)	Δθ (°C)
ethanol	*19,3*	*11,4*	*7,9*
1-butanol	*21,0*	*19,2*	*1,8*
1-propanol	*19,0*	*16,4*	*2,6*
pentane	*21,0*	*-2,1*	*23,1*

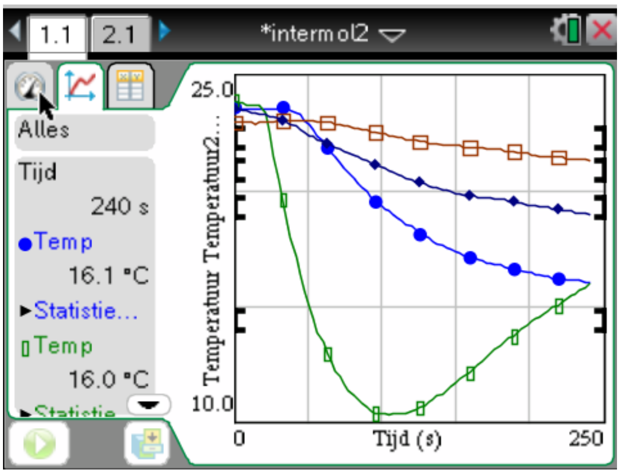
prediction Δθ (°C)	motivation
<7,9 *> 1,8*	*higher M* *lower M* *(both H-bonds)*
>7,9	*no H-bonds*

Exemplar Answers

1. Sort the substances according to increasing intermolecular forces and explain!
   pentane < ethanol < 1-propanol < 1-butanol

The substance will evaporate more slowly if there are stronger intermolecular forces. Ethanol, 1-propanol and 1-butanol have H-bonds as well as being subject to Vanderwaals forces and dipole forces. The intermolecular forces increase with the molecular mass of the substance. Pentane does not have H-bonds and will evaporate more quickly.

2. Identify the curves of the different substances



colour of the curve	name of substance
green (rectangle)	*pentane*
Light blue (circle)	*ethanol*
darker blue(diamond)	*1-propanol*
brown (square)	*1-butanol*

3. Explain why the temperature increases again after a while in the case of pentane.

All the pentane has evaporated, and the probe starts warming up to room temperature.

Rate of Reaction student notes

Magnesium reacts with hydrogen chloride to form hydrogen gas in the following reaction:

$Mg (s) + 2 HCl \rightarrow MgCl_2 + H_2 (g)$

First you will use a pressure sensor to monitor the increase of gas pressure in a flask as hydrogen chloride is added to magnesium. After the experiment you will have to think about several questions concerning reaction rates using the information from the experiment and what you know about factors that influence reaction rate. After discussion with your teacher you will carry out your own investigation.

Experiment

1. Place 25 ml of HCl solution (1 mol / l) in a flask of 250 ml.

2. Determine the initial temperature of the HCl-solution in the flask with a temperature sensor. Remove the temperature sensor after your reading.

3. Prepare to use the pressure sensor. Connect the pressure sensor through a plastic tube with a rubber stopper.

4. In this experiment we will measure the pressure for 300 seconds at a rate of one sample / second. Set the correct parameters.

5. Immediately after starting data collection add 5 cm magnesium ribbon into the flask and seal the flask tightly with the stopper which is connected to the gas pressure sensor. Make sure the flask no longer moves.

Warning: The measurements stop automatically after 300 seconds but keep track of the pressure. Be careful: the stopper will pop off the flask if the pressure exceeds 130 kPa. So gently remove the stopper if you reach 100 kPa.

6. Examine the resulting graph: Identify the time when you placed the stopper on the flask and when you removed it.

7. Select the steepest part of the graph for an interval of 50 seconds. Draw the best fit and determine the slope (gradient). The (initial) rate of the reaction is equal to the slope.

Evaluation

1. What is the (initial) rate of the reaction? (Please include the proper units!)

2. Give three factors that may affect the reaction rate of the reaction that you performed during the experiment.

3. Give several researchable questions considering reaction rates.

Rate of Reaction teacher notes

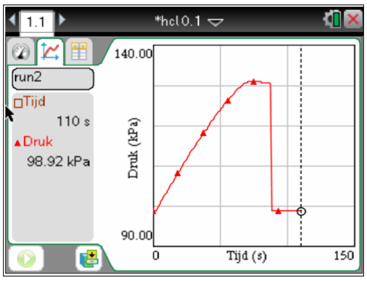
Equipment and Chemicals

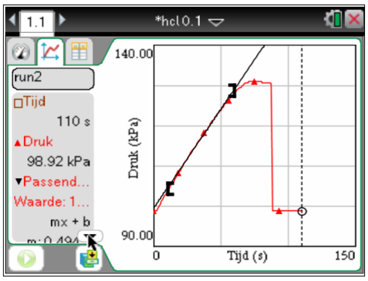
- TI Nspire CX
- temperature sensor
- gas pressure sensor
- Lab Cradle
- flask 250 ml
- cylinder 10 ml and 100 ml
- hydrogen chloride solution (HCl 1,0 mol/l)
- destilled water
- magnesium ribbon

Settings for measuring

Time based, duration 300s and 1 sample/second

Exemplar Results and notes

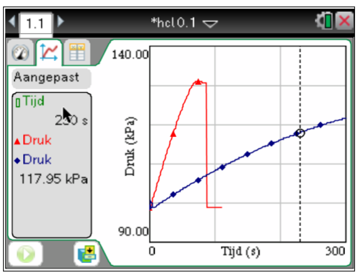


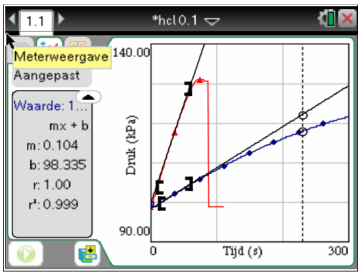


The slope represents the reaction rate.
v = 0,494 kPa/s
Three factors which influence the reaction rate:

- Concentration of the HCl solution
- Temperature of the HCl solution
- Surface area of Mg

For example you can investigate the influence of the concentration:
First run (red) = 25 ml HCl 1 mol/l
Second run (blue) = 25 ml HCl 1 mol/l + 25 ml distilled water (so lower concentration)
Results:





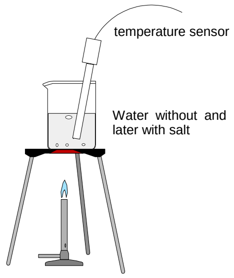
25 ml HCl 1 mol/l	v = 0,494 kPa/s
25 ml HCl 1 mol/l + 25 ml distilled water	v = 0,104 kPa/s

Into the cooking pot   student notes

Mrs. Küchenmeister is in her kitchen. She wants to cook spaghetti.
First she puts cold water and salt into the pot. After that, she heats the saltwater.
But her kitchenboy says: “First you must heat the water without the salt. When the water is cooking, you can put salt into it.”
“Why?” she asks. “I always heat up salted water for spaghetti. In my long life I have never done it in any other way.”
The boy replies that the heating point of saltwater is higher than that of water.
“That is why you need more energy to heat saltwater”, he says.
Is this true?

Experiment

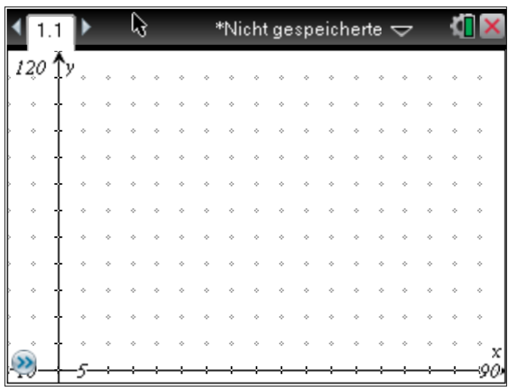
Prepare to measure with a temperature sensor.
Measure the temperature over a period of 15 minutes every 10 seconds.
Heat 100 ml water. When the boiling point is reached put about 15 g of salt into the water. Add another 15 g of salt after a few minutes.



Evaluation

1 Write down your observations.

2 Sketch the graph and interpret it.



3 What do you think? Who is right in the story?

4 Explain the change of the boiling point of water through adding salt.

Into the cooking pot   Teacher notes

Equipment Chemicals

- hot plate or gas burner
- beaker (V = 150 mL)
- support material
- graduated cylinder
- scale

- temperature sensor
- salt (30 g)
- water

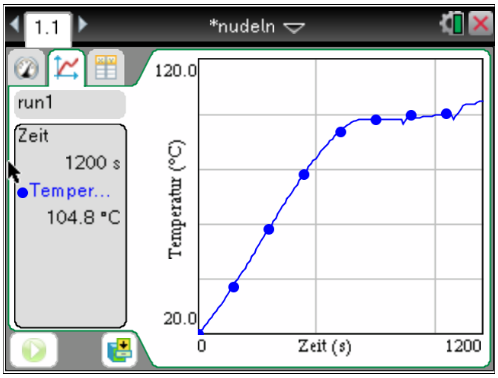
Settings for measuring

- Time Based
- Interval (seconds/samples): 10   Duration (seconds): 900

Exemplar Results and notes

1 After a few minutes the water boils. After the addition or 15 g of salt the boiling stopped for a moment. Later the salt water boils again.

2 The temperature of the water rises continuously. After a few minutes the boiling point of water is reached. Then the temperature remains constant. After the addition of 15 g of salt the temperature goes down but after a few seconds the temperature rises again. The same happens after the second addition of 15 g of salt. The boiling point of saltwater was now about 106 degrees Centigrade.



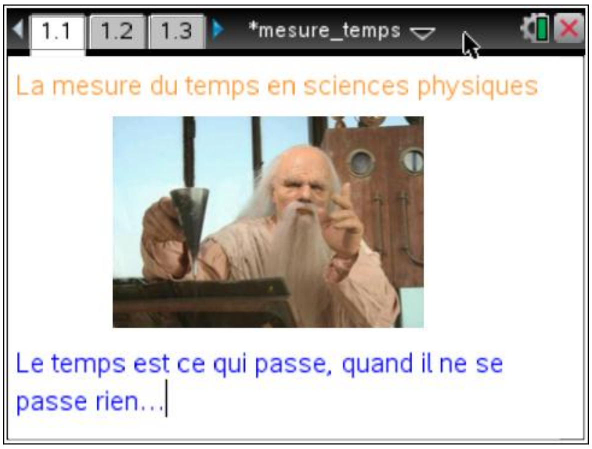
3 The boy is right.
But the experiment is not important for cooking spaghetti because you only need a little quantity.

4 Boiling is the transition from a solution to a gas. When for example a salt is in a solution the particles of salt obstruct the transition of the particles of this solution to become a gas. The boiling point of a solution is always lower than the boiling point of a mixed solution.

Investigating time   Student notes

Context of the activity:

"time passes slowly, when nothing is happening"



In the physical sciences, numerous phenomena depend on time. The measurement of time has always fascinated physicists.

Oscillations of a pendulum, the flow of sand in an hourglass or the water in a water clock, we suggest in this activity how to record some simple phenomena dependent on time, to analyze them to determine their characteristics. We shall also work on some parameters of these phenomena to see if it is possible to make a clock.

Learning Outcomes:

- Know how to interpret graphs: locate a point by its coordinates.
- Know how to determine an interval of time.
- Know how to calculate the rate of increase of a quantity.
- Use the measurements obtained to calibrate a clock

Experiment notes and instructions:

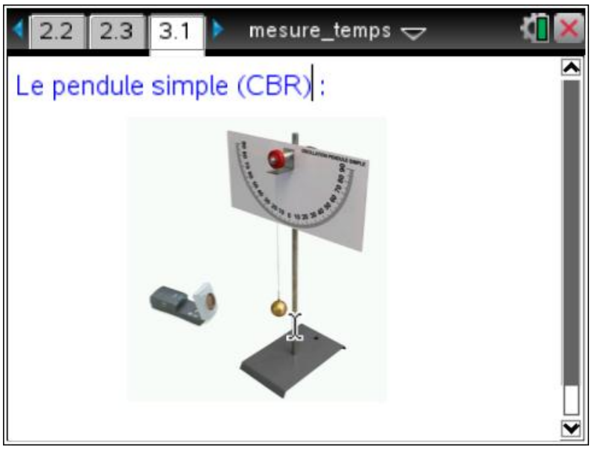
Six experiments are suggested.

Choose an experiment then follow carefully the instructions shown on the screens of your calculator.

We will record the motion of a rigid pendulum to which a 3D accelerometer is fixed. The position of the mass fixed to the rod of the pendulum can be adjusted

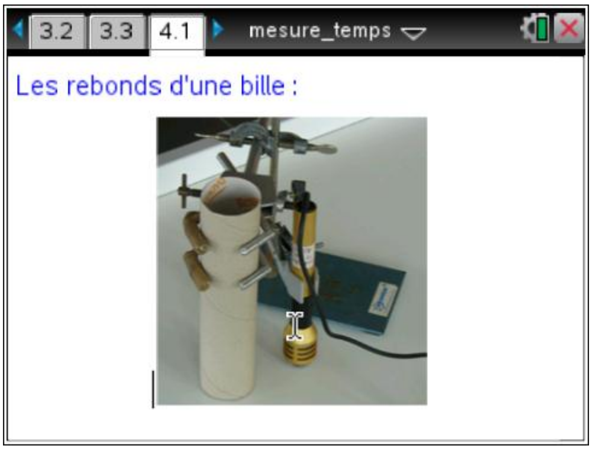
Pendulum

The movement of a simple pendulum is captured by a position sensor (CBR). The length of the pendulum is adjustable. Ensure that amplitudes for the pendulum are small.



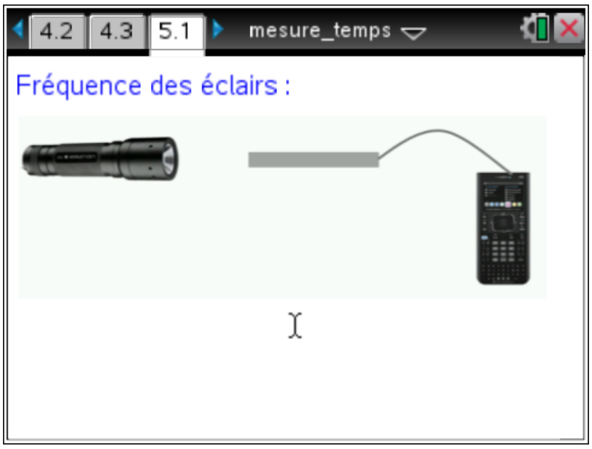
Simple pendulum

Drop a glass ball in the tube and record by means of the microphone the sound produced by the impact of the ball as it bounces. The periodicity of these bounces can be observed.



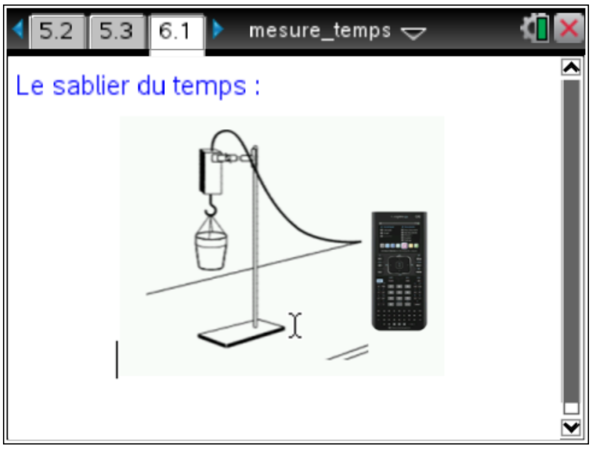
Bounce of a glass ball

A small lamp flashes at regular time intervals. We will record the light signal produced by the lamp using a light sensor. What is the frequency of these flashes of light?



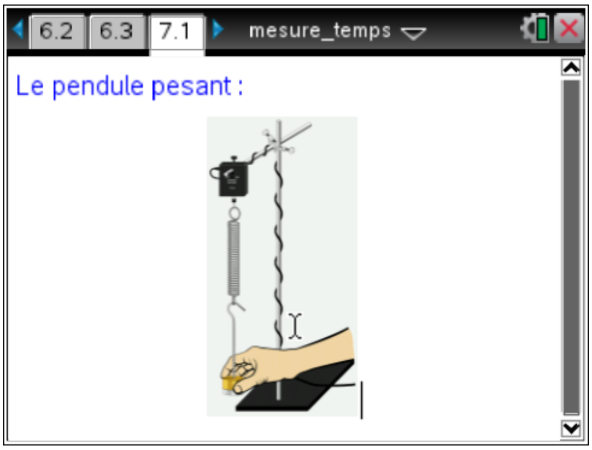
Twinkling lamp

The sand timer or hour-glass. Much used in the television quiz show " Fort Boyard " and by ancient Greeks to measure the time using water to give every speaker in the council the same speaking time during sessions taking place at night. Here a force sensor is used to record the changing weight of the bucket or funnel.



Funnel volume

The spring oscillator, stretched a few cm downwards will produce a series of oscillations the period of which we can measure. Change the value of the mass and compare the results.



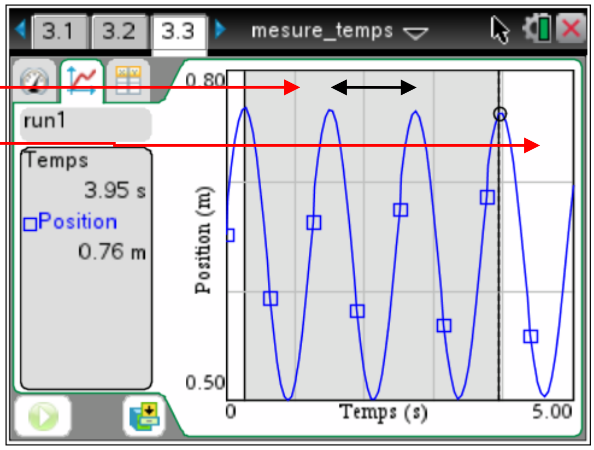
Spring and mass

Instructions for analysis of results:

t_1

t_2

One period



Calculate $\Delta t = t_2 - t_1$

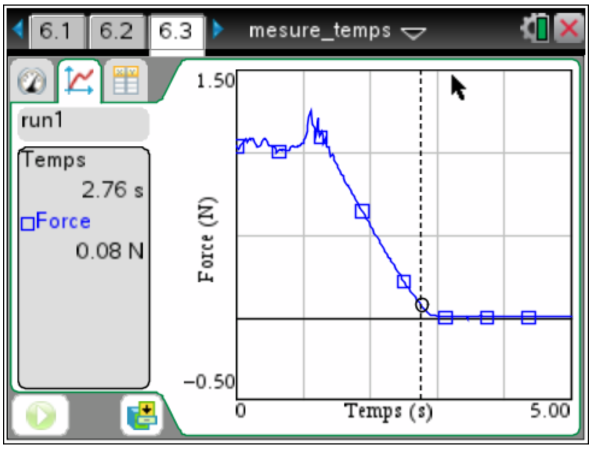
Calculate the duration of one period

…………………………………………………………

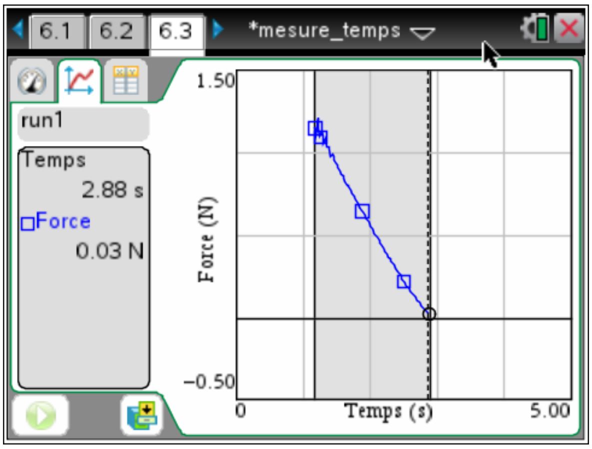
…………………………………………………………

Using a Sand Funnel:

Select the data which correspond only to the phenomenon of interest.



Exclude the data outside the selected region



Autoscale. Calculate the variation of force recorded during one second. Does it seem reasonable to be able to create a clock with this device?

………………………………………………………

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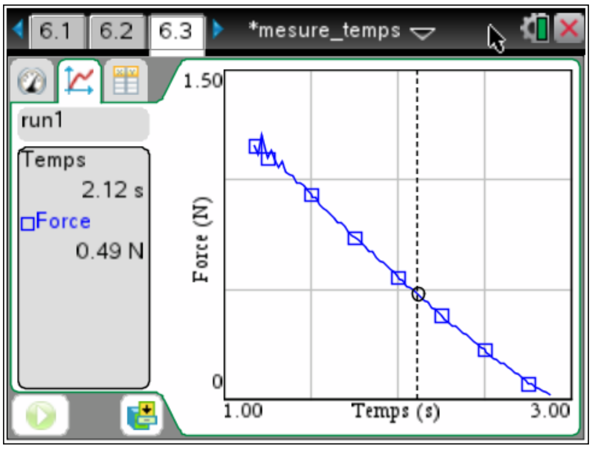


Extension work

For all the phenomena, what is the variable represented on the abscissa (x coordinate)?

……

The period of the clock pendulum is given by the relations:

- mass and spring oscillator

$$T = 2\pi\sqrt{\frac{m}{k}}$$

- swinging pendulum

$$T = 2\pi\sqrt{\frac{l}{g}}$$

Can you build a pendulum which beats seconds?

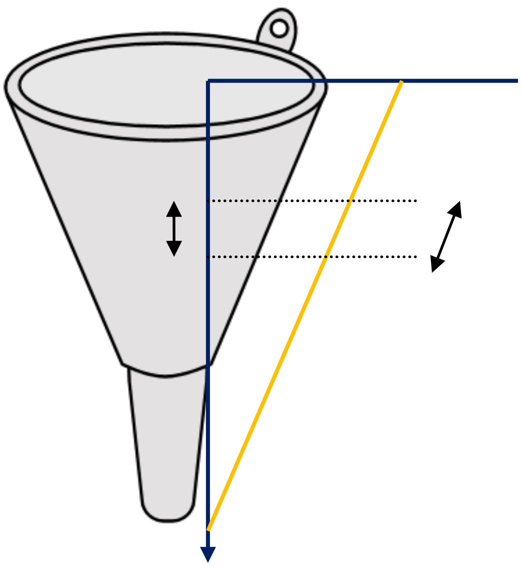
……

……

Suggest a scale for the funnel to show what vertical height of sand passes in one minute and so build a clock. Can you describe the way in which the volume of sand is changing?

……

……



Investigating time   Teacher notes

Key words:

time, measure, period, frequency, function

Complementary files:

Time-measure.tns;

Apparatus needed:

- Funnel, sand, balls, pendulums, tube pvc, flashing lamp
- Sensors: Force ; Light ; Microphone ; CBR2

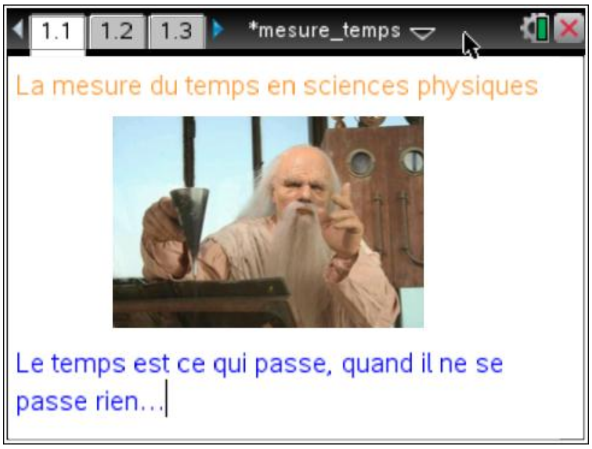
Overview of the science:

Generally, pupils encounter early in their study of the physical sciences, the difficulty of dealing with phenomena which depend on time.

The difficulties of analyzing graphs, measuring time intervals, or particular values become almost insuperable.

The objective of this activity is to propose a set of short experiments giving access to phenomena dependent on time.

These phenomenona are not inevitably periodic. The pupil will have to use some representation of the data to make measures of an essential characteristic (period, interval). They may propose the possibility of a modification to an experimental parameter to create a clock or a time measuring device.



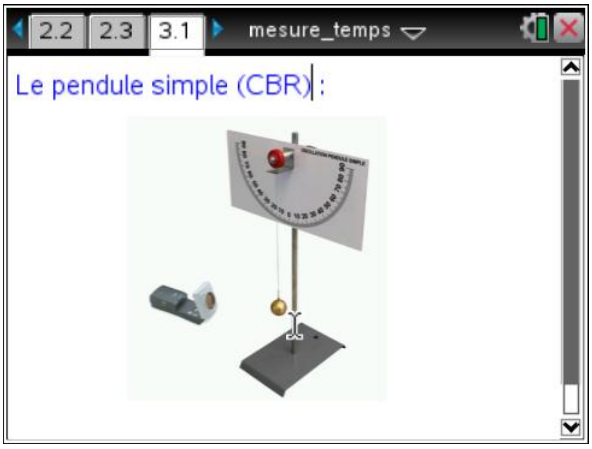
Experiment set-up and collection mode:

An accelerometer is fixed to a heavy pendulum.
- Connect the accelerometer to the Lab Cradle.
- Pull the mass about 10 °.
- Let the mass oscillate freely.

Example setup: Time based
5 samples per second for 40 seconds.

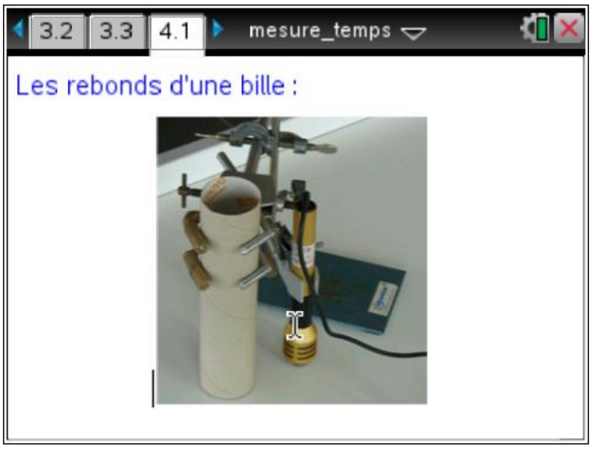
Place the CBR sensor in the plane of the oscillations of the pendulum.
- Connect the CBR to the Lab Cradle (digital input)
- Pull the bob about 10 °.
- Let the pendulum oscillate freely.

Example setup: Time based
5 samples per second for 40 seconds.



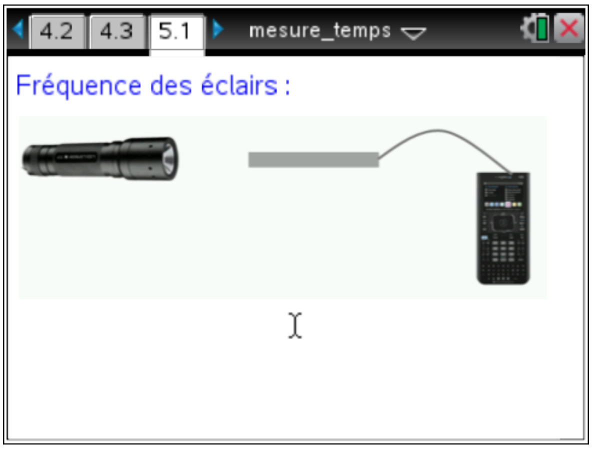
Verify that the microphone is in contact with the table. Set up the apparatus as shown in the photograph.
- Connect the microphone sensor to the Lab Cradle.
- Start data collection.
- Drop the ball down the tube so that it bounces as freely as possible.

Example setup: Time based
5 samples per second for 40 seconds.



Switch on the lamp (flashing mode)
- Place the sensor 10 cm in front of the lamp.
- Do not alter the position of lamp and sensor..

Example setup: Time based
5 samples per second for 40 seconds.

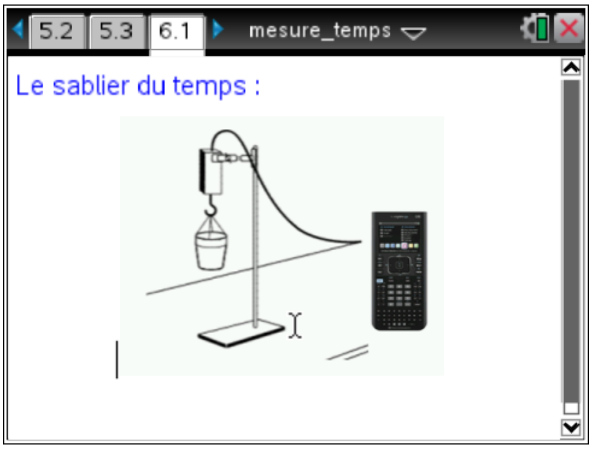


Construct the assembly illustrated in the diagram. Sand should be able to flow out of the bucket shown into a beaker underneath.

- Connect the force sensor to the Lab Cradle.
- Start data collection.
- Set the sand flowing.

Example setup: Time based

5 samples per second for 40 seconds.

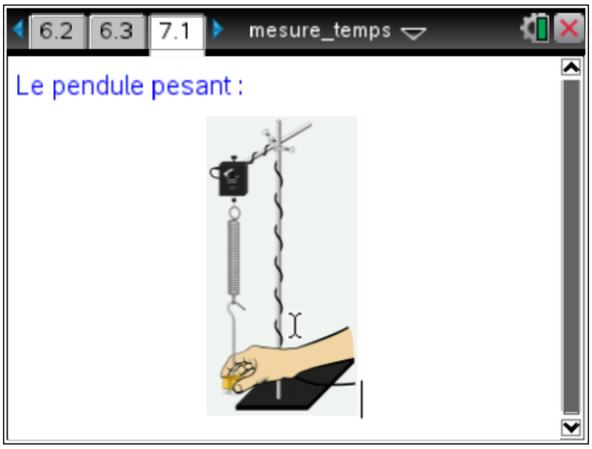


Set up the experimental assembly shown.

- Connect the force sensor to the Lab Cradle
- Set the mass oscillating vertically by pulling it down from its equilibrium position.

Example setup: Time Based

5 samples per second for 40 seconds.



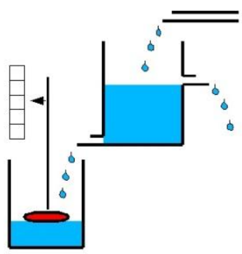
Experiment activity and tips:

The analysis consists of asking students to examine phenomena which seem periodic in some way. Then they have to identify some characteristic of the periodicity which can be measured to provide for example the period or frequency

The teacher should insist on the necessity of adjusting the scale of the graphical representation to show just several periods thereby using the biggest possible screen resolution.

Examples can be discussed collectively. The problem of the volume of the funnel can be rightly used to realize a clock. A historical investigation into the functioning of water clocks is possible.

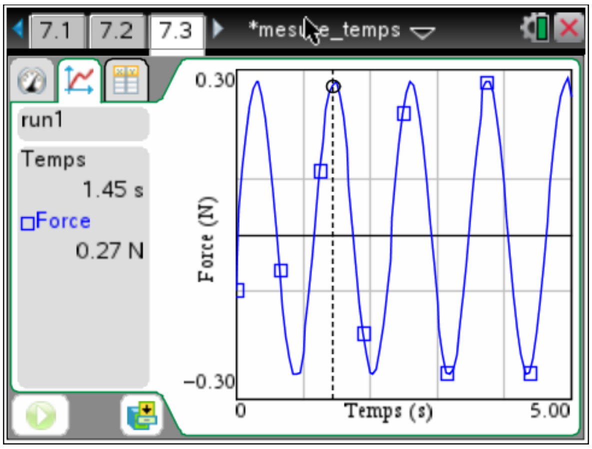
The Greek physicist Ctesibius, 270 BCE, used two bowls: the water passes from a vessel with constant water level (thus providing a constant flow) and drips into a second graduated vessel. Ctesibius perfected his system, by introducing a ballcock into the collecting vessel, connected with a cog which allowed it to activate a signaling mechanism (a bell for example) at fixed intervals.



Exemplar results:

System masses and spring

$$T = 2\pi\sqrt{\frac{m}{k}}$$

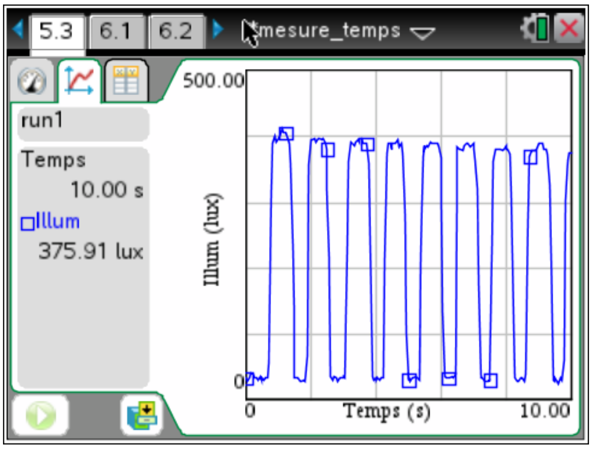


Pendulum

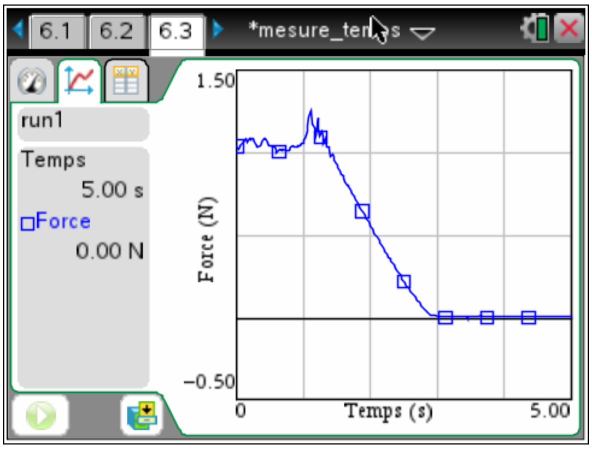
$$T = 2\pi\sqrt{\frac{l}{g}}$$

How to build a pendulum which beats seconds means adjusting m and/or k for the spring mass system or adjusting l for the pendulum.

Flashing lamp



Changing volume of sand in a funnel, represented by changing weight.



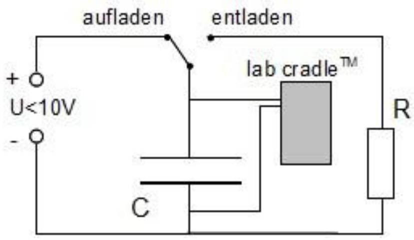
Charging and Discharging a Capacitor student notes

Determine the voltage change with time across the discharging capacitor.

Equipment

- A power supply, battery
- Capacitors, z. B. 1 µF, 4 µF
- Resistors, z. B. 10 kΩ, 22 kΩ, 33 kΩ
- Connection cables
- A hand-held computer (here, TI-Nspire CX™ CAS)
- A voltage sensor
- A Lab Cradle

Set up



Circuit plan

Settings

- Voltage: ca. <10 V
- Measurement mode: Time based
- Measurement time: 0,2 s (for example)
- Rate: 1000/s (for example)
- Triggering: voltage sensor, decreasing

Conduct and Evaluate the Experiment

(A) Formulate a hypothesis in words to explain the voltage change over time across the capacitor after discharge.
(B) Begin by constructing the circuit between the switch, a capacitor and a resistor from the list.
(C) Define and set suitable values for the measurement settings. HINT
(D) First, charge the capacitor. Then, measure the voltage change with time across the capacitor during discharge.
(E) Determine whether or not your measurement was successful and repeat the procedure if necessary. You may need to readjust or change the measurement settings. HINT
(F) Draw the curve.
(G) Derive a model for the change in voltage using the appropriate function. HINT
(H) Repeat the experiment with the same capacitor and at least two different resistors. Compare the calculated value of 1/RC with the handheld analysis. HINT
(I) Select one of the resistors already used. Repeat tasks (C) through (G) again using different capacitance capacitors. Compare the calculated value of 1/RC with the handheld analysis. HINT

To proceed with the project:

(J) Derive a general equation for the voltage across the capacitor as a function of the discharge time. Compare this with the functions determined in the experiment.

Additional exercise:

(K) Repeat the experiment so that the change in voltage across the capacitor is measured during charging. Complete the measurement and analyse and explain the graphs.

Charging and Discharging a Capacitor   Teacher notes

Examining charge and discharge processes using a capacitor is a standard part of the curriculum for upper-grade levels. To that end, the capacitor is charged and then discharged through a resistor so that the voltage and current changes over time can be explored. The simplified theoretical approach employs the well known equations for U(t) and I(t). In this student exercise, the discharge current I(t) should be measured as voltage U(t) = R•I(t) where the resistance value is R and then evaluated.

Equipment

- A power supply
- Capacitors,1 µF, 4 µF (for example)
- Resistors ,10 kΩ, 22 kΩ, 33 kΩ
- Connection cables
- A switch (such as a Morse key, for example)
- A hand-held computer with interface (TI-Nspire™ CX CAS with Lab Cradle ™)
- A voltage sensor

Conducting

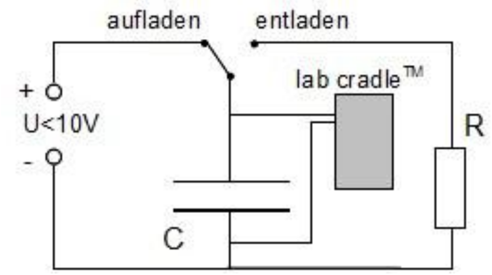
The capacitor (illustrated to the right) is charged (normally open switch) and then discharged through the resistor (normally closed switch). The switch must be kept depressed during the entire discharge process.

<u>Preparation and lesson time:</u> 45 minutes

Settings

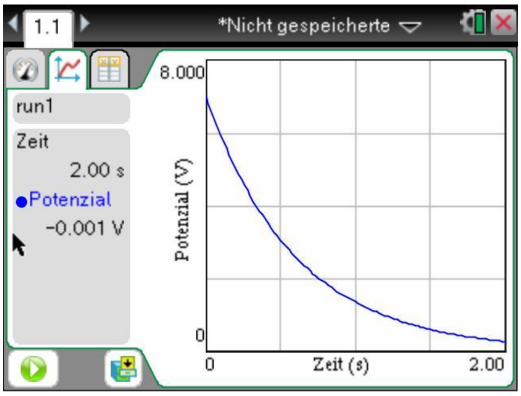
- Voltage: ca. 8V
- Measurement mode: Time based
- Measurement time: 0,2 s (for example)
- Rate: 1000 / s (for example)
- Triggering: voltage sensor, decreasing

Set up



Circuit plan

Experiment using TI-Nspire™



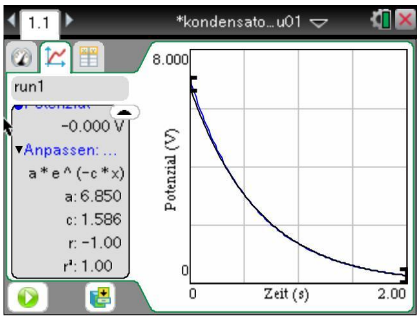
Graph

General Notes

Because the start of the discharge cannot be synchronised with the beginning of the measurement, a trigger will have to be used. To do this, go to the Experiment menu, select Advanced Settings, Triggering and then set the trigger threshold to 7 V, for example, with a decreasing signal. The threshold should be defined as somewhat less than the maximum charging voltage.
A pre-store of 20% or 30% could be used to show the entire discharge curve, but this may not be suitable for curve fitting.
Direct current sources of less than 10 V are suitable as power supplies.

Analysis

In the Analyse menu, select Curve Fit for the exponential regression, or better still, the regression natural exponential, as it gives $U(t) = U_0 \cdot e^{-t/RC}$.
The constant c in the returned coefficients is equal to $(RC)^{-1}$. In the illustration above,c=1.586, the discharge resistance was *R* = 10 kΩ, and the capacitance is given by *C* = 63 μF.



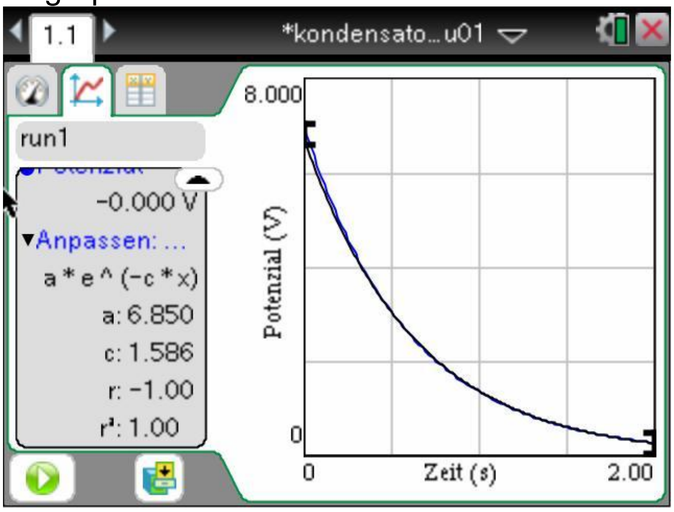
Exemplar results

For (E):

A measurement is successful when all of the measurement values appear to be located on a single curve.

For (G):

Example of a graph:

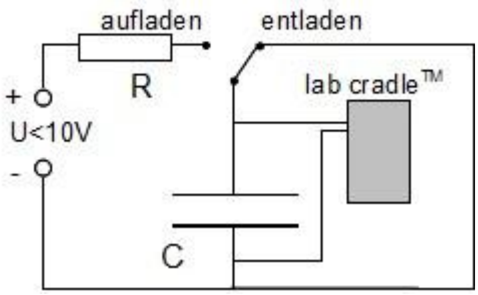


Table

C	R	10 kΩ	22 kΩ	33 kΩ
22 µF		0,22 s^{-1}	0,484 s^{-1}	0,726 s^{-1}
47 µF		0,47 s^{-1}	1,034 s^{-1}	1,551 s^{-1}

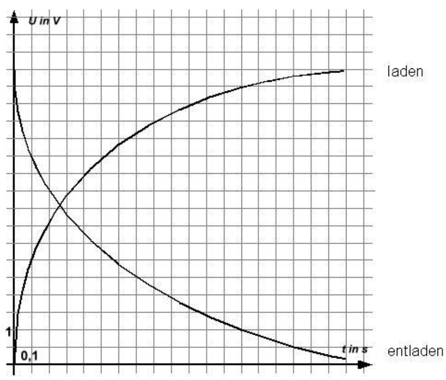
For (K):

New circuit diagram



The following is true for the voltage across the capacitor: $U_C = U - U_R$.
The exponential decrease of U_R gives the observed rate of change of U_C.

Example graph



Charging and Discharging a Capacitor

- Helpful HINTS for Students -

For (C)

For the given capacitors and resistors (see the worksheet), the following settings are appropriate:

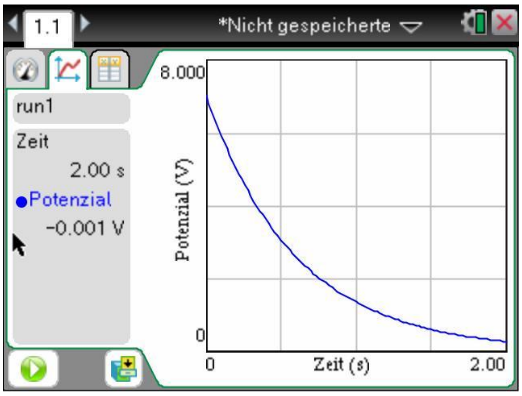
- Measurement time: 1 s (for example)
- Interval between two measurements: 0,001 s (for example)
- Triggering: Voltage sensor, decreasing

Further information:

A2. Time dependent measurements
A7. Triggering

For (E)

Example graph:



For (G)

Function type: Exponential function

Further information:

A10. Describe the data with an equalizing function
A11. Model the data with a function of your choice
A15. Model using sliders (application graphs)

For (H)

Suggestion for a measurement protocol:

For the various resistances, enter half of the discharge time (the time, in which the voltage has sunk to half the value).

For (I)

Suggestion for a measurement protocol:

For the various capacities, enter half of the discharge time (the time, in which the voltage has sunk to half the value).

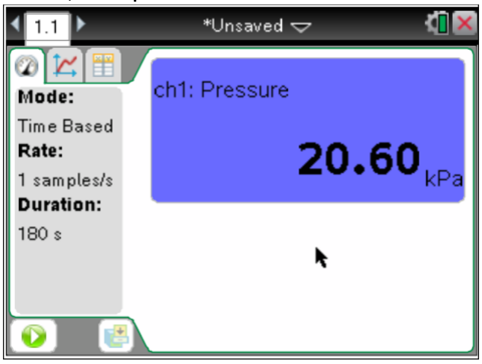
Investigating the sound of a cork pop   student notes

Material:

lab cradle, gas pressure sensor, syringe, TI Nspire HH/SW

Experiment set up

Connect the lab cradle to your HH or computer. Plug in the gas pressure sensor to ch 1 on the lab cradle. Attach the syringe to the gas pressure sensor. Make sure the plunger on the syringe is depressed and that the valve is closed. A window should pop up looking like Fig. 1. Choose from the menu, 1:experiment and then number 8:collection setup (Fig. 2).



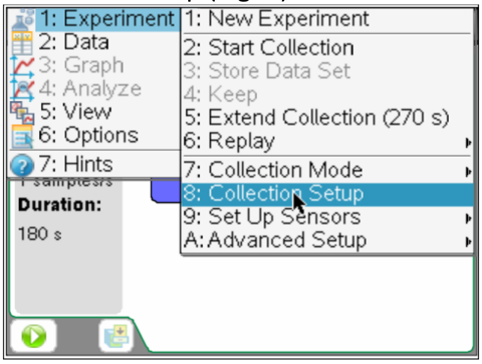
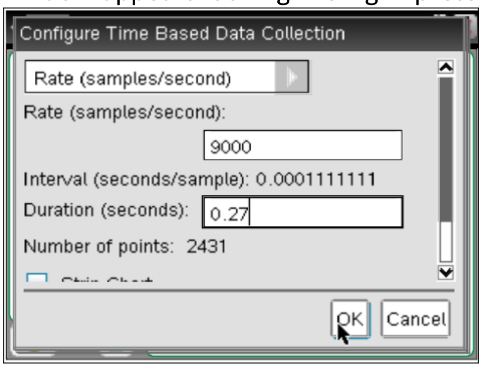


Fig. 1   Fig. 2

Change the samples/second and duration to the values showing in Fig. 3 then press OK. If a pop up window appears looking like Fig. 4 press OK. Note that the maximum numbers of points is 2500.



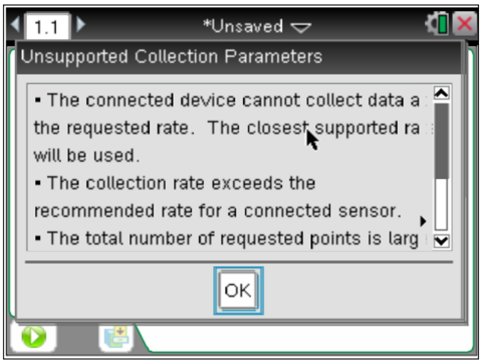
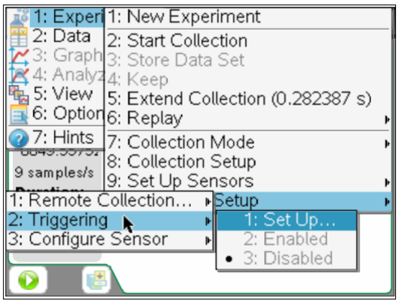
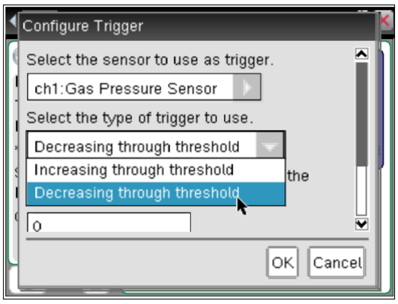


Fig. 3   Fig. 4

The "pop" happens in such a short period of time that we have to set up a trigger event to start measuring. This is called triggering and you can see below which alternatives you can choose under the menu to trigger your measurements. The pressure is decreasing when you start to pull the plunger and you have to check your own pressure sensor for an appropriate trigger value. In this example the pressure sensor shows 20.60 kPa at the beginning and 5 (kPa) is inserted for the trigger value. Pre-store is zero.





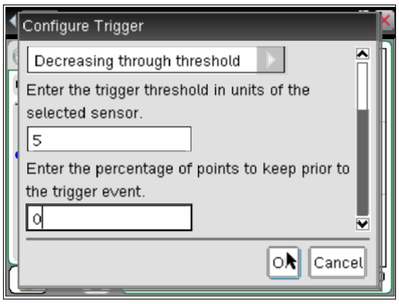


Fig. 5   Fig. 6   Fig. 7

Instructions

Now you are ready to go! Start recording and pull out the plunger from the syringe. You should hear a loud "pop" and get a graph which looks something like Fig. 8. Since you just want to look at a little bit of the graph you mark the bit showing in Fig. 8 just by clicking and dragging to highlight the region you want. Go to menu and choose the alternatives showing in Fig. 9 to zoom in to the part of the graph that you have marked.

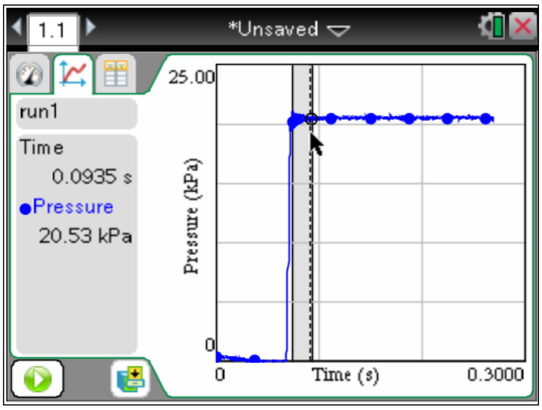


Fig. 8

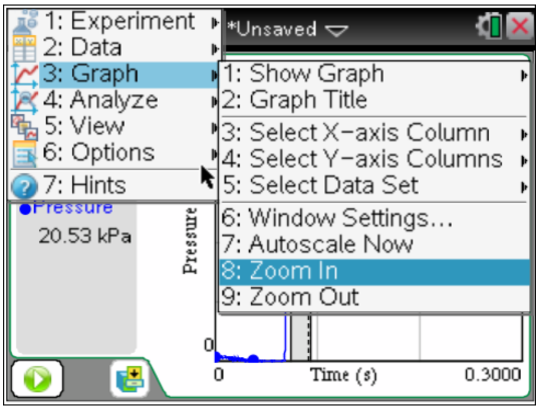


Fig. 9

Mark a whole number of periods, I have taken 10 and zoom in again. Look at Fig. 10 and 11.

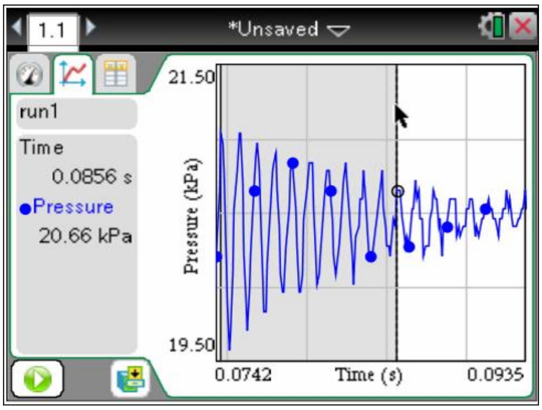


Fig. 10

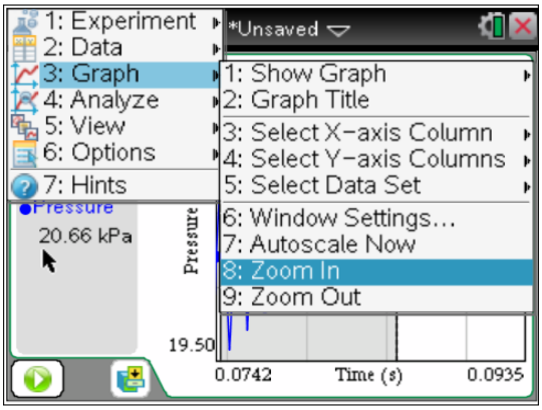


Fig. 11

Questions:

1. Find the period from the graph.

2. Use the period to calculate the frequency.

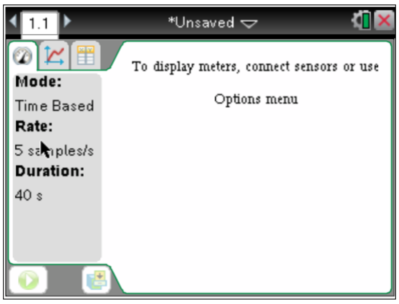
3. Use the frequency and the accepted value for the speed of sound to calculate the wavelength

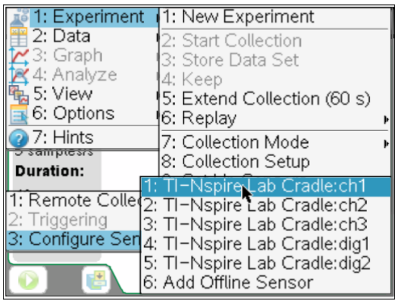
4. Which resonant mode dominates the sound?

Investigating the sound of a cork pop   teacher notes

Material: lab cradle, gas pressure sensor, syringe, TI Nspire HH/SW

In the student sheet you have all the settings needed for the experiment. If the handheld or computer does not recognize your sensor (Fig. 1) you have to press menu and choose experiment, advanced setup, configure sensor and choose the channel the sensor is plugged in to (Fig. 2). Find your sensor and choose that by clicking or press enter (Fig. 3). Now you are ready to start. (or re-insert the sensor).





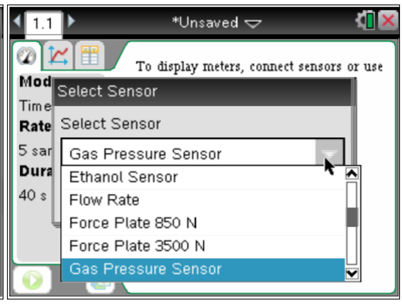


Fig. 1   Fig. 2   Fig. 3

Activity and Tips

When you are going to zoom in to the part of the graph you want to look at you just click at the starting point until you get the double arrows (Fig. 4) and then drag across using the touch pad, stopping at the end point (Fig. 5). For zooming in see instructions in the student sheet or guidance manual.

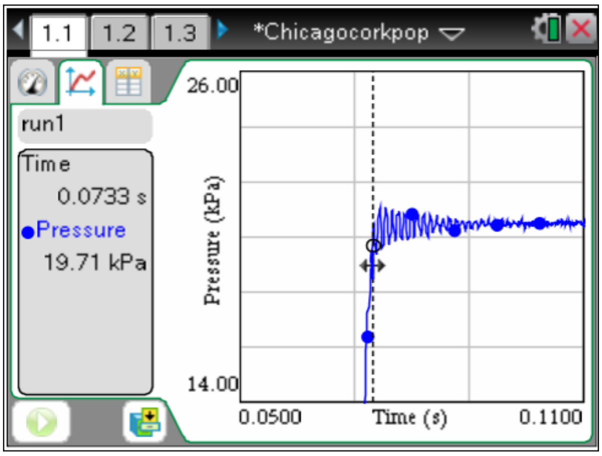


Fig . 4

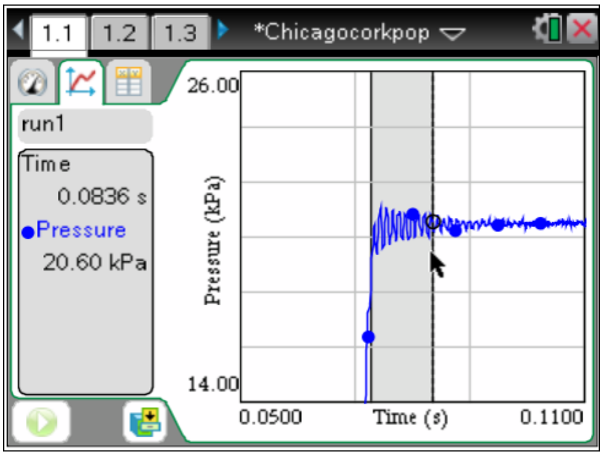
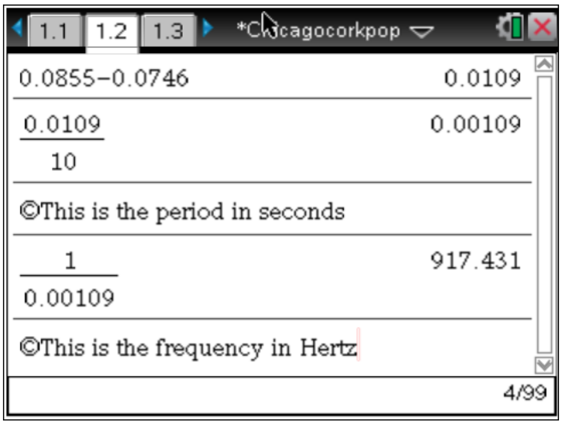


Fig. 5

You can see the calculations needed for the period and frequency in Fig. 6.
If you take the speed of sound to be 340 m/s, the wave length is calculated in Fig. 7.
In Fig. 8 the calculations show that the fundamental mode dominates the “pop”.

Exemplar Results



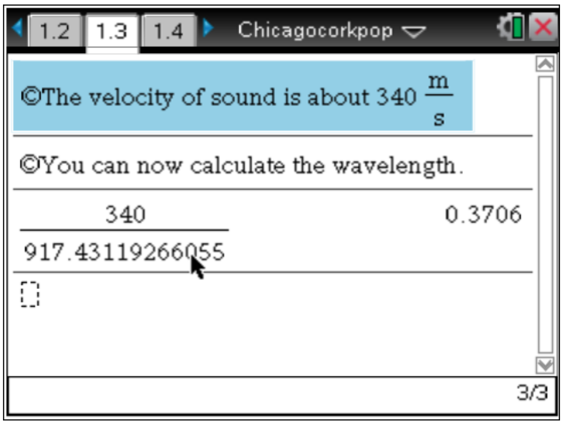


Fig. 6 Fig. 7

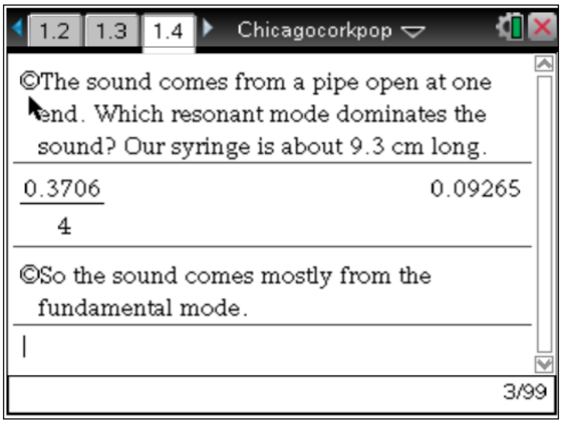


Fig. 8

For a pipe closed at one end, the fundamental mode occurs when the length of the pipe is $L = \frac{\lambda}{4}$. The syringe used in this experiment has $L \approx 9.3\ cm = 0.093\ m$ which is almost exactly the length needed for the fundamental mode if the wavelength is 0.3706 m .

This experiment shows that sound is produced by the sudden change in pressure stimulating the air column in the tube to resonate at its fundamental frequency. The note is the same as would be produced by blowing over the top of the tube, or in the case of a wine bottle by blowing over the top of the bottle!

Given the length of the tube and the calculation of the frequency this is also an effective method for measuring the speed of sound!

The falling basket ball student notes

Context of the activity:

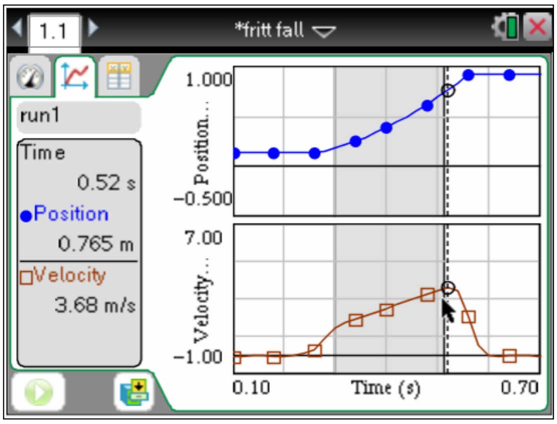
To use a position versus time graph and a velocity versus time graph to investigate a falling basket ball. Use the same graphs to carry out calculations of energy changes

Learning Outcomes:

Able to interpret graphs
Able to calculate averages
Able to calculate accelerations and energy changes

Instructions for part 1: the motion

You need an Nspire HH/SW, a lab cradle and a CBR 2. Put the CBR 2 at approximately 1.80 m from the floor pointing downwards with the help of a support and clamp. Look at the picture to your left. Connect the lab cradle to your Nspire/computer. Plug in the CBR 2 to the lab cradle. A window should pop up at your HH/computer showing the distance to the floor. You are going to use the mode time based and in the collection mode changes to 50 samples/second and make the duration time about 1 second. Let one person hold the basket ball under the CBR 2 but not too close to the detector, let the distance between the ball and the detector be about 15 cm and you are safe. Start the data collection by clicking the play button and do not let the basket ball go until you hear that the CBR 2 has started. You get two graphs, one showing position versus time and another showing velocity versus time. You are just going to look at the part where the ball is falling and in order to do that look at the velocity versus time graph and zoom in the part where the slope of the graph is constant. Look at the window to your right.



Instructions for analysis of results:

You are going to use your graphs and answer some questions. Some of the questions are the same but you have to use the graph mentioned before the questions. First you are going to look at the position versus time graph and answer these questions:

- How far did the ball drop?
- What was the average speed of the ball?
- Find the velocity at half rate at the fall time.

Now you are going to look in the velocity versus time graph and answer these questions:

- How far did the ball drop?
- What was the average speed of the ball?
- Find the velocity at half rate at the fall time.
- Calculate the acceleration of the ball.

Instructions for observations:

When you have finished the analysis and have answered all the questions above you are going to compare the results from the different graphs.

- Some of the questions were the same but did you get the same results from the different graphs? If not, why?
- What about the acceleration, do you recognize this value? The gravitational acceleration should be about 9.8 m/s^2. What about your value? Should it be higher or lower and why?

Instructions part 2: the energy changes:

You will use the data collected to calculate the change in potential energy.
You may need the Guidance Manual for this activity.

- Open up a new page, Lists & Spreadsheet. Go to the head of the list and press “VAR”. Choose “Link to” and “run1.position”. Now you have the distance between the CBR2 and the ball. What distance do you need to calculate the potential energy? Create a new list, B, with the values you need from list A.
- Open a new page, “Graphs” and look at the height versus time to make sure everything is ok.
- Now you want a third list, C, with the potential energy. Use the new list, B, and calculate the potential energy.
- If you look at the energy versus time graph you will see that the potential energy is decreasing. Why? What´s happening to the energy that´s missing?
- Create a new list, D, that contains the difference between the total energy and the potential energy. Look at the new energy versus time graph. This energy is increasing. Why? What is this depending on?
- Create a new list, E, by choosing the values for the velocity during run1. Look at the graph for energy versus velocity. What kind of graph is this? Is it linear?
- Create another list with the square of the velocity (v^2). Now look at the energy versus v^2. Is this graph linear? If it is, find the slope and try to find out what the slope depends on.

Instructions for observations:

When you have finished the analysis try to construct a formula for the motion energy, the kinetic energy.

The falling basket ball teacher notes

Key words:

Speed, gravitational acceleration, TI Nspire

Apparatus needed:

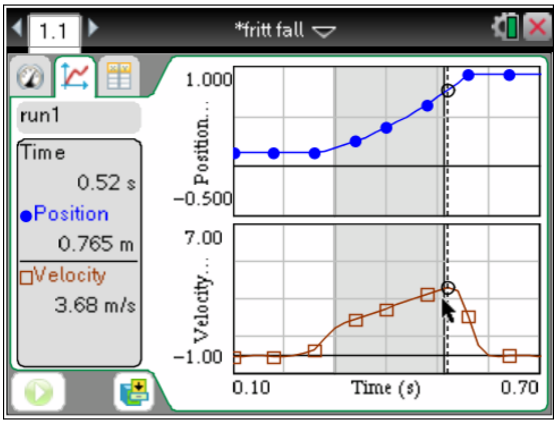
TI Nspire handheld, a lab cradle, a CBR 2, a support and clamp and a basket ball.

Overview of the science:

In this experiment the students are going to drop a basket ball and analyse both the position versus time graph and the velocity versus time graph. They are going to compare their results from the different graphs and discuss them. The acceleration should be close to the acceleration due to gravity.

Experiment set-up and collection mode:

Place the CBR 2 at approximately 1.80 m from the floor pointing downwards with the help of a support and clamp. Look at the picture to your left. Connect the lab cradle to your Nspire/computer. Plug in the CBR 2 to the lab cradle. A window should pop up at your handheld/computer showing the distance to the floor. You are going to use the time based mode and 50 samples/second for about 1 second. Hold the basket ball under the CBR 2 but not too close to the detector, let the distance between the ball and the detector be about 15 cm and you are safe. Start the data collection by clicking the play button and do not let the basket ball go until you hear that the CBR 2 has started. You get two graphs, one showing position versus time and another showing velocity versus time. You are just going to look at the part where the ball is falling and in order to do that look at the velocity versus time graph and zoom in the part where the slope of the graph is constant. Look at the window to your right.



Experiment activity and tips:

The students are going to use their two graphs and answer some questions. Some of the questions are the same but they have to use the graph mentioned before the questions. First they are going to look at the position versus time graph and answer these questions:

- How far did the ball drop?
- What was the average speed of the ball?
- Find the velocity at half time.

After that they are going to look in the velocity versus time graph and answer these questions:

- How far did the ball drop?

- What was the average speed of the ball?
- Find the velocity at half time.
- Calculate the acceleration of the ball.

When they have answered all the questions above they are going to compare the results from the different graphs.

- Some of the questions were the same but did you get the same results from the different graphs? If not, why?

Yes, they are going to get approximately the same results from the different graphs. If not, then they have done something wrong.

- What about the acceleration, do you recognize this value? The gravitational acceleration should be about 9.8 m/s^2. What about your value? Should it be higher or lower and why?

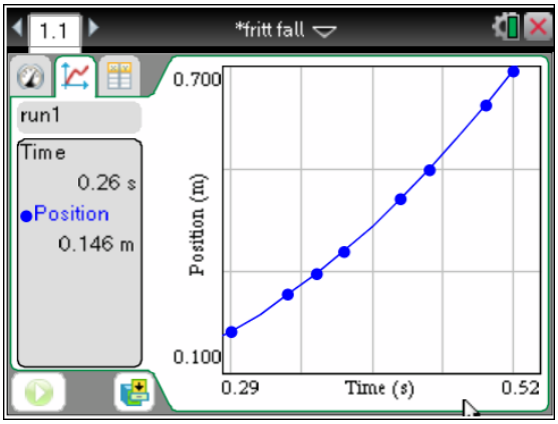
The acceleration should be approximately 9.8 m/s^2 and that is what they probably get. Perhaps they recognize it from the force due to gravity. It could be a little bit lower because of the air resistance.

Exemplar results for part 1:

From the position versus time graph:

- How far did the ball drop?

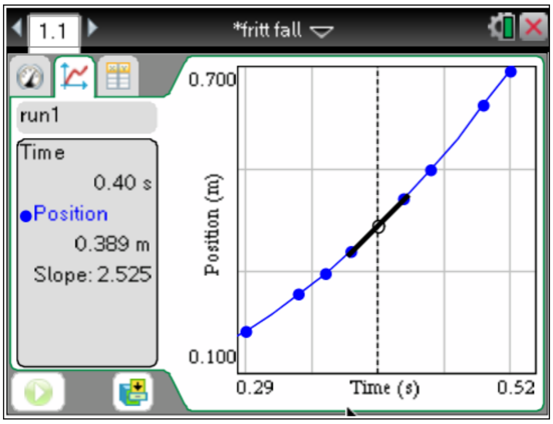
Find the position in your graph where the ball started and where it landed. In my example to the right I got $0.693 - 0.185 \approx 0.51\ m$.



- What was the average speed of the ball?

The average speed is

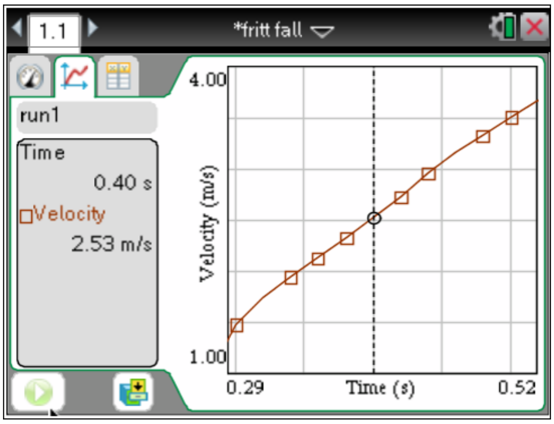
$$v = \frac{\Delta s}{\Delta t} = \frac{0.693 - 0.185}{0.50 - 0.30} \approx 2.5 m/s$$



- Find the velocity at half time.

You can find this in two different ways. You can do it by calculating the velocity in a very small interval around the 0.40 s mark. $v = \frac{0.442 - 0.341}{0.42 - 0.38} \approx 2.5\ m/s$. Another way to get this velocity is to use Nspire and find the slope for the tangent in this point. You can see it in the window to your left. Of course you get the same answer 2.5 m/s.

From the velocity versus time graph:



- How far has the ball dropped?

$s = v \cdot t = 2.53 \cdot 0.20 \approx 0.51\ m$. Here you get the average speed in your velocity time graph. Look at the window to your right. You can also calculate the area under the graph. You have a rectangle and a triangle

$$s = 1.49 \cdot 0.20 + \frac{(3.51-1.49)\cdot 0.20}{2} = 0.50\ m$$

- What was the average speed of the ball?

The average speed is the speed is initial plus final divided by 2, (1.5+3.5)/2 = 2.5 m/s in my example.

- Find the velocity at half time.

This is 2.5m/s.

- Calculate the acceleration of the ball.

Pick two points from the graph and calculate the acceleration:

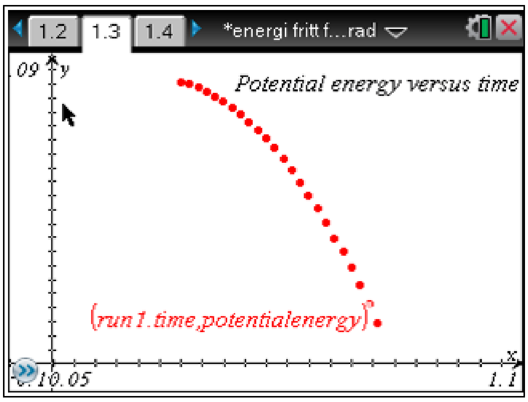
$$a = \frac{\Delta v}{\Delta t} = \frac{3.51 - 1.95}{0.50 - 0.34} \approx 9.8\ m/s^2.$$

Exemplar results and tips for part 2:

You, or your students, are going to use your graphs and lists to calculate the change in potential energy. I have found it best to do this as a demonstration together with my students.

Before you start you may want to strike the data you don´t need in order to get a nicer looking graph. You can also delete them after you have looked at the graph together and discuss why some points are unnecessary.

- Open up a new page, Lists & Spreadsheet. Go to the head of the list and press “VAR”. Choose “Link to” and “run1.position”. Now you have the distance between the CBR2 and the ball. What distance do you need to calculate the potential energy? Create a new list with the values you need by using list A. (B: = the dropping distance – A)

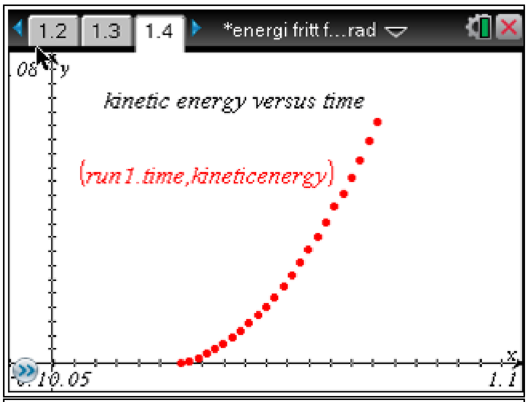


- Open a new page, “Graphs” and look at the height versus time to make sure everything is ok.

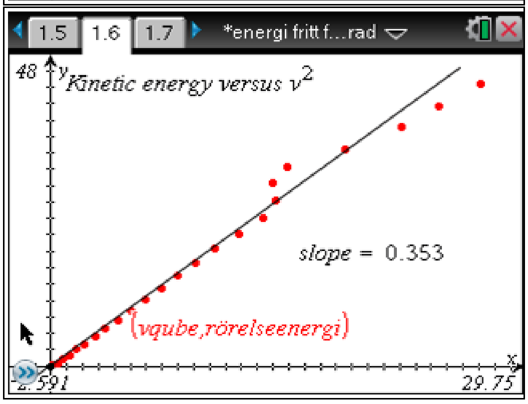
- Now you want a third list with the potential energy. Use the new list, B, and calculate the potential energy. (C: = mass · g · B) Our mass was 0.700 kg and g = 9.82 N/kg)

- If you look at the energy versus time graph you will see that the potential energy is decreasing. Discuss why? Try to get the students to figure out what´s happening to the energy that´s missing. (Some of the energy is changing into kinetic energy.)

- Create a new list that contains the difference between the total energy and the potential energy. (D: = Maximum energy – C) Look at the new energy versus time graph. This energy is increasing. Discuss why? Discuss what it is this depending on? (Velocity)



- Create another list by choosing the values for the velocity during run1. Look at the graph for energy versus velocity. Discuss what kind of graph this is? Is it linear, quadratic? Hopefully they agree with you that it looks quadratic.



- Create yet another list with the square of the velocity (v^2). Now look at the energy versus v^2. Is this graph linear? If you all agree that it is, find the slope by drawing a line that fits the points. (Slope = 353)

- Now discuss what the slope is depending on. Hopefully someone recognizes it as half the mass of the ball.

- Your formula for calculating the kinetic energy is: $E_k = \frac{mass \cdot velocity^2}{2}$

Speed of sound in air   student notes

Context of the activity:

Sound waves are mechanical waves and propagate in elastic material gases and liquids. There are no sound waves in a vacuum. The mechanics of these waves is complex because they result from displacements of atoms and molecules (in relation to their initial positions) in the particular media.
In a simple volume of material, this periodic collective and ordered motion, results in oriented displacements of atoms and molecules that we assume to be the same, overlapping the chaotic, disorderly and haphazard motion of the particles in the original undisturbed volume.
The intensity of sound waves decreases with the distance very quickly - partly because the initial energy spreads in all directions and extends to larger and larger surfaces and partly because the energy is dissipated in collisions between particles.
The propagation of sound waves depends on the structure of the medium in which it propagates and in particular on its density, pressure and temperature.

Learning Outcomes:

- able to carry out short time interval measurements.
- able to calculate the speed of sound
- able to compare the speed of sound obtained with the theoretical value.

Experiment notes and instructions:

1. Assemble the apparatus as in the photograph.

a) Place the tube vertically. Measure and record its length in the data table.
b) With the help of a universal bracket, place the microphone at the end of the tube so that it can detect the initial and successive sound echoes or reflections up and down the tube.

2. Connect Lab Cradle to handheld.

3. Open a new DataQuest document.

4. Connect the sensor to the Lab Cradle. It is automatically identified and the signal is zeroed at 2.5 volts.

5. Zero the sensor

6. Select triggering
CH1: Microphone → Increasing through threshold → Insert **0.1** → Insert **5** for the per-store.

7. Start recording the message "Waiting for Trigger Event **...**" will appear.

Near the sensor, make a sharp sound with a metal lid. You can also clap, click fingers or hit two pieces of wood together. This sharp sound will initiate the data collection.

8. If successful, the graph will appear as successive peaks, the first being the initial sound followed by its reflections. Repeat the process if necessary. If the graph is good, do not forget to save this test (run.1).

Position the cursor at the highest peak of each set to determine the time interval of successive reflections. Register these times in your data table.

9. Repeat the measurements five times.

Instructions for analysis of results:

Measure the length of the tube and room temperature. Fill the table with the data obtained.

Tube length (*m*)		
Air temperature (°*C*)		

Experiment	$t_{initial\ direct\ sound}$ (*s*)	t_{echo} (*s*)	Δt (*s*)	*uncertainty*	*d.m.*
1					
2					
3					
4					
5					

Δt_{mean}	

questions:

1 - The data table below, represent values of speed of sound in air at different temperatures. Plot speed of sound *vs* the square root of absolute temperature and find the mathematical expression that gives the relation between these variables.

θ (°*C*)	-100	0	15	20	100	500	1000
v (*m/s*)	263	331.4	340.4	343.3	386.9	548.8	694.8

2. From the recorded data, calculate the average interval time and its uncertainty.

3. Determine the speed of sound for the recorded temperature.

4. Calculate the speed of sound and the experimental uncertainty and compare with the theoretical value.

Speed of sound in air   teacher notes

Key words:
Sound waves, speed of sound, reflection, echo, TI-Nspire…

3. Apparatus needed:

- *TI-nspire Handheld with OS 3.1*
- *Temperature probe*
- *Lab Cradle*
- *Tube about 1-2 m long*
- *Microphone Vernier*
- *Tape measure*
- *Stand, bosses and clamp*

4. Overview of the science:
The speed of any wave depends upon the properties of the medium through which the wave is traveling. Typically there are two essential types of properties that effect wave speed - inertial properties and elastic properties.
The speed of a sound wave in air depends upon the physical properties of the air, mostly the temperature, and to a very small extent, the humidity. Humidity will affect the mass density of the air (an inertial property). The temperature will affect the speed of the particles, and this is the reason why the speed of sound in air depends on its temperature.

5. Experiment set-up and collection mode:
Assemble the apparatus as in the student sheet. This is a time based experiment with triggering.

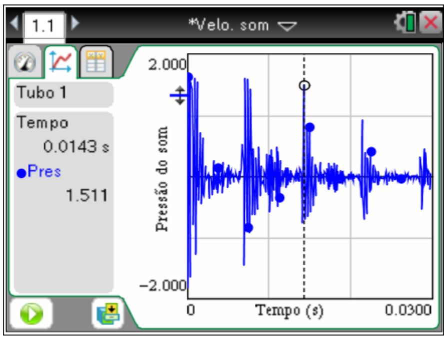
Zeroing is needed as the microphone sensor automatically zeros at 2.5 volts.

Triggering is clearly for increasing voltages, suggest 0.1 V and a pre-store of 5%

Experiment activity and tips:

The graph will show successive peaks, the first being the initial sound followed by its reflections. Repeat the process if necessary. If the graph is good, ensure that the run is saved.

Inter-peak distances should of course all be the same.

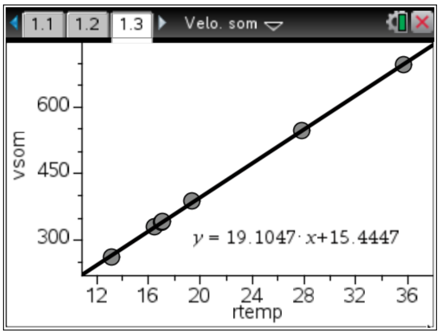


Exemplar results:

Tube length (m)		**1,232**			
Air temperature $(^\circ C)$		**22,1**			
Experiment	$t_{initial\ direct\ sound}\ (s)$	$t_{echo}\ (s)$	$\Delta t\ (s)$	*uncertainty*	*d.m.*
1	0	0,0072	0,0072	$4{,}0 \times 10^{-5}$	$4{,}8 \times 10^{-5}$
2	0,0072	0,0143	0,0071	$6{,}0 \times 10^{-5}$	
3	0,0143	0,0215	0,0072	$4{,}0 \times 10^{-5}$	
4	0,0215	0,0286	0,0071	$6{,}0 \times 10^{-5}$	
5	0,0072	0,0144	0,0072	$4{,}0 \times 10^{-5}$	

Δt_{mean}	**0,00716**

1. Plot speed of sound against the square root of absolute temperature and find the mathematical expression that gives the relation between these variables.



$$v(\sqrt{T}) = 19{,}15 \times \sqrt{T} + 15{,}44 \quad m/s$$

2. From the recorded data, calculate the average interval time and its uncertainty.

$$\overline{\Delta t} = 7,16 \times 10^{-3} \pm 4,8 \times 10^{-5} \quad s$$

3. Determine the speed of sound for the recorded temperature.

$$v(295.15) = 19,15 \times \sqrt{295.15} + 15,44 = 344,4 \quad m/s$$

4. Calculate the speed of sound and the experimental uncertainty and compare with the theoretical value.

$$v_{sound} = \frac{1,232 \times 2}{7,16 \times 10^{-3}} = 344,13 \quad m/s$$

$$\text{Relative error of length} = \frac{5,0 \times 10^{-4}}{1,232} \times 100 = 0.04\%$$

$$\text{Relative error of } \Delta t_{mean} = \frac{4,8 \times 10^{-5}}{7,16 \times 10^{-3}} \times 100 = 0.67\%$$

Total error = 0,04 % + 0.67 % = 0,71 %

$In. = 344,13 \times 0,0071 \times = 2,44\ m/s$

$$v_{sound\ obtained} = 344,13 \pm 2,44 \quad m/s$$

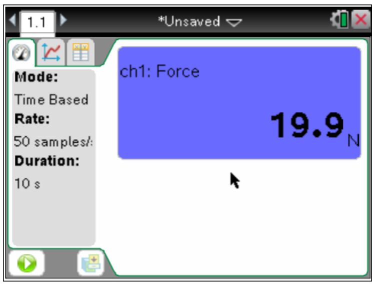
Relative error with respect to the theoretical value

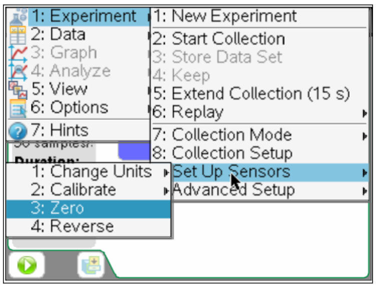
$$E_r(\%) = \frac{|344,4 - 344,13|}{344,4} \times 100 = 0,08\ \%$$

The Vertical Jump student notes

You are going to investigate your acceleration during a jump.

Connect the lab cradle to your Nspire/computer. Plug the force plate into ch 1 on the lab cradle. A window should pop up at your Handheld/computer which should look something like the window below to the left.

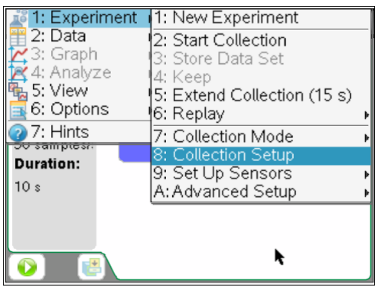


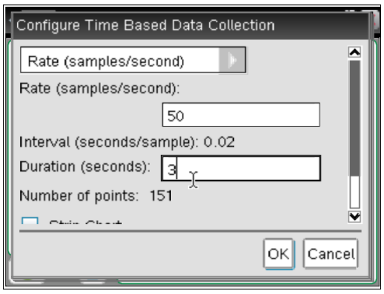


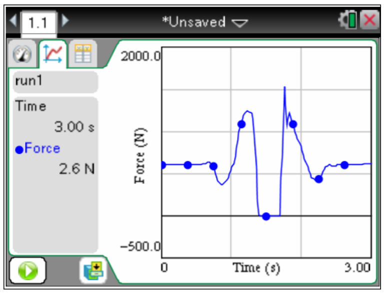
Instructions

You are now going to zero the force plate when no one is standing on the plate. See the window above to the right which alternatives you should pick under the menu.

You have to change the collection setup and change the duration to 3 seconds. See the two windows below to the left where you find this in the menu.







The person that is going to make the jump gets on the force plate and gets ready to jump. Another person pushes the play button at the lower left corner. A signal is made to the person standing on the force plate to start the jump when the measurements start. The window above to the right shows an example of what the graph could look like.

questions:

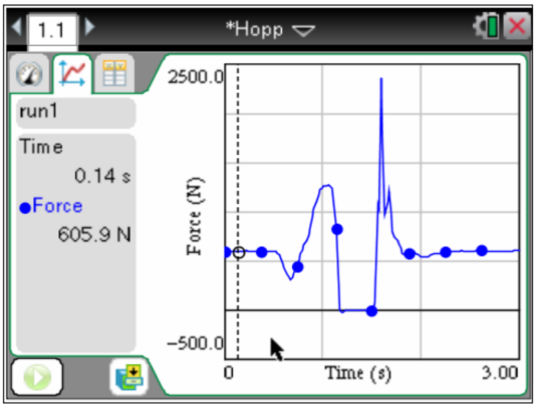
1. Mark in your graph these events: when the person is getting ready to jump, when the person begins to leave the force plate, when the person is completely in the air and when the person has fully landed on the force plate again.
2. For the two maximum forces construct a force diagram of the person when he/she leaves and hits the force plate and the forces that affect him/her. Look at the size of the forces in your graph.
3. Calculate the maximum accelerations at these two times using Newton's second law.

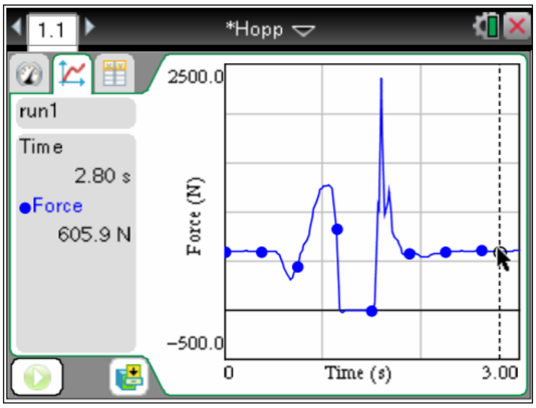
The Vertical Jump teacher notes

Apparatus

Force plate, lab cradle and Nspire (handheld or software)

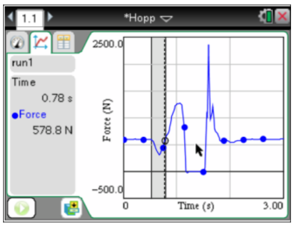
The measurements need to start before you make the jump. You can see in the graph when the jump starts and you also need the force when the person stands still to calculate the resultant of the forces when calculating the two accelerations in question number 3. I have marked two points in the graphs where the students can see their weight.



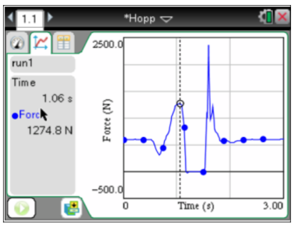


Exemplar answers:

Getting ready to jump

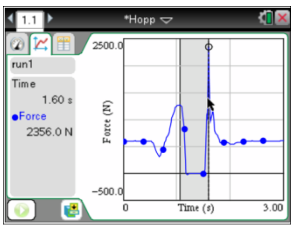


maximum force leaving

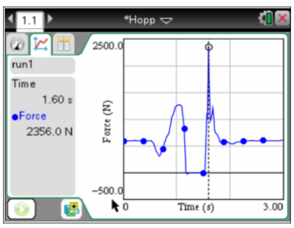


Leaving the plate

Including the free fall bit

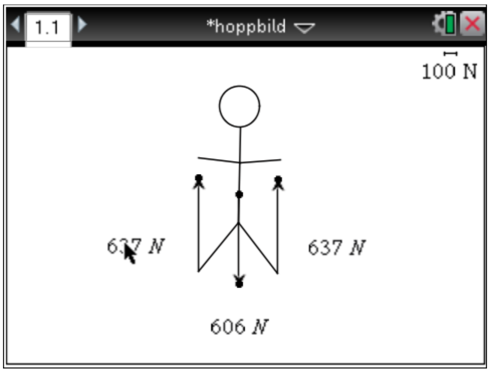


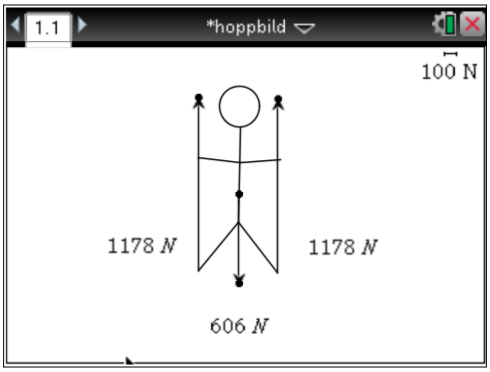
maximum force landing



Parts of the jump. Note that the interval actually in the air is where the force reads zero.

Leaving Landing





Turn the page

Calculations to get the accelerations:

Leaving: $F = m \cdot a$ where you get $F = 1274.8 - 605.8 \approx 669N$ and $m = \frac{605.8}{9.82} \approx 62kg$

$$a = \frac{669}{62} \approx 11m/s^2$$ pointing upwards.

Landing: $F = m \cdot a$ where you get $F = 2356 - 605.8 \approx 1750N$ and $m = \frac{605.8}{9.82} \approx 62kg$

$$a = \frac{1750}{62} \approx 28m/s^2$$ pointing upwards.

Discussions:

The students could think about why the graph looks different for every person and what the graph tells about the jump. They can then discuss whether the whole body gets this acceleration and how to make a jump if you want the whole body to get the same acceleration. Let the students jump again to explore!

They should explore simply squatting down and compare that to simply standing up.

Galileo's Experiment   student notes

Context of the activity:

The quantitative study of motion under gravity to determine a link between time and distance travelled, suggests that we need to measure time. There was, in Galileo's era, no precise instrument to measure time, it was necessary to invent it. Galilee had a musician's training and he could measure equal intervals of time by singing a tune. This is what he did in his first investigations.

Afterwards, he would use a bowl filled with water. He drilled a small hole in the base and welded in a slender cannula through which the water passed. The water passing through was collected in a glass bowl and carefully weighed. The weights of water so obtained were a measure of time.

In fact, what Galilee measured, he expressed in proportions.
By experimenting with the speed of a ball running down an inclined plane, Galilee was confronted with the problem of short time measurement. After several failures, he decides to distribute along the length of the track bells which will ring with the passage of the ball. And so he brought to light the existence of "uniformly accelerated motion ". The basis of modern physics was cast.

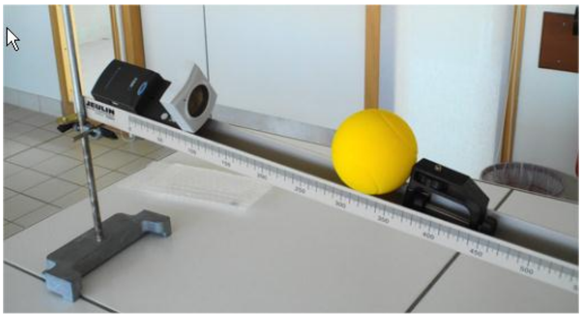
Learning Outcomes:

- Able to think like Galileo
- Able to relate the time intervals to the distance intervals and so understand what is meant by uniformly accelerated motion

Experiment notes and instructions:

- The measurements recorded in Dataquest will be used in the spreadsheet.
- Set up data collection for 5 seconds.

- Place the ball(bullet) at an initial distance of 15 cm
- Let the ball go, then begin data collection
- Repeat, if the recording contains bad data (extraneous peaks)



Instructions for analysis of results:

To analyze the graph obtained, change the presentation of the results so that points are not connected

Questions: Insert a spreadsheet and then load time measurements in column A and position measurements in column B

- Comment on the look of the graph.

……
……………………………………………………………………………

- What did the distance intervals covered in equal time intervals look like for Galileo?

……
……………………………………………………………………………

- How can you show Galileo's hypothesis to be true? (The distance covered by the ball is proportional to the square of the time)

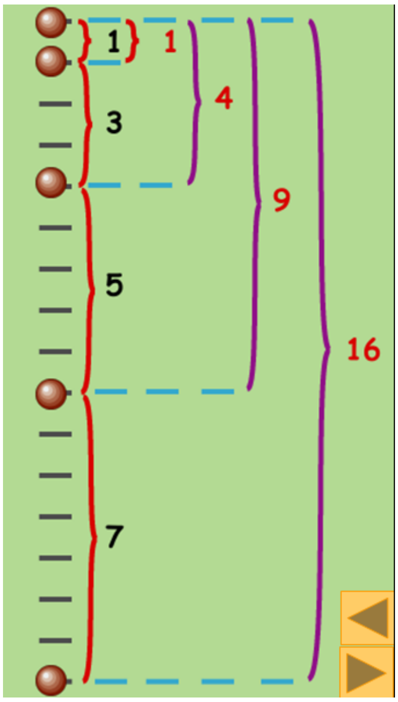
……
……………………………………………………………………………

Equal intervals of time and intervals of distance

- During the first interval of time, the ball covers one unit of distance.
- During the second interval, it covers three units of distance.
- During the third interval, it covers five units of distance.
- During the fourth interval, it covers seven units of distance.

Use the spreadsheet to show that the <u>total</u> distance covered is proportional to the square of the <u>total</u> time.

Total time units	Total distance units
1	1
2	4
3	9
4	16



Use the spreadsheet to show

$$\frac{d_2}{d_1} = \frac{t_2^2}{t_1^2}$$

This diagram will help you understand the connection between the distance intervals and the total distance.

- Using your spreadsheet, show that

$$d = a \times t^2$$

And find your value of the acceleration

Galileo's Experiment   teacher notes

Key words:

Time measure, Accelerated movement, Proportion

Complementary files: mrua.tns

Apparatus needed:

- Inclined plane…the bells are not needed
- ball of diameter large enough to be detected by the sensor
- CBR2
- TI-Nspire CAS

Experiment set-up and collection mode:

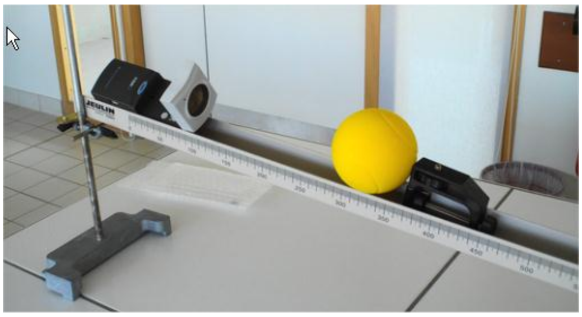
We suggest in this experiment using TI-Nspire to discover the thought process which lay behind the genius of Galileo.

- The measurements recorded in Dataquest will be then used in the spreadsheet
- Time based experiment for 5 seconds.

Galilee preparing his experiment

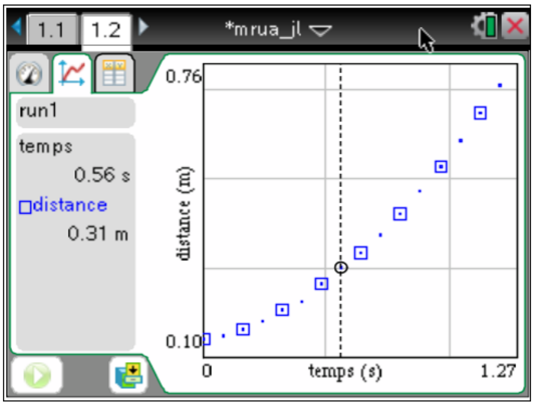
Experiment activity and tips:

- Place the ball not closer than 15 cm to the CBR2
- Let the ball go, then start data collection.
- Repeat if the curve is not smooth.

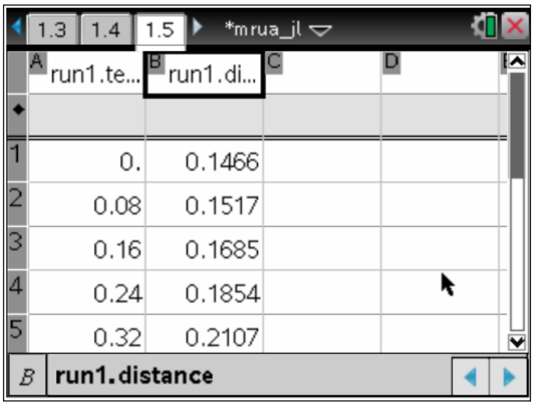


Exemplar results:

- To analyze the graph obtained, remove the option to connect the data points which you will find under options in the menu.

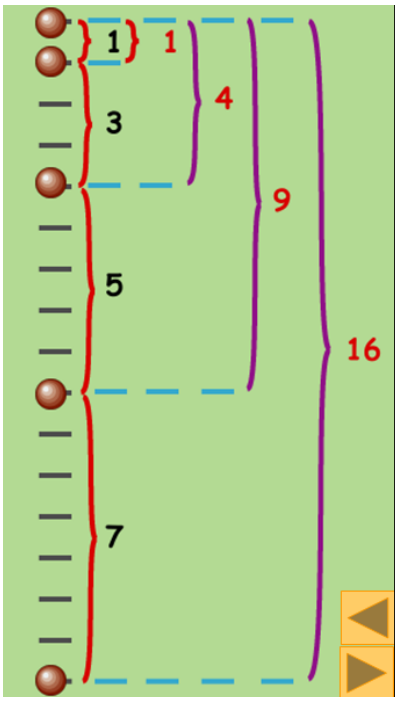


Insert a spreadsheet and insert time measurements in column **A** and position measurements in column B



	A run1.te...	B run1.di...	C	D
1	0.	0.1466		
2	0.08	0.1517		
3	0.16	0.1685		
4	0.24	0.1854		
5	0.32	0.2107		

B run1.distance



Intervals of time and outstrip

During a first interval of time, the ball covers one unit of distance.

During the second interval, it covers three units of distance.

During the third interval, it coversfive units of distance.

During the fourth interval, it covers seven units of distance.

Use the spreadsheet to show that the total distance covered is proportional to the square of the total time.

Total time	Total distance
1	1
2	4
3	9
4	16

Acceleration from the above data is approximately 0.7 m/s^2

Study of a buffer   student notes

In many biological, physiological, and industrial processes, the pH should remain constant within certain limits. A tool to keep the pH constant, is a buffer solution. A buffer solution ensures that the pH, within certain limits, changes little on addition of small amounts of acid or base. We examine in this lab which of the following solutions is the buffer solution:

A 150 ml of 0.1 mol/l acetic acid solution + teaspoon of Na-acetate

B 150 ml distilled water + teaspoon of NaCl

Experiment

Prepare to measure with the pH sensor. In this experiment we will measure the pH for selected events. (= adding drops of NaOH or HCl to the solution)

Prepare the two solutions and divide each solution into two beakers, four beakers in all.

Add drops of HCl to the solution A in the first beaker according to the data table. Do not forget to stir after adding the drops and recording the data point. After adding 20 drops of HCl, rinse the pH sensor with distilled water. Switch to the second beaker with solution A and start adding drops of NaOH solution according to the data table.

Repeat the procedure for solution B, not forgetting to rinse the pH sensor with distilled water before switching to solution B and when you switch from adding HCl solution to NaOH solution. Examine the pH changes brought about by the addition of small amounts of acid (HCl) and base (NaOH) to solutions A and B.

Data table

	amount of drops	**0**	**5**	**10**	**15**	**20**
Solution A	pH with HCl					
	pH with NaOH					
Solution B	pH with HCl					
	pH with NaOH					

Evaluation

1. Sketch the graph. Identify the axes. Connect with a smooth line all points.
   Indicated on the graph the different curves for:
   - Solution A (+ HCl)
   - Solution A (+ NaOH)
   - Solution B (+ HCl)
   - Solution B (+ NaOH)
2. Which solution is the buffer solution? Explain your answer.

3. How is the buffer solution composed?

   Choose from

   A) Strong acid + conjugated base from this acid
   B) Weak acid + conjugated base from this acid +

Justify:

4. Consider an additional research question concerning buffer solutions.
   Consult your teacher and continue with this research.

Study of a buffer teacher notes

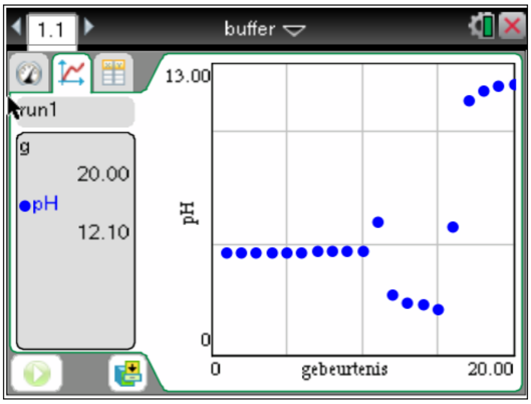
Equipment and Chemicals

- TI Nspire CX - pH-sensor - Lab Cradle - 4 beakers - tea spoon - stand with clamp	- acetic acid solution (CH_3COOH) (0,1 mol/l) - sodium acetate (CH_3COONa) - distilled water - sodium chloride (NaCl) - hydrogen chloride solution (HCl) (1mol/l) (drop bottle) - sodium hydroxide solution (NaOH) (1mol/l) (drop bottle)

Settings

Selected events

Tips and Exemplar Results



1.

	amount of drops	**0**	**5**	**10**	**15**	**20**
Solution A	pH with HCl	***4,6***	***4,6***	***4,6***	***4,6***	***4,6***
	pH with NaOH	***4,6***	***4,7***	***4,7***	***4,7***	***4,7***
Solution B	pH with HCl	***6,0***	***2,8***	***2,4***	***2,30***	***2,1***
	pH with NaOH	***5,8***	***11,4***	***11,8***	***12,0***	***12,1***

2. Which solution is the buffer solution? Explain your answer.

   Solution A. The pH of the solution remains substantially constant after the addition of small amounts of acid or base.

3. How is the buffer solution composed?

   Choose from

   A) Strong acid + conjugated base from this acid

   B) Weak acid + conjugated base from this acid

Motivate: **acetic acid = weak acid and acetate = conjugated base**

4. Consider an additional research question concerning buffer solutions.
   Consult your teacher and continue with this research.

   What is the buffer capacity?

Appendix

The Guidance Manual

The following pages are in landscape format for ease of use.

The page numbers in the contents identify pages within this last section.

German T³ Physics Authoring Team

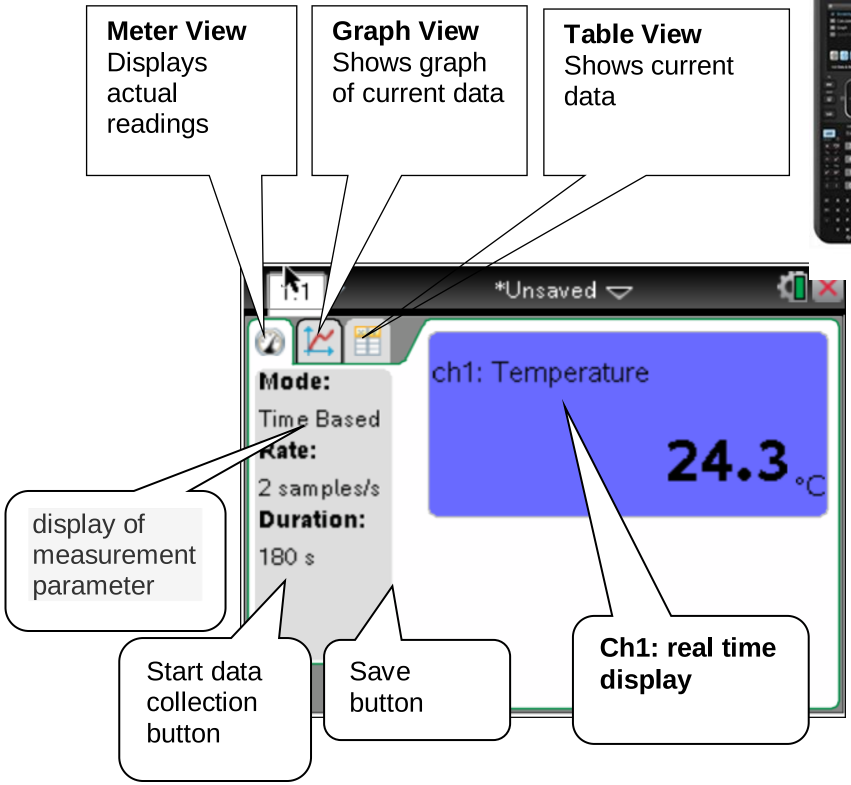
Instructions for data collection and analysis using TI-Nspire© technology (TI-OS 3.x)

Editors Dr. Karl-Heinz Keunecke and Mirco Tewes
Tranlsation Ian Galloway

Contents

Data acquisition with Dataquest

When a probe is connected the screen below will appear.



Single Channel Measurement

1. Data acquisition with TI-Nspire ™ CX
(minimum sample time 0.02s)

The CBR2 is connected directly via USB to the handheld.

2. Data acquisition with TI-Nspire™ CX (minimum sample time 0.02s)

Many probes can be connected via Easy Link

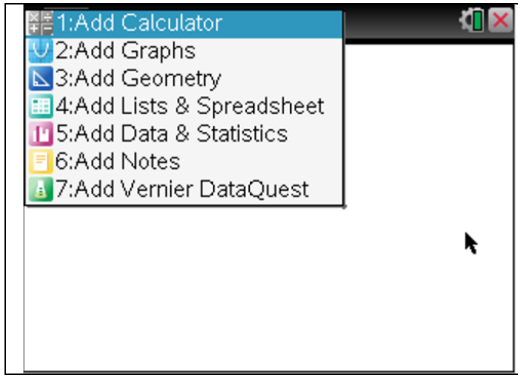
Multi-Channel Measurement

Data acquisition using Lab Cradle and TI-CX NspireTM
(Data acquisition with 12 bit accuracy and a sampling rate up to 10^5/ s)

Up to three analog and two digital probes can be connected to the cradle. The Lab Cradle recognizes all Vernier probes and automatically sets default values for each probe as ameasurement parameters. (shown in the display of measurment parameters window)

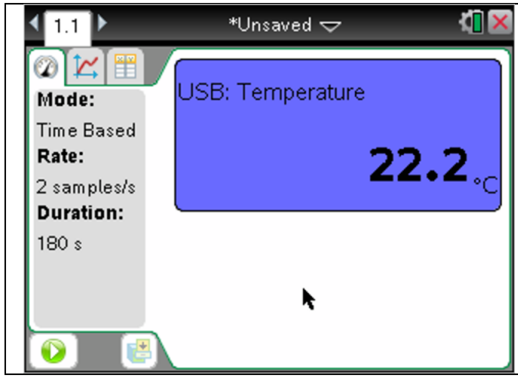
A1. Datenerfassung mit der TI-Nspire™ Technologie – erste Messung | TI-Nspire™ OS 3.x

1



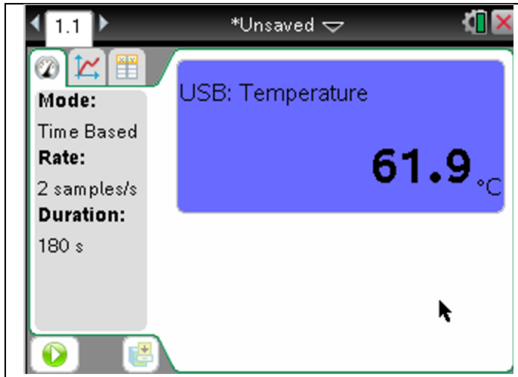
This screen is seen when a new document is begun. Select Vernier DataQuest for easy data collection using probes and the Lab Cradle

2



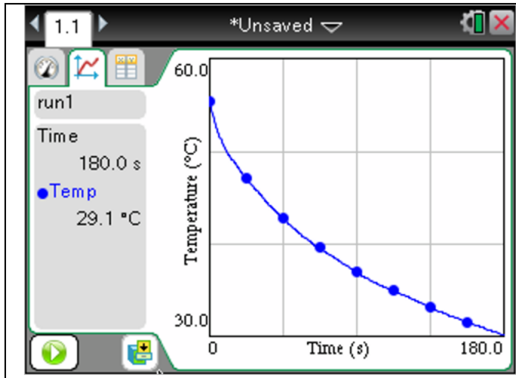
A temperature probe is plugged in and automatically detected. The current value is displayed. Preset data collection parameters, 2 samples/s for 180s are displayed in the left hand detail window.

3



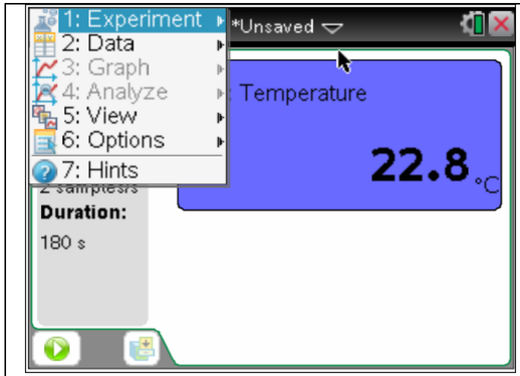
The probe is placed in hot water, pulled out, wiped dry and placed on the table. Data collection is started by clicking the start button.

4



The measured values are displayed as a function of time 180 s after the measurement is completed.
If you click on the Save button, they are stored under run1 (run1.time and run1.temperature).
Note: The points on the graph are data markers not measurements.

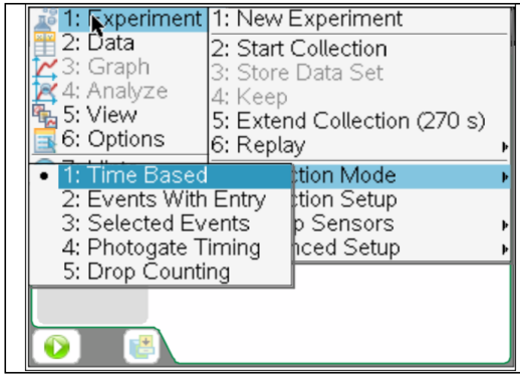
1



After starting the application DataQuest and connecting the sensor the measured value is automatically displayed. The default measurement parameters can be changed.
Press menu then

1: Experiment

2

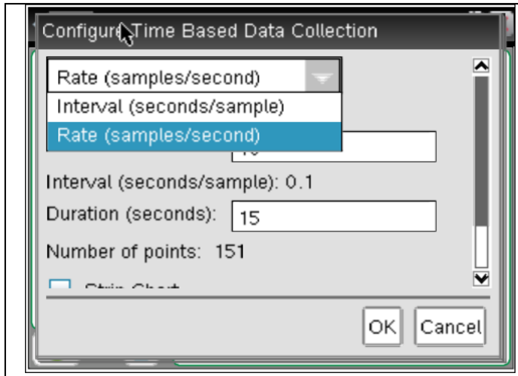


Select mode for data collection

For time-based measurements select

7: Collection mode
1: Time-based

3



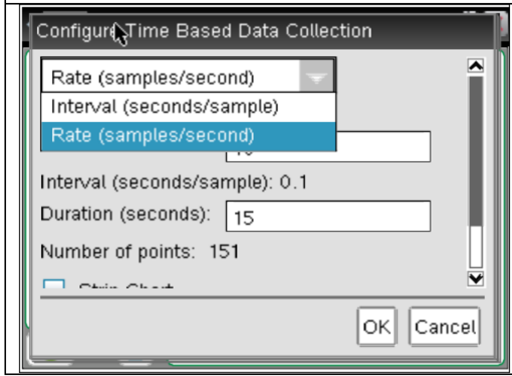
sampling Rate

There are two variants:

Rate in samples / second or

Interval in seconds / sample

4

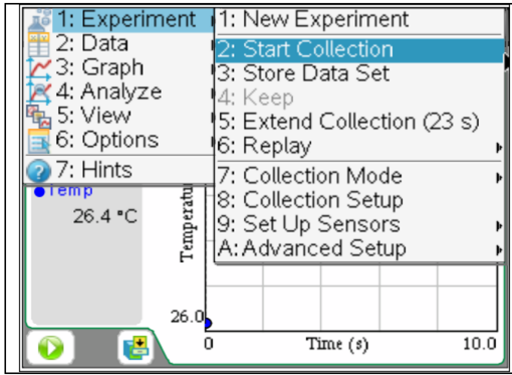


Measurement time set

After specifying the duration in seconds the number of points is determined automatically.

The settings are finished with OK

5

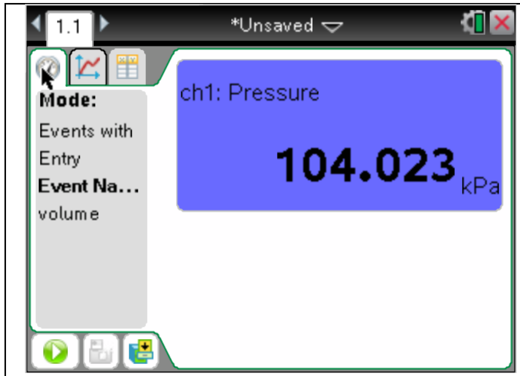


Start the data acquisition

by pressing menu then 1:Experiment, 2:Start_Collection

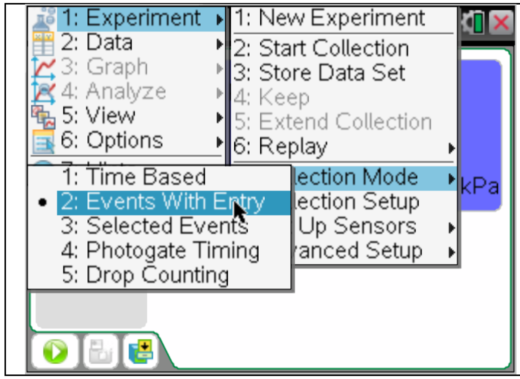
or by clicking on the icon

1



A pressure probe has been connected. We want to collect individual measurements entering a second value(volume) by hand.

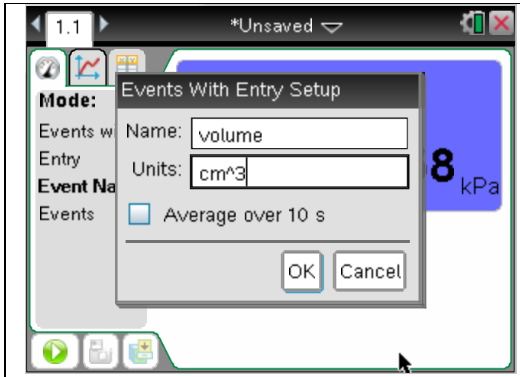
2



Events with Entry:
(Single measure, with additional input)

menu then
1: Experiment,
7: Collection mode
2: Events with Entry

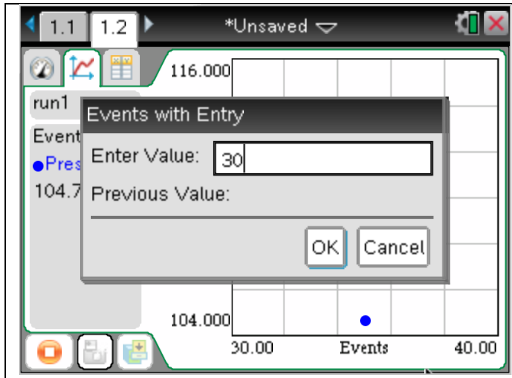
3



Specifying the input values:

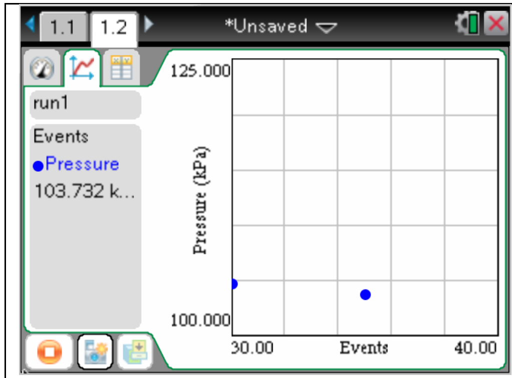
The name and unit of the entered value(volume, cm ^ 3) is entered and completed with OK.

4



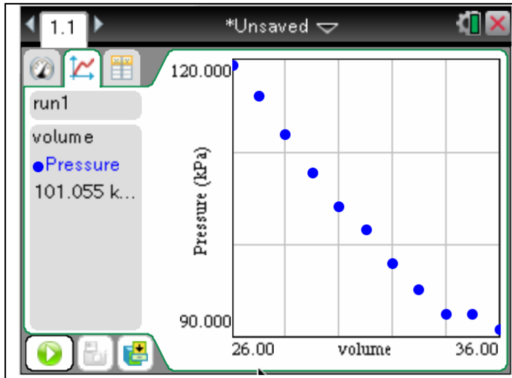
the first measurement is made when the start button is pressed. The value of the second variable (volume) is entered after pressing . Pressing OK then graphs the pair.

5



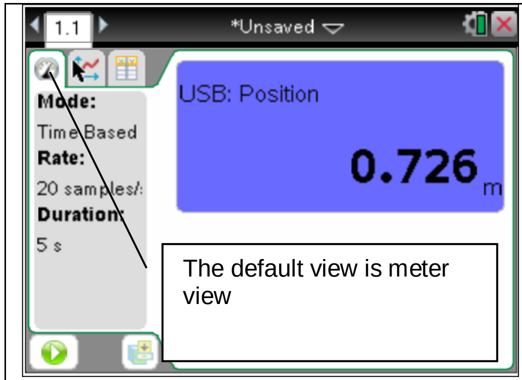
The graphed point is shown at the left. The second point simply shows the current value of the probe. Click again and the window in **4** appears with the previous value of the second variable entered

6



Collect all the measurements in this way. The window scales automatically. Press the start button to stop data collection.
Press the save button to save the collection.

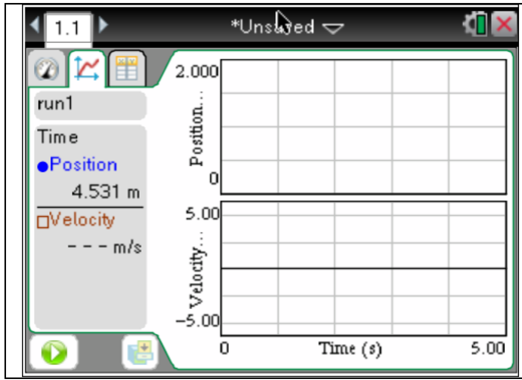
1



A sensor connects automatically to DataQuest.

The current value is shown and default data collection parameters are displayed.

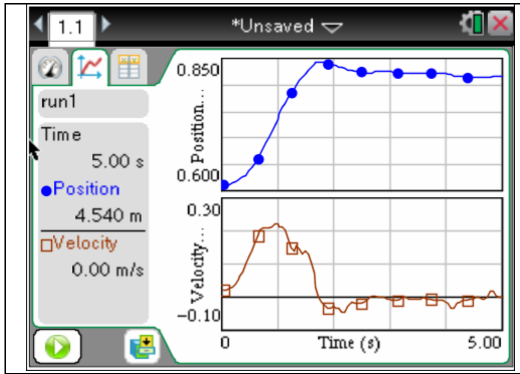
2



Measurements can be displayed as a graph or table.

menu then
5: View
2: Graph or
3: Table

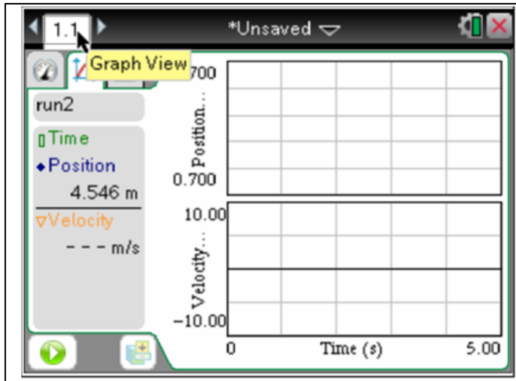
3



Start measurements:

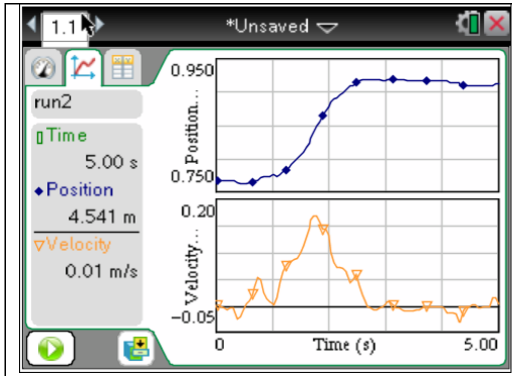
menu then
1: Experiment,
2: Start Collection
or
Click on the start button. The measured values are collected as run1.

4



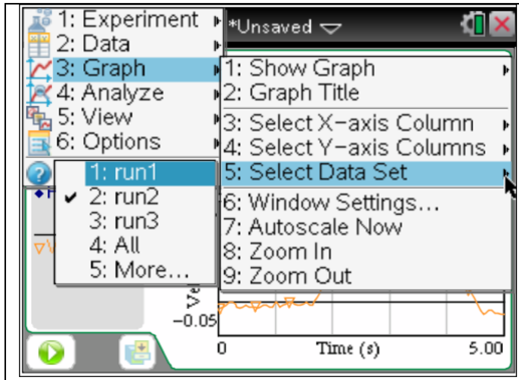
Saving measurements. After clicking on the save button the data set is stored as run1. If the start button is pressed the previous data set is overwritten.

5



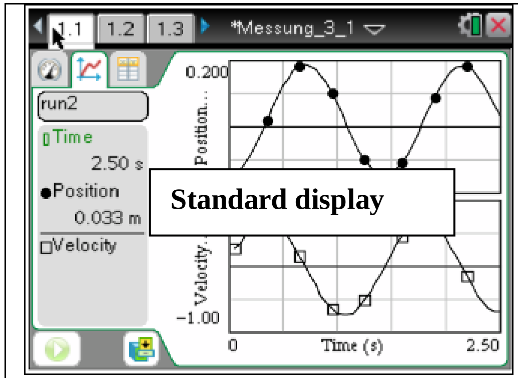
Pressing start displays the new data set as run2

6



Show a particular run
Menu then
3: Graph
5: Select Data Set
In the menu that opens, all pre-existing measurements (runs) are shown.

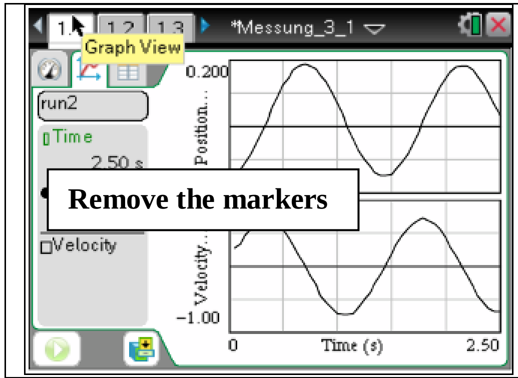
1



The motion of a pendulum has been recorded with an ultrasonic sensor.

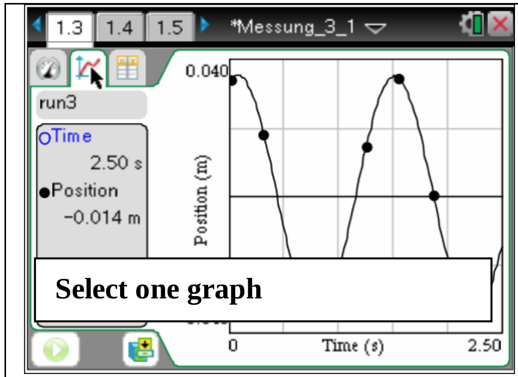
In the standard display the different variables are identified with different markers as shown in the parameter (detail) window at left.

2



Remove the markers:
menu then
6: Options
1: Point Options
In the next dialogue box replace Regional with None and confirm with OK.

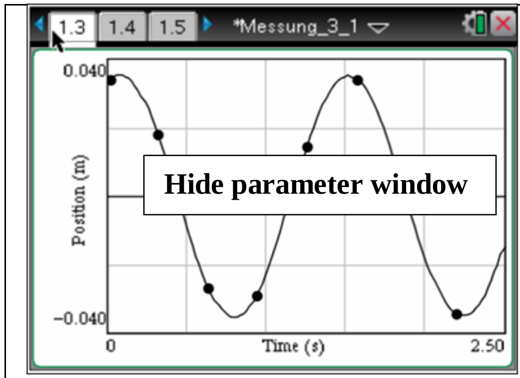
3



Select one graph

menu then
3: Graph
1: show graph
In the submenu select the desired graph.

4

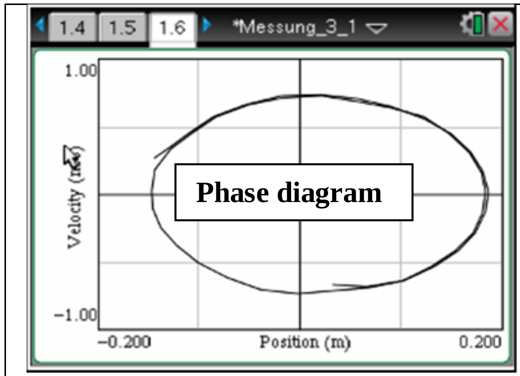


Hide the measurement parameters (detail) window

menu then
6: Options
6: Hide Details

Repeat to show it again

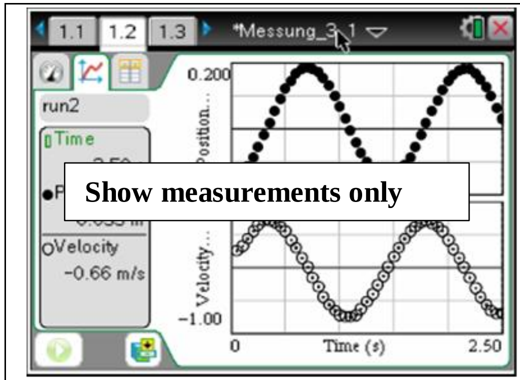
5



Phase diagram:

Menu then
3: Graph,
3: Select X-Axis Column
2: Position,
4: Select Y Axis Column
3: Velocity

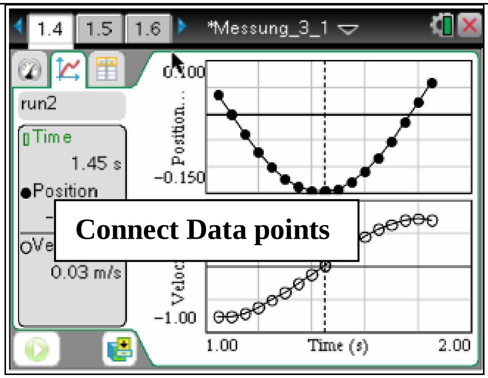
6



Show measurements only

Menu then
6: Options
1: Point Options
Then select: All
Untick Connect Data Points

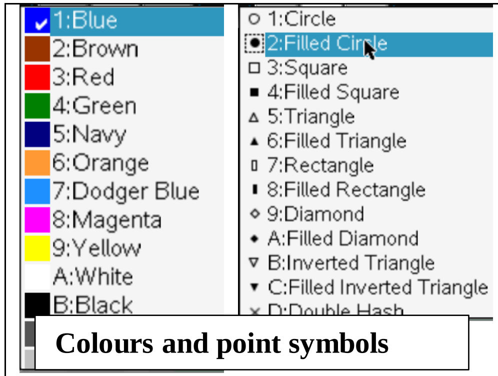
7



Connect points:

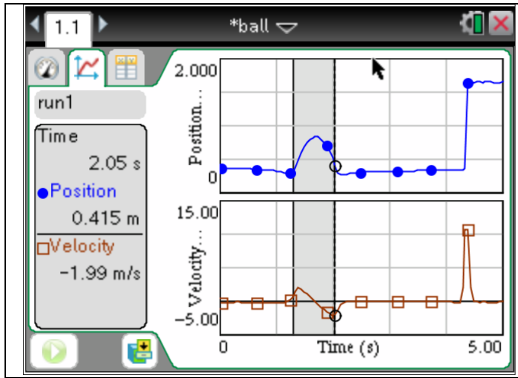
Menu then
6: Options
1: Point Options
Tick Connect Data Points

8



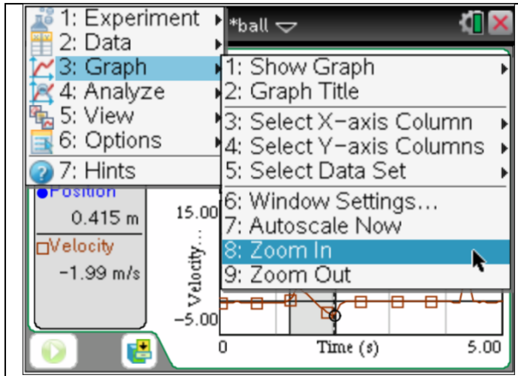
Choose colors and symbols:
The cursor should be placed in the detail window.
press enter then
2: Colour
e.g. run1. position
and also the point markers
3: Point marker (point symbol

1



The area of interest is selected by moving the cursor to the lower limit then clicking and holding for a few seconds the cursor button in the centre of the nav-pad Drag to the upper limit and click again.

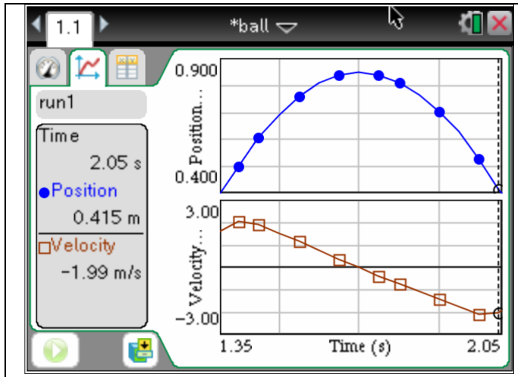
2



Enlarging the selected area.

Menu then
3: Graph
8: Zoom in (enlarge)

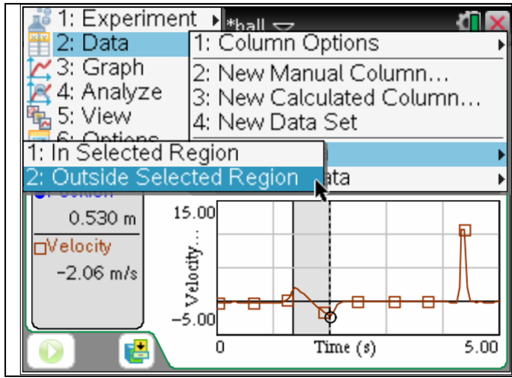
3



If the wrong selection is made use autoscale to return to the full data set.

Menu then
3: Graph
7: Autoscale Now

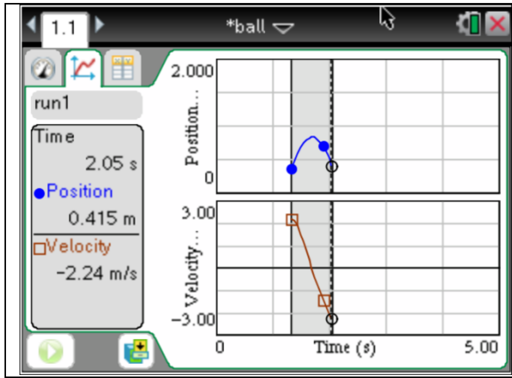
4



All the data are available although not displayed. If the non visible data are not wanted for further analysis then they should be removed using strike data.

Menu, 2 then 5, followed by strike data in or otuside selected region.

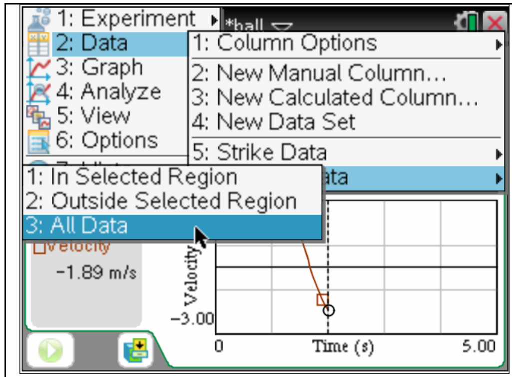
5



Menu then

2: Data
5: Strike Data,
2: Outside selected region

6

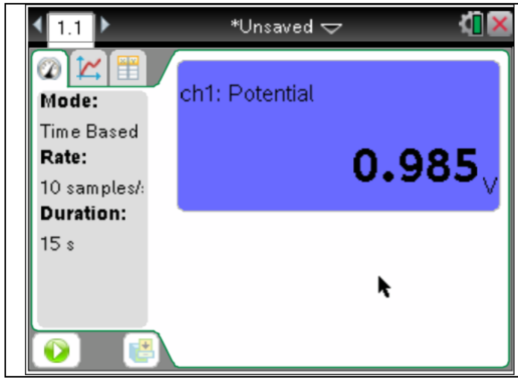


To restore the data

Menu then

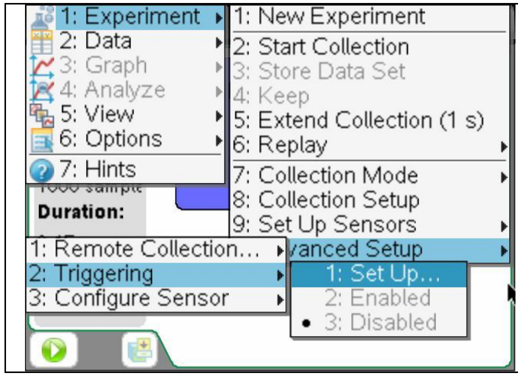
2: Data
6: Restore Data
3: All data

1



The Lab Cradle is connected to the handheld or PC. At least one sensor must be connected.
First adjust rate and measurement time.
(see instruction A2)
.

2

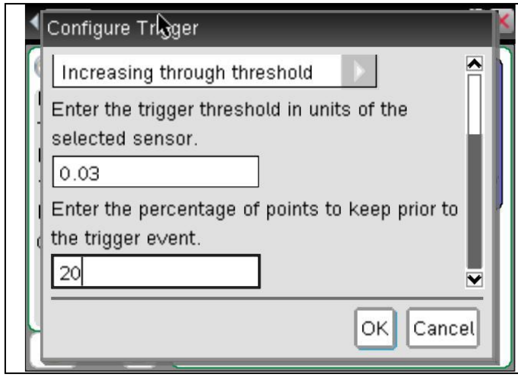


To select triggering:

Menu then

1: Experiment,
A: Advanced setup
2: Triggering
1: Set Up

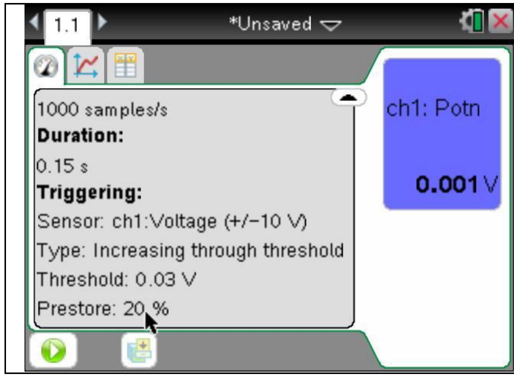
3



Selections are:

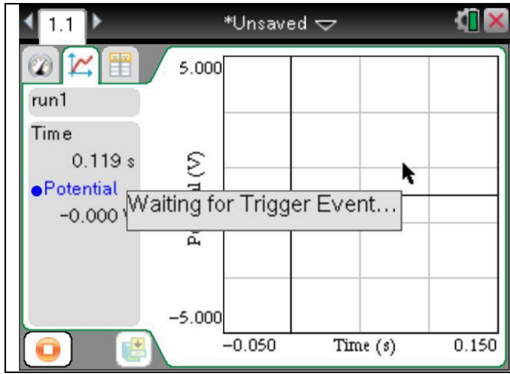
Sensor for triggering,
Type of trigger: increasing or decreasing through the threshold.
Trigger Threshold.
Points to be kept pre-trigger.

4



After pressing OK the detail window showing the parameters selected will be displayed.
Now, the start button is pressed.
The display changes to the graph mode.

5

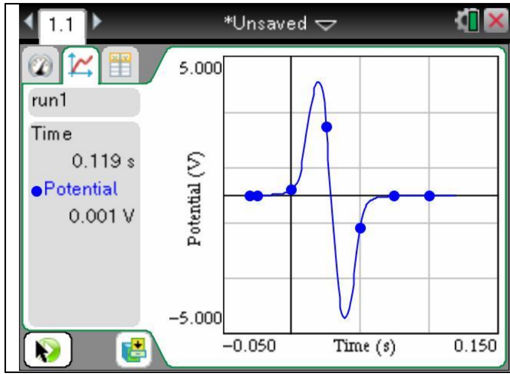


On the screen you will see

Waiting for the trigger event ...

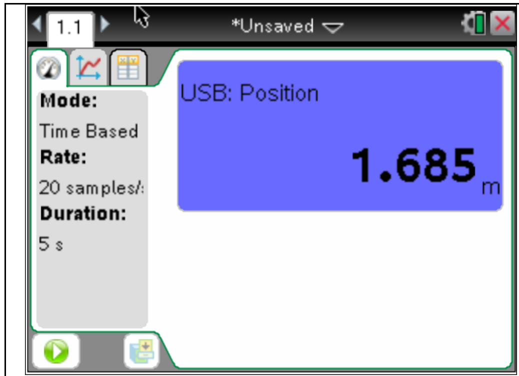
Measurements start when the trigger threshold is reached from above or below.

6



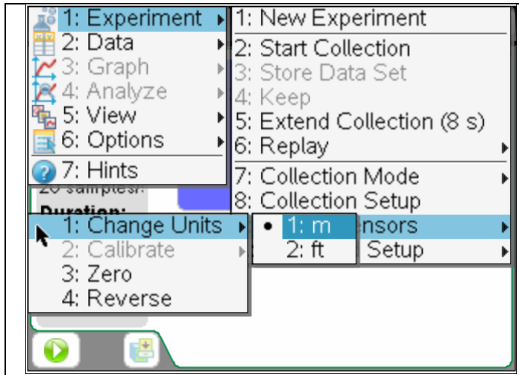
After triggering the data, including the pre-trigger data are displayed graphically.
The origin is set at the trigger point.

1



In DataQuest applications can be varied depending on the sensor settings.
If several sensors are connected you will be asked to apply changes to each.

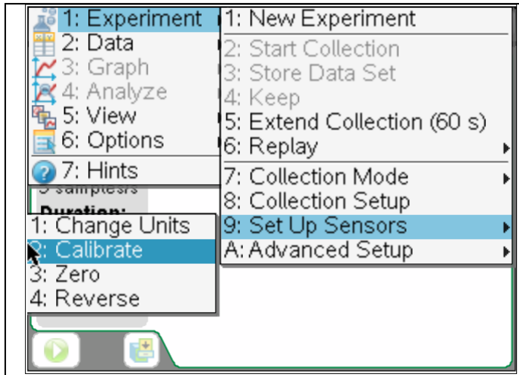
2



Change units:

Menu then
1: Experiment,
9: Set Up Sensors
1: Change Units

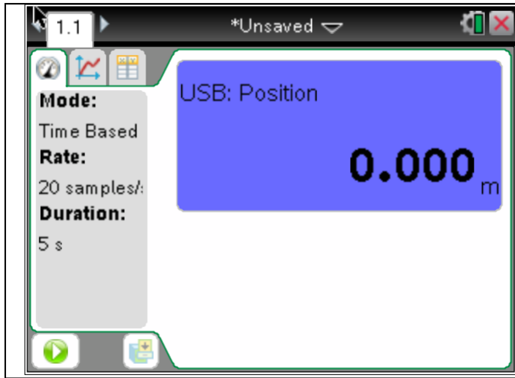
3



Sensor calibration:

Menu then
1: Experiment,
9: Set Up Sensors
2: Calibrate

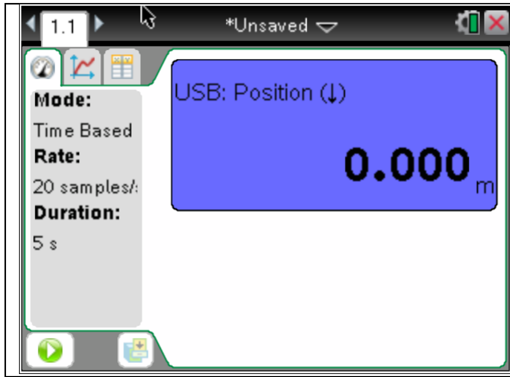
4



Zeroing

Menu then:
1: Experiment,
9: Set Up Sensors
3: Zero
Zero or close to zero will be shown. If not, repeat the adjustment.

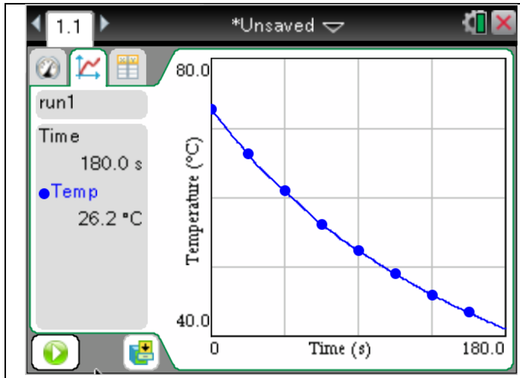
5



Sign reversal:

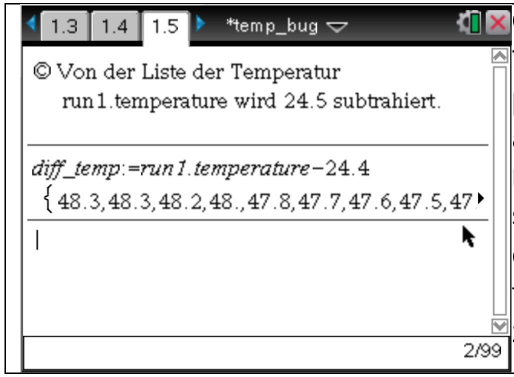
menu then
1: Experiment,
9: Set Up Sensors
4: Reverse

1



A temperature probe cools in air and the data are recorded. The data are lists stored in individual files beginning with run. It is often useful to process the data in other representations.

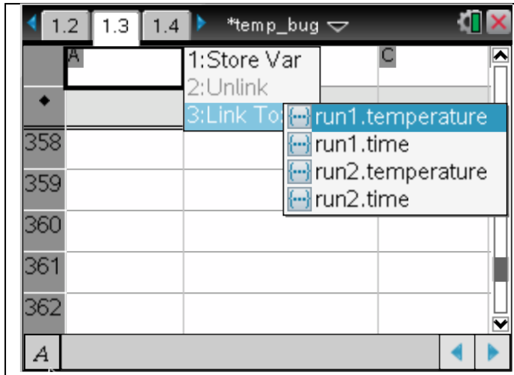
2



Calculator:

The temperature of the probe is approaching the ambient temperature. 24.4. **run1.temperature-24.4** subtracts 24.4 from each element and ensures that the readings approach zero.

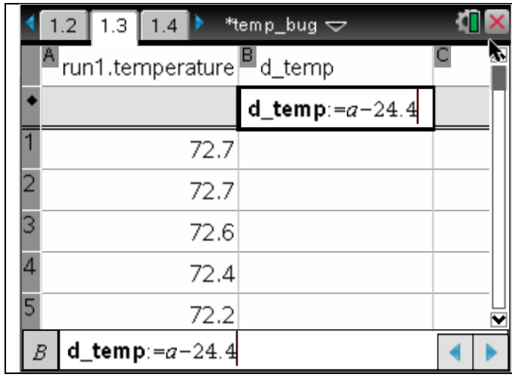
3



Lists & Spreadsheet:

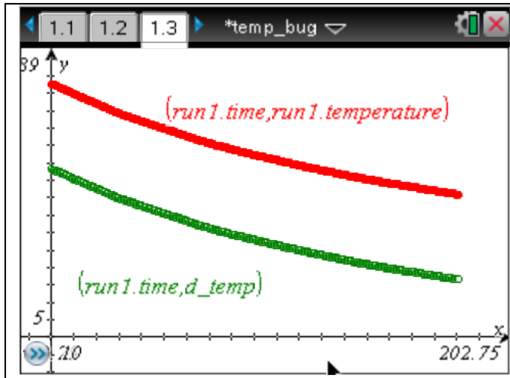
We want to put the temperature data in the spreadsheet. Move into the name cell for column and click the **Var** button. Then **Link to** and choose from the variables given.

4



We want to subtract 24.4 from each temperature in column A or **a**.. Insert name, d_temp into column B. Then move to the calculation cell below and click once. The column name appears. Insert **a-24.4** and press enter.

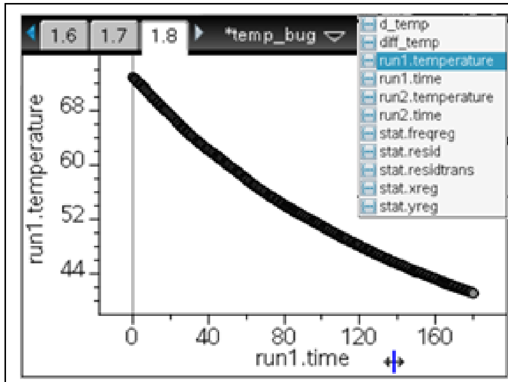
5



Graphs:

Open a graph page, then menu, graph type and scatter plot. Then press **Var** and select the variables for the x and y axes. Shown here is s1 for the original data and s2 for the corrected data.

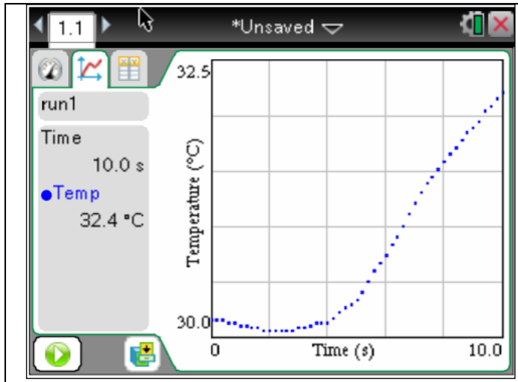
6



Data & Statistics:

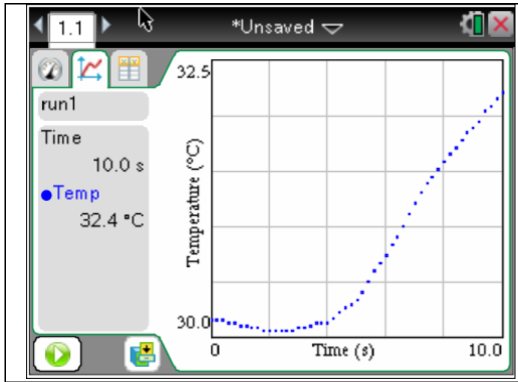
Moving the cursor over the areas to the left of the y-axis and under the x-axis reveals a box, click in it. The variables available are shown, simply select what you want.

1



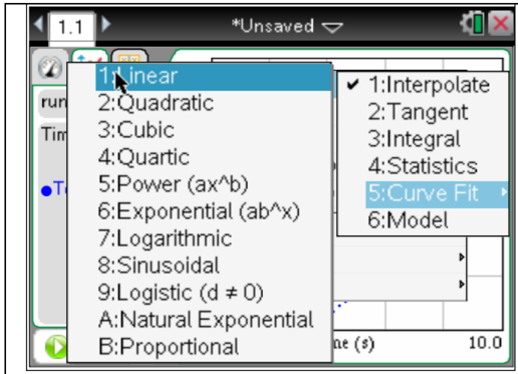
Part of a data set is to be described by a function using automatic curve fitting. (See A11 as an alternative.)

2



The function will be fitted after the required part of the data is selected. Select the upper and lower limits of the data set.
(see A6)

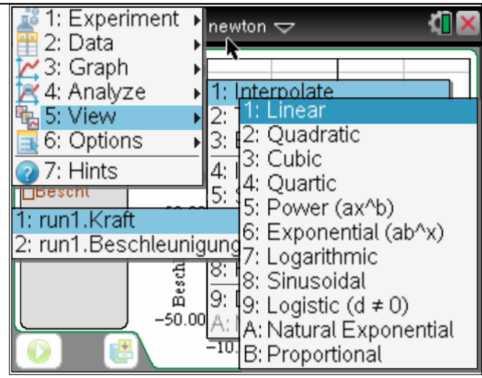
3



Here a portion of the graph is described by a linear function:

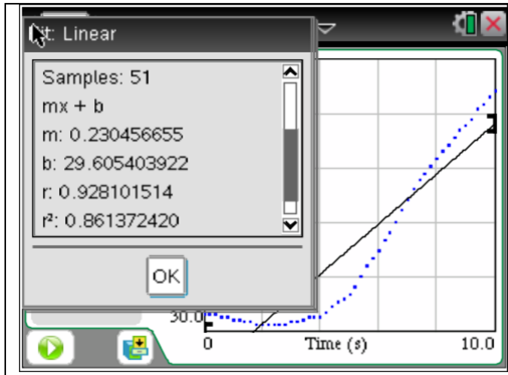
menu then
4: Analyze
6: Curve Fit
1: Linear

4



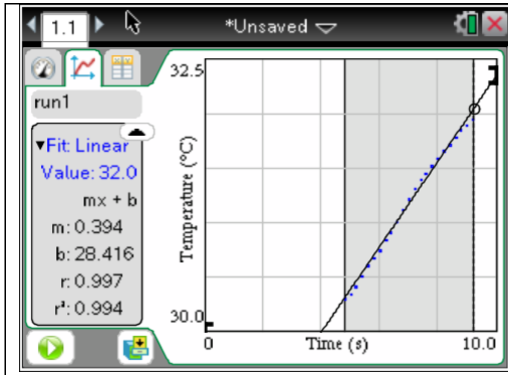
Note:
where measurements are made with multiple probes, the particular channel or variable must be specified before curve fitting.

5



The curve is fitted to all the data selected. If it looks as if the curve (a linear function here) does not fit well, click and hold the square brackets to move them to new limits. The curve will change automatically.

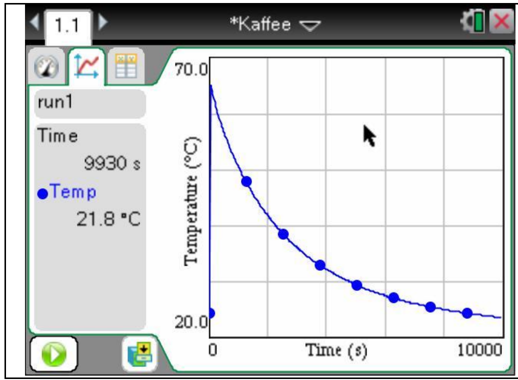
6



The fitted function can be removed.

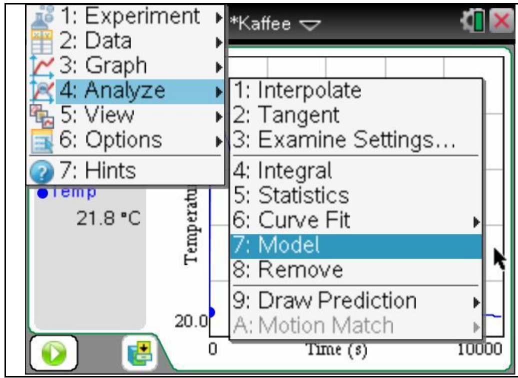
menu then
4: Analyze
8: Remove
.

1



The temperature-time data for a drink cooling to the ambient temperature are to be modeled. In the Curve Fit menu there is no suitable function.

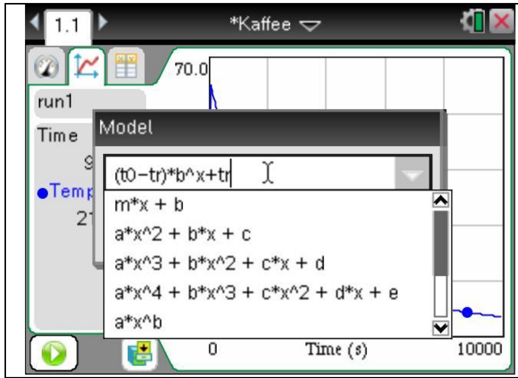
2



The equation and its related parameters must be set..

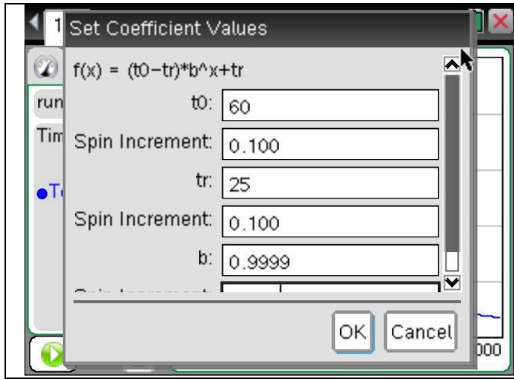
Menu then
4: Analyze
7: Model

3



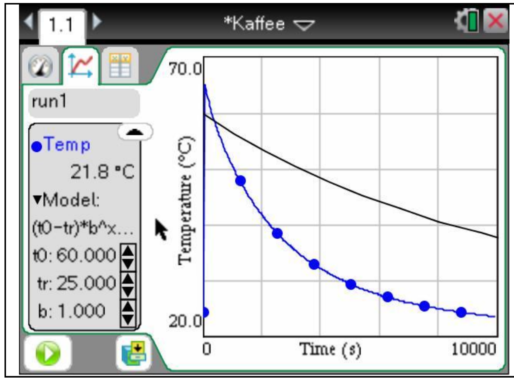
DataQuest ™ offers several functions. Entering your own functions is possible (here (tr-t0) * b ^ x + tr).
The variables of the terms in x are detected as a parameters..

4



After OK, the starting value and the increment (spin increment) are selected for modeling the relevant parameters.
OK completes the input

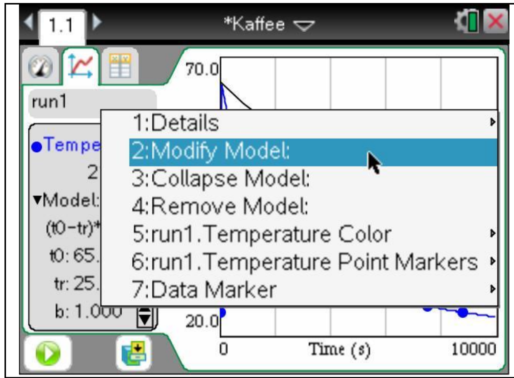
5



Each parameter can then be adjusted by pressing the up or down arrow for each one.: .

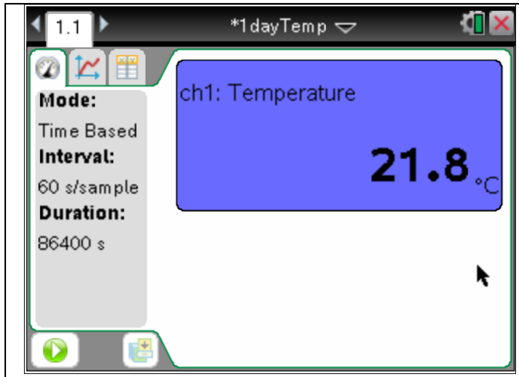
Fine adjustment for start value and step size of the parameters is made by right clicking in the detail window. Ctrl then menu.

6



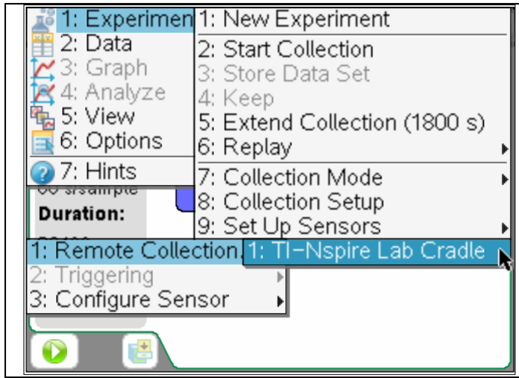
right click in detail window then
2: Modify Model
as in step 4
to show parameters for the current function
right click then
1: Details,
4: Model

1



Measurements can be collected by the Lab Cradle without being connected to handheld or computer
This only requires setting up the parameters when connected.
(A2).

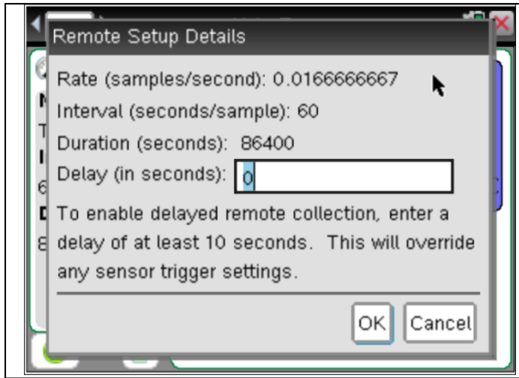
2



Menu then

1: Experiment,
A: Advanced setup
1: Remote Collection
1: TI-Nspire Lab Cradle

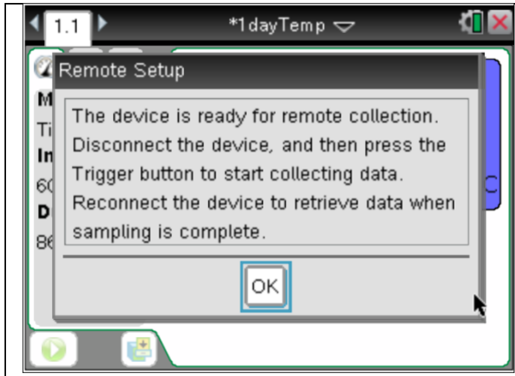
3



A delay time) to start measurements is entered. Pressing OK begins the countdown.

Note: this mode is only enabled for delays of at least 10 s.

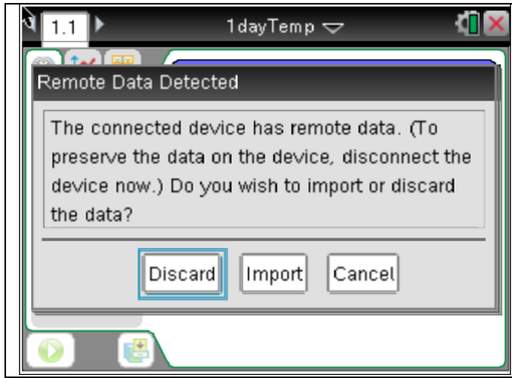
4



The Lab Cradle can now be disconnected from the computer or handheld..

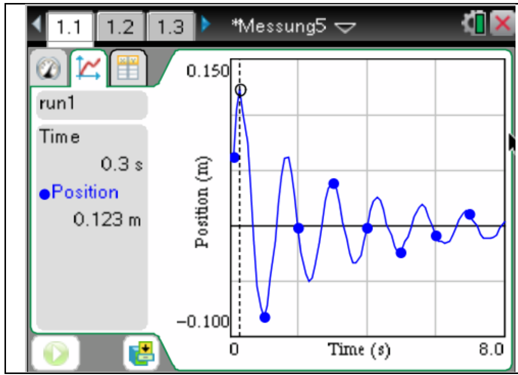
Measurements are started by pressing the green trigger button on the Lab Cradle or after the preset delay time.

5



When the measuring period is over, the Lab Cradle is reconnected. Press the Import button and the data are transmitted and displayed graphically

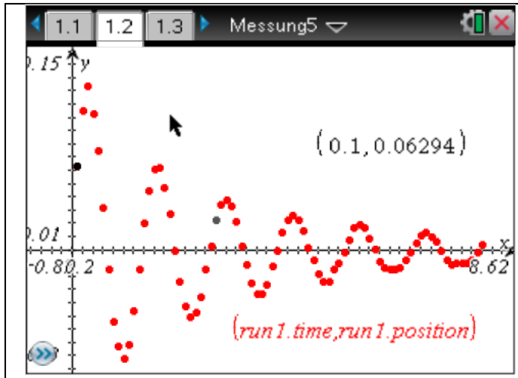
1



For further investigation of graphs the coordinates of individual data points can be moved into a table.

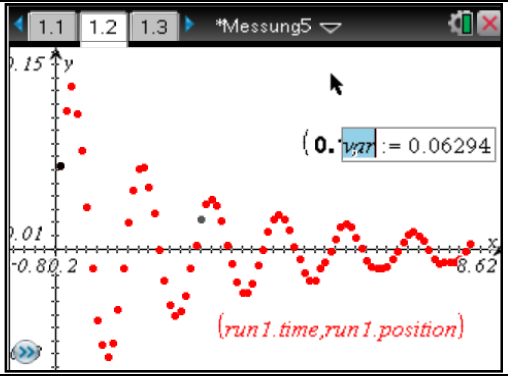
The measured data are opened in a graph application

2



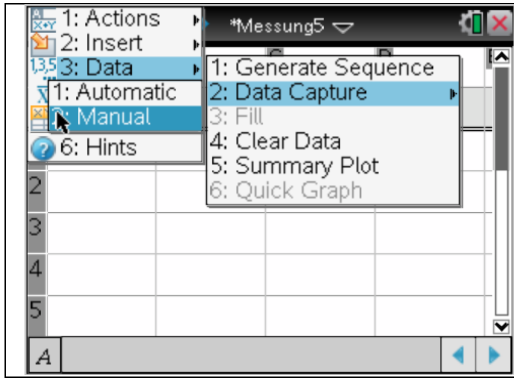
In the Graphs application: Menu then
3: Graph type
4: Scatter plot
To show coordinates of a measurement point: menu
7: Points & Lines
2. Point On
With one click a data point is highlighted with a second the coordinates are displayed.

3



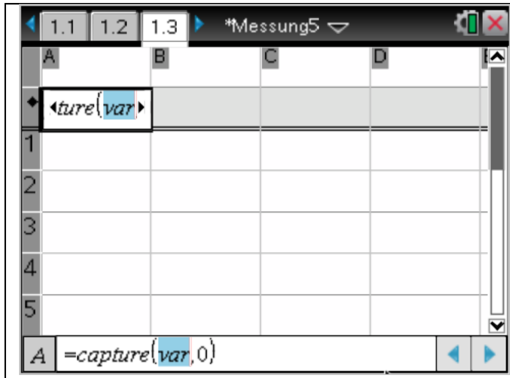
The first coordinate is highlighted, then press CTRL then var. Enter the variable name, zeit (time). Similarly for the second co-ordinate enter a name, here mwert (mvalue)

4



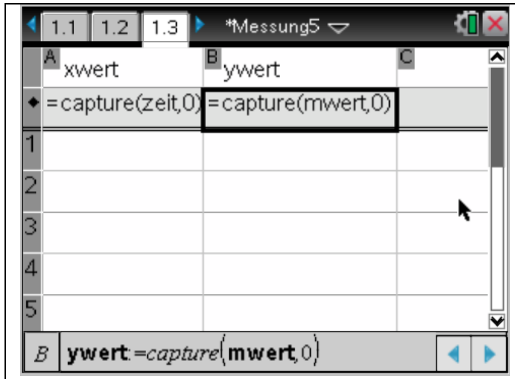
Lists & Spreadsheet:
To transfer the selected coordinates to a table:
menu then
3: Data
2: Data Capture
2: Manual
(With 1: Automatic, all the points transferred)

5



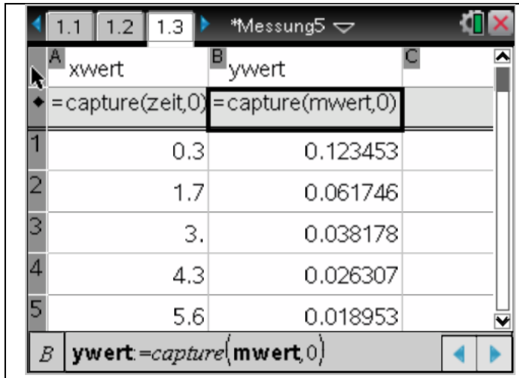
The formula cell is clicked, then press the var button and then the name of the first coordinate, here zeit (time). This is repeated in the next column for the second variable

6



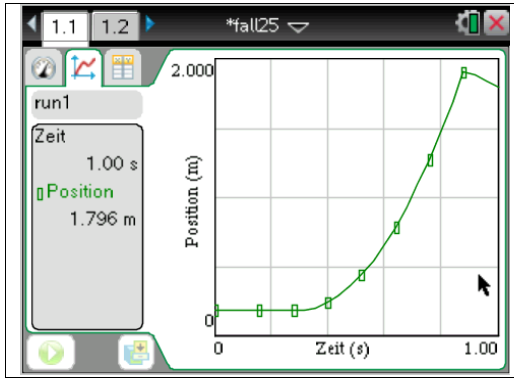
The table is now prepared. For a graphical representation the columns have to be named, here xwert and ywert (xvalue and yvalue)

7



Now you go back to Graphs and grab the point (zeit, mwert). Move it over the first point to be transferred into the table. Transfer it with CTRL followed by dot (capture button). Repeat for the rest.

1

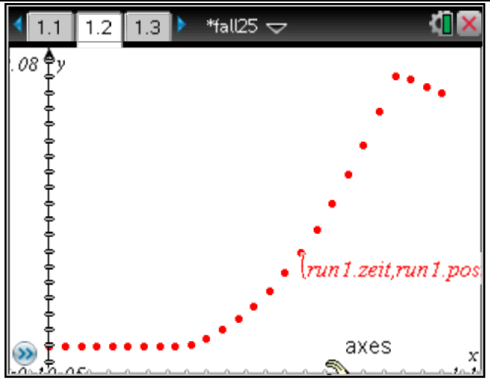


DataQuest:

For this graph the average speed of a falling ball during a specified time interval using the position during the fall.

.

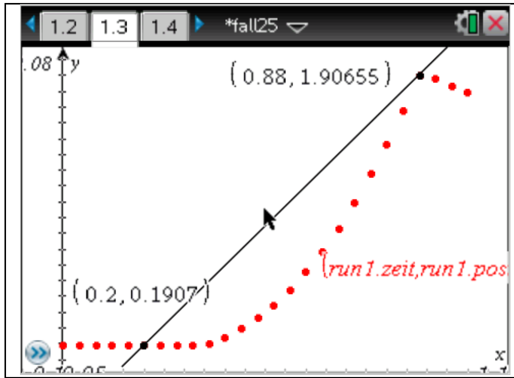
2



Open Graphs:

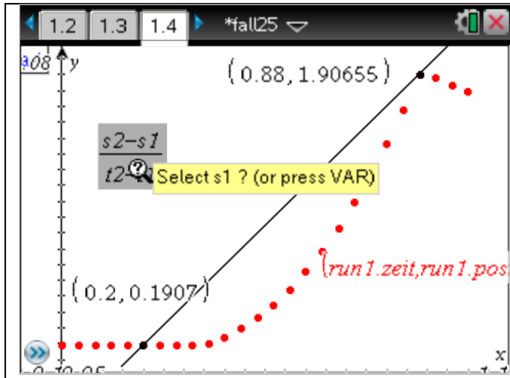
To identify two points
menu then
3: Graph Type
4: Scatter plot
Run1.zeit and run1.position entered for x and y.
(use var: list of variables)
menu ,
4: Window (window)
9: Zoom Data

3



Determining the points:
Menu then
7: Points & Lines
2: On Point
Then select the two points with the cursor.
To draw connecting line:
menu then
7: Points & Lines
4: Line: draw a straight line through the points

4



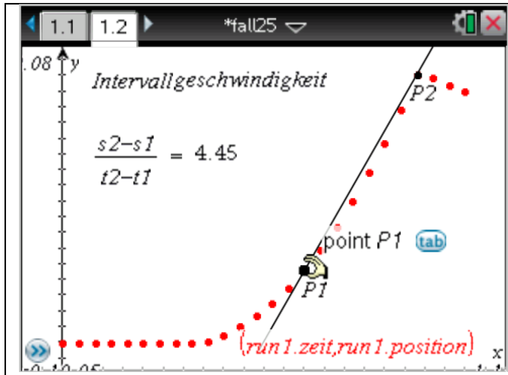
To calculate Velocity in the interval:
menu then
1: Actions
2: Text

Click in the opened text box and enter (s2-s1) / (t2-t1).

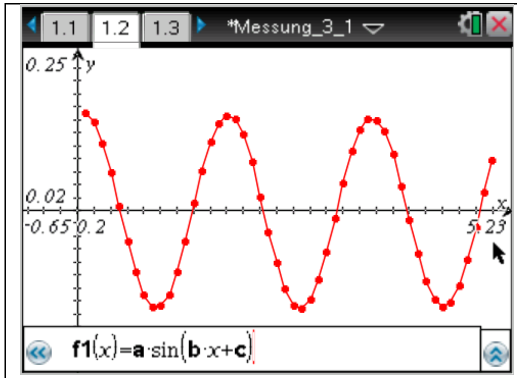
menu then
1: Actions
2: Calculate

Move the cursor over the text box and select s1, t1, t2 and s2 from the coordinates of the points with the cursor. The result is placed to he right of the text box

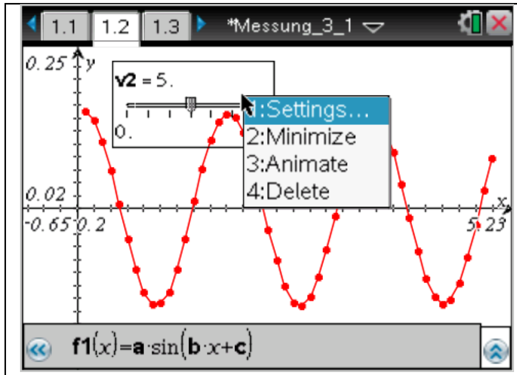
5



To increase the clarity, the coordinates can be hidden and reference made to the points P1 and P2.
{Using the gripping hand points can now be moved on the graph.
The current gradient of the interval is automatically updated.
It can be incorporated into a table (A 13).

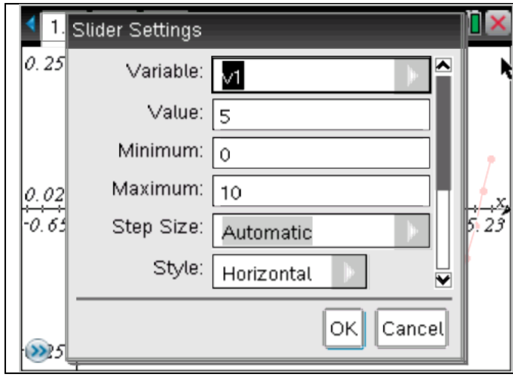


The measured data are displayed in Graphs with Menu then,
3: Graph Type
4: Scatter plot
x: run1.time
y: run1.position.
menu then
4: Window (window)
9: Data zoom (zoom stat)
Then the modeling term is entered in the input line (function window). The graph can be drawn only if a, b, c values have been assigned
.

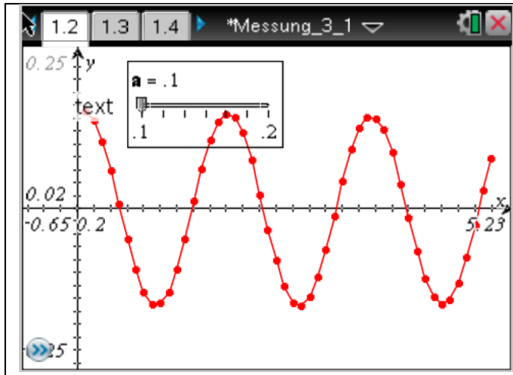


The parameters a, b, c in f1 (x) are set by sliders. In this way the model can be adjusted to fit the data.

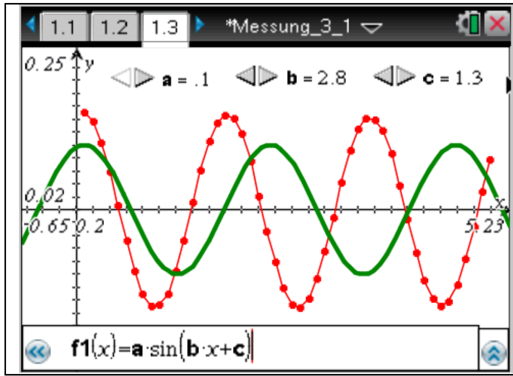
Menu then
1: Actions (actions)
A: Insert Slider
right click (ctrl then menu)
1: Settings
The settings menu is shown.
.



the name of the parameter and its range is indicated (a, initial value: 0.1, min: 0.1 and max: 0.2). This should possibly be determined well in advance so that the data curve and function of the graph do not differ too much
.

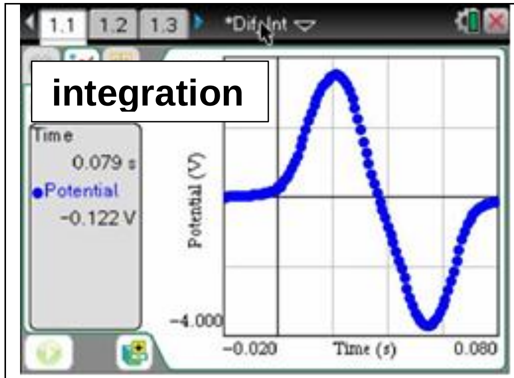


The slider appears.
For the parameters b and c, new sliders are made.
Wne several sliders are needed, they can be reduced by right click then
1: Settings
2: Minimize



After all the parameters are attached to sliders, the function f1 (x) is represented graphically.
Now the slides are set so that the difference between the data and the modeling function is minimized.

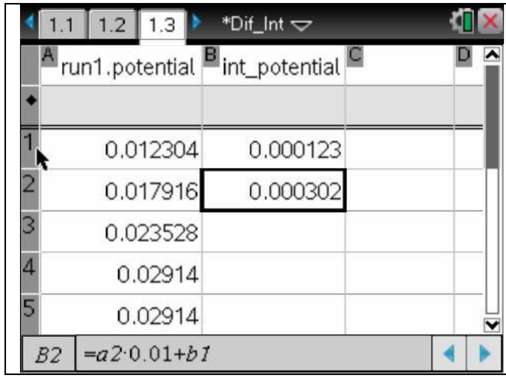
1



For graph of induced voltage u (t_i) can be approximately integrated by summing over i the rectangular areas

$$s(t_i) = \sum_{k=0}^{i} u(t_k) \cdot \Delta t$$

2



***In List & Spreadsheet*:**

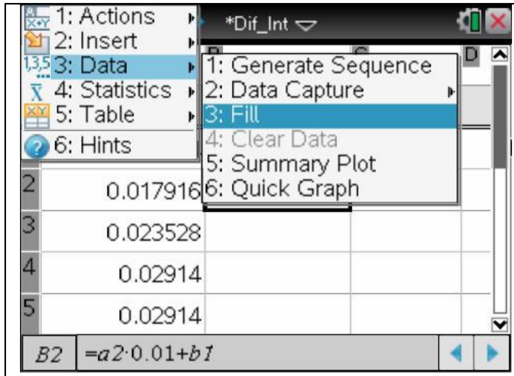
The data "run1.potential" are entered in column A. In B the summation is calculated (Δt = 0.01s):

B1 | = a1 ·Δ.t

B2 | = b1 +a2 ·Δ.t

B101 | = b100 + a101 ·Δ.t

3



only the formulas for the cells B1 and B2 need be entered. The remaining calculations can be made by the computer:

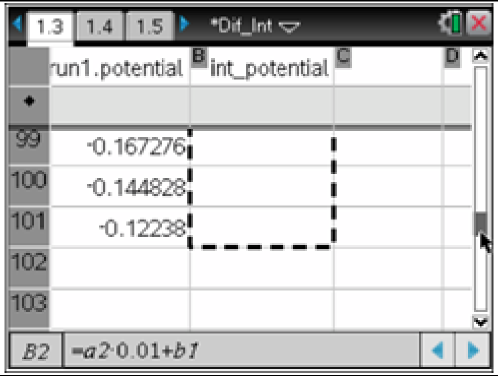
menu then

3: Data

3: Fill

click in cell B2, and then…

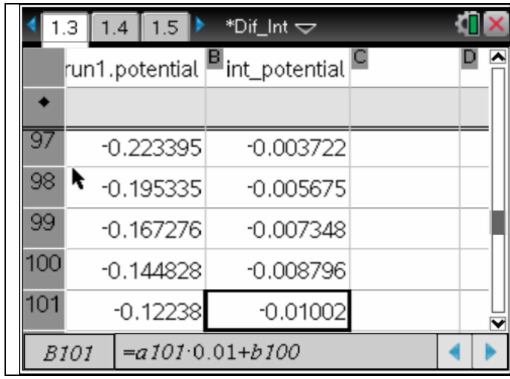
4



… use the nav pad to click down to the end of A and press enter ...

Or hold down the CTRL key and drag the cursor down to row 101.

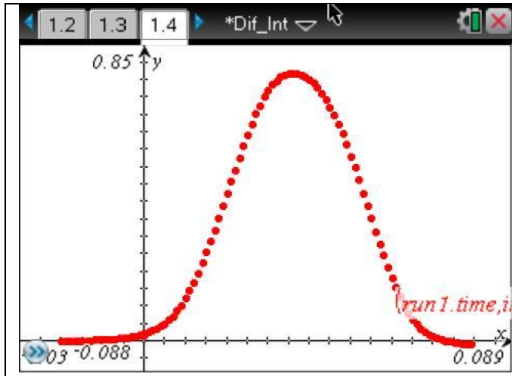
5



the summation is calculated in the last line.

For a graphical representation of column B, a variable name is entered in the top row column B (int_potential).

6



In Graphs:

menu then

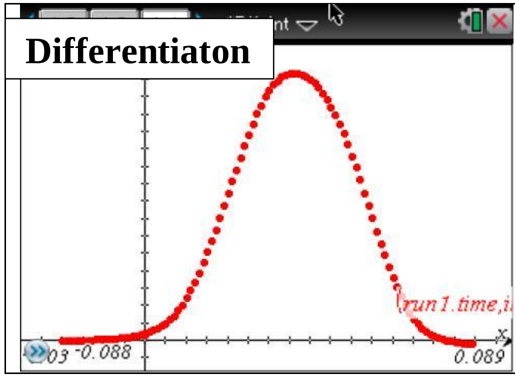
3: Graph Type

4: Scatter plot

Press button var for the variable list, and for x enter run1.time and for y enter int_potential

Differentiaton

1

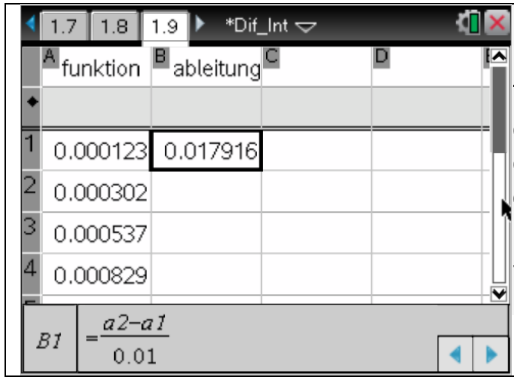


To approximate the derivative function of this graph, rates of change are calculated in the measurement interval Δt. These are the differential quotients

$$\frac{f(x_{i+1})-f(x_i)}{\Delta t}$$

Determined for each interval.

2

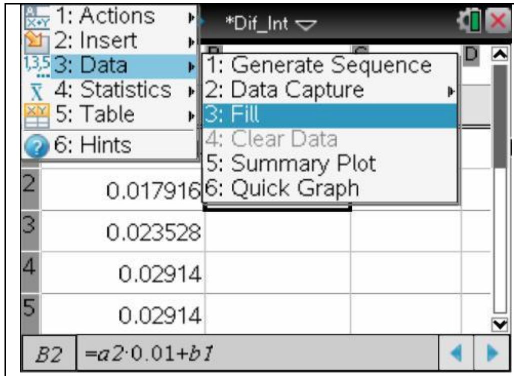


In List & Spreadsheet:

The data (int_potential) are entered in column A. In column B the differential is calculated (Δt = 0.01s):
B1 | = (a2-a1) / ΔT

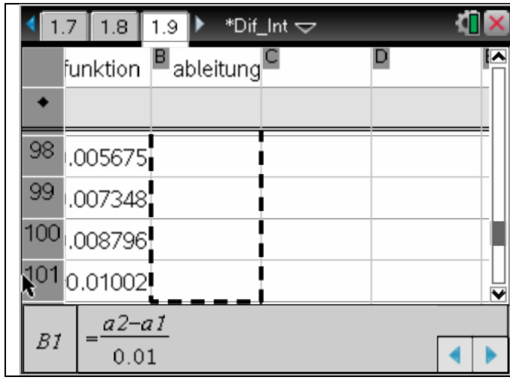
B101 | = (a101-a100) / ΔT

3



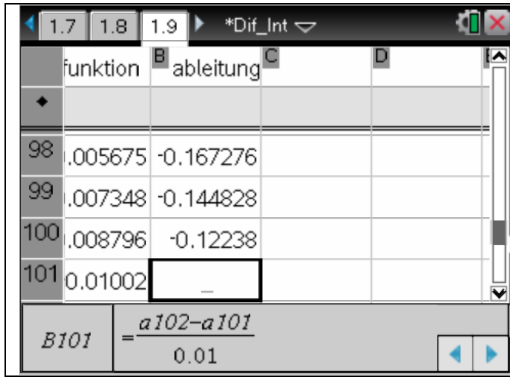
Only the formula for cell B1 has been entered. The remaining calculations can then be performed by the computer:
Click on cell B1
menu then
3: Data
3: Fill (Fill)
Click in B1 and ...

4



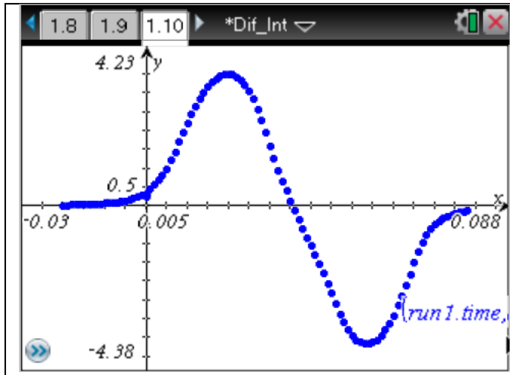
… either click down with the nav pad or hold down the CTRL key and drag the cursor down to row 101.

5



Then the difference quotients are calculated down to the last line. For a graphical representation of column B a variable name entered in the top row, here ableitung (differential).

6



In Graphs: menu then
3: Graph Type)
4: Scatter plot

In the function entry line press the Var button and enter run1.time for x and int_potential for y.