Selected Papers on
Hands-on Science

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This book is composed by a selection of papers published in the proceedings books of the first four editions of the annual International Conferences on Hands-on Science. The most relevant papers therein were selected and reviewed by the conferences' program committees. They are exclusive responsibility of the authors and are essentially published herein as submitted, in interest of timely dissemination.

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Foreword

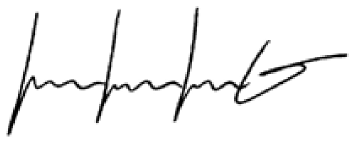
The International Association "Hands-on Science Network" was established in the sequence of the Comenius 3 project "Hands-on Science" partially financed by the European Commission in the frames of the Socrates Program, from October 2003, coordinated by the University of Minho and involving over 200 institutional members from all over the EU. Now the Hands-on Science Network is a non-profit organization legally registered in Portugal. With a broad open understanding of the meaning and importance of Science to the development of our societies, each individual and of the humankind, the main goal of the Network is the development and improvement of science education and scientific literacy by an extended use of investigative hands-on experiments based learning of Science and its applications.

Among the many activities we organised, our annual conferences (and workshops) were especially successful. Apart from allowing and promoting an open broad and friendly exchange of experiences on good practices and all aspects and perspectives on Science Education, among the one thousand participants, over 500 very interesting and meaningful works were published. It represents a set of work material of the highest interest to the Science and Science Education community. Among those a good number of papers are of especially high quality and relevance.

The papers herein were selected and reviewed by the conferences' program committees and the board of the Hands-on Science Network. The papers are organised chronologically *per* conference allowing also, in some way, to access the evolution in these matters on last 5 years. My first paper will give the readers an idea of the goals, planning methods and strategies of the Hands-on Science project.

We think this book will be an invaluable tool to all readers and are looking forwards to welcome the active involvement of all in our Hands-on Science Network

…towards a better Science Education…



Manuel Filipe Pereira da Cunha Martins Costa
(Chair)

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The Hands-on Science Network (*www.hsci.info*) exists to promote the development of science education and scientific literacy. It encourages a generalized use of innovative active hands-on experimental investigative approaches to science and technology education. In raising the profile and attractiveness of Science in Education, we aim also to increase the desirability of a career in Science for all.

Experiential Phenomena as Experimental Activities in Science Laboratory based on the Human Body – Four Cases

Sotiropoulos D, Tsagaroulaki K, Svarnas T, Metaxa A and Kalkanis G

Introduction

The main scope of this paper is to elevate an idea of hands on science experimental procedure: the use of the human body as a means for experiential interdisciplinary activities. These activities can easily be placed under the general umbrella of Science Technology Society (STS) teaching. STS education addresses learning of science concepts in the context of real life experiences and with application to real life problems and issues (Lutz, 1996) [1]. The human body and its functions are easy to understand and affects and interests every human being that is the main reason it can be a good vehicle of promoting students to be involved with measurements in a laboratory procedure. Thus we develop four experimental activities: a) counting heart and human respiration rate using a microphone attached to a computer; b) calculating human response time when a ruler falls and the acceleration of a human punch, using a range sensor; c) counting body's temperature in various circumstances: after body exercise and during woman's period using thermometers and temperature probes and d) oral hygiene with the use of a PH sensor.

Methodology

For the whole intervention we propose the scientific /educational method which is a pedagogical approach of the historically recognized scientific research method. That method through which scientist, researcher, man, had research, is researching and will continue to research natural world [2]. In every activity we used software, which developed under the simplest form so that it can be used for any other similar procedure to support it. The software acts supplementary giving in every step of the methodology the necessary elements such as videos and pictures, which are used to activate the students and to give them the appropriate guidance through the experimental procedure. The way the software is used can be altered according to the kind of the laboratory that is chosen each time. The software provides also the

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necessary worksheets that the students used to follow the scientific / educational method. The worksheets were developed under simplicity and directness of executing specific acts.
The first implementation took place with students of the Pedagogical department of the University of Athens. These students are future teachers so they should acquire certain experimental skills and general knowledge about human body and health.
Generally speaking that kind of procedures can be implemented in the two last grades of primary education, to the last grade of high school according to the curriculum mostly in the educational zone which is known as the interdisciplinary activities zone or as introductory lessons to science experimentation. That kind of procedures could familiarize students with sensors, computer software and experimental practice.

Experimentation

Counting heart and human respiration rate using a microphone attached to a computer

In many researches it is clear that most of the students confuse the cardiac rate with the breath. Although both functions are interdependent the rate of the breath is not identical with the rate of heartbeat. In order to establish this kind of difference we used a simple way of measure the heartbeat and the rate of the breath (without using expensive measuring tools). Using a microphone that is attached in a certain point on the neck, we measured, through a program of processing sounds (e.g the shareware software Goldwave) the heartbeat. An image taken from this software is given in Figure 1.
If the sound is not clear enough using the previous mentioned software (or any similar to that) it can be cleared so that the sound is heard loud and clear (experiential). From this graph students can measure the cardiac rate (measurement/calculation). After that students put the microphone near the nose and an image like Figure 2 will print to the screen.

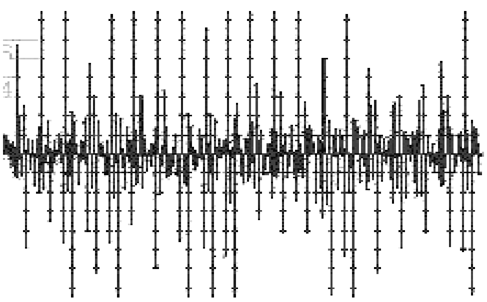

Figure 1. Heartbeat of a student

Figure 2. Rate of the breath of a student

This kind of software depends on timeline so it is easy to estimate the heart and breath rate from these graphs. In addition using the microphone we can measure the rate of the breath before, during and after certain activities, in order to correlate

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them with the heartbeat. We can also use people who are smokers or people who don't exercise regularly in order to underline the bad affects to our health in these circumstances. The kind of the activities that finally are adopted depends on our didactic approach and the school level.

Calculating human response time when a ruler falls and acceleration of a human punch, using a range sensor

Furthermore an activity we suggest is that one which uses a range sensor that measure the distance of a moving body. In this activity we use a ruler that falls and we have placed the sensor in order to measure the change of the height of the lower part of the ruler. The time-height graph that the sensor's software is producing is the one of Figure 3.

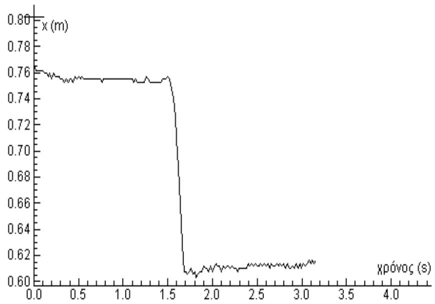

Figure 3. Catching a fallen ruler…

The experimental process is carried out by two people. The first person holds the ruler in a certain height above the sensor and the second person is ready to catch the ruler when it falls (the activation is given with a sound). In that way we measure the time one person takes to react so we can discuss a lot for the way the human brain works.

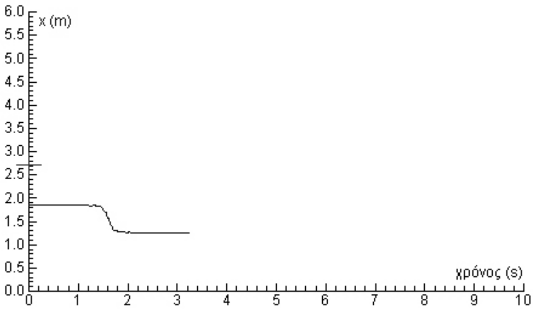

Figure 4. Graph of a human punch

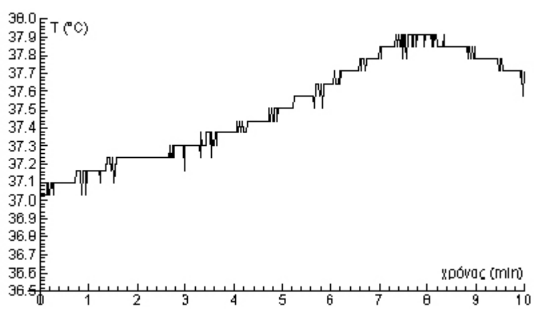

Figure 5. Body temperature

To enrich the reports concerning the human brain but also to deal with experimental procedures relevant to the velocity and the acceleration, using the same sensor we

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propose the measurement of the velocity and the acceleration of the human punch. One graph measuring distance and time has the formulation of that in Figure 4. Furthermore we can compare two graphs from two students with very different body shapes and expand the possible results in specific Biology and Physics lessons.

Counting body's temperature in various circumstances: after body exercise and during woman's period using thermometers and temperature probes.

In this activity is attempted to measure the human body's temperature in many different situations. The temperature in a laboratory can be measured using sensors or digital home thermometer. Then the measurements are recorded and appear in graphical representations like this one in Figure 5. We can also measure the temperature of a number of people and extract specific conclusions through dialogues about the variation or not of the experimental data.
In the next experiment we propose (in latest grades) that the girls can measure their temperature during their period. This is something that apart the other (science) benefits can help the students, not only girls of course, to socially mature and to stop having taboos about human body through a scientific procedure. Furthermore the measurements, in general, outside laboratory can help students to introduce in everyday life the scientific method and with particular references they could estimate the value of the measurement.

Oral hygiene with the use of a PH sensor

Even though the PH sensor is constructed to measure the PH of chemical solutions, through specific procedures can help students to estimate how acid or basic is their slaver. Generally speaking our slaver has specific PH that remains steady and varies after drinking or eating and there are many factors that can influence the PH in our mouth. In many circumstances the reason for having problems with our teeth is what we drink or what we eat. So it is good to know what affects our oral hygiene. In addition the PH of our mouth indicates more for the whole health of a person. For that, we organize experimental procedures using a PH sensor and appropriate worksheets. Maybe the whole procedure sounds difficult to be made but finally it is less difficult than it sounds and can help the students to understand and interconnect these factors that can give them good health.

Conclusions

The most encouraging element of all the procedure was the huge interest that students showed from the beginning of the experimental procedures. It is also good to be mentioned that students with low expectations of themselves appeared to be more skilful in that kind of experimental practice than we expected. Most of the problems encountered concern the use of the sensor's software but this is something we were expecting as soon as the implementation was limited in time. We can overcome that kind of difficulties with the extensive use of sensors and

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software in introductory laboratory. Nevertheless more conclusions can be extracted if more research take place, but the first elements indicate that this kind of experimental activities can cultivate experimental skills with an easy and pleasant way and help students to become scientific literate members of our society.

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Gravitropism Hands-on Device

Oikonomidis S, Grigoriou V, Kaponikolos N, Kanavi S and Kalkanis G

Introduction

Gravitropism is simply a plant's response to gravity. When a plant, or part of a plant such as the root, grows with gravity, it is called positive gravitropism. When the shoots grow against gravity, it is referred to as negative gravitropism. Plants are accustoming to the Earth's 1g pull from a very young age, even before the seedling has grown into the light. The research of gravity sensing is very exciting right now because the exact mechanism is not known. To better understand gravity sensing it is important to be aware of some of the components. The specialized cells and tissues for sensing gravity are called statocytes. The receptor receives the signal that was sent from the statocytes and then transduces it into physiological information. Sensing ends here and the signal then moves into the transmission phase.

Materials and method

Our device consists of an electric motor which is connected with a rubber band to a round metal disc. The metal disc rotates with an angular velocity of 1rad/s approximately. A piece of steel pipe 1m long is welded at the centre of the metal disc. As a result, the pipe is rotating at the same speed as the metal disc. At the other end of the steel pipe, we placed vertically a 1.2m long wooden axle (Figure 1). At the ends of the axle we hanged two cotton balls which contained lentils seeds with a short thread. The seeds are making circles 24 hours per day.

More specifically, we used a power supply which could provide variable voltages (10-12V) and it could change the setting of the current, thus the sense of rotation in the electric motor. The electric motor is working with direct current and with maximum input voltage 12V. The maximum rotation speed is 2,400rpm. Because of the small size of the motor axle, we cut and fitted a cd-case. Then we welded a piece of a steel pipe 1m long at the centre of a metal disc. The metal disc was fitted in a base which could be rotated through the electric motor. At the end of the pipe we fitted a horizontal axle where we putted 3 small magnetic balls as counterbalance. We also putted two small cotton balls which contained the seeds.

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Figure 1. Experimental apparatus

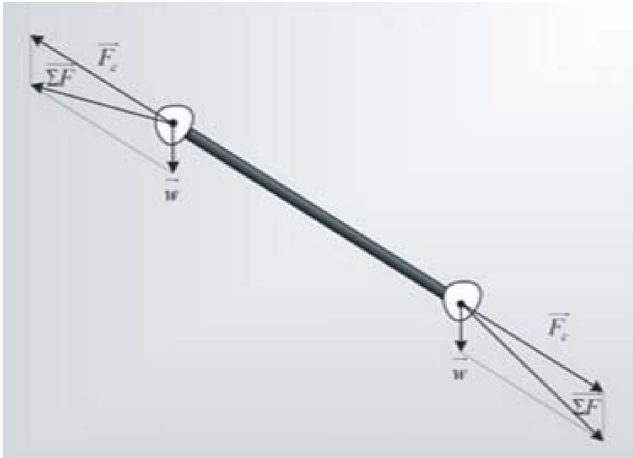

Figure 2. Forces applied at the seeds

Educational proposal

According to our method, the didactical approach that is supported by a worksheet should follow five steps: trigger of interest, express of hypotheses, experimentation, express a theory and generalize. This experiment refers directly to the third part of the following method and it can be used for measuring various natural and mathematical quantities such as period, frequency, angle, time, velocity, length. In order to achieve the accomplishment of the student objectives, it is better for the experiment to consist of two parts: the first one with an experimental setup where the cotton balls with the seeds would be motionless and an experimental setup where the cotton balls with the seeds would be rotated. Thus, it would be feasible to make comparisons between the two different ways of grow. In the fifth step here students are called to generalize their assumptions, we can put some questions in order to direct them. Particularly, we can ask them:

1. What are some general observations of the typical downward growth of a seed?
2. Is there anything that happens that is different from what you expected?
3. Using the data provided, how fast is the seed growing?
4. Why is it important to know how a seed normally grows?
5. What are some sources of error in this experiment?
6. How does the growth rate of this gravistimulated seed compare to the typical downward growth of a plant? Is it hindered or enhanced?
7. Supposed you see a plant's orientation and that no other reason affects plants grow, can you determine the effective gravity?
8. Can you make any hypothesis about the importance of gravity sensation of a plant in the space?

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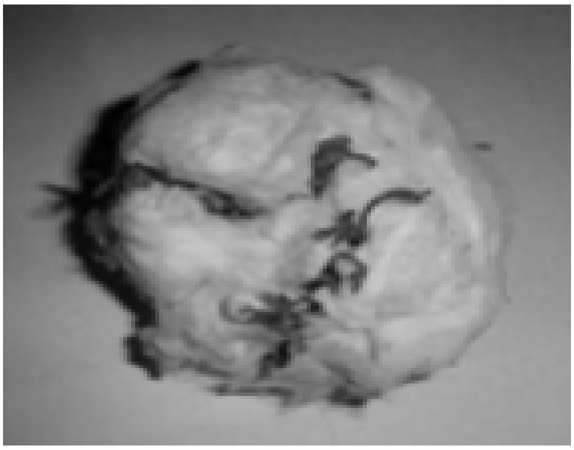

Figure 3. The grown seeds

Figure 4. Proposed apparatus

This exercise may fulfil a large variety of student objectives that can be accordingly applied to the student level. These objectives can be divided into two categories, not only cognitive but also psychomotor.

To be more specific, students (in the cognitive segment) are expected:

- To predict the normal response of a seed when grown down with gravity.
- To predict the response of a seed when it is being rotated.
- To compare the growth patterns of seeds those have been rotated to those that are growing down with gravity.
- To compare the growth and angle of orientation of seeds according to angular velocity of the device.
- To identify why it is important for a plant to have gravity sensing.

And in the psychomotor segment are expected:

- To explain why it is important to have a control for an experiment.
- To measure the growth and change in seed angle over time.
- To interpret data generated in tables and graphs.

Experimental results

Our experimental results didn't comply fully with our expectations, due to the fact that seeds grew in a small rhythm. According to theory, seeds were supposed to grow parallel to the resultant of their weight and the centripetal force. This means that seeds should not grow vertically to the ground but to make an angle (Figure 2).

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That wasn't what we experimentally noticed. The seeds grew so that shoots appeared to form a small angle with the vertical axis to the ground, but that wasn't too obvious (Figure 3).

Suggestions

As a future enhancement, we propose an experiment based at the aforesaid, where students can study various factors that determine seeds' grow such as light and orientation. With this they will have to handle more variables and study the importance of each one at the seed grows. The required changes in the experimental setup are small, as an electric bulb is needed and a mechanism that turns the vertical axis in various angles (Figure 4).

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Hands-on Activities with LEDs and Light

Voudoukis N, Oikonomidis S and Kalkanis G

Introduction

A serious motive for this work constituted the following questions. Is it possible to execute simple hands-on experiments with LEDs in order to find Planck's constant, electron's charge, the energy required to light the LED, the frequency of light emitting from the LED and to investigate the relation between the frequency and the energy of light emitted by the LED.
For this reason an experimental process was designed and the results was very encouraging. The activity is also proposed for the students of High school that have been taught the nature of light and basic elements of Quantum Physics (photons, Planck's constant etc). Nevertheless it is necessary a theoretical framework as an introductory fundamental lesson-material for LEDs and their way of light emission.

Theoretical framework

Light Emitting Diode (LED) is a special diode that emits light when connected in a circuit and biased in the forward direction. Otherwise it is a semiconductor device that emits incoherent narrow-spectrum light when electrically biased in the forward direction. This effect is a form of electroluminescence. The colour of the emitted light depends on the chemical composition of the semiconducting material used, and can be near-ultraviolet, visible or infrared.
An LED is a special type of semiconductor diode. Like a normal diode, it consists of a chip of semiconducting material impregnated, or *doped*, with impurities to create a structure called a *p-n junction*. As in other diodes, current flows easily from the p-side, or anode to the n-side, or cathode, but not in the reverse direction. Charge-carriers-electrons and electron holes flow into the junction from electrodes with different voltages. When an electron meets a hole, it falls into a lower energy level, and releases energy in the form of a photon as it does so. LEDs will only light with positive electrical polarity. When the voltage across the *p-n junction* is in the correct direction, a significant current flows and the device is said to be *forward-biased*. If the voltage is of the wrong polarity, the device is said to be *reverse biased*, very little current flows, and no light is emitted. LEDs can be operated on an alternating current voltage, but they will only light with positive voltage, causing the LED to turn on and off at the frequency of the AC supply.

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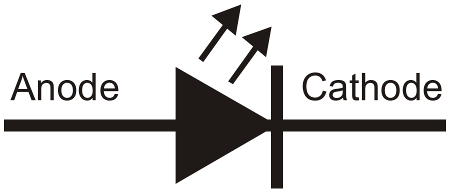

Figure 1. LED schematic symbol

The wavelength of the light emitted, and therefore its colour, depends on the band gap energy of the materials forming the *p-n junction*. In silicon or germanium diodes, the electrons and holes recombine by a *non-radiative transition* which produces no optical emission, because these are indirect bandgap materials. The materials used for an LED have a direct band gap with energies corresponding to near-infrared, visible or near-ultraviolet light.

LED development began with infrared and red devices made with gallium arsenide. Advances in materials science have made possible the production of devices with ever shorter wavelengths, producing light in a variety of colours. The refractive index of the package material should match the index of the semiconductor, otherwise the produced light gets partially reflected back into the semiconductor, where it gets absorbed and turns into additional heat.

In nonradioactive recombination the energy released is dissipated in the form of lattice vibrations and thus heat. However, in band to band radioactive recombination the energy is released with the creation of a photon with a frequency following equation $E=hf$ where the energy is approximately equal to the bandgap energy $E=hf=hc/\lambda$ where c is the velocity of light in a vacuum and λ is the optical wavelength.

This spontaneous emission of light from within the diode structure is known as electroluminescence. The light is emitted at the site of carrier recombination which is primarily close to junction, although recombination may take place through hole diode structure as carriers diffuse away from the junction region. However, the amount of radioactive recombination and the emission area within the structure is dependent upon the semiconductor materials used and the fabrication of device.

When sufficient voltage is applied to the chip across the leads of the LED, electrons can move easily in only one direction across the *junction* between the *p* and *n* regions. In the *p region* there are many more positive than negative charges. In the *n region* the electrons are more numerous than the positive electric charges. When a voltage is applied and the current starts to flow, electrons in the *n region* have sufficient energy to move across the junction into the *p region*. Once in the *p region* the electrons are immediately attracted to the positive charges due to the mutual Coulomb forces of attraction between opposite electric charges. When an electron moves sufficiently close to a positive charge in the *p region*, the two charges "re-combine". Each time an electron *recombines* with a positive charge, electric potential energy is converted into electromagnetic energy. For each recombination of a negative and a positive charge, a quantum of electromagnetic energy is emitted in the form of a photon of light with a frequency characteristic of the semi-conductor material (usually a combination of the chemical elements gallium, arsenic and

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phosphorus). Only photons in a very narrow frequency range can be emitted by any material. LED's that emit different colours are made of different semi-conductor materials, and require different energies to light them.
The electric energy is proportional to the voltage V needed to cause electrons to flow across the p-n junction. The energy E of the light emitted by an LED is related to the electric charge e of an electron and the voltage required to light the LED by the expression: $E = eV$.

Materials

1. battery 4,5 V
2. breadboard; cables
3. digital voltmeter; spectrometer
4. resistor 220Ω
5. five LEDs : red, orange, yellow, green, blue.

Experimental procedure

Implementation–design of the circuit

The circuit is shown in Figures 2, 3, 4 and 5. We used battery V = 4.5 Volt, resistor R= 220Ω (1/4 Watt) and five LEDs of different colours (red, orange, yellow, green, blue). The resistor is to protect the LED from too much current and to minimize the amount of current and voltage available to the LED. So we built five different circuits as we changed the LED D.
We select the value of R equal to 220Ω. This is a proper value. In Figure 2, when the forward voltage drop of an consequently

$$R = (V-VLED) / I$$

We suppose VLED = 1.9Volt and I = 12 mA. LEDs operate at relative low voltages between about 1 and 4 volts, and draw currents between about 10 and 40 *milli*amperes. Voltages and currents substantially above these values can melt a LED chip. So

$$R = (4.5-1.9)/ 12 \times 10^{-3} = 216.7\ \Omega.$$

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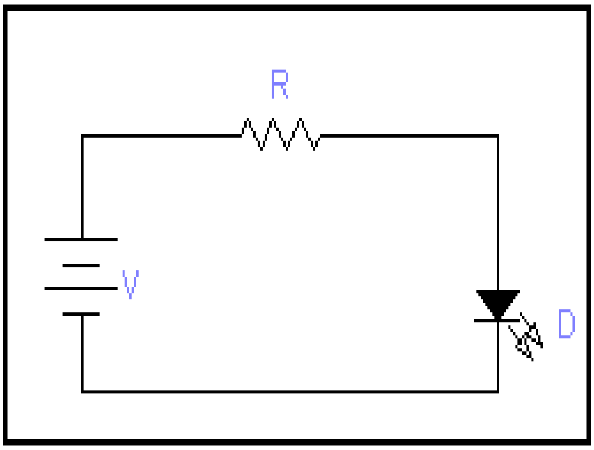


Figure 2

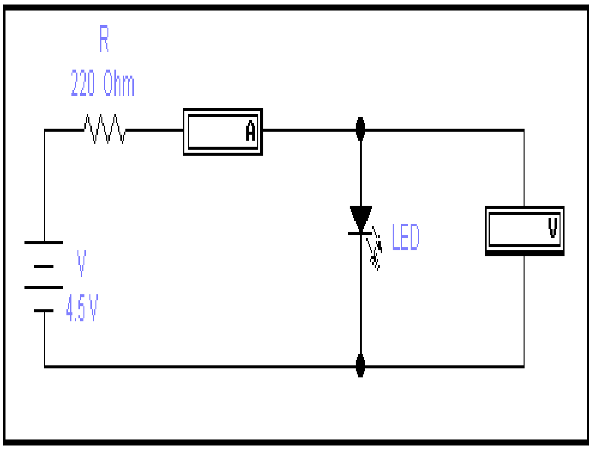
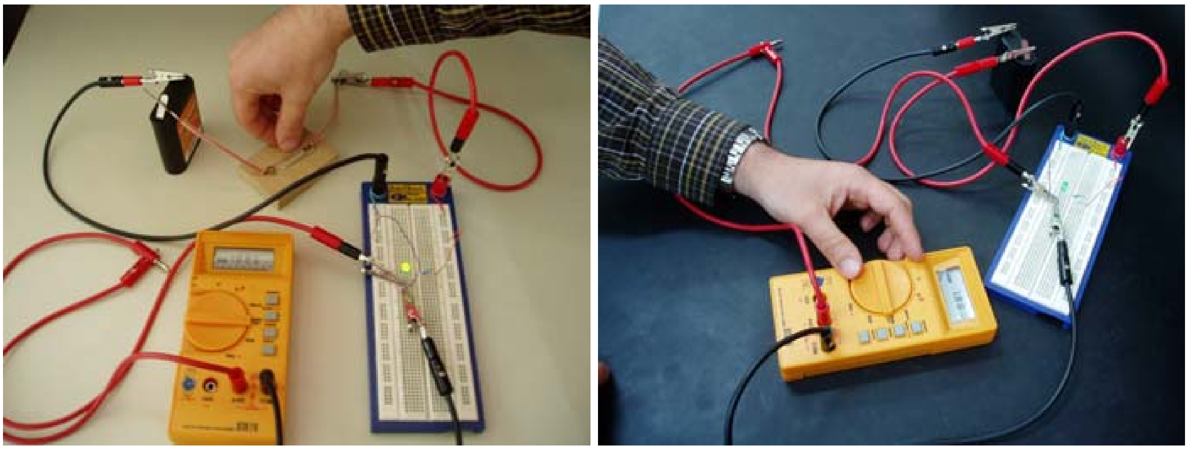


Figure 3



Figures 4 and 5. The experiment

Measurements of voltage across LED

We measured, with the voltmeter, the voltage across the leads of the LED. We turned on the digital voltmeter, connected the probes of the voltmeter across leads of the LED's and recorded the potential difference in volts across each of the LEDs. We constructed a data table (Table 1).

LED colour	Voltage ac. LED (V)	Energy (eV)	Energy (*x* 10^{-19} Joule)
Red	1.77	1.77	2.83
Orange	1.81	1.81	2.90
Yellow	1.91	1.91	3.06
Green	2.03	2.03	3.25
Blue	3.05	3.05	4.88

Table 1

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Finding the energy (an LED emit) from the voltage

LED colour	Voltage across LED (V)
Red	1.77
Orange	1.81
Yellow	1.91
Green	2.03
Blue	3.05

Table 2

The electric energy is proportional to the voltage needed to cause electrons to flow across the p-n junction. The different coloured LEDs emit predominantly light of a single colour. The energy of the light emitted by an LED is related to the electric charge of an electron and the voltage required to light the LED by the expression: $E = eV$ Joules. The constant e is the electric charge of a single electron and has absolute value 1.6×10^{-19} *C*.

Estimation of wavelength with use of spectrometer and calculation of the corresponding frequency

LED colour	Wavelength λ (nm)	Frequency f (x 10^{14} Hz)
Red	680	4.41
Orange	620	4.84
Yellow	580	5.17
Green	540	5.56
Blue	440	6.82

Table 3

Figure 6

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The spectrometer can be used to examine the light from the LED, and to estimate the peak wavelength of the light emitted by the LED. Suppose we observe the red LED through the spectrometer, and we find that the LED emits a range in colours with maximum intensity corresponding to a wavelength as read from the spectrometer of λ = 680 nm or 680 x 10^{-9} m. The wavelength is related to the frequency f of light and the speed c of light (c=3 x 10^8 m/s) with the equation c = λ f. So we have f = c / λ and for the red LED is f = 4.41 x 10^{14} Hz.
We repeat the procedure for the four other LEDs.

Making plot of frequency against voltage.

With use of data of Table 4 we are able to plot frequency against voltage and make a prediction of mathematical function between them.

LED colour	Voltage across LED (V)	Frequency f (x 10^{14} Hz)
Red	1.77	4.41
Orange	1.81	4.84
Yellow	1.91	5.17
Green	2.03	5.56
Blue	3.05	6.82

Table 4

Calculation of Planck's constant

We calculate Planck's constant if take as granted that e = 1.6 x 10^{-19} *C*
We have hf = eV so h = eV / f

LED colour	Voltage across LED (V)	Frequency f (x 10^{14}Hz)	h (x 10^{-34} Js)
Red	1.77	4.41	6.42
Orange	1.81	4.84	5.98
Yellow	1.91	5.17	5.91
Green	2.03	5.56	5.84
Blue	3.05	6.82	7.16

Table 5

Calculation of electron's charge

We calculate electron's charge if take as granted that $h = 6.63 \times 10^{-34}$ Js
We have hf = eV so e = hf /V

LED colour	Voltage across LED (V)	Frequency f (x 10^{14} Hz)	e (x 10^{-19} C)
Red	1.77	4.41	1.65
Orange	1.81	4.84	1.77
Yellow	1.91	5.17	1.79
Green	2.03	5.56	1.81
Blue	3.05	6.82	1.48

Table 6

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Verification

We take e = 1.6 x 10^{-19} *Cb* and $h = 6.63 \times 10^{-34}$ J s
With use of V measurements we calculate the frequencies

LED colour	Voltage across LED (V)	Frequency f (x 10^{14} Hz)
Red	1.71	4.13
Orange	1.74	4.20
Yellow	1.85	4.46
Green	1.94	4.68
Blue	2.96	7.14

Table 7

The results are very close to the experimental values.

Conclusion

The experiments are successful because the experimental values and the correlated results are very close to the theoretical values. Also these experiments are very simple hands-on experiments that can be executed by students.

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