Capstone Project

Physics Toys

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Introduction.

In this work I describe what science toys I'll choose for my "Physics Toys" book. The Physics Toys book is designed to introduce **classroom activities** with certain **physics toys** (hand-on physics) based on **phenomena-based learning,** where **gender equality** is also taken into account.

In the first chapter I discuss classroom activities with physics toys and why it is beneficial to use them. I also explain what "phenomena-based learning" signifies. Gender equality in physics teaching is a concern because there is lack of girls in physics classes in Finland. I write about gender differences in learning science and solutions as provided from earlier studies. This awareness has prompted me to write a book, which will cater to both genders equal.

From this background I define reasoning for selecting what toys are to be part of "Physics toys" –book. The purpose for this book is to help students to understand and help teachers to teach difficult concepts in physics and to make lessons in physics more interesting. In the second chapter I write about criteria and why each toy has been selected.

In the third chapter I introduce Laws of Thermodynamics –phenomenon and colors -phenomenon, as they will be presented in the "Physics toys" book. I explain how theories in learning referenced in chapter one influences the structure of the text. I write about physics in toys (briefly) and how it is used to explain phenomena behind the toys.

Chapter 1: Theories behind teaching physics with toys.

From my own experience I've noticed that science toys in lessons inspire students. I've actively used science toys in classroom demonstrations for several years now. Also other teachers from my school are using these toys and their feedback has been encouraging, and inspires me to find new toys for classroom use and to write a book with a new approach to teaching physics.

Classroom demonstrations

Classroom demonstrations are widely used in almost all physics classes from elementary school to university all over the world. Physics and other sciences have been taught with demonstrations from the early eighteenth century (Turner, 1987). Classroom demonstrations serve a number of purposes. One important purpose is to clarify the phenomena presented in class. Using classroom demonstrations has been so obvious to teachers that there hasn't really been doubts about their benefits. However, demonstrations without proper explanations or interaction with students may cause misconceptions and debase learning among students. (Kraus, 1997) With thorough planning, explicit explanations and interactions with student, classroom demonstrations become useful tools that increase learning. An additional benefit from classroom demonstrations is that they increase students' interest in science.

Demonstrations in the book are planned so that students can undertake independent inquiry with a toy (hands-on activity). Hands-on activities in science are considered very useful to children's scientific learning. (Satterthwait, 2010; Haury & Rillero, 1994) Hands-on activities are thought also to increase positive attitudes towards science, even though there is no clear evidence to support that. (Ornstein 2006). The text in the book will be written so that peer interaction and cooperative learning (which supports hands-on activities (Satterthwait, 2010)) are taken into account.

Teaching physics with toys:

Toys are widely used as classroom demonstrations in physics lectures (Guemez, Fiolhais C & FiolhaisM, 1987), as they are known to be very useful and good tools to motivate students in science studies. Some toys are also considered to be very interesting from a scientific point of view. (Guemez et al., 1987) Sometimes the difference between a toy and a classroom demonstration is very negligible. Some of the demonstration apparatus used in classrooms have been so amusing and induced such amazement that they ended up being used as toys for children and also for adults (e.g., desktop toys) (Turner, 1987).

From my own children I have noticed that children love to play. And when the play is voluntary and created by children's own imagination they can play for long periods of time in one session, whereas concentration on housework or toward structured tasks does not last for a very long time. Through play, children absorb scientific and other knowledge consciously and unconsciously. (Turner, 1987) Toys are considered to be non –threatening to children and therefore exceptional teaching tools. (Sarquis J.L & Sarquis A.M, 2005) With applicable toys in play, it is possible to guide children to scientific thinking.

Hasse (2008) carried out research with physicists and found a connection with childhood experiences and becoming a scientist. *"…physicists often perceive experiences in their childhood as the first step into their professional identities as physicists. These experiences involve recollections of the ability to think scientifically (e.g., 'go beyond the surface'), and the ability to play with toys which can be connected to the practical life of physics."* (Hasse, 2008 p. 149) Play and playful minds are associated with early childhood, but they exist and can be observed in high school students. Some toys are used not only for children to play, but increase the interest of students in science. *"We believe that toys may play a role in introducing young people to science and to the scientific method."* (Guemez et al., 1987 p.63)

There are many ways to demonstrate phenomena, but I narrowed it down to toys and more accurately to "science toys". The term "science toys" is not defined but it is used to describe toys that are "cool tools" to teach concepts of science (Arbor Scientific, 2010). The purpose of using science toys in the classroom and in my book is mainly to encourage students to have scientific thinking, increase interest in the subject, and to help them to understand the phenomena in an interesting and amusing way. Toys are found to be a valuable way to learn hands-on science where reality might be richer than theory from a textbook. (Guemez et al., 1987)

Scientific toys are useful in many fields of physics. (Turner, 1987) Using toys as classroom demonstrations and hands-on activities in high school is proper because some toys include university level physics. Therefore some science toys can be used by advanced students to create small research projects, which might be one step towards a student continuing a career as a professional scientist. (Hasse, 2008) Some toys include serious physics that appears in journals and literature. Some examples about publications in physics from toys selected to my book are: "Levitron" (Berry, 1996; Dullin & Easton 1999; Jones, 1997), Rattleback (Garcia & Hubbart 1988) and "Euler's disc" (Moffat 2000).

Phenomena-based learning:

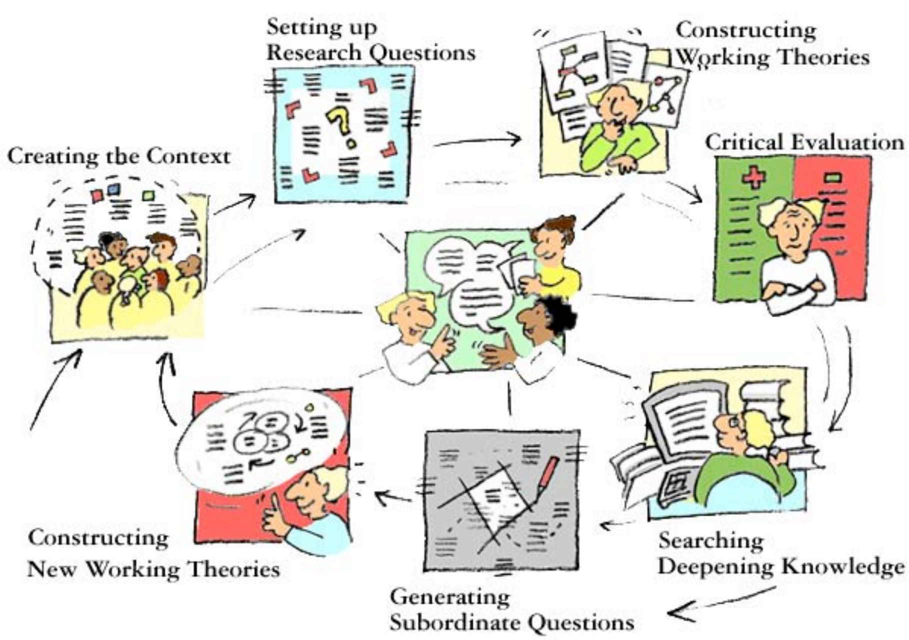
I entitled my book, "ilmiöpohjainen oppiminen" (straight translation would be: phenomena-based learning) which is considered to be a noteworthy new conception of learning. It is considered to be part of the curriculum after 2014, as stipulated by the National Board of Education. (Finnish National Board of Education 2010) After looking at different theories of learning, I noticed that I had misunderstood whole theory of "ilmiöpohjainen oppiminen" and realized that my idea for the book is a mixture of different learning theories but not fully explained by any one of those.

“Ilmiöpohjainen oppiminen”

“Ilmiöpohjainen oppiminen” is a new concept of learning, which is now a project run by the Finnish National Board of Education and Otavan Opisto in Finland. Results of that project will be published 2011. (Finland National Board of Education 2008) The starting point in “ilmiöpohjainen oppiminen” is real comprehensive phenomena where inquiry is school-subject independent and the need for inquiry comes from the student. From phenomena like “piracy” student can expand inquiry in the direction of interest. For example, from “piracy” one group of students may return a paper about piracy in Somalia (ships) or a presentation about the pirate party (a political party that strives to reform laws regarding copyright and patents) in Sweden. The way “ilmiöpohjainen oppiminen” is presented supports the use of progressive inquiry, problem based learning, project based learning and using portfolio methods in schools. (Jones, 1997)

Progressive inquiry

Progressive inquiry is a pedagogical model where students’ work and approach to problems is similar to that of scientific research communities. It was developed by Kai Hakkarainen and his colleagues in the University of Helsinki 2004. Progressive inquiry describes the elements of expert-like knowledge practices in the form of a cyclic inquiry process presented in the picture below. (Muukkonen, Hakkarainen & Lakkala, 1999).



(University of Helsinki, Muukkonen, Hakkarainen & Lakkala, 1999)

Problem-Based Learning

Common principles with “Problem-based learning” and “Project-based learning” is that students come up with idea of solving problems while the teacher is more listening and advising than teaching. In both theories students work in groups and solve problems by using different educational activities. Project-based learning differs from problem-based learning in that projects take a considerable length of time and the result of the project is an end-product (for example, a report, thesis or model). In problem-based learning the student might spend the entire time studying a problem. (Helle, Tynjänä, Olkinuora, 2006)

What all these theories have in common is that students are active and they try to solve the problems and find the solutions while the teacher is more of an advisor than a teacher. These theories give students the freedom to set up problems and find out the solutions in their own way. The problems and projects are broad concepts that are not school–subject-dependent.

Phenomena-based learning

The “Physics Toys” book presents phenomena-based teaching methods. In science there are many phenomena that are difficult to understand. Most of the physics books are written so that the theory comes first, and demonstrations and applications are presented only after the theory. Phenomena such as magnetism can be so wide-ranging that the theory can include many chapters of a physics book. In my book, the goal of the exercises is to understand why and how things happen. Experiments are presented that use (hands on) physics toys, and they are built so that each experiment approaches the phenomena from different angles. As in Project-based learning and Problem-based learning, students are active in finding a solution to a problem but the problem is provided by a book or by a teacher. Phenomena are also school subject dependent because all phenomena in the book are science-related and exercises are designed to provide an understanding of phenomena from a scientific point of view. As with progressive inquiry, understanding the phenomena takes many steps and each step will deepen the knowledge about the topic. Any departures from the progressive inquiry steps are highly structured and supervised.

Because “ilmiöpohjainen oppiminen” is not official theory yet in Finland and it is not translated to English, I am naming my idea of approaching science phenomena as “phenomena-based learning”. I discussed the term and this approach to the phenomena with Dr. Joe Redish (University of Maryland) and the term “Phenomena-based learning” as I understood it is enthusiastically approved by him.

Gender equality:

In Finland there are about 35 000 students taking part in the final exams in high school. More than 60 % of students are female. About 5000 students take part in the physics exam. From those 5000 only about 20 % are females. (Finland National Board of Education 2008) So there is lack of girls in physics classes. There must be reasons to explain this significant difference. There is a gender difference but is it because of the subject (is physics more suitable for boys?) or is there a difference because teaching and books are favoring boys. I assume that there are gender differences in thinking and learning, and from the literature I tried to find out what those differences are. I also assume that physics teaching is favoring boys in part because almost all the physics books are written by men, and the structure of these books supports the way the writers think and learn.

Gender differences

I have noticed that there is a difference in how males and females learn. Every time I have tried to talk about it I get the answer: "WHAT DO YOU MEAN! Are you saying that girls are stupid?"

When we understand what is the difference is between how boys and girls learn, we can better help them to understand difficult concepts.

Marano (2003 p.38) writes, "Males and females are different from the moment of conception, and the difference shows itself in every system of body and brain." Differences that affect learning between males and females might come from differences in their brains or the way the children are raised.

Brains consists of gray matter, white matter and cerebrospinal fluid.
Marano (2003 p.42) writes: "Gray matter is made up of the bodies of nerve cells and their connecting dendrites". Marano (2003) also describes that female brains have higher concentration of gray matter, so the female brain is more densely packed with neurons and dendrites. The male brain has more white matter and cerebrospinal fluid. White matter is made of long arms of neutrons providing distributed processing throughout the brain. Marano (2003 p. 42) further writes: "*It gives males superiority at spatial reasoning.*" Ruggiero, Sergi and Lachini (2008) found that there is a male advantage in spatial information and mental rotation (MR), which involves manipulation and transformation of three dimensional objects solely in the head, but not a significant difference in perceptual discrimination in distance.

So is the difference in spatial abilities the reason why there are fewer girls in science classes?

Brownlow, McPheron and Acks (2003) inquired about spatial abilities and especially mental rotation (MR). Spatial skills like MR start to develop in childhood, and training is beneficial to both males and females. Brownlow et al. (2003) found that while women may have a lower MR ability overall, many women do not have a lower MR ability, and that this deficit may not be an important reason for women to avoid physical sciences.

Frantz (2007) notes in her article that there are differences in mathematical ability and spatial-rotation tasks due to biology, but that it is possible to reduce the gap between males and females. Frantz (2007) refers to McGlone's (2006) study where he could improve females' results on the Vandenberg-Kuse Mental Rotation Test by a psychological trick increasing student's perception of their higher abilities. It might prove nothing, but it gives us (teachers) hope that we can make difference by changing the way to teach science in the classroom.

Marano (2003) notes another vital difference in brains between males and females. Marano (2003 p. 42) states: "*White matter also carries fibers that inhibit "information spread" in the cortex. That allows a single-mindedness that spatial problems require.*" Marano's (2003) says that it could be that the white matter in the female brain is concentrated so that it enables the female brain to excel in language tasks. Therefore females tend to be better in languages. Despite the differences in brain size and structure, males and females score equally in tests of intelligence.

I think these findings are known by everybody and therefore not surprising to me. I think everybody knows them. I have noticed in the classroom that boys are better in "single minded" / "tunnel vision" - exercises like solving equations and girls are better drawing a big picture about concepts where you have to consider many things at the same time. I have also noticed that physics books are written mostly by men and there spatial and "single minded" thinking is the normal way to approach phenomena. This approach might be easy for most of the boys but maybe it is confusing to girls. Some experiments in books assume that basic principles and machines are familiar to students. Maybe there are girls that have never looked at machines to understand them just because their brains are wired in a different way. And if you don't see examples of phenomena, it is more difficult for you to understand phenomena.

Along these lines, Udo, Ramsey, Reynols-Albert and Mallow (2001) noticed in their research about science anxiety, boys reaped some additional benefit when they were taught by a male. The same thing happened to girls when they were taught by a female.

Solutions

So are there ways to teach that will especially help girls to learn physics?

The contextual approach to teaching physics is the theory that involves the use of real-life contexts to explore an area of study (Wilkinson 1999). According to Wilkinson's references, a contextual approach will enhance interest and is a motivating factor — especially to girls.

Lee and Burkam (1996) found in their research that, particularly in middle school, physical science hands-on laboratory experiences are beneficial to girls but have no influence on boys. Girls and boys play with different toys when they are children. Some contexts might already be familiar to boys before they enter school. Hasse (2008) found in her research that male physicists refer more to childhood hands-on experiences (e.g., take apart objects and scrutinize their inner parts) whereas female physicists observed nature more visually. Therefore it is important to have hands-on experiments when new concepts are taught.

I have noticed that it is helpful to girls to first present the big picture of concepts and from there deepen the knowledge. For boys there is no difference. As Marano (2001) writes, girls seem to use "top-down" and boys "bottom-up" thinking.

Chapter 2: Building criteria to choose the toy.

Price

First and maybe the criteria that will narrow the selection of toys the most is the price. I want that all the schools in Finland be able to buy these toys and therefore I don't want to add too many things to the book. The toy kit with the "Physics Toys" –book will cost no more than 1000 Euros so I have to be very selective with phenomena and with toys I'm going to choose for the "Physics Toys" -book. I want to cover topics that are difficult to students or increase interest towards physics so each phenomenon is carefully picked from the Finnish curriculum.

Phenomena

I have been teaching physics from year 2004 in high school. We had a new curriculum in 2006. There are 8 different physics courses in Finnish high school curriculum. Each course takes 7 school weeks and includes approximately 30 hours of teaching. Reason for collecting toy kit is to help students to understand and teachers to teach difficult physics phenomena with toys. Below is the list and description of physics courses and reasoning why each phenomena are selected to the "Physics Toys" –book.

Physics 1

Physics 1 –course is introduction to physics and it is compulsory to all students. Therefore it is simple course where basic concepts like SI-units, basic kinematics, astronomy and radiation are presented. In this course the topics are simple. For a physics teacher it is important to make topics interesting so that students could select voluntary physics courses (2-8). From this course there is no phenomenon that I'm going to select but I hope teachers will use some toys out of context just to make lessons more interesting.

Physics 2 (Pressure, Laws of thermodynamics, Energy)

Physics 2 is the first voluntary physics course including basic principles of heat, pressure and energy. For students gas laws and laws of thermodynamic have been difficult topics to understand. I selected pressure to be one phenomenon in the book because many of concepts in Physics 2 -course are based on pressure and I knew that there are many science toys where pressure is involved. When I was searching for toys to explain pressure I was positively surprised that there are also toys to explain laws of thermodynamics. In Physics 2 -course energy is introduced for the first time. I included energy to the "Physics Toys" -book but it is a wide phenomena concerning topics also from other physics courses.

Physics 3 (Light behavior, Colors, Sound)

Physics 3 is about waves and it is an easy course to teach, because there are many ways to demonstrate waves, sound and light. Most difficult topics in this course to students are properties of light like diffraction, interference and light behavior on boundary surfaces. Because Physics 3 course is the last freshman physics course and selections to second year in high school may depend on this course I want to cover many topics from this course with toy physics. I selected light behavior, colors and sound. “Colors in white light” is usually topic that physics books ignore but it is topic that is extremely important to girls so I wanted to have colors to be one phenomenon in the “Physics Toys” –book.

Physics 4 (2D movement, Buoyancy)

Physics 4 is a course where kinematics, forces and momentum are essential. From my experience the most difficult phenomena are buoyancy, 2D (two dimensional motion) movement and momentum. For momentum there are toys to teach with but I have experienced that these toys do not work as well as computer based measurements with collision track, so I did not choose momentum to be in the “Physics Toys” -book. I included Buoyancy and 2D motion because for these phenomena I can easily find hands-on toys for students to play with.

Physics 5 (Angular momentum, Circular motion)

Physics 5 –course is about angular motion, rotating motion and gravitation. For students these concepts are pretty difficult. Usually I concentrate to moment of inertia, circular motion, rotation and angular momentum. Angular momentum is maybe the most difficult topic but there are great toys to explore it so that is one phenomenon I selected. At the beginning of this process I didn’t want to add any other phenomena from this course but I found a toy (flying pig) that is so amusing that I wanted to add circular motion to be one phenomenon in book.

Physics 6

Physics 6 is course about electricity and it includes; electric field, electrical circuits and electronics. Most students find it easier than previous physics courses. I think that electricity has to be taught with real instruments and it is good time to students to learn how to use different equipments for measurements. From this course I didn’t select any phenomena to be taught with toys. For electricity toys I should have used a lot of money and from my 1000-euro budget it would have been too much. Schools in Finland have usually good equipments to demonstrate electricity.

Physics 7 (Magnetism, Electromagnetic induction)

Physics 7 is considered by students to be the most difficult physics course in Finnish high school. The course includes magnetism, electro-magnetic fields and electromagnetic induction. Electromagnetic induction is very difficult for students but there are some toys to explain how it works. Magnetism is not a very difficult topic but it is very important to everyday life. So I selected electromagnetic induction and magnetism to be part of the “Physics Toys” –book.

Physics 8

Physics 8 –course is about modern physics radiation and matter including topics like radiation, electromagnetic radiation and nuclear physics. In this course physics is more theoretical and there are not too many toys to demonstrate it. I didn't select any phenomena from this course.

Additional phenomena (Bernoulli's effect)
Bernoulli's effect is always neglected in physics curriculum and books. I wanted to add it because it is important in everyday life and it is a very interesting phenomena to demonstrate.

Selected phenomena
At the end I started with 13 phenomena knowing that I need to remove one to two phenomena later from the book because of the price of the toy kit. I started with Pressure (course 2), Laws of thermodynamics, Energy (2-5), Light behavior (3), Colors (3), Sound (3), Buoyancy (4), 2D motion (4), Angular momentum (5), Circular motion (5), Magnetism (7), Electromagnetic induction (7) and Bernoulli's effect.

Availability

After choosing the phenomena I started to select toys for the kit. I started to work online searching for toys that could explain the required feature of selected phenomena.

I contacted a few "science toy"-companies to make sure that, if I find a toy from the company, they could ship it to Finland. Arbor Scientific responded to me and I knew the company to be reliable from earlier experiences.

I went to visit Arbor Scientific company in Ann Arbor, Michigan and I was very impressed about the way they treated customers. I spent five hours in their conference room just testing all the toys that I wanted to see. That time spent was very critical to my work. I found many new toys but I had to also drop a few toys away from the kit because they didn't work the way I wanted. Arbor Scientific did not have all the toys I wanted for the "Physics Toys" -book but they promised to find the missing ones for me.

To my surprise some toys could not be sent to Finland because of Finnish legislation. Green laser, which I wanted to be part of light behavior phenomenon, was too powerful and therefore prohibited in Finland without special permission, so I decided to drop that from the kit.

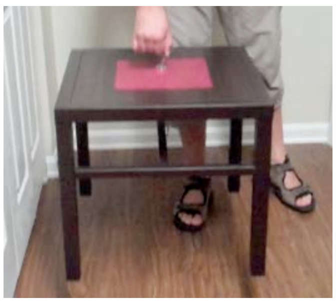
Toy feature, quality

I wanted all the selected toys to be inexpensive and reliable. The toys have to include some neat physics and it should to be easy to use for the teacher. Most of the toys are going to be used by students so they had to be durable. Following is the description about the toys that I selected for each phenomenon.

Pressure

To explain pressure and influences that pressure can create I tried to find simple and funny toys where the physics is not too difficult. In Finnish curriculum we introduce pressure with force and area so I selected toys where pressure creates forces and vice versa. First I selected “Atmospheric Mat”, “Pressure globe” and “Water rocket”. I had some experience with those toys so it was easy to select them. These toys are easy to use, inexpensive and reliable. In all of them pressure or underpressure is creating forces which have interesting outcomes.

While I was testing toys in Ann Arbor I tested hollow prism I fortuitously found out that “Hollow prism” is a great demonstrator to show underpressure. When I tried to empty the hollow of prism from water nothing happened because water surface tension and underpressure kept water inside the prism. I was very enthusiastic about that occurrence so I know it will work well with students.




Laws of thermodynamics

At the beginning I did not know that I could find toys that explain laws of thermodynamics. When I was visiting Arbor Scientific I saw “Reversible Thermoelectric Demonstrator” and realized that with that toy 2nd law of thermodynamics could be explained.

To explain 1st law of thermodynamics there has to be toys that Pressure-Volume diagram could be explained. With “Elasticity of Gases Demo” pV-diagram can be made in constant temperature. I found also “Fire Syringe” where rapid increase of pressure creates fire. Later when I was testing toys with my colleague Vijaya Sudha Narayanan (Sudha) from India I noticed that with “Water rocket” rapid decrease of pressure creates vapor in the bottle. That is as the pressure crashes down rapidly and thus decreases temperature and dew point is reached in bottle. The same experiment can be done with “Pressure Pumper Kit”. After these experiments student should know how to explain physics in a “Drinking bird”.

“Reversible Thermoelectric Demonstrator” and “Ice melting blocks”, are meant to demonstrate zeroth law of thermodynamics. With these new toys I can demonstrate laws of thermodynamics expect third law, which is more theoretical explanation. I’m very excited about my findings because it is the first time I have found a way to demonstrate this phenomenon.






Energy

Energy is phenomenon with wideappication and which is part of almost every physics courses. I tried to find toys that could explain energy transformation processes or where conservation of energy could be explained. For most of the energy toys I had some experience before. So “Radiometry”, “Colliding Steel Spheres”, “Magnetic accelerator” and “Euler’s disc” were tested in practice before I left Finland. In these toys there are interesting aspects physics to demonstrate transformation of energy.




Light behavior

For light behavior I planned to have “Laser viewing tank” to explain how light travels through boundaries. It looked great in pictures but when I was testing it in Ann Arbor I found out that it didn’t work the way I wanted. Then I received information that I couldn’t use green laser in that demo because of Finnish legislation. “Laser viewing tank” is quite expensive and most schools have already good tools to demonstrate light. Due these factors I chose not to have Light behavior in the “Physics Toys –book”.

Colors

From the beginning I planned on having colors to be one selected phenomenon in book. Colors have great influence in everyday life and in my opinion there are a lot of physics principles involved in colors.

I had earlier selected “Hollow Prism” to demonstrate pressure but it is really used to demonstrate dispersion (spectrum) of white light. Colors may form from white light in “Newton’s Ring Apparatus” because of reflection and interference.
With “Quantitative Spectroscope” diffraction can be demonstrated and it is a great tool to observe spectrum of different light sources. These toys describe different ways to create colors from white light.



White light can be formed from different colors. Additive colors can be demonstrated with “RGB Snap Lights and spinner”, which I had used before and found it very interesting and reliable. President of Arbor Scientific Peter Rea recommended a new toy called “White Lightning Stick” to demonstrate additive colors. It is replacing the toy I was looking for and after a short test it was easy to approve that toy.

One month after my Ann Arbor trip I went with Sudha to attend a Science Teachers convention at New Jersey. There I took part to Buzz Putnam’s workshop: Exciting demonstrations using “cool tools” for Light, Color, Sound & Waves. One of the demonstrations was using “Color Addition Spotlights” tool to create white light with additional color spotlights. The demo is too expensive for the kit and it uses a different electrical system so I developed a cheaper experiment with the help of Sudha and my mentor from UMD Dr. Matthew Bobrowsky using “Electromagnetic Flashlight” and filters.

After additional of colors also subtractive colors have to be demonstrated. That can be done with “RGB Snap Lights and spinner”. The same phenomenon can be explored with “Quantitative Spectroscope”, “Electromagnetic Flashlight” and filters.

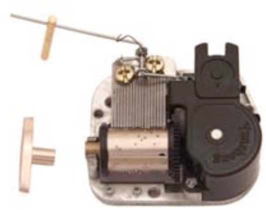




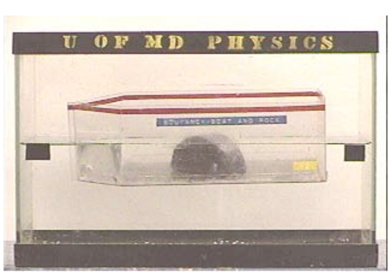
Sound,
Even though sound physics is not covered to a very large extend in the Finnish curriculum I concentrated only on the phenomena called resonance in sound. As resonance is based on interference and standing waves so “Standing Wave Kit” is useful to demonstrate physics in sound. From Buzz Puttman’s workshop I got an idea to add “Boomwhackers” which explains standing waves in plastic tubes in a very funny way. I had experience about “Singing rods” earlier so it was easy to add that toy to the kit. With help of Matthew Bobrowsky I was able to build a demo using toy called “Sound tube” where moving air creates sounds in a corrugated plastic tube.

One very happy occasion happened in Muncie Indiana when I visited Burris High School and I met my classmate Mike Dodrill from Ball State University. We studied there in Dr. Jim Watson’s “Teaching physics (with toys)” –class and he is teacher in high school like me. From his lab I got an idea to use an old toy “Music Box Mechanism” to demonstrate resonance.



Buoyancy
In my opinion buoyancy is one of the most interesting physics phenomena. Buoyancy is based on Archimedes’ principle, which is pretty difficult for students to understand. Archimedes’ principle basically means that force of buoyancy is equal to weight of displaced fluid. To make buoyancy understandable weight of displaced water has to be explained. I couldn’t find a proper boat or submarine to demonstrate it. Luckily Matthew Bobrowsky showed me how they demonstrate buoyancy in the University of Maryland so I’m building a toy, which uses boat and “Steel Sphere Density Kit” from a company called Educational Innovations. Another ways to explore weight of displaced fluid is to use “Cartesian diver” , “Hot Air Balloon” or “Galileo’s thermometer”.






Two dimensional motion (2D)

There are many different ways to demonstrate 2D motion. This phenomenon was easiest to me because I had experience with most of the toys. “Vertical Acceleration Demonstrator” is an old demonstration tool, which is very effective in classroom because it surprises students. I saw one version of “Ballistic Car” in UMD’s Physics lab and luckily found it at Arbor Scientific. It is just another way to demonstrate vertical and horizontal movement.

In Ann Arbor I saw the “Energy Lab” where they used a toy car, speedometer and ramp to measure how far will the car fly in air. At the beginning it seemed too expensive but when I realized how many different demonstrations I could create with it and how interesting that would be to students. I decided to add “Energy Lab” to the kit.

I have had some experience with “Monkey Hunter” and I think it is a great toy but it is very expensive. Peter Rea recommended that I try “Air-Powered Projectile” instead. It is a rocket based on air pressure where it can be shot with angle to air. I tested it with Sudha and I was allowed to try in Joseph Boettcher’s physics lesson in Montgomery Blair High School. Students were so enthusiastic to do the experiment that it convinced me to select the toy for the kit.




Angular momentum

Angular momentum is one of the most difficult topics along with Electromagnetic induction for Finnish High School students. It is important to make these topics more life related to everyday life for the students. I concentrated on conservation of angular momentum, which needs hands-on experiments and toys to make the phenomena easier to understand.

I have had experience of the “Rotating Platform” where students can experience for themselves how angular momentum affects to them. “Gyroscope” and “Power Ball” were also familiar and both of them are hands-on activities so students can feel and sence angular momentum. From Ann Arbor I found two new cool toys for explaining angular momentum. “IR Controlled UFO Flyer” and “Perpentual Top” are something new for Finnish science teachers.



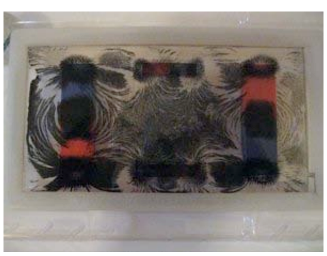


Circular motion

I ordered “Flying pig” just out of curiosity. When I got the toy I was so excited about the physics in the toy that I added one more phenomenon to the “Physics toys” – book. I’m sure that this toy will be a success in science classes in Finland next year. With one toy students can explore circular motion and do many different experiments to calculate different variables.

Magnetism

In magnetism I focused only on the properties of a magnetic field. I wanted to find a device that shows a magnetic field in three dimensions. I have one that kind of toy in my lab back home but it is not manufactured anymore. Arbor Scientific have one but it is too expensive for the kit. I tested “Viewing film” but it didn’t work the way I wanted. Finally I found “Magnetic Field Pattern Window” from Educational Innovations and it works well for the purpose I want. Using a toy called “Magnaprobe” three-dimensional observations can be done by students with hands-on activity. “Magnaprobe” gives a very good picture of magnetic field lines, directions and forces in magnetic fields. “Small Clear Compasses” are very useful demonstration tool to explore magnetic fields in coil or around magnet. I haven’t seen those in Finland so I think many schools will be interested of having them. Magnetic field of one magnet exerts forces on another magnets and “Levitron” is a very visual and cool tool to demonstrate forces along angular momentum. Levitron’s magnet may be also used also to observe its magnetic field.



Electromagnetic induction

Electromagnetic induction is very widely covered in the Finnish curriculum. In the “Physics Toys” -book I’m focusing on eddy currents and on the principle of how electromagnetic energy is created. I had some experience with the “Lenz law apparatus”. I tried to extend the demonstration so that the difference between eddy currents in different metals could be percieved. This tube is made from copper so if I can get the same dimension of tube but made from some other metal it will be effective.

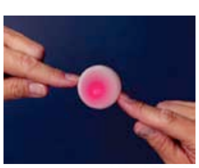
To demonstrate how electromagnetic energy is generated there are great toys to explain it like “Electromagnetic Flashlight”, “World’s simplest motor” and “Genecon”. With “Genecon” you can create electricity and also restore it to a “1 Farad Capacitor”. After restoring “Genecon” works as electromagnetic motor. “Perpetual Top” is a toy udes to demonstrate angular momentum but in order to explain how the toy works students have to know about electromagnetic induction.



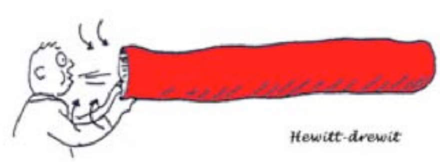


Bernoulli’s effect.
I wanted to have Bernoulli’s effect in the “Physics toys” book as it is a very interesting phenomenon to demonstrate. I got some suitable explanation from Matthew Bobrowsky about Coanda effect, Bernoulli’s effect and Magnus effect. I just couldn’t find enough toys to add Bernoulli’s effect in my book. After a short discussion with Sudha I decided to have this as an additional student projects because some of these experiments you can create just using cheap equipments like papers and straws.

Fun
I have selected some toys that are very interesting but are not included under any particular phenomena. So I collected all these toys under the section ”Fun”.This section is just meant to add interest in physics classes. These toys are included to the kit because they are cheap and include great physics concepts. Some of these cool toys are “Energy Ball” to demonstrate electric current, “Eyepops” (Coanda effect), “Rattleback” (friction/energy/angular momentum) “Mirage” (optics), “Fun Fly stick” (electrostatics), “Doppler ball” (sound behavior), “Bernoulli Bags” (Coanda) and “Balloon helicopter” (sound, Coanda),





Chapter 3: Structure of the "Physics toys" –book

In this chapter I explain how I'm going to present each phenomena in the "Physics toys" –book. I selected "Laws of Thermodynamics" and "Colors" to explain my idea I have. First the big picture around phenomenon is described, which according to my studies is important to girls. Then each phenomenon is approached with few different kinds of demonstrations. Each demonstration will have a slightly different angle to the phenomenon. After each demonstration students have to explain what happens and teacher is recommended to use pair sharing if possible. Eventually there will be answers and description about phenomena with physics laws. In the "Physics toys" -book a written explanation to each demonstration is given. Teacher can choose how explanations are given to students.

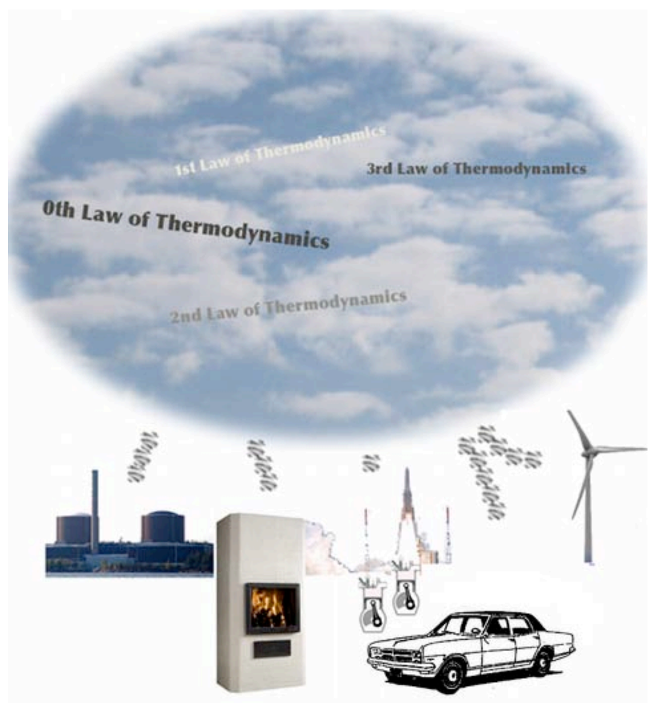
Laws of thermodynamics -phenomenon

Before students study "Laws of Thermodynamics" -phenomenon in the "Physics Toys" -book they must have some knowledge about energy, gas laws, conductivity and pressure.

Background information

First surroundings of topic will be presented with easy language followed by understandable picture:

Thermodynamics is a science of energy conservations (physics of heat, energy, gas and entropy). Thermodynamics developed after steam engine was invented early 1800. All thermal reactions follow certain patterns so in early 1900 Laws of Thermodynamics were created. Thermodynamics includes so much everyday physics from fireplaces to cars and to nuclear plants. It is important to learn and understand what different laws means and how they influence to everyday life.



0^{th} Law of Thermodynamics

First students learn 0^{th} law of thermodynamics by doing demonstrations 1 and 2.

Demo 1.

In the demonstration there are two plates with ice cubes. One is a thermal insulator and other one is a thermal conductor. An ice cube placed on the conductor melts in a few minutes while the icecube placed on the insulator doesn't melt at all. Students will answer to the following questions:

<u>Which plate has higher temperature?</u>
<u>From where does thermal energy transfers to the ice cube?</u>

Students try to find out the answers in small groups. They will explain their answer to teacher.

Demo 2

In the second demonstration students have to measure the temperature of each plate just to make sure that there is no misconception in what causes ice cube to melt. Students will answer to following questions:

<u>Why is the thermal conductor cooler?</u>
<u>Why is the table under thermal conductor is cold?</u>
<u>Explain how a thermometer works?</u>

Explanation

In Demo 1 and Demo 2 thermal energy was transferred from the plate, which is a good thermal conductor to the ice cube. Therefore the ice cube on the thermal conductor melted faster and the plate's temperature thus becomes lower. Thermal energy will transfer as long as there is temperature difference.

0th Law of Thermodynamics:
"In an isolated system objects will reach thermal equilibrium"

Thermal energy from temperature probes in Demo 2 will transfer to or from the probes as long as there is temperature difference in system.

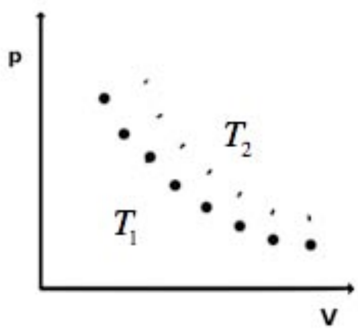
"If two systems are in thermal equilibrium with a third, they are also in thermal equilibrium with each other."

1^{st} Law of Thermodynamics

Students get to know the 1st Law of Thermodynamics by demonstrations 3,4,5 and 6.
In Finnish curriculum calculus is not a part of high school physics so the theory of thermodynamics is explained without Calculus.

Demo 3

To explain work done by a gas pV-diagram has to be introduced. Students are asked to create two different pV-diagrams with two different temperatures with "Elasticity of Gases Demo". Pressure will be calculated from force (weight) and area (tube).



Demo 4

With "Pressure pumper kit" pressure can be added to the bottle. When pressure increases the temperature also rises. After a short while temperature decreases to room temperature.

Why does temperature rise when pressure is increased?
Why does temperature decrease after a short period of time?

Demo 5

The second demo for the 1^{st} Law of Thermodynamics a student can experiment with the rapid change in pressure by using a "Fire Syringe".

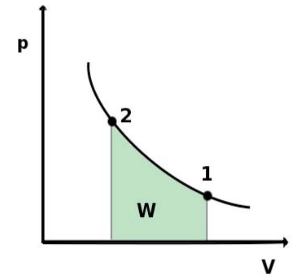
Why does the cotton in the tube catch fire?

Demo 6

In Demo 7 by using a "Pressure pumper kit" a rapid change in pressure can be made to form clouds inside the bottle.

Explain why clouds are formed in bottle.

Explanation

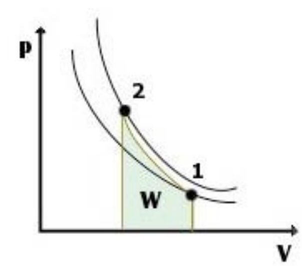


In Demo 3 the relation between pressure and Volume is studied. To decrease volume in system higher pressure is needed. To decrease volume also work has to be done on the system. When weights are released the system works to the gas expands to the riginal volume.

In Demo 4 relation between temperature and work can be understood. When work is done on the system by increasing pressure, temperature rises. After a short while temperature difference between bottle and room temperature is neglected by radiation.

1st Law of Thermodynamics:
Change in internal energy equals change in heat added to the system and work done to the system.

$$\Delta U = \Delta Q + \Delta W$$



In Demo 5 and 6 one special process from the 1st Law of Thermodynamics case called adiabatic process took place. Adiabatic process is a thermodynamic process where heat is not transferred in or to the working fluid or the thermodynamic process is so rapid that heat cannot transfer through surface.

2nd Law of Thermodynamics

Students get to know to 2nd Law of Thermodynamics with Demos 7 and 8.

Demo 7

In this demonstration students work with the “Reversible Thermoelectric Demonstrator” where they can see how temperature difference between two cups is decreasing and at the same time producing energy. Students will have to answer the following question:

<u>Where does the motor gets the energy to operate?</u>

Demo 8
Demo 8 is the reverse of demo 7. With electricity (work) one glass of water is cooled and another is heated.

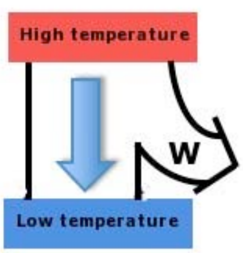
From these experiments students understand how the temperature in the glasses change. They also have to come up with the idea of why and how it happens.

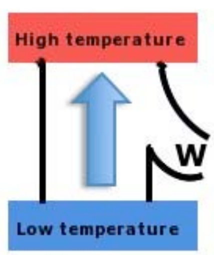
Explanation
Entropy and 2nd Law of Thermodynamics is explained briefly.

Entropy is a statistical quantity, which expresses the level of disorder in system.

2nd Law of Thermodynamics:
Isolated system tends to go towards greater disorder a.k.a. towards greater entropy.

In Demo 7 and 8 examples of 2nd Law of Thermodynamics were presented. Demo 7 is an example of heat engine where heat energy is transformed to work. In demo 8 thermal energy is transferred from one glass to another and energy is needed, so it is taken from the cell i.e electrical energy is used..





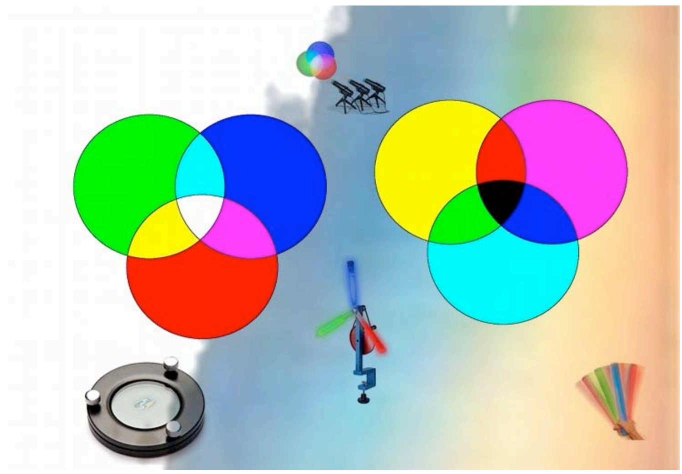
Colors -phenomenon

Before students study "Colors" -phenomenon in the "Physics Toys" -book they have some knowledge about physics of waves.

Background information

First students study a short introduction of the topic.

> All colors that we see are electromagnetic radiation. Human eye is sensitive to electromagnetic radiation where wavelength is between 400nm – 700nm. Human eye has three different receptors called cones for colors. All of them are sensitive to certain wavelengths. One is sensitive to longer wavelengths, one to middle wavelengths and one for shorter wavelengths. In eye there is also rod shells, which are sensitive to brightness of the light. Brain is creating color from the information it gets from the eye. Color is combination of the information from cones and rod shells and therefore color that human sees might not the same that can be measured from light source.



Creating colors from white light

Students learn different ways to create colors from white light by doing demos 1 to 3.

Demo 1

In this demonstration students use a "Hollow Prism" to create spectrum. First they will fill the prism with water and then with alcohol. Students will answer following questions.

<u>Why are colors are formed when white light passes the prism?</u>
<u>Why is the spectrum is different with different liquid</u>?

Demo 2

Students will use "Newton's Ring Apparatus" and white light source to create colors. Students will answer the following questions.

<u>Explain why you can see colors in glass plate?</u>
<u>Look at the plate from different angles, Why do the colors change?</u>

Demo 3

In this demo students will use the "Quantitative Spectroscope" to observe spectrum from different kind of light sources like light bulb, sunlight, electromagnetic flashlight and fluorescent lamp.

Explanation

In Demo 1 colors are formed by dispersion. White light refracts in a prism creating a spectrum where each color is visible.

Refraction:
"Change in direction of wavelength due the change in its travelling speed."

Dispersion:
"Speed of electromagnetic radiation in medium depends on wavelength. Therefore refraction index is not equal. Dispersion can be seen when different wavelengths of white light refracts in a prism creating spectrum"

In Demo 2 colors are formed by reflection, refraction and interference. As "Newton's Ring Apparatus" has two glass plates where one is planoconvex while the other is flat and different colors are slightly separated. Because of interference at certain angles some colors are more intense than others. That's why observing angle affects to colors that are seen.

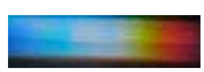
Interference:
"Interference is addition of two or more waves creating a new wave using superpositioning."

Reflection:
"Reflection is wavelength's change in direction when it interfaces boundary of two different media and reflects towards media where it was originated"

In Demo 3 different spectrums from different sources.


Fluorecent Lamp


Light Bulb

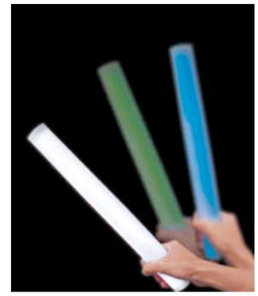

Sun Light

Additive and subtractive colors

In demonstrations 4,5 and 6 students will create white light with additive colors and get to know what subtractive colors are.

Demo 4

In this demo students will use "White Lightning Stick" to find out what colors are needed to create white light.



What colors do you need to create white light?
How do computer screens create their colors?

Demo 5

In this demonstration 3 "Electromagnetic Flashlight" and filters are used to create white light. Students will answer following question.

What is the color of the shadow cast by a white object placed in its path?

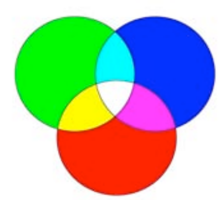
Demo 6

"RGB Snap Lights and spinner" might be a demonstration that the teacher will do in front of all students because as snap lights last only for 12 hours.

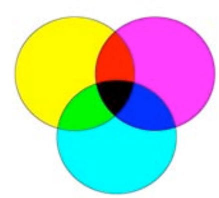
First the teacher will show additive colors. Then by using black tape each of the spinners RGB lights are blocked to create subtractive colors.

Explanation

In Demo 4 three different colors are used to create whitish color. These colors are red, green and blue also called primary colors. All the other colors can be created using these three colors. In computer screen each pixel has "lamp" for each primary color. The eye will mix lights from the lamps together creating colors.



In Demo 5 subtractive colors are formed. Shadow block light from one source. So if red is blocked color of the shadow is cyan.



In Demo 6 all these phases from additive to subtractive colors can be seen when teacher will demonstrate the experiment.

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