Session Tu 3a: Poster session

D. Sebestyen: "Art and physics – a meeting point of two cultures" (3p)

I. Zotkin et al: "Research in meteor flows evolution using new generation intellectual device" (3p)

B. Mushailov and A. Kaloshin: "Researches for predicted resonant objects behind Jupiter orbit" (6p)

K. Turzyniecki: "On the process of electron acceleration and synchrotron radiation" (4p)

F. Albuquerque et al: "The body concept and the teaching of sciences" (6p)

T. Romanovskis and R. Mahnke: "Physics of non-physical phenomena: traffic jams" (7p)

H. Onishi and H. Kawakatsu: "Entropy education for all" (9p)

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D. Grech and Z. Mazur: "Financial stock market behind the Brownian motion" (7p)

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C. Caruana: "Teaching radiation physics concepts and techniques to archaeology students" (8p)

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S. Markova and D. Klykov: "New principles of educational texts creation" (3p)

C. Fazio et al: "Modelling environments: two examples involving different learning strategies" (10p)

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J. Koupil and F. Lustig: "School measurement studio controlled by LabVIEW" (5p)

M. Enghag and J. Bernhard: "Miniprojects in physics give the students initiative and ownership to their learning" (15p)

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M. Martins et al: "Building a European virtual university - a thematic network approach" (6p)

G. Ireson: "Physics through the medium of sport" (3p)

K. Ojanen et al: "Co-operative teacher education: 'Physical methods in biological research' – an advanced course for senior high-school students at the university of Turku" (9p)

J. Smit and M. Lemmer: "Reaching new students in the north west province, South Africa" (4p)

N. Beverly: "Learning mechanics within the context of biomechanics" (9p)

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Art and physics - a meeting point of two cultures

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Art and reality

In the print called "Belvedere", created by M.C. Escher, a ladder begins inside and ends outside a building but can still be climbed normally. A man and a woman are looking out through two openings in the same wall, one directly above the other, although the man is looking away from and the woman toward us.

The main message of this print is the *impossible reality*, coming from the *correctly depicted details*. It warns the physics teachers that in order to give a correct overview of the real world, they should not make a similar mistake. It says to us that we have to open our students' mind also to the *relationships* between the chapters of physics, - besides teaching the separate chapters - otherwise they will have a false image about the realities of the world.

More generally, our final aim must be to help our students gain possession of an overview not only of physics, but also of the whole culture. On the way to reach this aim, and at the same time making physics more interesting and understandable, I try to find the meeting points of the so called "two cultures", between physics and art, history, or music.

The topic of this presentation is to show some ideas of how to create a connection between physics and art. I have classified the collected examples in three groups, expressing three aspects.

I. Works of art, as hypotethical models, visual, didactic explanations, or illustrations of an abstract theory in physics.

1. Examples disobeying physical laws

- **Perpetuum mobile**

Escher's print, the *"Waterfall"* is used in several physics textbooks as an illustration of the impossible *perpetual motion*. There is an impossible waterfall that feeds itself.

"The regular gravity affects the moving water, but the nature of space disobeys the laws of physics." (Hofstadter) [1]

- **Impossibility in a conservative field**

At the first glance Escher's print *"Ascending and descending"* seems to be a realistic depiction of a building and some monks. But as we know, there must be a mistake somewhere in a continuously descending, or ascending staircase, if it creates a closed curve.

This can be a good illustration of an impossible case when we teach the characteristics of the gravitational potential, or the potential in an electrostatic field.

The artist's own comment reflects his humour as well:

"The inhabitants of these living quarters would appear to be monks, adherents of some unknown sect. Perhaps it is their ritual duty to climb those stairs for a few hours each day. It would seem that when they get tired they are allowed to turn about and go downstairs instead of up. Yet both directions, though not without meaning, are equally useless. Two recalcitrant individuals refuse, for the time being, to take any part in this exercise." [2]

- **Frame of reference**

In the *"Gallery"* Escher depicts an *impossible juxtaposition of viewpoints*, showing an *infinite extent* at the same time and making the habitual application of the frame of reference unacceptable.

- **Perspective illusion**

Several illogical details are presented with a touch of humour in Hogarth's *"Absurd perspectives"* by consciously *breaking the rules of perspective*.

In Magritte's painting, in the *"Carte Blanche",* we also come across a physical impossibility: *The different planes of space are confused. The Lady is riding in the foreground and background at the same time.*

2. Structure of matter

The regular division of a plane and the symmetry make Escher's works known as illustrations of crystallographic chapters. The *"Sky and Water"* can be used to illustrate this problem:
"In the structure of a crystal, what is of greater physical importance, the atoms, or the spaces between the atoms?"
The base of this application can be found in Escher's words about this work:
"In the horizontal central strip there are birds and fish equivalent to each other. We associate flying things with sky, and so for each of the black birds the sky in which it is flying is formed by the four white fish that encircle it. Similarly, swimming makes us think of water, and therefore the four black birds that surround a fish become the water in which it swims." [2]

3. Expanding universe.

Martin Rees uses in one of his books Escher's works as models to explain the essence of the expanding Universe.
According to his comment on the print *"Cubic Space Division",* if the rods of the lattice are extending at the same rate, the nodes are moving away from one another, due to Hubble's law, but there is no preferred node and there is no centre of expansion.
In the very far past the Universe was probably in a much more pressed form, as we can see it today, approaching the horizon due to the finite speed of light. This can be illustrated by the *"Angels and devils".*

II. Physical laws, as forms of expression for artists or as bases of technical tools to create works of art or to make them enjoyable.

1. Optics

- **Mirror effect**

We can find a lot of works of art using the reflection made by mirrors.
The convex mirror in Jan van Eyck's painting*, "The Arnolfini Marriage"* makes it possible to show the total view of the room and the persons in it.
The example of *the optical effect as form of expression* is Magritte's *"False mirror",* illustrating an Austrian physics textbook.

- **"Anamorphic" works**

The optical illusion of anamorphosis means a distorted picture, which, without distortion, can only be seen from a special angle or in reflection in a cylindrical reflecting surface. The example of the first case can be Holbein's painting: *"The Ambassadors".* The skull on the floor is recognizable only from a special angle.

The example of the second case can be seen in Dali's works, as the next two pictures show. *"The female nude"* and *"Harlequin"* can be discovered in these pictures by using a cylindrical mirror.

- **Holography**

In the Dali Museum we can see Dali's first 3 dimensional collage, "*on whose technical aspects the Hungarian physicist Dennis Gabor, the father of holography, worked together with Dali"*, as I - being a Hungarian - read it proudly in the book of the Museum. [7]

- **Camera obscure**

A special type of the camera obscure, invented by Kepler, was probably used by Canaletto to create his paintings about Venice.

- **Painting with dots**

Seurat's paintings consist of countless tiny, colourful dots. It reminds me of the process how a *photo emerges from individual photon impacts*.

III. Works of art as models of the process of recognition and scientific thinking.

1. Model of scientific thinking

Escher's print *"Day and Night"* can be the model of scientific thinking.

Here we can see the progression of polders into the diamonds and, coming back to the real world at a higher level, the diamonds into the birds. This is similar to the two-way movement from the experimental observation to the abstract theory and, at the other level, by experimentally checking the theory, back to the real world.

2. Subjectivity in scientific thinking

The subjective element plays an important role in Vasarely's work, *"Gestalt"*: *the eye is able to change the protrusive figures and the elements turning up as concave figures.*

Extending this thought, we can illustrate the subjectivity inherent in observation, measurement and interpretation.

To find meeting points between physics and art, here we saw examples to show that some works of art can illustrate the theories of physics, some of them can be models of the process of scientific thinking and sometimes physical laws can help to create works of art or to make them enjoyable.

<u>References:</u>

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Research in Meteor Flows Evolution
Using New Generation Intellectual Device

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ABSTRACT

The preliminary results of application of new intellectual device "time - position sensitive detector of radiation " for registration of meteors and meteor rains are given.
On the basis of theoretical and observational data on distribution and evolution of meteor rains the fundamental problem of their origin and interrelations with concrete comet is considered.
The developed author's theory of tide evolution considerably raises the accuracy of comet's activity and non-stationary meteoric flows forecasting.
On the basis of mathematically proved classification of meteor flows and unification of their brightness the statistical estimation of small body movement distribution in near the Earth space is received. The population of some meteor and bolide flows by large fragments in determined. It is necessary to know it, first of all, because of increasing number of new space vehicles, launched into near the Earth space and in connection with the problem of comet-asteroid danger.
In the frames of the developed theoretical approach to two-frequency resonance phenomenon the role of "resonant" comets and asteroids in formation of meteor flows (rains) is estimated.
The establishment of correlation between meteor flows (rains) and parental body allows to find the answer to the question of centaur ("asteroids" of comet origin) identification.
To establish global monitoring of meteors it is supposed to create a permanent observational network on the basis of stationary expedition bases and departments of Moscow State University.

INTRODUCTION

Systematic researches of small bodies distribution in near the Earth space become rather urgent now due to the problem of comet-asteroid danger and growing amount of space vehicles. Because of their small sizes the direct observation of small bodies is not possible. They become visible only on burning in the upper layers of the Earth's atmosphere.
The meteor flows are original channels, by which comet substance gets on the Earth and becomes accessible for research. The comets consist of the relict protoplanet substance practically not changed in their nucleuses, therefore researches of meteoric flows can revile some questions of Solar system origin.
The meteoric observations are carried out by a number of separate professional observant groups now. The information in this field quickly becomes outdated, as the comet orbits and meteoric flows are changeable, and the technical devices, recording them, are improved quickly.
In the 60-ties of the 20-th century using wide-angle Shmidt telescopes, the set of qualitative meteor images (basic supervision for definition of meteor height) was received. Many astronomers thought, that researches cinematic meteor characteristics can be finished.
But it is not right. The meteoric flows population is changeable because of non-uniform distribution of particles along the orbit. Meteoric flows radiant can change because of the influence of comets - mother or the large planets. A part of flows are non-stationary. The most famous non-stationary

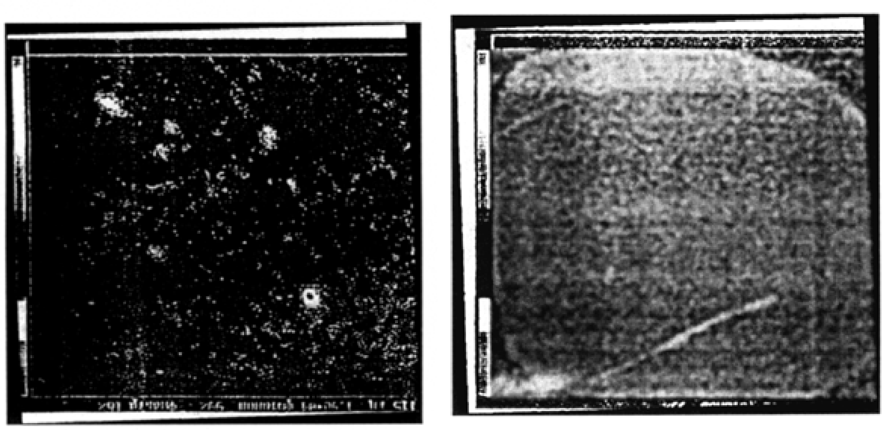
meteoric flows: Leonids, Draconids. In the time intervals between splashes such flows are become weak or completely disappear. For example, the rain Cityusid, was observed in the 70-tees of XIV century with density about 1800 meteor / hour! This flow has completely disappeared during the next years.
Some assumptions of possible appearance of some new flows and about splashes of some weak flows in future are made on the basis of the comet's orbit evolution theory. For example, the hypothetical flow of Shwassman-Wahsman 3 comet, which should approach the Earth orbit in 2006 and 2022, or Vartanian comet (2018).

METEORIC FLOWS EVOLUTION

The modeling of particle distribution of meteoric substance along the orbit shows that it concentrates in narrow and long pipes, instead of extended clouds, as it was supposed earlier. Therefore flows in one year can give significant number of meteors, and in other they can nearly disappear.
The constant monitoring of meteoric flows would allow to prove the correctness of this assumption, and to check a hypothesis about existence of complicated complexes from comets, asteroids and meteoric flows, connected generically.
Particles of meteoric flows, are moving in space on elliptic orbits. The comparison of orbital elements of meteoric flows and comets will allow to prove their common origin. But gravitational influence from massive bodies of Solar system, first of all of large planets, can result in essential changes of orbits of meteoric flows and comets, and consequently, to appearance of pseudo-correlation between them.
To find generality of meteoric flows and appropriate comets origin it is necessary to know their physical-chemical properties, including spatial distribution of meteoric particles substance clots (definition of their structure).
This comparison has become possible with the creation of new generation intellectual device - " time - position sensitive detector of radiation ", allowing to receive object images with real spatial coordinates, and also high-quality spectra. With the help of this detector we will be able to determine not only coordinate, but also time of photon arrival.
This device surpasses in sensitivity and resolution all existing modern high-sensitivity digital video-cameras (with a wide field of view), and also ccp-matrix.

EXPERIMENTAL RESULTS

Figure shows the results of observations, using mirror telescope SAI MSU, of the chosen part of the sky without the high-sensitivity detector (fig. a) and with it (fig. b).
After realization of laboratory testing of the detector with quickly moving objects, this device was successfully applied during the observations of Lirid meteoric flow (April 21-22, 2002).



METEOR MONITORING NETWORK

The Moscow State University is the largest university in Russia. It has many stationary educational bases of “field” departments both on the territory of Russia and on the territories of the nearest states. Among such bases it is possible to name:

Ust-Port
(geographical department) 69,5 ^{o} N (latitude), 84 ^{o} W (longitude),

White sea biological Station
(biological department) 67 ^{o} N (latitude), 33 ^{o} W (longitude),
3. Zvenigorod station
(biological and
geographical. department) 55,8 ^{o} N (latitude), 37 ^{o} W (longitude),

4. Bakhchsarai station (Ukraine)
(geographical. department) 44,8 ^{o} N (latitude), 34 ^{o} W (longitude) .

MSU departments:

5. **Puschino** 55 ^{o} N (latitude), 37,5 ^{o} W (longitude),

6. **Sevastopol (Ukraine)** 43 ^{o} N (latitude), 33 ^{o} W (longitude),

7. **Astana (Kazahstan)** 48 ^{o} N (latitude), 75 ^{o} W (longitude).

Researches of Predicted Resonant Objects behind Jupiter Orbit

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ABSTRACT

In the early authors works the most probable orbits of hypothetical asteroids (between Jupiter and Saturn orbits), moving in orbital Lindblad resonance 1:2, 2:3 with Jupiter and 2:1 with Saturn were calculated on the basis of external and internal variants of the three bodies task limitation in account of century and resonant influence from Saturn. The estimation of probable orbits is based on the natural assumption that required asteroids can exist for a long time, if their orbit elements are in the field of orbital stability.

Now 4 asteroids are already have been found in precalculated zones, moving in orbital two-frequency resonance 1:2 with Jupiter:

2000 GM137 (a = 7. 867 a.u., e = 0.120, i = 15 º .858)
2000 VU2 (a = 6.951 a.u., e = 0.555, i = 13 º .744),
1998 HO121 (a = 7.111 a.u., e = 0.587, i = 11 º .989),
2001 QF6 (a = 7.123 a.u., e = 0.687, i = 24 º, 302) accordingly

and one asteroid in 2:3 resonance with Jupiter

2000 QJ46 (a = 5.911 a.u., e = 0.674, i = 4 º .382). They are all in Lindblad resonance 2:1 (internal variant of commensurability) with Saturn. The orbits of all five asteroids are situated in precalculated, most probable zones of required resonant objects search.

Since 2000 in Semeiz observatory of RAS using the telescope "Ceiz-1000" CCD ST-6, and also in international observatory "Peak Terskol" (2-meter telescope " Ceiz "with CCD“ Photometrics ") the search of specified precalculated objects are carried out.

The preliminary results of our own search observations reviled the detection of some more candidates to the required resonant objects. But they were observed on the limit of applied equipment sensitivity.

SMALL BODIES in SOLAR SYSTEM

In Solar system at the distance from the Earth not exceeding 100 a.u. the total number of small bodies with sizes more than 1 km (body of smaller diameters is called meteoroids) is approximately 1 billion. According to the place of their birth and their physic-chemical structure, these bodies are subdivided into two types: asteroids (small planets) and comets.

ASTEROIDS

Asteroids are bodies formed between the orbits of Mars and Jupiter. The comets were formed in an external part of Solar system - behind the orbits of Uranium and Neptune.

The significant part of asteroids is situated in tore belt ("the main belt") between orbits of Mars and Jupiter. Asteroids moving along libtation - steady orbits caused by average movement resonance with Jupiter (Gecuba, Gilda, Tula groups) and with Mars are among them. Asteroids with diameters more than ~100 km, are steady at splitting, smaller asteroids can be products of splitting.

Orbit eccentricity of asteroids of the main belt are 0,1÷0,3, but in some cases it reaches 0,8. Due to this, some asteroids penetrate inside Mars and Earth orbits.

COMETS

The formation of comets on the periphery of planetary system occurred owing to gravitational instability in dusty subdisk, divided into a set of dusty condensations, transformed into comet nucleuses during their evolution. Now many comets coincide the boundary of Solar system (~10^5 a.u.). Some comet families with aphelia, between orbits of Jupiter and Neptune are observed much closer to the Sun.

The main part of short-periodical comets with small orbit inclination to the ecliptic plane was formed in a Kuiper belt, situated at distance ~35 ÷ 70 a.u. from the Sun.

More than 500 objects of this belt with orbit large half-axes from 35 up to 50 a.u now are found. Nine objects of asteroid type moving along quasi-circular orbit in the vicinity of steady triangular libration Neptune points are "troya asteroids" belonging to Neptune family. They are found at distance from 32 up to 35 a.u. from the Sun. Orbit eccentricity of Kuiper belt bodies are small, and their diameters are 100÷300 km. The diameter of the biggest objects of Kuiper belt can achieve 1000 km (2000 WR 106).

At certain assumptions, because of gravitational influence of planets - giants and large bodies behind Neptune belt, some objects of Kuiper belt could move to Neptune orbit and further to the Sun during the life of Solar system. The concrete estimations of substance mass moving to the Sun of from behind Neptune belt depend on mass distribution in the belt and orbit elements, which is still unknown now.

The less massive objects (comet nucleus) of Kuiper belt can move much closer to the Sun, than more massive objects of this belt.

RESONANT ZONES

In the internal part of Kuiper belt the significant role is played by resonance of average movements with Neptune and Uranium. Behind Neptune objects can exist for long time, if the elements of their orbits correspond to the areas of steady movements (areas of orbital stability).

Libration steady objects of Kuiper belt can be kept for long time only in the average movements field: 6"9÷7".4, 8".6÷8".8, 10".71÷1".2, 12".2÷12".4, 12".8÷13".1, 14".3÷14".6. Their stability is connected with the absence of "approaches", i.e. the existence of non-zero distance between Neptune, Uranium and the object. Pluto is also connected by Lindblad orbital resonance 2:3 with Neptune.

Libration orbits in resonant zones are close to the steady stationary solution. It provides their "survival". Despite the century disturbances from planets – giants: Uranium, Saturn, Jupiter, and also "resonant influence" of Uranium and mutual gravitational influences behind Neptune bodies, these bodies can be caught by Neptune (and Uranium) in an orbital resonance. In this case they can exist for long time, having orbital stability.

More than 200 libration-steady objects moving in orbital resonance of the lowest orders with Neptune and Uranium are found already. More than 50 objects, approximately 100 km in diameter are among them. The number of similar objects named Plutonino can be thousands.

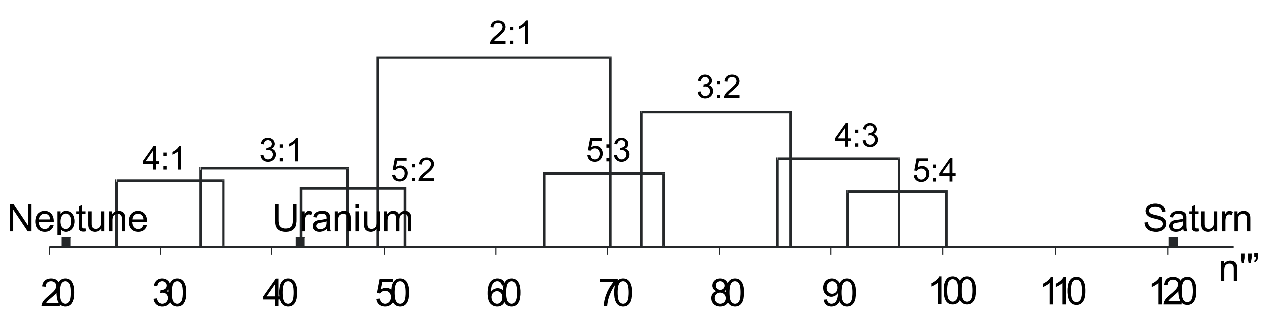
Kuiper belt objects, discovered since 1992, do not allow to explain the deficiency of observable mass of Solar system substance, even in the account that the greatest part of Coiper belt bodies cannot be observed. The number of these objects can be ~10^5. The existence of several behind Neptune belts is possible in the field of 100≤ a ≤2000 a.u. Discovery of very large behind Neptune object 2000 WR 106 with diameter about 1000 km allows to assume the presence of large planets behind Neptune orbit.

The authors have calculated 10 Lindblad hypothetical resonant zones (areas of average movements) behind Kuiper belt in the interval 60 ≤ a ≤ 2000 a.u.

Orbital elements of the new objects testify that their average movements belong to the resonant zones calculated by the authors.

name	large half-axis a (a.u).	eccentricity e	Inclination i^0
2000 CQ 105	57.161	0.389	19.635
2000 YW 134	57.881	0.281	19.770
2000 YC 2	58.691	0.381	19.839
1999 RJ 215	59.393	0.417	19.742
2001 KG 77	59.574	0.426	15.627
1999 DG 8	63.096	0.050	34.531
2000 PS 30	63.786	0.452	2.773
1999 CF 119	90.319	0.572	19.665
1999 CY 118	91.278	0.621	25.567
2001 FZ 173	91.811	0.639	12.165
1996 GQ 21	92.994	0.589	13.361
2000 OM 67	97.646	0.598	23.392
1999 TD 10	98.857	0.876	5.957
1999 RZ 215	100.844	0.693	25.528
1999 CZ 118	115.331	0.673	27.731
1995 CN 55	115.546	0.935	4.927
2000 PJ 30	118.749	0.759	5.726
1999 RD 215	119.467	0.683	25.912
2000 CR 105	231.069	0.809	22.708

a



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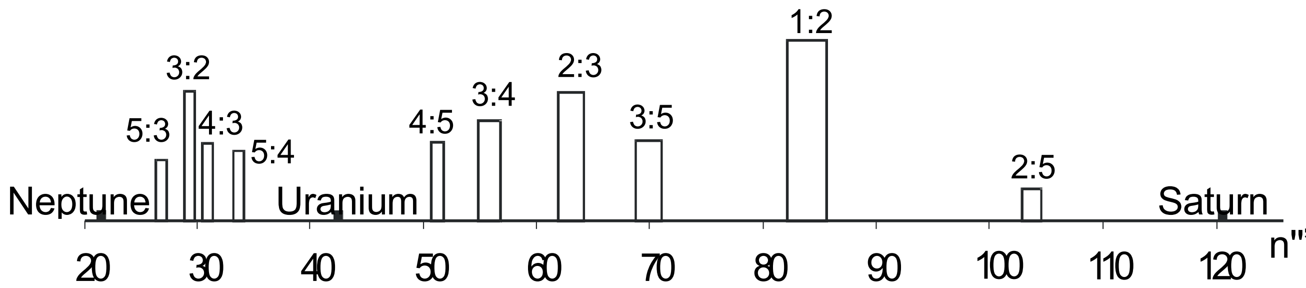

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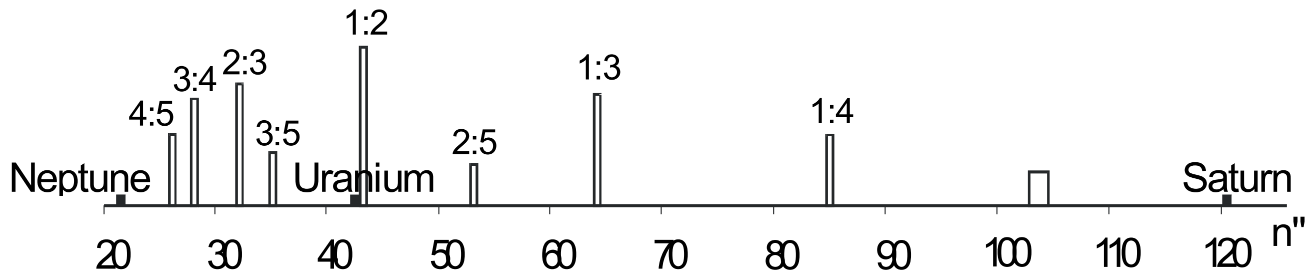


The arrangement of various order and multiplicity resonant zones, corresponding to commensurabilities with Saturn (a), Uranium (b) and Neptune (c).

On the basis of the analytical decision of the limited elliptic three bodies task, in view of overlapping resonant zones of planets - giants, within the framework of the partial determination concept, the zones of average movements and the characteristics of steady orbits of hypothetical resonant objects between the orbits of Saturn, Uranium and Neptune were found. The determining influence on the parameters of such zones is rendered by orbital resonant interactions with planets - giants.

Three objects are already found now in precalculated resonant zones between Saturn and Uranium moving in an orbital commensurability 2:5 with Saturn:

2001 SQ73 (a = 17.504 a.u., e = 0.178, i = 170.449),
Asbolus (a = 17.910 a.u., e = 0.618, i = 170.637),
1999 XX143 (a = 18.029 a.u., e = 0.460, i = 60.759).

And 9 objects between orbits of Uranium and Neptune connected by two-frequency orbital resonance 1:3 and 1:4 with Saturn are found:

2000 SN331 (a = 19.731 a.u., e = 0.047, i = 110.554),
1998 QM107 (a = 19.976 a.u., e = 0.134, i = 90.380),
Pholus (a = 20.334 a.u., e = 0.574, i = 240.703),
2001 XA255 (a = 20.528 a.u., e = 0.266, i = 100.441),
2000 CO104 (a = 22.146 a.u., e = 0.054, i = 30.233),
Nessus (a = 24.403 a.u., e = 0.517, i = 150.653),
2001 KF77 (a = 24.410 a.u., e = 0.152, i = 40.432),
1996 RX33 (a = 26.273 a.u., e = 0.289, i = 80.990),
1998 TF35 (a = 26.354 a.u., e = 0.381, i = 120.621).

Within the framework of external variant of three bodies limited task in account of century disturbances from Saturn and resonant disturbances from Saturn (internal variant) the most probable orbits of hypothetical asteroids, taking place in orbital commensurability with Jupiter and Saturn between their orbits were found.

Since 2000 in Semeiz observatory of RAS using the telescope "Ceiz-1000" CCD ST-6, and also in international observatory "Peak Terskol" (2-meter telescope " Ceiz "with CCD“ Photometrics ") the search of specified precalculated objects are carried out.

Now four asteroids moving in orbital 1:2 Lindblad resonance with Jupiter are found already:

2000 GM137 (a = 7.867 a.u., e = 0.120, i = 150.858)
And 2:3: 2000 VU2 (a = 6.951 a.u., e = 0.555, i = 130.744),
1998 HO121 (a = 7.111 a.u., e = 0.587, i = 110.989),
2001 QF6 (a = 7.123 a.u., e = 0.687, i = 240.302),
and one asteroid with 2:1 Lindblad resonance with Saturn (internal variant of commensurability):
2000 QJ46 (a = 5.911 a.u., e = 0.674, i = 40.382).

The minimal values of the observed star magnitudes adequate to the most favorable observation conditions of the given asteroids lies in the interval $17^m.2 \div 18^m.9$, and maximal achieve the 25-th star magnitude.

The orbits of all five asteroids belong to precalculated most probable zones of required resonant objects search.

CONCLUSIONS

The significant number of orbital resonance between average movements of the large planets, companions, asteroids, short-periodical comets is observed in Solar system. The maximal amplitudes of resonant effects are achieved at lowest orders resonance. For this reason the resonance of the high orders (fourth and higher) in dynamic systems do not cause any appreciable effects.

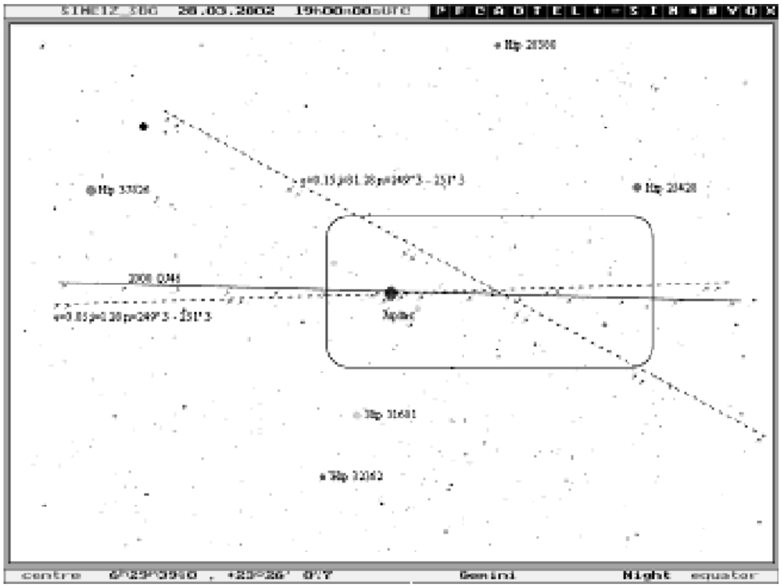
The orbital resonant interactions result in stability of orbits with libration movement type. The bodies seized in resonance, can exist for long time, having orbital stability.

Predicted in last decade by the authors of the present work the new class of objects behind the Jupiter orbit (between orbits of planets - giants Jupiter and Neptune, and also resonant objects behind Neptune) are found now.

The development of observation equipment and realization of systematic search supervision will allow to fill the discovered family of "resonant bodies" of Solar system in the near future.

The research of orbital resonance is the extremely urgent task at the decision of fundamental cosmological problem connected with the origin and evolution of Solar system.

Areas of resonant asteroids localization between orbits of Jupiter and Saturn a- case of 1:2 commensurability with Jupiter, b - case of 2:3 commensurability with Jupiter, c - 2:1 resonance with Saturn.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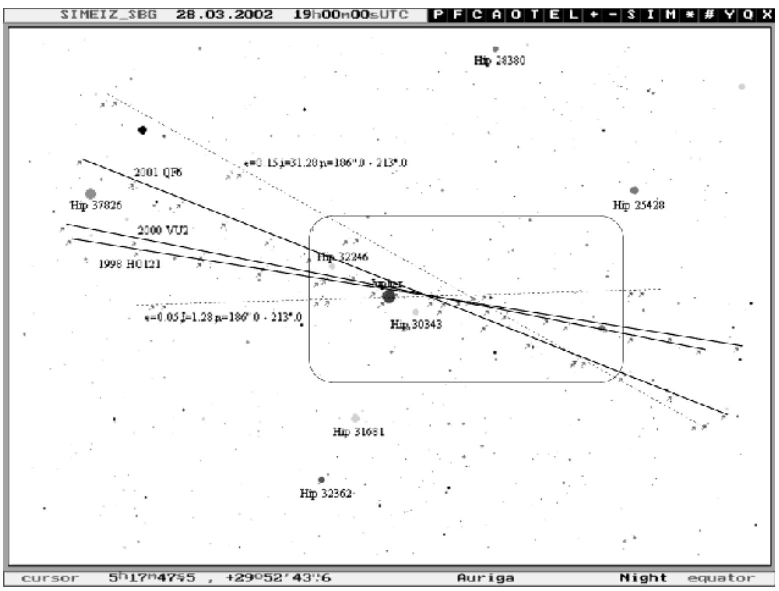
a)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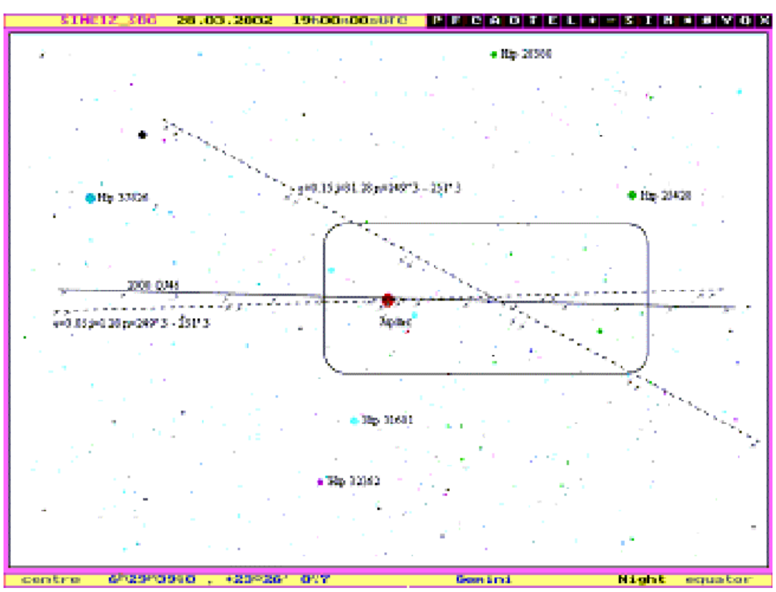
b)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c)

ON THE PROCESS OF ELECTRON ACCELERATION AND SYNCROTRON RADIATION

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In the paper was presented a dynamical as opposed to relativistic approach to the analysis of the process of electron acceleration. The formulas are obtained for electron mass, momentum and kinetic energy as functions of velocity measured in the laboratory frame. Also the electromagnetic field radiated by the accelerated electrons is calculated. Angular distributions of the synchrotron radiation have been found.

1. Introduction

Experiments show that electrons can be accelerated even to very high velocities in two ways: by a stationary electric field [2] and by interactions with gamma photons in the Compton experiments [3]. The acceleration of electrons in a homogeneous electric field and acceleration due the Compton effect lead to the same effects.

The theory of the process of acceleration of electrons in electric field and their radiation

2.1 Assumptions:

1. On the basis of Maxwell's [4] and Bartoli's [5] anticipations, which were confirmed experimentally by Lebedev [6] and Nichols and Hull [7], we will assume that light particles constituting this beam have inertial mass. On the basis of Einstein's [8] anticipations, supported by positive results of the research of Dyson, Eddington and Davidson [9] we will assume that light particles also possess gravitational mass. The inertial and gravitational mass of light particles are equivalent and equal.
2. From Newton's second law results that the changes of kinetic energy dE_k of charged particles occurring in the process of electromagnetic interaction are connected with the changes in their momentum according to the equation $dE_k = d\mathbf{p}\cdot\mathbf{v}$. For the particles of momentum $p = mc$, moving with the speed of c, this equation takes form $dE = dm\cdot c^2$.
3. We will introduce the notion: "an elementary particle of action of electromagnetic radiation", further called shortly "action particle" or "energon", and denote it by ε. These particles are emitted from their source with velocity c determined in relation to the source at the moment of emission.
4. To every action particle we can ascribe the elementary mass m_ε, momentum $p_\varepsilon = m_\varepsilon c$, and according to the equation $dE_k = d\mathbf{p}\cdot\mathbf{v}$, energy $E_\varepsilon = m_\varepsilon c^2$.
5. Electromagnetic fields are formed by elementary particles of the action.

2.2 Entirely Inelastic Collisions of Action Particles with Free Electrons

Let us assume that in the area between cathode and anode with the potential difference U there exists a homogeneous electric field E. To this field we introduce a free electron with mass m_o. In the process of interaction the electron absorbs energons from the electric field.

Initially, we will assume that the electric field interacts with the electron in the process of entirely inelastic collisions (in reality is impossible because in this case the principle of energy conservation will not be valid). If, however, it was possible, the electron would absorb all energons colliding with it and emit none, due to which its velocity, mass, momentum and energy would increase.

The change of the momentum after absorbing a given amount of energy particles of total mass ΔM_ε will be equal to the momentum of the absorbed particles ε. So we can write:

$$(m_0 + \Delta M_\varepsilon) \cdot v = \Delta M_\varepsilon c, \tag{1}$$

where v is the velocity of the electron after absorbing the mass ΔM_ε.

After transforming we obtain expression for the absorbed mass as the function its velocity:

$$\Delta M_\varepsilon = \frac{m_0 \cdot v}{(c - v)}, \tag{2}$$

which corresponds to absorbed energy

$$\Delta E_\varepsilon = \Delta M_\varepsilon c^2 . \tag{3}$$

If β = v/c, we obtain the kinetic energy of accelerated electrons as a function of velocity

$$E_\varepsilon(v) = \frac{m_o \cdot c \cdot v}{(1 - \beta)}. \tag{4}$$

Now the total mass of the accelerating electron consist of m_o and ΔM_ε can be expressed as:

$$m^*(v) = \frac{m_0}{(1 - \beta)}. \tag{5}$$

The momentum of such electron is equal to:

$$p^*(v) = \frac{m_0 \cdot v}{(1 - \beta)}, \tag{6}$$

while its kinetic energy $E_k{}^*(v)$ will be equal of the energy of absorbed energons $E_\varepsilon(v)$:

$$E_k{}^*(v) = \frac{m_0 \cdot c \cdot v}{(1 - \beta)}, \tag{7}$$

where m*(v), p*(v) and $E_k{}^*(v)$ refer to entirely inelastic collision of energons with free electrons located in the electric field.

But formulae (5), (6) and (7) show that the mass, momentum and kinetic energy of the electron increase faster than it was indicated in Bucherer's [10] experiments. Therefore we have to consider partially inelastic collisions.

2.3. Partially Inelastic Collisions of Action Particles with Accelerated Electrons

During such collisions an electron absorbs only a part of the mass and energy carried by energons. The remaining part must be returned to the surroundings in the form of scattered radiation. The energy of scattered radiation depends on the momentary velocity of the electron and on the direction of their radiation, so that the total momentum and total kinetic energy of the system of photon and electron are conserved.

In order to derive a formula consistent with the experiment describing the real increase of the mass of an accelerated electron, so that the principles of the conservation of energy and momentum are fulfilled, we have to introduce a coefficient of reduction of the mass of an accelerating electron - φ(v). This coefficient should depend on the velocity of an accelerated electron and should be smaller than a unit.

After taking into consideration the part of the energy radiated by the accelerated electron (and the mass connected with it), its mass will be changed according to equation

$$m(v) = \varphi(v) \cdot \frac{m_0}{(1-\beta)}, \tag{8}$$

while its momentum changes according to the equation:

$$p(v) = \varphi(v) \cdot \frac{m_0 \cdot v}{(1-\beta)}. \tag{9}$$

The scattered energy in the form of electromagnetic radiation and connected with it mass will change according to the equation:

$$E_s(v) = [1-\varphi(v)]\frac{m_o \cdot c^2}{1-\beta}. \tag{10}$$

In compliance with the principle of conservation the kinetic energy of accelerated electrons will be equal to the difference between the energy of incident action particles and the scattered action particles, that is to say

$$E_k(v) = E_\varepsilon(v) - E_s(v). \tag{12}$$

Putting (4) and (10) to (12) we obtain

$$E_k(v) = m_0 c^2 \left[\varphi(v) \cdot \frac{1}{(1-\beta)} - 1 \right]. \tag{13}$$

By combining (9) and (13), considering that $dE_k = dp\ v$, we obtain the equation

$$\varphi(v) \cdot \frac{c}{(c^2 - v^2)} + \varphi'(v) = 0, \tag{14}$$

Which results in:

$$\varphi(v) = \sqrt{\frac{(c-v)}{(c+v)}} < 1. \tag{15}$$

So, the mass of an accelerated electron will change according to the formula:

$$m(v) = \frac{m_0}{\sqrt{1-\beta^2}}, \tag{16}$$

the momentum p(v) corresponding to it:

$$p(v) = \frac{m_0 \cdot v}{\sqrt{1-\beta^2}}, \tag{17}$$

and the kinetic energy $E_k(v)$

$$E_k(v) = m_0 c^2 \left(\frac{1}{\sqrt{1-\beta^2}} - 1 \right) \tag{18}$$

It means that the real increase of the kinetic energy of an accelerated electron ΔE_k is proportional to the energons mass ΔM_ε absorbed by the electron and equals their energy ΔE_ε. Because $\Delta M_\varepsilon = m(v) - m_o$, i.e.:

$$\Delta E_k = \Delta E_\varepsilon = \Delta M_\varepsilon c^2. \tag{19}$$

The energy of the scattered radiation can be found from the formula:

$$E_s(v) = m_0 c \cdot \left(\frac{1}{1-\beta} - \frac{1}{\sqrt{1-\beta^2}} \right) \tag{20}$$

On the basis of the principles of energy and momentum conservation for the system: electric field - accelerated (decelerated) electron - scattered radiation, we can obtain the value of the angle of the scattered energy as a function of the velocity of the accelerated electron.
In the case free electron accelerated in the electric field the radiation is contained in a cone with angle $2\theta(v)$, where

$$\cos\theta = \beta \tag{21}$$

2.5 Synchrotron radiation

If the electron accelerated to velocity v_o passes through the area of the magnetic field its path is curved. The electron loses part of its kinetic energy, its velocity decreases to the value v and their radius of orbit slightly diminishes. Emitted energy in the form of electromagnetic radiation is the result of the diminishing speed of electron. The quantity of the emitted energy is equal to the lost kinetic energy of deceleration electron. This energy is emitted in a cone with angle $\theta(v)$, where

$$\cos\theta = \beta \tag{22}$$

3. Conclusions:

From the presented theory it follows that:

1. The effect of the increase of the mass and energy of electrons accelerated in an electric field is a dynamic effect, caused by the interaction of the particles forming the electric field with the accelerated electrons; it is not a relativistic effect.
2. Both the mass and energy of accelerated electrons are drawn from the electric field.
3. The increase of the mass of accelerated electrons equals the mass of absorbed photons, ΔM_ε.
4. The kinetic energy of accelerated electrons equals the energy of absorbed photons $E_k = \Delta E_\varepsilon$.
5. The process of the increase in the mass and kinetic energy of electrons is accompanied by the process of the energy scattering in the form of electromagnetic radiation.

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THE BODY CONCEPT AND THE TEACHING OF SCIENCES

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Izabel Brandão[1]
Universidade Federal de Alagoas

INTRODUCTION

Historically the body appears in many ways and, in any circumstance, society constructs and expresses the body and vice-versa. The diversity of conceptions of life and world is what leads to the existence of the many body meanings. In this sense, politics (Figure 1), religion (Figure 2), socio-cultural values (Figure 3) and science (Figure 4) have built their own conceptual framework and symbolism which emphasises a differentiated hierarchy of values which is identified with their specific paradigms in what refers to the questions related to the body.

Our perspective is based on an ecofeminist approach which conceives the educational praxis as a democratic action, with a dialogical and constructive view (Freire: 1978, 1997, Slicer: 1998). In order to develop this study we will attempt to identify the different body concepts by means of images chosen to represent such conceptions throughout the times. Hence our objective is to discuss a number of aspects relating to the various concepts of the body in its many dimensions (cultural, biological and social), and how they are shaped in images and in accordance with textbooks presented in elementary school level.

FIG.1: POLITICAL Lampião, a Brazilian (anti) Hero (1938)

FIG.2: RELIGIOUS Bernadino Luini, John Baptista’s head, 1527/31

FIG.3: SOCIO-CULTURAL SCIENCE “As Banhistas” (Women Bathing)

THE TEACHING OF SCIENCE

In spite of the fact that the body has a social dimension, its conceptualisation has been organised from the very first level of teaching in a primarily biological dimension which does not consider the social-cultural context. As a biological entity, the body is a group of components (Figure 5 and 6) that can be described from the anatomical, physiological and chemical viewpoint. In the context of contemporary education, the body is, thus, studied in many disciplines, including sciences.

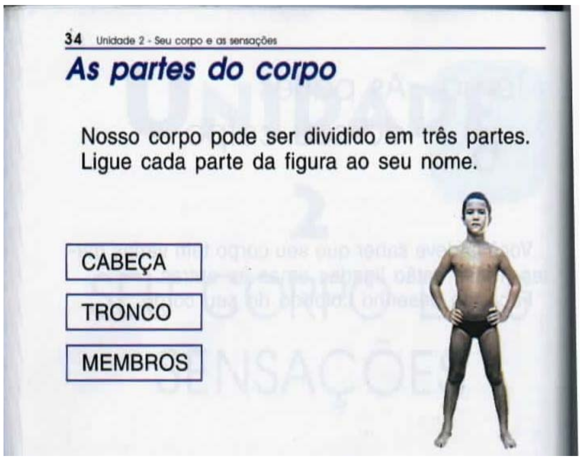


FIG. 5: The parts of the body

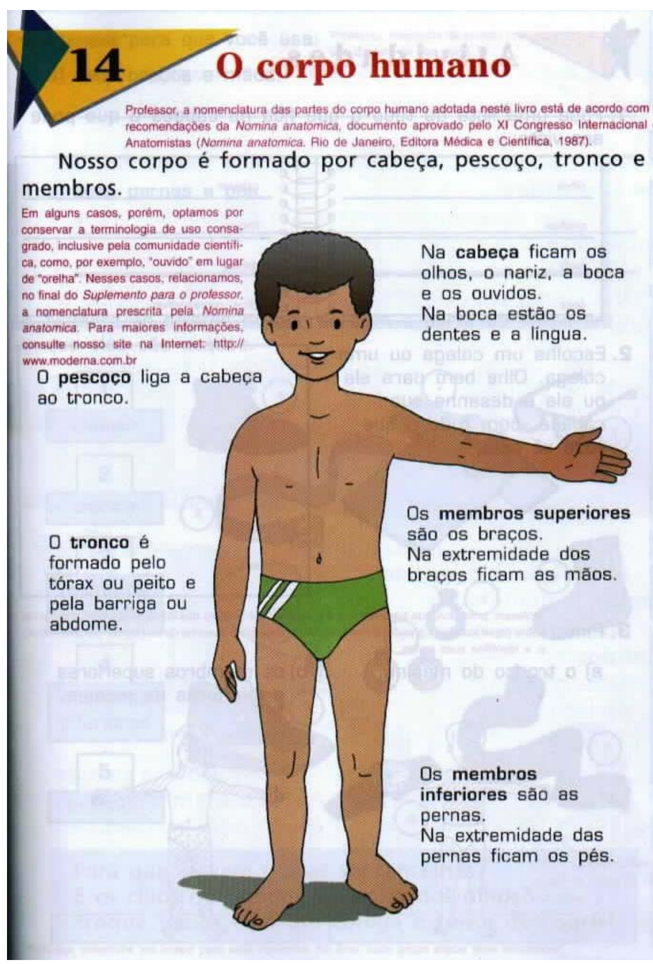
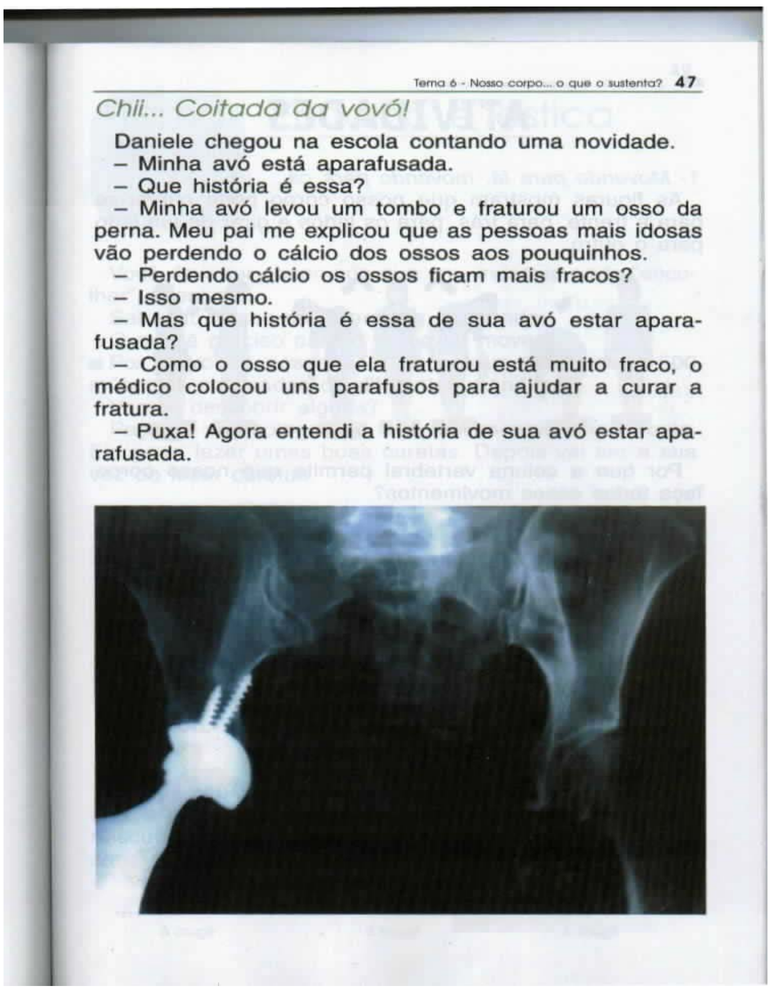


FIG.6: The parts of the body

CASE STUDY: THE PARTS OF THE BODY

In order to explore this issue, we shall illustrate it through the analysis of Figure 7, through the perspective of: content, language and image.


Tema 6 - Nosso corpo... o que o sustenta? 47

Chii... Coitada da vovó!

Daniele chegou na escola contando uma novidade.
– Minha avó está aparafusada.
– Que história é essa?
– Minha avó levou um tombo e fraturou um osso da perna. Meu pai me explicou que as pessoas mais idosas vão perdendo o cálcio dos ossos aos pouquinhos.
– Perdendo cálcio os ossos ficam mais fracos?
– Isso mesmo.
– Mas que história é essa de sua avó estar aparafusada?
– Como o osso que ela fraturou está muito fraco, o médico colocou uns parafusos para ajudar a curar a fratura.
– Puxa! Agora entendi a história de sua avó estar aparafusada.

Figure 7 – A case study

TRANSLATION

Ooh!... Poor grand mother!

Daniela arrived at school with a novelty.

My grand mother has a screw (is "screwed").

What do you mean?

My grand mother fell down and broke a bone of her leg. My father explained that old people loses the calcium from the bone.

And if someone loses calcium, do the bones get weaker?

Yes, that's it.

And why is your grand mother "screwed"?

As her bone is weak, the doctor put some screws to help the reconstruction of the fractured bone.

WOW!! Now I understand why your grand mother is "screwed".

CONTENT

- Although it presents the novelty of a X-ray figure, it doesn't connect the figure with a real correspondence
- It gives a wrong message about the ageing process and bone health

- It doesn't connect between the issue and the possibility of happening the same situation with children, for example, a fall during playing activity leading to a bone injury
- The social identity of the grandmother is absent for she is presented just as an X-ray-ed figure

LANGUAGE

- It is presented in a sexist way: all the male characters (the father and the doctor) in the text are the ones with the 'knowledge' for explanations.
- It reinforces the exclusion of the woman in the context of knowledge.

IMAGE

- It presents an X-ray image but doesn't explain anything about the technique
- It present the grandmother's body as a fragment not connected with a social identity.
- It is not totally explored in its significance.

CONCLUSION

In the context of contemporary teaching of science, the body is presented through a rock-solid, fragmented and conservative approach, not present connections with others existing dimensions, i.e., out of the social context, not only through the image but as well through the used language. We recommend that the text and the teaching resources which deal with images must be presented in a form that drives for a transforming teaching.

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Physics of nonphysical phenomena: traffic jams

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Traffic jams provide an actual research subject in theoretical physics. The autors discuss the question of introducing the complex research topic interesting to everyone in physics teaching.

Introduction

Any student is familiar with everyday phenomena outside the usual range of physics, such as vehicular traffic. Automobile traffic on highways and traffic jams are phenomena determined by psychophysiology of drivers who make decisions and free choices within the traffic regulations. At the same time these phenomena are efficiently approached by means of theoretical physics not included either in the highschool or university basic courses [1]. Solution is found in a simple model of N cars moving on ring road of length L. The model allows to introduce all the concepts necessary to explain the traffic jam as a selforganizing phenomenon similar to condensation of gas.

Experimental observation of jam

The most familiar result of traffic jam analysis is the Treiterer's [2] diagram presenting the distance-time relation for cars on an American freeway (Fig.1). The diagram shows emergence of a jam with no obvious reason (out of nothing) and propagation of a jam wave opposite to the direction of moving cars. Evidently, the jam begins with a stochastic (unconscious) pushing on the brakes by one of the drivers causing a chain reaction of braking in all the following cars and a complete stop at the point x=8000 ft=2.4 km. The jam wave travels at speed 16 km/h opposite to the direction of motion an ends at point x=6000 ft=1.8 km.

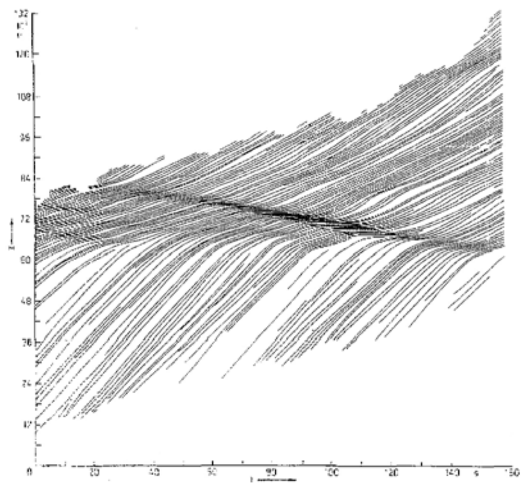

Fig.1 . Emergence of a "phantom traffic jam". The depicted vehicle trajectories were obtained by Treiterer and Myers (1974) by areal photography [2].

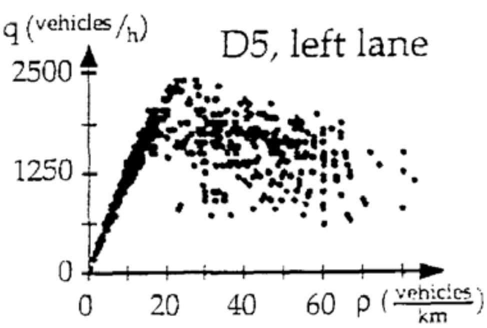

Fig.2. Experimental fundamental diagramm. The free and congested traffic regimes can be separated by critical density 25 veh/km [3].

As in any self-organizing system with nonlinear interaction, a microscopic disturbance (fluctuation – unconscious breaking of one driver) in a metastable state triggers formation of a new macroscopic structure. In the present case, the free motion became unstable, car clusters emerged in the traffic flow. This phenomenon resembles formation of droplets at the gas-liqiud phase transition.

The ring road and basic concepts
The highway traffic may be studied either from the microscopic approach focusing on the motion of individual cars, or from the macroscopic approach considering the whole traffic flow. Treiterer [1] has studied the motion of individual cars by airborne videotapes. Behaviour of a set of cars is studied by sensors that count the number of vehicles and measure their speed. Two variables are determined: the traffic flow $j=dn/dt$ [veh/h], i.e., the number of cars *dn* counted within time interval *dt*, and average speed. By counting the number of vehicles within distance *dx* the traffic may be characterized by density $\rho=dn/dx$ [veh/km].

The 3 characteristics are related by the equation: $j=\rho\cdot v$. Typical experimental data are shown in Fig. 2. The fundamental diagram demonstrates two distinctive regimes of motion. A high flow (the left branch in Fig. 2) is reached in free traffic $\rho<\rho_{cr}$, when the vehicles are relatively independent and everybody drives at high speed. The other regime – the Stop-and-Go traffic is a congested motion. The measurements in this regime are rather scattered. At a high traffic density the vehicles are correlated, the traffic flow and speed are insignificant.

Notice that free and congested traffic on the highway is equivalent to free motion of molecules in a gas while the Stop-and-Go traffic corresponds to the equilibrium of gas and liquid.

Free traffic
Let us assume that *N* cars move at speed *v* along a ring of length *L* and travel a full circle within time $T = L/v$.
Flow density is $\rho=N/L$.
Flow current $j=\rho\cdot v$
By introducing the concept of dynamic pressure $p=½*\rho\cdot v^2=const$ we may compare the traffic to molecular motion in gas.

Traffic jam in the ring road model
To help the students to understand formation of the jam wave and analyse the Treiterer's jam diagram let us consider a simple model of the motion along a circle. A cluster of the length of 4 cars has emerged on the circumference L=8 D (Fig.3). Each car occupies length D (the length of the car plus the safety distance). The road in front of the first car is free and it moves at the maximum allowed speed $v_g=D$ [m/s]. It takes T=4 s to cover the free distance. When the first car has reached the end of the cluster, the next car begins to move, and so on. Examining the motion over the time interval of 32 s we find that velocity of the cluster is $v_-=-8D/32=-D/4$ [m/s] in the clockwise direction (jam wave) while mean velocity of the cars is $v_+=8D/32$=D/4 [m/s] in the counter-clockwise direction. Thus, mean velocity of cars with respect to the cluster is $v_f=D/2$ m/s. Density of cars in the free part is ρ=1/4 and velocity $v= D$ m/s. Within the cluster the density is 1 and velocity of a car with respect to the cluster is D/2 m/s.

Dynamic pressure in the free space (gas) $p_g=½*\rho\cdot v^2=1/8$ and in the cluster (liquid) $p_f=1/8$ are equal: $p_g= p_f$.

All the velocities are seen in the diagram of motion as a function of time (Fig. 4). The similarity with the experimental diagram obtained by Treiterer is obvious. They help to comprehend the jam wave of Fig. 1, and time-distance diagrams of software simulations (Fig. 5).
The model allows constructing of a GIF animation to visualise the Go-and-Stop traffic (http://62.27.84.56/medien/41034750516.GIF). A lot of Java applets simulating traffic flow can be found in internet (http://www.trafficforum.org).

The Go-and-Stop regime is similar to the gas-liquid equilibrium. The motion of an individual vehicle in the free space is equivalent to transfer of a molecule from the liquid to gaseous state (evaporation) while joining to the cluster corresponds to condensation.

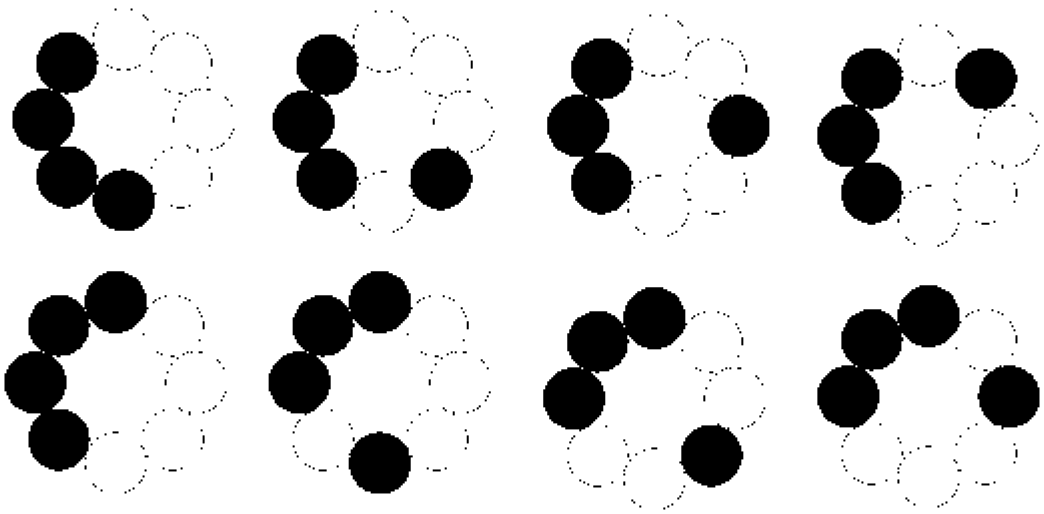

Fig. 3. The Go-and-Stop regime in the circular model. The first car moves in the free space at speed $v = D$ [m/s]. When it reaches the car in front, the next car starts to move, and so on.

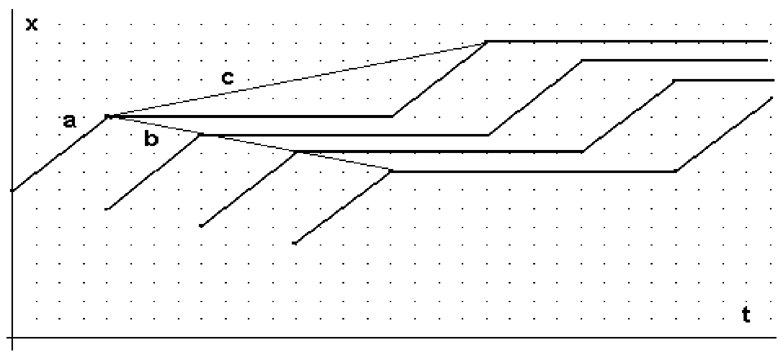

Fig. 4. The space-time curve of the Go-and-Stop traffic in the simplified circular model. The slope of the straight line shows velocity of the car in the free space, the slope of line b shows velocity of the jam wave, and the slope of curve c – the average velocity of a car in the traffic direction.

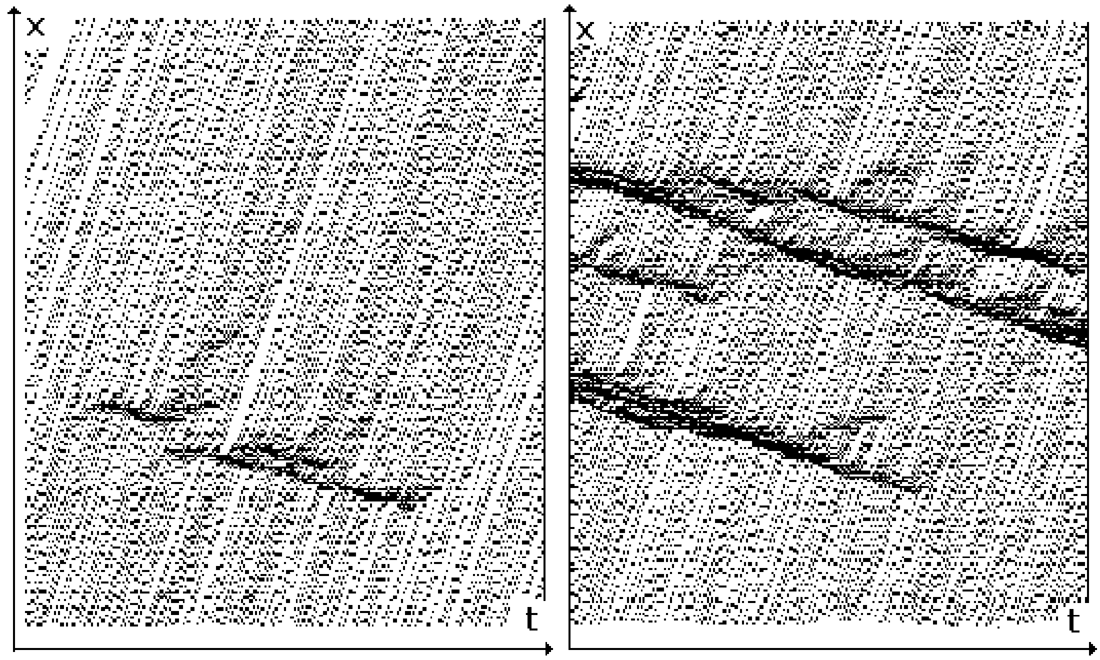

Fig. 5. Displacement of an individual vehicle as function of time obtained by traffic simulation in the cellular automaton model [4]. Left - 80 and right - 120 cars on a ring with 1000 cells [5]. Similarity with Fig. 4 and the Treiterer's diagram (Fig. 1) is obvious.

The mathematics of human behaviour and the optimal velocity model (OVM)

The traffic jams are caused by drivers – humans. In the state of free motion a driver may realize his/her free will (within the limits of traffic regulations): brake and speed up the car independently of what other drivers do. With many cars on the highway the drivers need to co-operate. What is the mechanism of co-operation? An important factor is the distance x to the vehicle in front of a particular car depending on which the driver of the car changes the speed. Different groups of researchers offer different models for the speed of safe traffic as a function of x. We propose a simple model [6]

$v_{opt}(x)=v_{max}*x^2/(d^2+x^2)$, (1)

where v_{max} is maximum of allowed speed and d – the distance of interaction between two cars (safety distance).

The relation may be used to study the traffic within the frameworks of both Newtonian dynamics and thermodynamics. Newtonian equation of motion is presented as

$F=const(v_{opt}-v)$.

The bigger is the difference between the speed of a car and the optimum speed, the bigger force may be applied to accelerate the vehicle by pushing the gas pedal. The equation was used to study the motion of 60 cars and two possible states were found: the free state and jam [7]. Solution of a system of nonlinear equations necessary to obtain a result within this model takes too much time on preparations, explanation, and calculations to be recommended in teaching.

From the expression (1) we obtain the speed as a function of traffic density ρ:

$v=v_{max}/(1+b*\rho^2)$ (2)

and farther the traffic flow equation and dynamic pressure within the model.

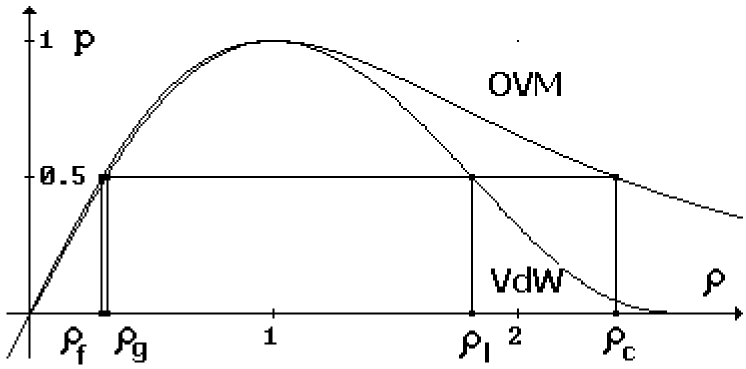

Fig. 6. The phase equilibrium diagram $p(\rho)=½\cdot\rho\cdot v^2$ within optimal velocity model (Eq. 2, $v_{max}=2\surd2/3$ and $b=1/3$) and Van-der-Walls gas model obtained by the computer algebra system Derive. At pressure $p=0.5$ densities $\rho_f=0.298$, $\rho_c=2.4$ are for free and congested traffic regimes within OVM and $\rho_g=0.316$, $\rho_l=1.813$ are densities of gas and liquid in Van-der-Waals model.

Van der Waals "highway"

Let us imagine a Van der Waals gas in a circular tube. Depending on the density behaviour of the gas is described by the dimensionless Van der Waals equation
$(\pi + 3*\rho^2)(3/\rho-1)=8*\tau$, (3)
where $\pi=p/p_{cr}$ is the reduced pressure, $\rho=\rho/\rho_{cr}$ is the reduced density, and $\tau=T/T_{cr}$ is the reduced temperature. Traditionally the gas-liquid equilibrium curve is obtained by integration from the Maxwell's law of equal areas. For the equilibrium curve there also exists a rather awful transcendent equation. Evidently, Gibbs was the first to find a parametric solution for the equilibrium curve [8].

With the computer algebra system it is possible to use the parametric solution of the equilibrium curve for the traffic jam analysis on the Van der Waals highway. The parametric description of the gas-liquid equilibrium curve may be obtained with a subsidiary function $f(y)$ [9]
$f(y)= (y*\text{COSH}(y)-\text{SINH}(y))/(\text{SINH}(y)*\text{COSH}(y)-y)$ (4)
It is convenient to choose the entropy difference per molecule between gas and liquid as the parameter.

The volume of the gas and liquid as a function of entropy difference is given by
$u_f=\exp(-s/2)f(s/2)$, $u_g=\exp(s/2)f(s/2)$ (5)
Reduced densities of the liquid and gas are
$\rho_f=3u_f/(1+u_f)$, $\rho_g=3u_g/(1+u_g)$, (6)
respectively. With a subsidiary function g:
$g=1+2*\text{COSH}(s/2)f(s/2)+f(s/2)^2$ (7)
dependence of pressure on parameter s at the gas-liquid equilibrium is presented by
$\pi=27f(s/2)^2(1-f(s/2)^2)/g^2$ (8)

Under assumption that there is only dynamic pressure $p=½\cdot\rho\cdot v^2$ in the Van der Waals gas, dependence of the speed on density is obtained as $\surd(2p/\rho)$ and the traffic flow is $j=\rho\cdot v=\surd(2p\cdot\rho)$. The relevant diagrams may be compared with the optimal velocity model. As seen from Figs. 7 and 8, the optimal velocity model is in good agreement with the Van der Waals gas model in the vicinity of the critical state (ρ=1).

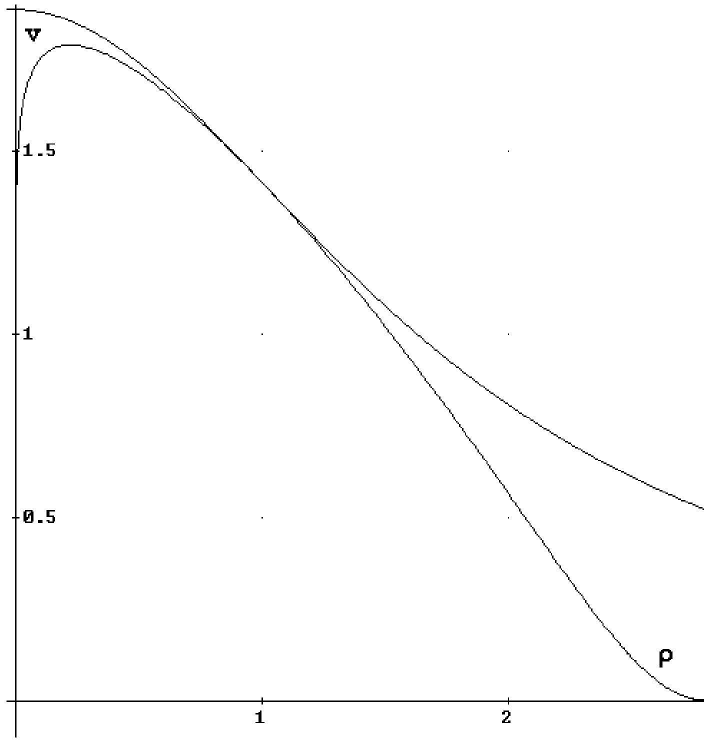

Fig. 7. Velocity as a function of density in the optimal velocity model compared with the speed on the Van der Waals "highway".

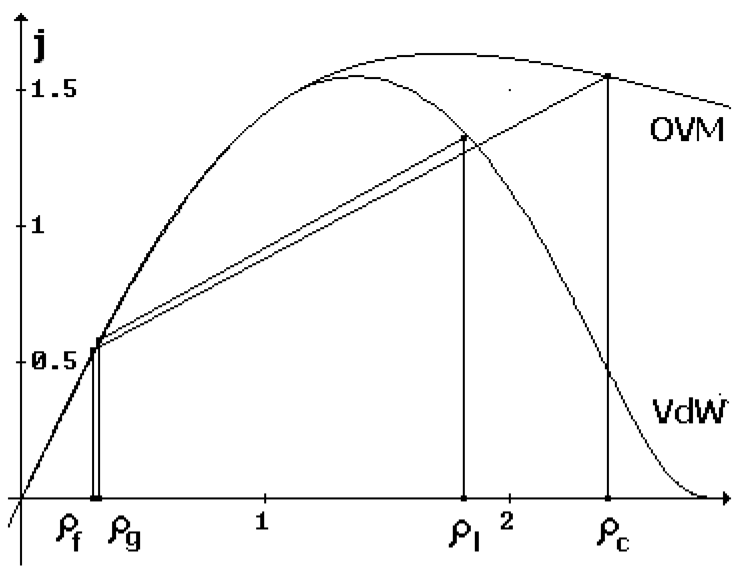

Fig. 8. The fundamental diagram in the optimal velocity model ($j=\rho\cdot v$, Eq.2, $v_{max}=2\sqrt{2/3}$, b=1/3) and in the Van der Waals model ($j=\sqrt{(2p\cdot\rho)}$). The two slopes correspond to the phase equilibrium at pressure p=0.5.

Finally we may conclude that similarity between a traffic jam and the gas-liquid equilibrium is close enough to apply the thermodynamic concepts of phase equilibrium to describe the traffic. On its turn, the motion of cars, especially the traffic jam, may serve as a good illustration of gas-liquid equilibrium, evaporation, and condensation in the basic physics course.

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Entropy Physics for All !!

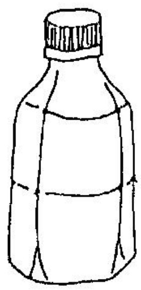
□ for sustainable society □

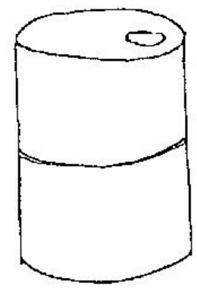
Haruka Onishi and Hiroshi Kawakatsu ,Kagawa University , Japan

□. Why it is difficult to get a pure water?

Question

Which is most expensive, A water, B wheat or C gasoline?





A Water 1kg sold at the convenience	B Wheat 1kg sold at the convenience	C Gasoline 1kg sold at the gas

Answer

A 1kg of water

<Data> in Japan

1kg of water = 180yen = 1.5Euro

1kg of wheat = 170yen = 1.4Euro

1kg of gasoline = 95yen = 0.8Euro

What do you think about the answer?

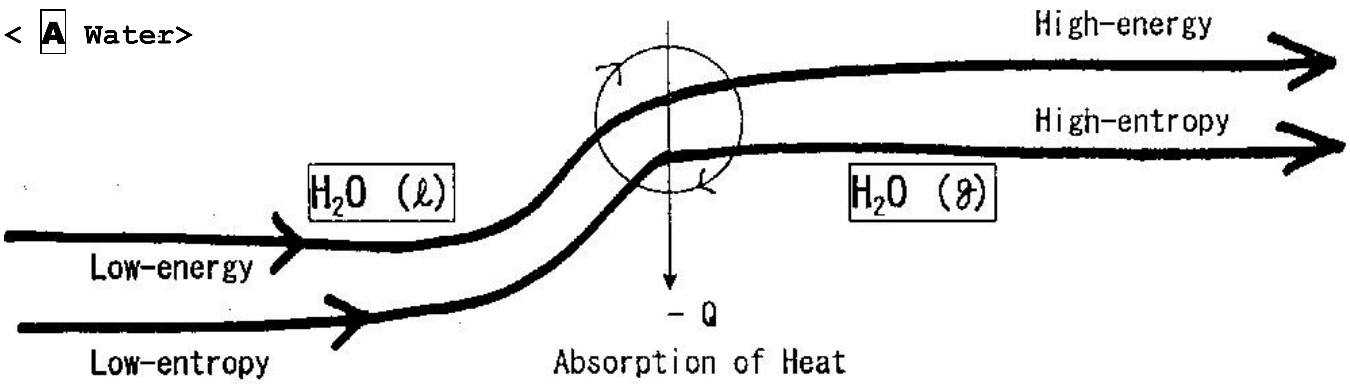
How about in your country? Why is gasoline so cheap? Why water is more expensive? Do you think that we pay just the cost? Please fill in the blank with your opinion.

For human, we cannot live for one week without wheat. We cannot continue running the different industries for one month without the gasoline. Yet, we can’t survive for three days without drinking water. This is why water is important for all of us.

~ For better understanding about the importance of water ~

□. Characteristic of the water from the viewpoint of entropy

< A Water>

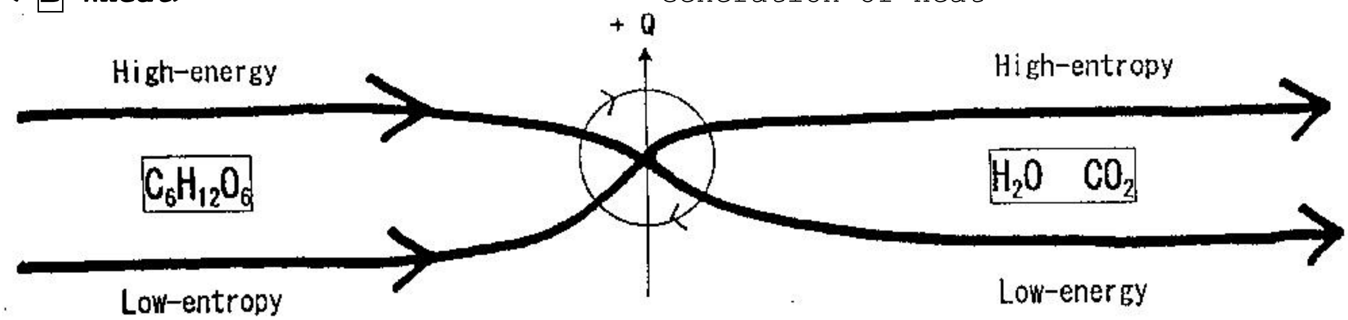


~ Both energy and entropy change into High ... ~

But ...

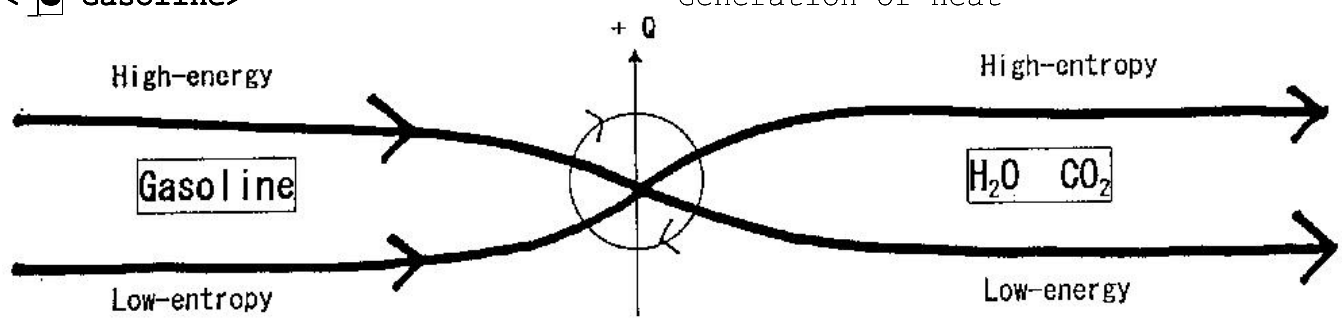
< B Wheat>

Generation of Heat



< C Gasoline>

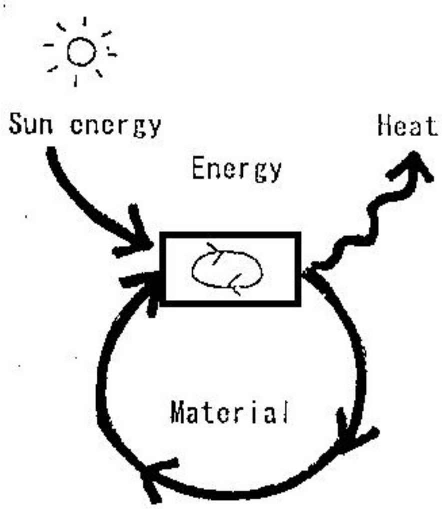
Generation of Heat

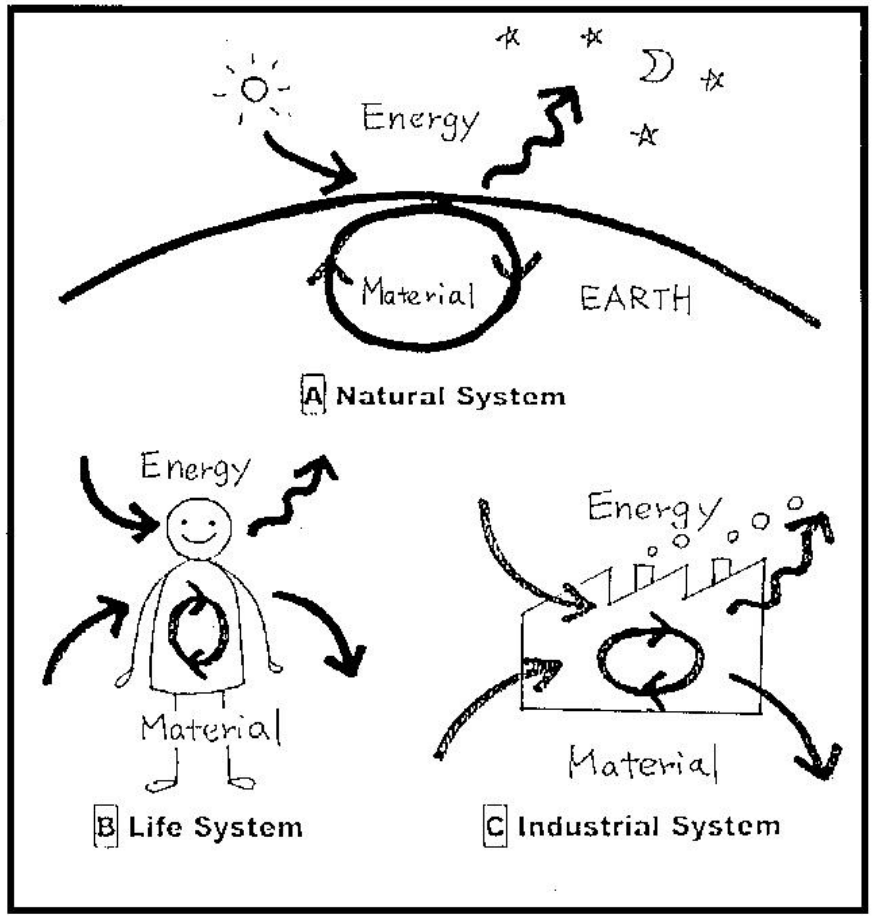


For example, at first wheat is high-energy and low-entropy. After the consumption cycle, it will be changed into high-entropy and generates heat. Gasoline is the same. But water is different. After the cycle, it changes into high-energy and high-entropy from low-entropy and low-energy (Refer of Fig. **A**). It absorbs the heat. To compare, only water absorbs the heat in this process, the others generate it.

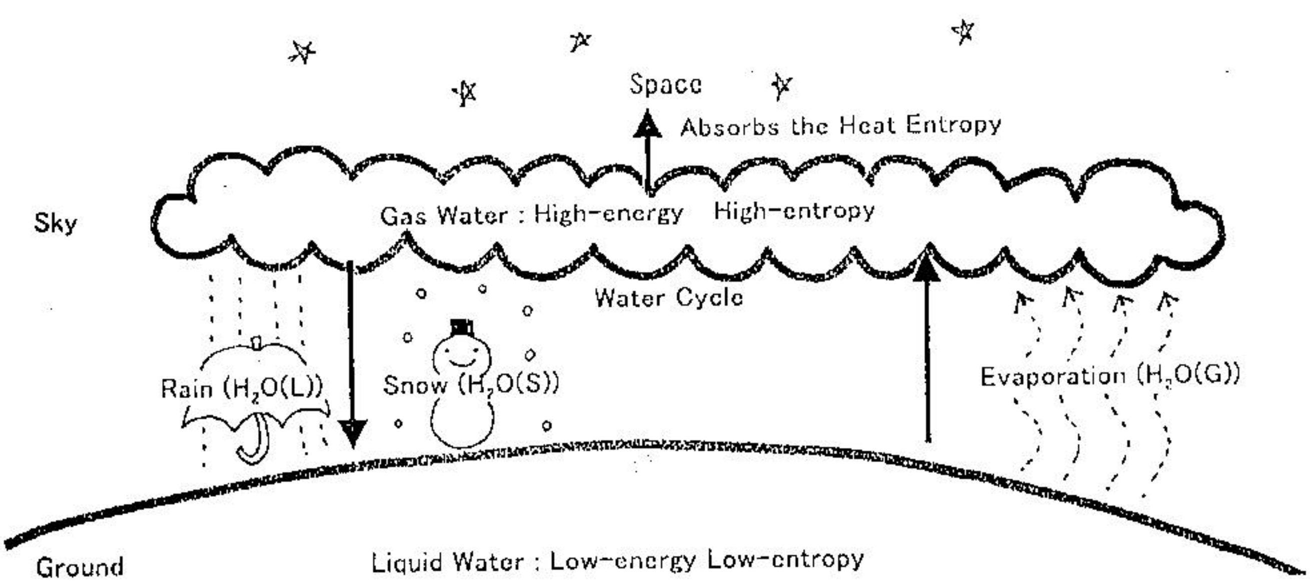
~ So water keeps "each" and "whole" system stable ~

(1) To keep the thermal balance and stability of the cycle of "each" system





(2) To keep the thermal balance and keep stability of the cycle of the "whole" system



□. One of the broken reasons is “Efficiency”.

It breaks the rink of these cycles as for time and space.

I think there are three efficiencies.

< Three Efficiency >[3]

(1) E_1=Km/h

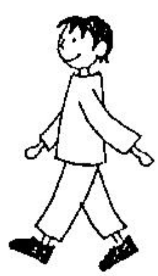
(2) E_2=Km/kcal

(3) E_3=Km×Person/kcal

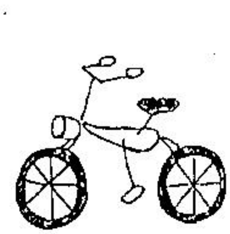
Question

What is the best efficient means of transportation?

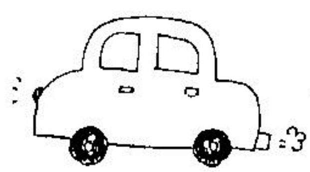
Let’s answer the each efficiency: (1), (2), (3) !!



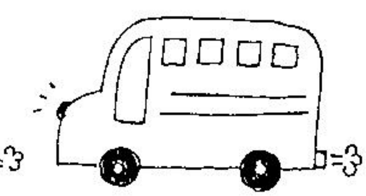
Walk



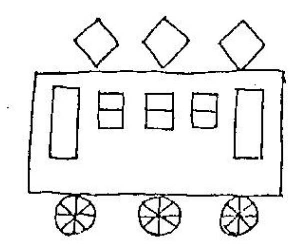
Bicycle



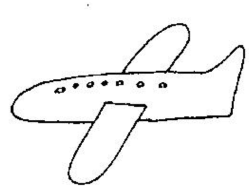
Car



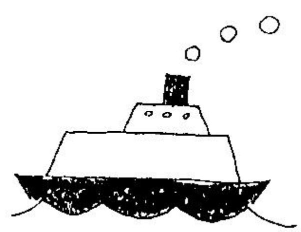
Bus



Train

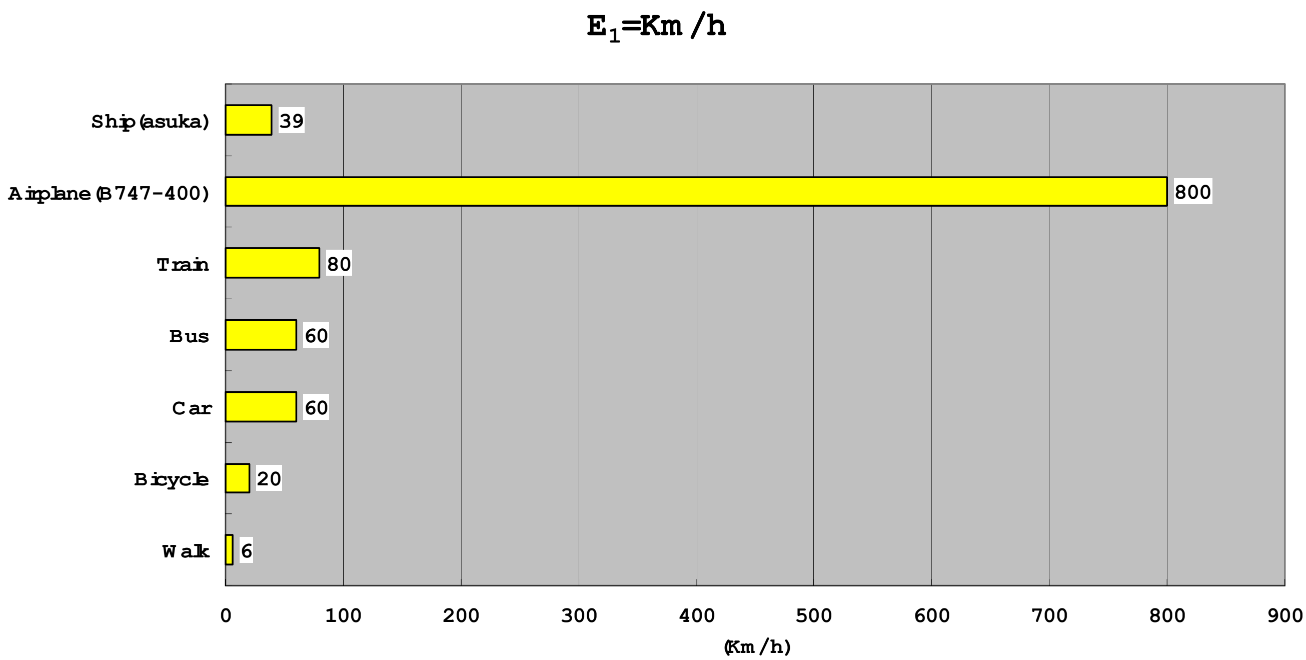


Airplane

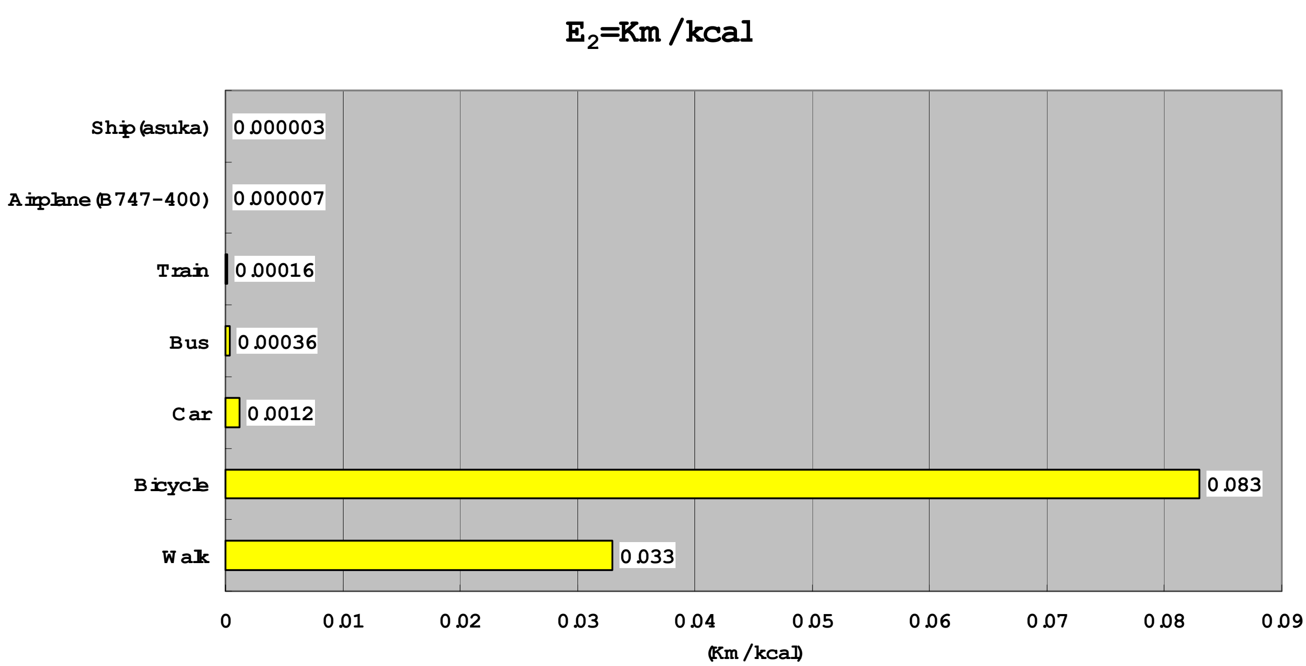


Ship

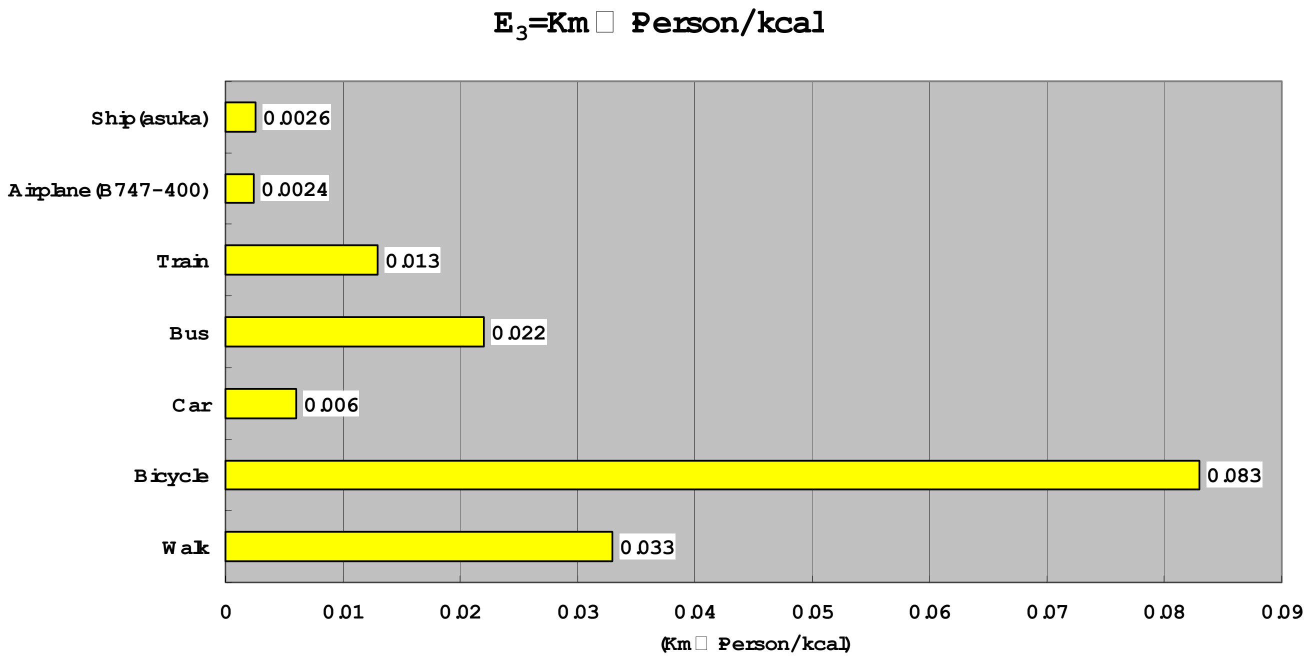
(1) Answer " E_1=Km/h "



(2) Answer " E_2=Km/kcal "



(3) Answer " E_3=Km×Person/kcal "



Data

	A	B	C	A/B	A×C/B
	Speed (Km/h)	Consumption energy(kcal/h)	Person	(Km/kcal)	(Km×Person/kcal)
Walk	6	180	1	0.033	0.033
Bicycle	20	240	1	0.083	0.083
Car	60	50000	5	0.0012	0.006
Bus	60	170000	60	0.00036	0.022
Train	80	500000	80	0.00016	0.013
Airplane (B747-400)	800	110000000	340	0.000007	0.0024
Ship (asuka)	39	15000000	860	0.000003	0.0026

Note□ We show "Consumption energy" in more detail.

Walk: consumption=R.M.R(relative metabolic rate: walk)×time(min),
=3×60min=180kcal/h

Bicycle: consumption=R.M.R(bicycle)×time(min),
=4×60min□240kcal/h

Car: 1L → 10□□ , 60□□/h → □L/h
1L□8400×10^3cal, 6L/h×8400×10^3cal=5.0×10^7kcal/h

Bus: 1□ → 3□□ , 60□□ → 20□/h
1L□8400×10^3cal, 20L/h×8400×10^3cal=1.7×10^8kcal/h

Train: 2.2□□□□□□□t□□□
80□□/h×2.2□□□□□□□t□□□□176□□□/h
□176×10^3×60^2J/h
□633.6×10^6J/h
□15.1×10^7cal/h
Generation of efficiency =30□ ,
15.1×10^7cal/h×100□30=5.0×10^8kcal/h

Airplane: 1□ → 0.06□□ 800□□/h=1.3×10^4□/h
1L□8700×10^3cal,
13000L/h×8700×10^3cal=1.1×10^8kcal/h

Ship: 11770×2□23540 HP(horsepower)
□1765500kgm/s
□6360000000kgm
□63600000000J
□1.5×10^7kcal/h

□. Conclusion

Result of continuing industrial activities without the viewpoint of entropy, pure (Low-entropy) water has decreased now. Let us look back the history of transportation. Discoveries are always inclined to have efficient vehicle□car□ What do you think about continuing more and more efficient society 'E_3' ? Please write your Idea!!

Hint: How do you throw away total amount of Entropy?
If it can't throw away, continuing cycle is impossible.

We should teach all students and people "Entropy" idea as one of the fundamental key concepts in dealing with environmental problems!!

(1) **Let us stop generating HEAT more than, what is required within the cycles on the earth.**

All energy changes into heat and is release to cosmic space. Water connects each cycle. This material in the cycle is found within the earth and we can't just throw it away. Only heat entropy can be thrown away outside the earth, in this way, earths' sustainability will be preserved.

If we produce more heat, we can't couture the material and heat cycle in the earth effectively.

(2) One cycle is link to each other cycles.

For example, airplane generates more heat than bicycle. We have to throw away the entropy to keep low-entropy in our own system. If not, the system will be broken apart at last. So we have to link not only one cycle, but also other cycles.

An invitation to all: Let the concept of entropy be the basis of the research it keeps its own system low-entropy state. So then our society and nature

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Towards New Application of Physics: Econophysics at Wroclaw University

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Abstract:

The schedule of new econophysics BSc course established at Wroclaw University is presented. The course is organised as a result of cooperation between two departments: Department of Physics and Department of Economy. A stress on interdisciplinary aspects of this course and its continuation to MSc or ME (Master of Economy) is given.

1. INTRODUCTION

In the last decade there is a growing interest in application of computer science methods and numerical simulation in various problems concerning biology, genetics, sociology, economy, etc [1]. Many of these problems may now be successfully treated as nonlinear phenomena in many body dynamical systems. This is why links between physical methods (both theoretical and numerical) and various processes that seem to be far from physics (like these in economy) exist. Financial markets, its indices and exchange rates seem to behave like completely disordered systems but it is not true. Exact analysis shows the existence of long- and short-range correlations [2, 3] what confirms that many phenomena in economy can be described in a different way than typical Brownian motion.

On the other hand, numerical simulation, like the one taken directly from the consideration of famous Ising model in solid state physics, is a very good tool to describe main types of investors and mutual influences between them [4]. This enables to build a toy-model of the market and to investigate which parameters have the main impact on the financial market behaviour and financial crushes in particular.

Although there is still a long way to answer main questions connected with market behaviour, first steps have already been done by physicists. They adopted physical methods to investigate financial phenomena [5]. Application of physical terminology and methodology in economy gave birth few years ago to a new discipline in science called econophysics. It seems that econophysicists will become soon the most needed specialists by such employers like banks, insurance companies, financial market institutions etc.

2. HOW IT WORKS AT WROCŁAW UNIVERSITY?

Taking this into account we decided to open at Wrocław University a new 3-yrs course leading to B.Sc. degree in econophysics. The structure of the course has been composed by myself in cooperation with leading econophysicists in the world and econophysics creators – M. Ausloos (Liége) and E. Stanley (MIT). A very new idea was to make this course interdisciplinary one, so students were able to attend simultaneously lectures given at both Departments i.e. Physics and Economy. Finally, I wanted B.Sc. econophysics graduates to have an open choice in further postgraduate education. The idea was to give B.Sc. graduates two opportunities: the 4-semester course at postgraduate level in Department of Physics, leading to M.Sc. degree in physics, or the 4-semester postgraduate course in Department of Economy, leading to Master of Economy (ME) degree. All administrative procedures have been completed on time and legal problems have been solved fast thanks to distinctive help of the staff from the Economy School at our University. The proposed econophysics course will be one of the first interdisciplinary courses of that kind in the world offering a free choice between physics and economy for graduates.

3. THE SCHEDULE OF THE COURSE AND ITS CONTENTS

We present below the schedule of the course made in cooperation with the staff from the Economy Department. All lectures and tutorials are divided into several main groups:

1) mathematics
2) physics
3) economy and econophysics (splitting maths, physics and economy)
4) computer methods

The last one deals with basic concepts of computer science, simulation methods and numerical technique. It helps students to get know how to apply numerical methods in analysis of time series and how to make a simple simulation of dynamical processes (with the stress on application in economy).

The first course started in October 2002. We accept approximately 60 students with a good mathematical background. In the future our graduates will find a job as professional financial analysts. The best postgraduate students will have an opportunity to do research at Ph.D. level at Department of Physics or Department of Economy.

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FINANCIAL STOCK MARKET BEHIND THE BROWNIAN MOTION

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Analysis of stock market indices as time series is presented and compared to the Brownian motion. It is shown how long range correlations can be found and what the Hurst exponent can tell us about the forecast in financial stock market. The problem needs to be deeper investigated by econophysicists.

1. INTRODUCTION

Many of the problems concerning biology, genetics, sociology, economy, etc may now be successfully treated as nonlinear phenomena in many body dynamical systems. This is why these problems are nowadays in focus of interests for physicists around the world [1]. In particular, exact analysis of financial market indices shows the existence of long- and short-range correlations what confirms that many phenomena in economy can be described in a language of disordered systems [2].

This new approach to make research in economy with the use of tools and methods from physics gave birth few years ago to a new discipline in science called econophysics. Simultaneously, the ideas of new courses for physics students appeared. It seems that physics graduates with knowledge and skills on analysis of time series, simulation methods and numerical technique will become soon the most needed specialists by employers like banks, insurance companies, financial market institutions etc.

We present an example of a topic for further investigation in this field.

2. RANDOM WALK AND BROWNIAN MOTION

The concept of random walk is well known for physicists. Let x_i (i = 1, 2, 3, ...) are subsequent values of some process then one may write

$$x_{i+1} = x_i + \Delta x_i \qquad (1)$$

If Δx_i is the set of random variable values governed by the normal distribution scheme then (1) is called one-variable *Brownian motion* (a kind of *random walk*). One may easy simulate such a random walk as seen in Fig. 1a. Subsequent values Δx_i are here chosen by a random number computer generator and satisfy

$$< \Delta x > = 0 \text{ and } \sigma^2(x) = <(\Delta x)^2> = 1 \qquad (2)$$

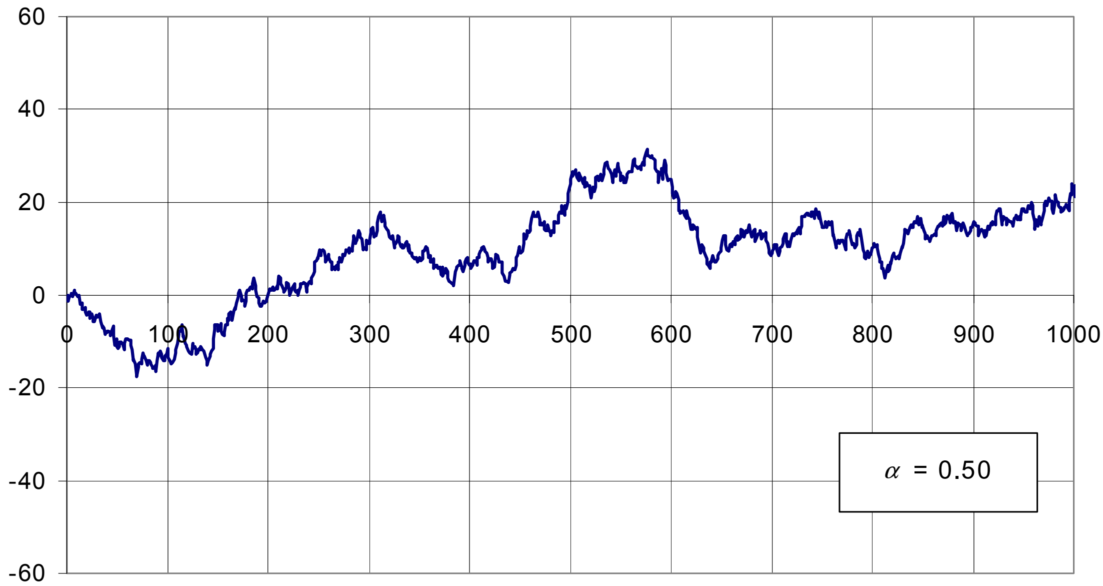

Figure 1a. An example of the Brownian motion generated with the use of computer.

3. DETRENDED FLUCTUATION ANALYSIS AND THE HURST EXPONENT.

The random walk shows statistical property connected with the power law dependence. It leads to the notion of so called Hurst exponent [3] (the fractional dimension of the random walk). One of the procedures to find this parameter is called Detrended Fluctuation Analysis (DFA) [4] and looks as follows:

Step 1.: The time series of random one-variable sequence $x(t)$ of length N is divided into N/τ non-overlapping boxes of equal size τ. The time variable t is discrete and evolves by the single unit between $t = 1$ ($x(t = 1) = x_1$) and $t = N$ ($x(t = N) = x_N$). Thus each box contains τ points and N/τ is an integer.

Step 2.: The linear approximation of the trend in each τ-size box is found as:

$$z(t) = at + b \tag{3}$$

Step 3.: In each τ-size box one calculates the root mean square deviation between $x(t)$ and the local trend $z(t)$:

$$F_i^2(\tau) = \frac{1}{\tau} \sum_{t \in i-th\,box} (x(t) - at - b)^2 \tag{4}$$

and the average fluctuation over all N/τ boxes:

$$\left\langle F^2(\tau) \right\rangle \equiv \frac{\tau}{N} \sum_{i=1}^{N/\tau} F_i^2(\tau) = \frac{1}{N} \sum_{t \in i-th\,box} (x(t) - at - b)^2 \tag{5}$$

A power law behaviour is expected:

$$\left\langle F^2(\tau) \right\rangle \propto \tau^{2\alpha} \tag{6}$$

where α is the Hurst exponent.

It was proved by A. Einstein in 1908 that for the Brownian motion if $N \rightarrow \infty$ then $\alpha \rightarrow ½$. This corresponds to the famous Einstein's statement that in the case of Brownian motion a distance R travelled by a particle is related to the time of motion T as:

$$R \propto \sqrt{T} \tag{7}$$

The value $\alpha \neq ½$ implies the existence of long-range correlation (so called fractional Brownian motion) contrary to the ordinary Brownian motion with $\alpha = ½$, where such correlation simply do not exist. Examples of random walk with $\alpha \neq ½$ are given as plots in Figs 1b, 1c.

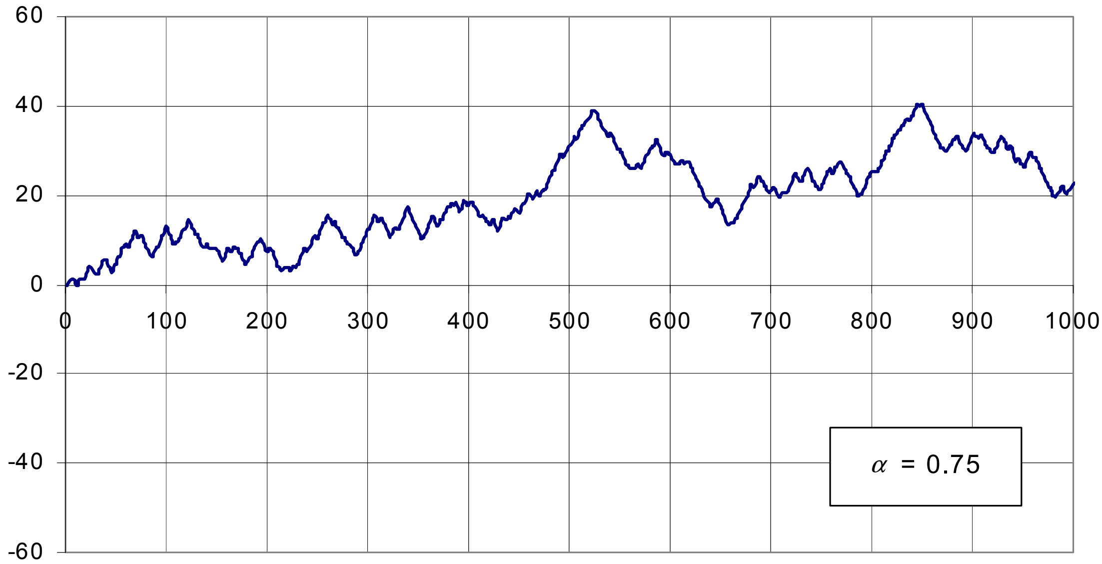

Figure 1b. A plot of random walk with the Hurst exponent $\alpha > 0.5$. The random walk is 'smoother' than for $\alpha = 0.5$

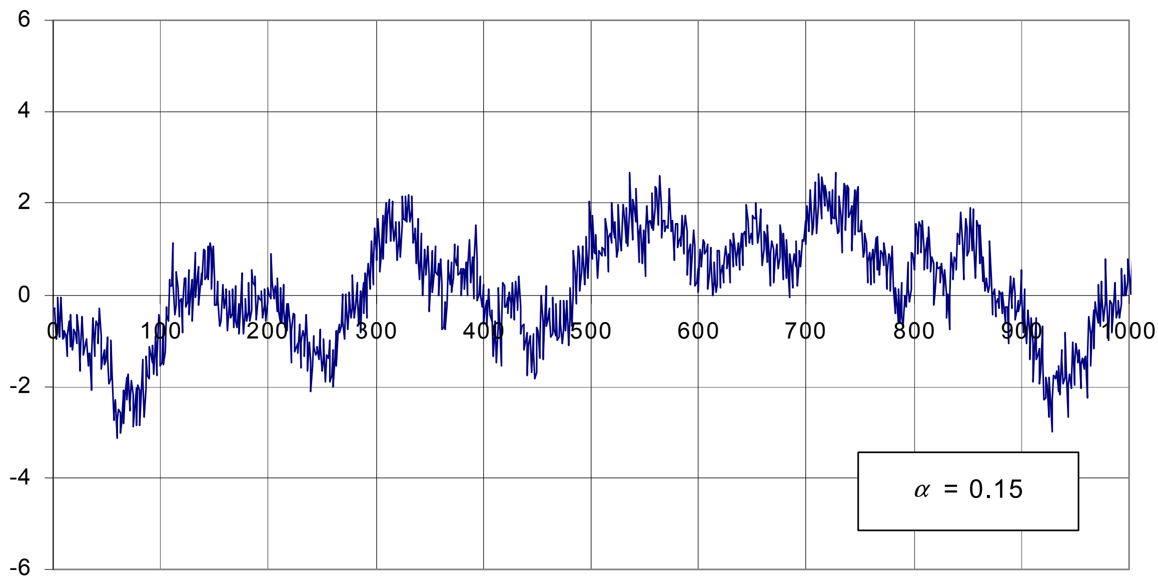

Figure 1c. Plots of random walk with the Hurst exponent $\alpha \neq 0.5$. It is seen that the roughness level of the random walk increases for smaller α values.

We also show in *Fig. 2* the plot $\log\langle F^2(\tau)\rangle^{1/2}$ versus $\log\tau$ for the simulated Brownian motion. It gives us the straight line with the slope of ~0.5 as expected. All necessary calculations and the plots have been done with the use of MS Excel spreadsheet.

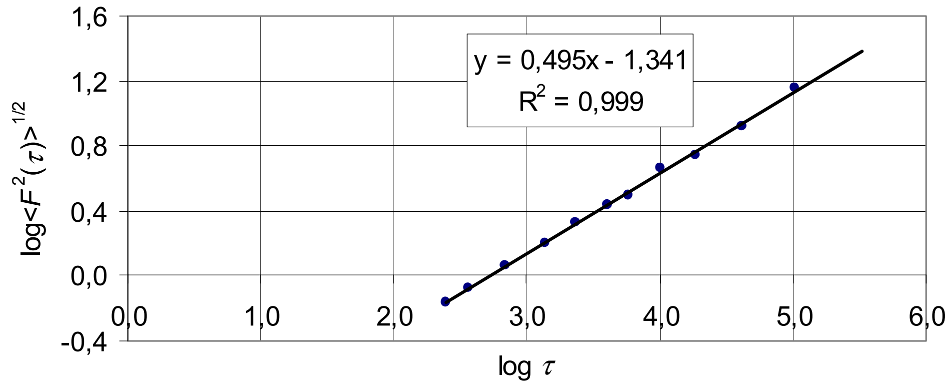

Figure 2. The slope of this line drawn for data from Fig. 1a equals 0.5. This confirms we deal with the Brownian motion.

4. HURST EXPONENT AND FINANCIAL STOCK MARKET

Let us discuss Dow Jones (DJIA) index versus time as time series. Taking sufficiently large number of data ($\sim 10^3$) we may check what kind of random walk it is. The examples of financial data series are given in Figs 3a, b. From the plot of returns it is seen they are both random walk processes but of different types. In the first case (Fig. 3a) returns are much wider. The estimation of the Hurst exponent from corresponding $\log\langle F^2(\tau)\rangle^{1/2}/\log\tau$ lines confirms the difference in α values ($\alpha = 0.5$ and $\alpha = 0.7$ respectively). It suggests that long-range correlation ($\alpha > 0.5$) may exist for some periods of financial data (Fig 3b).

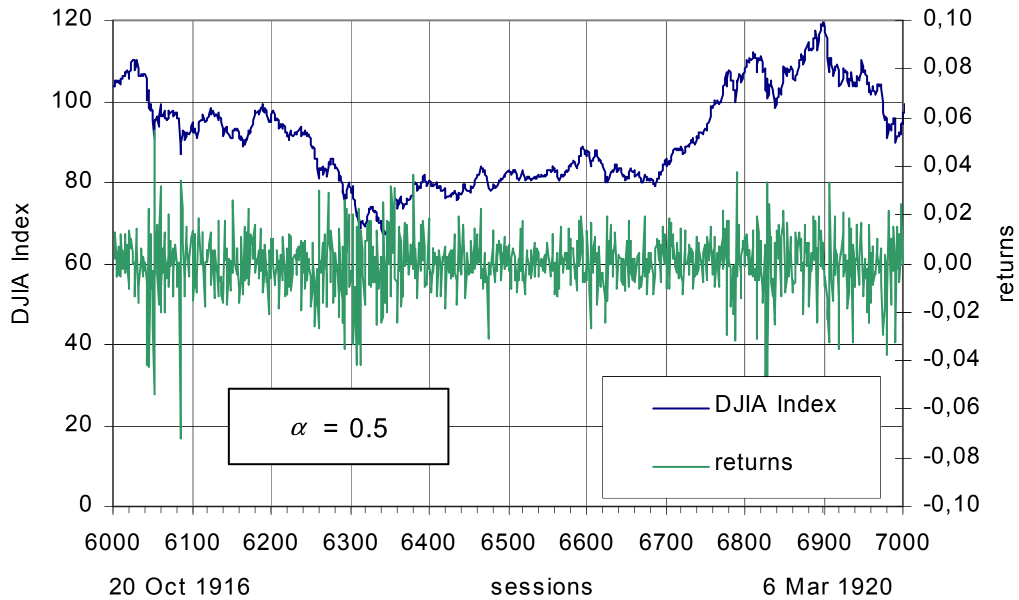

Figure 3a. The DJIA index plot for the period: 20 Oct 1916 – 6 Mar 1920 corresponding to $\alpha = 0.5$. The green plot represents returns.

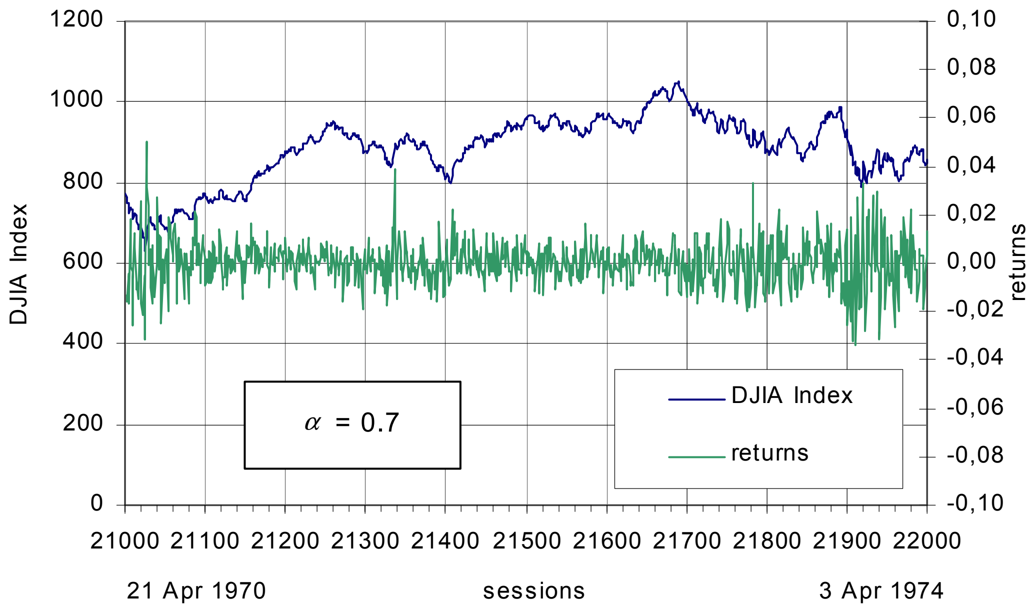

Figure 3b. The DJIA index plot for the period: 21 Apr 1970 – 3 Apr 1974, corresponding to $\alpha = 0.7$. The green plot represents returns and is more 'quiet', with smaller level of 'oscillarity' than the one for the Brownian case ($\alpha = 0.5$). It is an agreement with the theory.

In order to probe the existence or not of *locally correlated* or *decorrelated* sequences we have to turn to the notion of *local* α *value* [5]. The procedure to find it is similar to the one already discussed but now a number of data N we take into account is finite and small.

The local Hurst exponent in the i-th point $\alpha_{loc}(i)$ is calculated from DJIA financial data series in the interval $<i - N + 1, i>$. The choice of the N value is a matter of intuition. We took N as a few hundreds sessions which gives a good linear approximation to $\log<F^2(\tau)>^{1/2}/\log\tau$ plot. The box of N points is then moved every one session giving the whole $\alpha(t)$ dependence in the required region of financial data. The results are shown in Figs 4 a, b, 5 for the chosen data series in 80-ies and 90-ies. The local Hurst exponent differs visibly from 0.5 what gives us a message that the financial market is locally non-Brownian and has short- and medium-range correlation enabling (at least theoretically) to make some predictions.

5. PREDICTION HYPOTHESIS IN THE FINANCIAL MARKET.

We have checked many DJIA runs in various periods and have investigated corresponding local Hurst exponent plots. Few examples of this comparison are explicitly given in Figs 4a, 4b, 5. There is no doubt that some correlation between trends in DJIA index and the corresponding local Hurst exponent plots exists. All the important changes in DJIA index trends (not small corrections) have their reflection in drastic drop down of the Hurst exponent to some critical value which depends in turn on the medium-range behaviour of this exponent. Such important minima in α-plots with corresponding changes of DJIA index trends are marked by circles in Figs 4b, 5.

It is important to notice that in most cases the minima in Hurst exponent precede the change in DJIA index. Even if both trends occur simultaneously, an attentive observer can distinguish, looking at Hurst exponent, whether the change in DJIA index during last few sessions is just a small correction or represents a major change in the trend being so far. It is of enormous importance for all investors giving an additional hint on the evolution of financial stock.

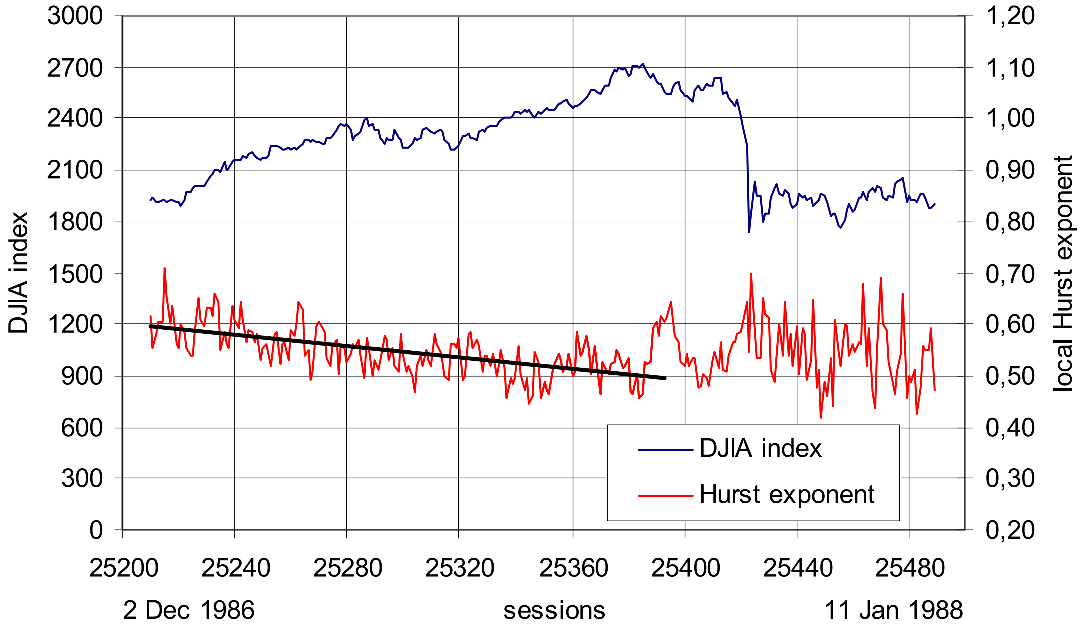

Figure 4a. The constantly decreasing trend (solid line) of the local Hurst exponent which changes from $\alpha = 0.7$ to $\alpha = 0.45$ is the signal of the serious danger for investors. The big crash is expected soon – 14 Oct 1987.

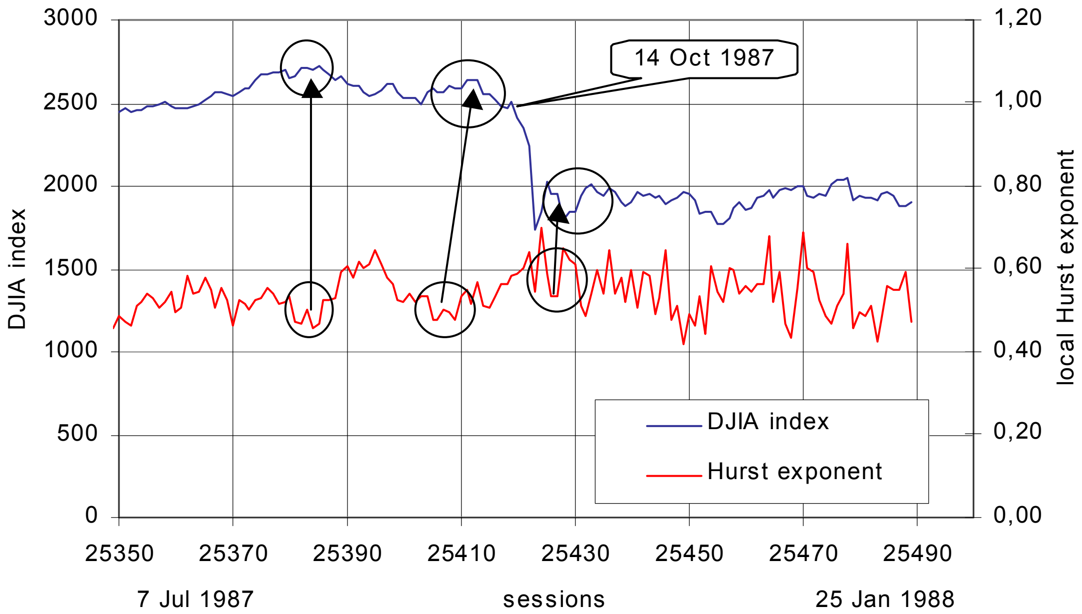

Figure 4b. The detailed structure of the October 1987 crash in the New York financial stock and the corresponding behaviour of the local Hurst exponent. The respective trends are marked in circles.

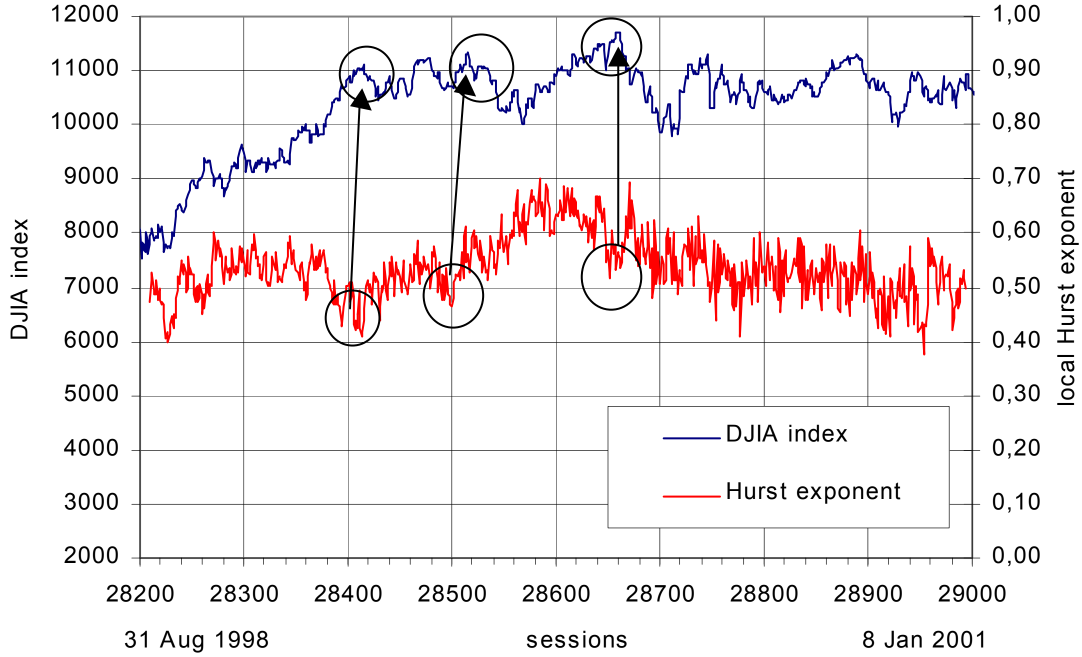

Figure 5. The trend comparison between the DJIA index and the local Hurst exponent in the end of the 20th century. The important signals causing changes in trends are spotted in circles.

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The role of the medical physics educator in a faculty of health sciences

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Abstract

The function of a faculty of health sciences is to achieve excellence in the education and training of students who aim to enter the health professions as well as to provide continuing professional development courses for those already working in the health care field. As the various health professions seek to expand their roles, curricula must be constantly revised in order to respond to changing educational needs. These roles and needs are in turn modulated to a large extent by the rapid advances in medical device technology and changes in international and national legislation and recommendations regarding the safe and efficient use of these devices. In these circumstances the medical physics educator must reflect on his own role within the health care educational structure and must continuously update his own knowledge of the physics underlying the new technologies in order that he may offer quality education to his students and be effective as an agent of change within the health care system. This paper seeks to define in more precise terms the role of the medical physics educator, identify the factors which impact on the role, describe the present role as practiced in various health faculties in European and US universities and suggest future directions for role development.

Key words: medical physics education, medical devices education, medical technology education, medical equipment education , health technology education

Introduction

The role of the medical physics educator in a faculty of health sciences has historically not been well defined. Often the various health professions are themselves not completely clear on what is required of the medical physics

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educator except that their students need some 'physics'. The requests for servicing have in practice ranged from physical chemistry to molecular biophysics, physiological physics and the physics of medical 'devices' (the legal term used when referring to medical equipment). In the past the scenario has more often than not read as follows. The physics department of the university was contacted by the board of studies of the particular health profession for physics servicing. The physics department then transferred this request to a member of its staff who had had some form of contact with the medical field. The latter was in turn presented with a vague remit by the course coordinator of the particular health profession. The physics educator then set up learning objectives based on those areas of physics that he considered relevant to this remit. This approach more often than not led to instruction based on learning objectives which were unsuited or even irrelevant to the everyday practicalities in the exercise of the health professions. Moreover as the physics educator was not part of the health care team there were often few of the practical insights required for real understanding and applicable knowledge. The 'theory-practice gap' was often simply too wide. Sometimes a medical physicist working in the medical physics department of a local hospital was asked to do the teaching. In such cases problems have been known to arise owing to insufficient academic background or teaching ability on the part of the educator. The results have been in many cases disaffection on the part of the students and a low level of motivation and enthusiasm on the part of the medical physics educator. The above 'ad-hoc' arrangements fail to address the fact that *successful medical physics instruction requires an academic person with a solid foundation in physics and mathematics who is willing to apply his knowledge exclusively to health care and the education of health care professionals*. Today the trend is for the medical physics educator to be part of the faculty of health sciences staff. A higher success rate in terms of student and staff satisfaction has been observed. In such cases the medical physics educator is part of the health sciences education milieu and therefore closer to the day-to-day problems of the clinical setting. However even in such cases the physicist is often at the margin of things as he does not have a clear and easily identifiable role. In order to improve the situation it is essential that the role be better defined, internationally recognised and measures taken to increase its profile. This paper seeks to define in more precise terms the role of the medical physics educator, identify the factors which impact the role, describe the present role as practised in various health faculties in European and US universities and suggest future directions for role development. This would lead to a better appreciation of the role by the other health professions and the production of more meaningful learning objectives. The medical physics educator may then be a better partner to other health care educators who aim to produce quality education for their students and hence be effective agents of change within the health care system.

Role definition

It is proposed that that the role of the medical physics educator *focuses* *exclusively on the medical efficacy and safe use of medical devices. This is a wide-ranging yet clear and unambiguous role which has a legal basis and can be easily appreciated by the other health professions.* The legal definition of a medical device has been made quite clear in recent years in international legislation [1-4]. Medical devices include patient monitoring devices, medical laboratory instrumentation, diagnostic imaging equipment, radiotherapy equipment, physiotherapy equipment, prosthetic devices, surgical equipment, patient support equipment and others. As this remit is very wide it is further proposed that other areas of study particularly those with a heavy biomolecular, biochemical and physiological component would be much better serviced by other departments (for example biophysics, biochemistry, molecular biology, physiology etc). Medical devices range from simple physiological measuring instruments to the intricacies of a magnetic resonance imager and provide an excellent opportunity for the medical physics educator to make the best use of his expertise and knowledge of modern physics. This role should be reflected in all aspects of the academic role that is teacher, researcher and subject matter expert (consultancy).

The teaching role would be best defined in terms of the general learning objectives suitable for instruction in medical device use. It is proposed that the learning objectives in the case of specific medical devices should be based on the following generally applicable areas of knowledge and expertise:

- Properties of the human tissues, systems, fluids, pathology etc which the medical device seeks to measure, correct, replace etc
- Physics principles underlying the equipment and technique
- Structure of commercially available equipment
- Operator controls on commercially available equipment
- Possible biohazards to patient, staff and others
- Measureable physical performance indicators which are directly related to medical efficacy or risk of biohazards
- Equipment and technique protocol design variables which impact medical efficacy
- Equipment and technique protocol design variables which impact risk of biohazards
- Methods of maximising medical efficacy whilst minimising risk
- Recognition of possible artefacts resulting from equipment malfunction or inappropriate technique
- Care of equipment
- Quality assurance and quality control of the equipment and technique
- International and national legislation and regulations regarding the use of the equipment
- Other topics of relevance to the particular medical device (for example room design)
- Future developments envisaged

These general areas of knowledge and expertise are designed to ensure that learning encompasses both the physicist's rigorous approach to equipment and the practical competency requirements of the health professions. It would also help in avoiding the extremes of superficiality or unnecessary physics detail which often afflict such courses.

The level to which each area of knowledge or expertise is taught would depend on the specific role of the particular profession.

In his role as researcher the medical physics educator would *have both a clinical and educational* research role. Clinical research on the efficacious and safe use of medical devices should be an ongoing process. This could range from investigations into the proper use of equipment in the clinical areas to new medical applications of existing commercial devices or improved quality control protocols. Where adequate staff and material resources are available improvements in existing devices and the development of new devices is possible. Research in medical devices is often multidisciplinary and provides a perfect opportunity for teamwork. Educational research in curriculum and instructional design development as applied to medical device education is essential in an age when new pedagogical methods and learning technologies are also expanding at a fast rate.

In his role as subject matter expert the medical physics educator would give advice to university and hospital administrators regarding the efficacious and safe use of medical devices (for example the commissioning, assessment and quality control of equipment) and advise legislators regarding the development and implementation of new legislation regarding these devices

Factors impacting the role

The major factors impacting the role of the medical physics educator are the rapid development of medical device technology, the expansion in healthcare services, the increase in pressure for quality health care from patient rights associations and bodies charged with accrediting healthcare organisations, the increase in awareness of the importance of occupational standards, the role development aspirations of the various health professions and changes in international and national recommendations, directives, regulations and legislation regarding the safe and efficacious use of medical devices (including specific *educational* requirements for the operators of these devices).

As medical institutions adapt their organisational objectives in reponse to these factors there is a need for increased medical device training of students and retraining of hospital staff. This leads to frequent changes in curricula. Clinical and educational research needs to be increased as hospital and academic decision makers must be informed by research in order that change be affected in a coherent and efficient manner.

Present role

In the case of undergraduate teaching the role is largely restricted to the professions of radiography (diagnostic and radiotherapeutic) [5-11] and optometry [12-13]. Teaching in the case of radiography is in the areas of equipment, image quality, radiotherapy planning and radiation protection. Owing to the known deleterious bioeffects of ionising radiation this teaching has been regulated [14,15] and as a consequence is becoming quite structured. Physics teaching in optometry is in the areas of geometrical and physical optics, photometry, ophthalmic instrumentation and lens design. Some teaching is also done in physiotherapy (physical therapy) in the areas of ultrasound, laser, shortwave, microwave, infra-red and ultraviolet therapies [16-18]. The extent of teaching in all these courses varies between and within countries. Teaching in medical and nursing schools is almost non-existent notwithstanding the fact that these professions use medical devices on a regular basis. Dental school curricula include basic X-ray imaging and the physics of dental prosthetic materials. In the case of postgraduate professional development course teaching is extremely variable. Again owing to the bioeffects of ionising radiation most work has concentrated in the areas of medical imaging (professions of diagnostic radiography and radiology) and radiotherapy (therapeutic radiography and oncology) [14, 15, 19 - 25].

In terms of clinical research a lot of effort has been has been put into the quality control of medical imaging and radiotherapy devices and radiation protection of patients and staff [26, 27]. Few universities today have the resources required to develop new devices however a lot of research is being carried out on new medical applications of existing commercial equipment. Little educational research has been carried out regarding curriculum development and instructional design applied to medical device education and the little that has been done is again mostly limited to medical imaging and radiotherapy.

As a subject area expert (consultant) the role has again been limited to advice to academic and medical facility administrators regarding the commissioning, use, assessment, quality control and safe use of medical imaging and radiotherapy devices, advice on radiation protection and advice on the implementation of new legislation regarding radiation protection [28].

Future role development

The structured approach to medical device education being developed in radiography, radiology and oncology education should be extended to the other health professions (particularly to those professions that are experiencing an increasing use of equipment for example the medical, nursing, medical laboratory scientist, physiotherapy, pharmacy professions). Medical devices undergo rigorous testing before being allowed on the market. However the user has a major influence on the efficacy and safety of the device and errors in the use of medical devices are not uncommon and are a source of concern. Research indicates that many professions are not comfortable with technology and fear harming the patient [29 - 36]. There is now a legal basis for medical and dental students to have a course in radiation protection included in their curriculum [14]. Particular emphasis must be given to the creation of a scientific attitude towards medical devices (for example equipment selection and specifications, accuracy, avoidance of operator errors, basic quality control and maintenance, calibration, malfunction detection) among all health professions in order that choice and management of equipment may be improved to the benefit of patients [37, 38]. This is particularly important at a time when responsibility for proper and safe use of devices is increasingly shifting towards the user. The expansion of technology will lead to the need for new professions. A new profession that is being developed is that of a medical device scientist. Some universities have already set up BSc courses in this area [39, 40]. Attention needs to be given to the creation of an awareness for a wider ethical approach to the use of medical devices (for example just allocation of technology resources). Harmonisation of curricula on an international scale in medical device education is essential in order that mobility of health workers be facilitated. Education of the public particularly in view of the shift towards home care and the emphasis on individual responsibility toward personal health care has become important [41-43]. Cooperative multidisciplinary instructional strategies should be introduced to foster the health professional team approach to health care. Students must be taught the ability to communicate better to patients the medical procedures involving medical devices in order to reduce medical device anxiety among patients

Clinical research will expand as the number of new medical devices increases. Opportunities are increasing in the medical applications of lasers, new materials, computers, robotics, biosensors, imaging techniques, combination device-drug products and others [44 - 46]. Educational research may concentrate on the use of information technology (for example) computer simulation in medical device instruction as training on human patients is considered unethical. Educational research would target the development of curricula for those professions who have little medical device instruction in their present curricula and the development of curricula for professions which are moving to university based education or which are in the process of developing higher degree programs.

As the number and complexity of medical devices increase the subject matter (consultancy) role would expand. This would be particularly true in those countries where the number of qualified medical physicists is low or where physicists have other perhaps more attractive opportunities to exercise their scientific skills.

Conclusion

The role of the medical physics educator has been limited to those professions traditionally viewed as requiring a high physics input. This has had the effect of reducing the impact of the role on health care education. As a consequence the level of appreciation of the role by other health care professions is low. As there is little medical technology input in the curriculum of many health professions most health professionals are ill-equipped to face medicine's technological future. Many health professionals are not at all at ease when it comes to the use of equipment with the result that highly sophisticated and expensive medical equipment in hospitals is under-utilised, used in a non-efficacious or even in an unsafe manner. This leads to the possibilities of missed diagnosis and/or direct injury to patients. As medicine becomes more technology oriented the medical physics educator will become an integral part of the health care team. The dearth of medical physicists working in the clinical areas in all countries is leading to a higher demand for consultancy services. There is a danger that the subject matter expert (consultancy) role would encroach on the teaching role. To reduce this danger there should be an attempt to incorporate some clinical medical physics techniques (for example routine quality control of equipment) into the roles of the various other health care professions. This would provide an opportunity for role expansion for these professions and at the same time allow the medical physics educator more time to concentrate on areas which require a high level of physical and mathematical expertise such as the development of better quality control tools or the development of new medical devices. As the pace of technology increases research published in academic journals, conference proceedings and on health oriented websites is reaching a point where keeping up with developments has become difficult. Specialisation is becoming necessary as no medical physics educator can possibly keep up with medical device development in all fields of medicine.

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Teaching radiation physics concepts and techniques to archaeology students

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Abstract

This paper provides a model of the development of a radiation physics curriculum designed for archaeology students together with an analysis of the problems encountered in teaching physics to non-scientifically-oriented arts students. The analysis is based on ten years teaching experience of the area within a university arts faculty. An overview of the applications in archaeology of radiocarbon and thermoluminescence techniques (used in the dating of human remains and artefacts), medical imaging techniques (radiography and computerised tomography scanning used in the study of the structure of human remains and artifacts), ground-probing radar and side-scan sonar (used in the location and exploration of buried and underwater remains respectively) and proton induced X-ray emission (PIXE) (used in provenance studies of human artifacts) is also provided.

Key words: curriculum development, radiation physics education, archaeology education, applied physics education

Introduction

Many physics based archaeological techniques involve the use of radiation (Pollard & Brothwell, 2001; Renfrew & Bahn, 2000; Aitken, 1990; Aitken, 1974). As the number of techniques is large and the allotted time for physics teaching in archaeology courses is low, the curriculum design process must include a careful needs analysis so that essential competencies are not omitted. Moreover as entry competencies in physics for arts students are not sufficient there is a further requirement for attention to be given to refinement of prior knowledge and the elimination of misconceptions. The stages of the curriculum design process used by the author in the formulation of a university unit of lectures on physics methods used in archaeology delivered at the Department of Archaeology of the University of Malta is described. This is followed by a short description of the principles of some of the physics methods included in the curriculum and a brief indication of envisaged future developments in the said curriculum.

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Curriculum design process

The curriculum design process employed is summarised in Table 1. The first column lists variables which impact the curriculum. The second column describes action taken to analyse the variable and its effect on the curriculum. The final column describes outcomes in the actual curriculum and instruction. In order to ensure that the curriculum would be relevant to the archaeology profession a needs analysis was carried out (Watkins, Leigh, Platt & Kaufmann, 1998). The three stakeholders that is the students, the university archaeology department and future employers have similar yet distinct goals and needs. Care was taken to ensure that needs were analysed from the point of view of the archaeology profession as opposed to that of the physics profession. Essential competencies were identified keeping in mind the milieu in which students would be eventually undergoing practice and the limited teaching time. Instructional objectives were then set up to address these competencies (Dick, Carey and Carey, 2001). Entry competencies were identified using questioning based on a radiation physics concept inventory on the lines of the Force Concept Inventory (Hestenes, Wells & Swackhamer, 1992). An appropriate instructional strategy was then devised to overcome prior knowledge deficiencies. Possible misconceptions were identified from personal experience and the literature (Boyes & Stanisstreet, 1994; Millar, 1990). Learner attitudes that may impact heavily on the attainment of learning objectives were identified, analysed and addressed

Variable	Action	Outcome
Stakeholders goals and needs.	Stakeholders goals were identified and a needs analysis carried out. The stakeholders : Students: need to be able to demonstrate competency in radiation methods used in archaeology to be able to go on to further studies or find employment. University archaeology dept: need students proficient in techniques of interest for archaeological research sites Future employers: (museums, tourism organisations, conservation institutes etc): goals and personnel needs.	Competencies were required in the following general areas of archaeological expertise: 1. Location and exploration of buried and underwater remains 2. Dating of artifacts 3. Provenance of artifacts 4. Study of metal artifacts 5. Study of human remains *There is a requirement that all methods must be of a non-destructive nature owing to the uniqueness of many archaeological artifacts.*

Teaching time	An analysis of the length of the topics in relation to contact time was carried out. Problem - limited contact time: 14 lecturing hours 1 hour tutorial session 35 hours personal study time Decision: few topics in depth or comprehensive-yet-somewhat shallow survey of methods?	Comprehensive – survey of methods *plus an in-depth study of at least one method from each archaeological area of expertise* (chosen according to relative importance in eventual performance context ie research or employment). This was considered essential in order to avoid the superficiality that often characterizes such cross-disciplinary courses. The in-depth methods chosen were: 1. Location and exploration of buried and underwater remains: ground-probing radar and side-scan sonar. 2. Dating of artifacts: radiocarbon and thermoluminescence dating 3. Provenance of artifacts: Proton Induced X-Ray Emission (PIXE) 4. Study of metal and pottery structure: radiography 5. Study of human remains: radiography and computerised tomography (CT) scanning
Competency analysis	Competencies in each of the above areas were analyzed and those required of an archaeologist (as opposed to a physicist) were identified.	A list of instructional objectives was set up for each of the above areas. Since students would eventually be involved in sample collection it was considered essential that they have an in-depth knowledge of the precautions to be taken to ensure integrity of the samples.

Entry competencies	Entry competency analysis was carried out (previous qualifications and an initial questioning session using a radiation physics basic concepts inventory similar to the Force Concept Inventory). Missing baseline competencies in radiation were detected in most students as all students were non-science students. Presence of some mature students with very little previous encounter with science (but highly motivated).	Pre-course handout on atomic and nuclear structure, radioactivity, particles, waves, photons, instrument structure and specifications, basic principles of measurement (uncertainty etc) was produced.
Misconceptions on radiation physics	High level of misconceptions was expected. Literature search on misconceptions in radiation physics was carried out to identify possible misconceptions. Some misconceptions identified were: particle radiation vs photon radiation, radiation vs radioactivity, longer wavelength means 'bigger wave' means higher energy, atomic vs nuclear processes, disintegrating nucleii turn completely into energy and mass and volume decrease, X and gamma radiation makes things radioactive.	Concepts were differentiated by means of a list of operational definitions. Conceptual revision or knowledge refinement instructional strategies were employed (concept mapping, questioning etc). Lectures were planned and delivered keeping these misconceptions in mind.
Mathematics ability.	The mathematical content of the lectures was carefully analysed as students were not familiar with advanced mathematical techniques.	No unnecessary mathematics or derivation of formulae were included (formulae were given in the form which would be required for archaeological calculations). Use of required necessary calculator functions was included.

Learner attitudes		
High level of 'physics anxiety'	A literature search was carried out to explore reasons for physics anxiety among students.	One of the explicit hidden educational goals was that students would have a positive experience of physics. An informal lecture environment was created, students were taught in their own department and not at the physics department. Handouts were given for all lectures so that students would not fear missing important points (they could therefore concentrate on understanding instead of taking notes). Each in-depth topic was completely independent of the others so that students would not fear that problems in one topic would lead to a similar situation in others.
"Do we really need all this?".	This is more often than not a consequence of 'physics anxiety'. It is also compounded by a feeling still present among some archaeologists that science methods are not 'real archaeology'.	The need for physics methods in archaeology was demonstrated by various case studies (video format when possible) derived from the literature. It was also emphasised that science methods are not there to compete against traditional archaeological methods but are there to complement these methods. Problem sheets were based on real archaeological problems and case studies.
"Why these measurement uncertainties, isn't science supposed to be precise?"	This is really a misconception about science.	This common misconception was discussed (uncertainty and precision, random variability in nature, bias and inaccuracy …).

Table 1: Variables impacting the curriculum, action taken and outcome on the final curriculum and instruction.

Physics methods in archaeology

A short description of the 'in-depth' techniques follows. Sources for further reading can be found in the references.

Ground-probing radar (GPR) and side-scan sonar are two powerful remote sensing imaging techniques which have been used extensively for the discovery and exploration of buried and underwater remains. The former is used to image underground features whilst the latter is used in underwater archaeology (in the case of wrecks which are not completely buried under the sea bottom). They are essentially both emission-reflection-detection techniques. GPR uses electromagnetic radiation of frequency in the range 25MHz to 1GHz whilst side-scan sonar makes use of ultrasound of frequencies in the range 100 – 500kHz. In both cases the higher the frequency the higher the image detail ('spatial resolution') but the lower the penetration depth owing to high attenuation of the beam (Scollar, Tabbagh, Hesse, & Herzog, 1990; PORT Maritime Information Gateway, 2002)

Radiocarbon dating is used to date organic materials. It is based on the principle that all living things maintain a certain constant specific activity of the radioactive isotope C-14. When a living object dies this activity starts to decrease with a half-life of 5730 years. By measuring the present activity of the material one can work out the time between death and present. (Aitken, 1990; Universities of Waikato (NZ) and Oxford (UK), 2002)

Thermoluminescence dating is used to date non-organic materials like pottery and hence complements radiocarbon dating. Certain materials in the pottery are capable of storing energy from radiation emitted by radioactive materials in the surrounding soil. The longer the material has been buried the higher would be the stored energy. The latter is therefore a measure of the time since burial. The energy is released as visible light when the material is heated (hence *thermo*luminescence). The amount of emitted light is a measure of the original stored energy and hence the time since burial. (Aitken, 1990)

PIXE is a very sensitive means of measuring trace elements in materials. The material is bombarded by a thin beam of protons from an accelerator which knocks inner shell electrons out of atoms in the sample. The vacancies in the inner shells are then filled by outer electrons. This is followed by the emission of X-radiation the frequencies of which are characteristic of the elements in the sample. Since materials from a particular source would have a particular mix of trace elements the provenance of the material can be established. The method is non-destructive, requires only a small amount of sample, highly precise and capable of the simultaneous analysis of a wide range of elements.

Radiography is a means of producing an image of the internal structures of an artifact making use of the fact that different structures and materials in the artifact attenuate X-rays to varying amounts (differential attenuation). Rays passing through the artifact are detected by film or more recently by digital sensors. The latter makes possible the use of digital image processing techniques. Higher energy X-rays are required to penetrate metal than human remains (higher energy X-rays are produced either by using a higher voltage to accelerate electrons onto the target in the X-ray tube or by using a gamma-ray emitting radionuclide). (Corfield, 1995; University of Pennsylvania Museum of Archaeology and Anthropology, 2002)

Computerised tomography (CT) produces images of cross-sections of the object (tomograms). A thin fan of X-rays slices through the object in the cross-sectional plane of interest. A line of digital sensors detects the X-rays emerging from the sample. Mathematical algorithms are then used by the computer to calculate the structure of the artifact slice and produce the image. Images of a series of contiguous slices can be reformatted as a three-dimensional image which can be viewed on a computer workstation. The technique has been used extensively in the study of mummies (Jones, 1992).

Future developments

Some possible areas for future developments of the curriculum and for research have been identified:

- Are there significant learning-style differences between physics and archaeology students? How would these differences impact the curriculum?
- Are there means of increasing the in-depth topics (eg X-ray fluorescence, neutron activation analysis) without overloading the unit?
- Should one introduce an element of physics practical work - again without overloading the unit?
- Is there scope for computer-based learning?

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Harmfulness of noise and proposals of its reduction based on noise intensity research in primary and secondary schools of Częstochowa and Opole

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Introduction

Due to rapid processes of industrialization and urban development at the turn of 20th and 21st centuries noise became one of the most fundamental and at the same time dangerous threats to man. The cause of this state of affairs is amongst others the clear increase in number of noise sources in our direct dings both at home as well as at work and even at school. Due to the fact that young people stay at school a few hours each day it was interesting to find to what extent they are exposed to noise influence. An opinion poll was conducted to find out this influence and its results are included in this paper Furthermore, an analysis of possible prevention against harmful noise effect on school youth was presented. The research area included the selected primary and secondary schools in Częstochowa as well as the selected schools in Opole.

Noise and its harmfulness

One of the most intense stimuli beside visual sensations with information about the surrounding world are auditory sensations i.e. acoustic vibrations which influence man and are audible within freguency range from 16 Hz to 20 kHz. If vibrations occurring in such a range are burdensome or harmful, they are commonly described as noise. The most frequently used measure of noise is sound level expressed in decibels [dB]. The range of sounds occurring in sound level environment is rather vast starting from threshold values i.e. level 0 [dB] which are capable of eliciting auditory sensations in man (auditory threshold) up to the values causing physical sensation of pain – 130 dB (pain limit).
It is to be stressed that noise may exert a negative influence not only on man's health but also on flora and fauna. Noise harmfulness depends on its intensity, character of changes in time, structure of acoustic spectrum, duration of influence. In the acoustic spectrum of noise there may be components of infra – and ultrasounds which exert an additional harmful influence on human organism.
Vibrations frequently occur along with noise i.e. mechanical vibrations transferred onto the building structure or human body as a result of direct mechanical contact between vibration source and recipient.
Nowadays in the urbanised world we deal with the universal occurrence of noisy and vibratory phenomena. The most frequent physical sources of noise in nature are:

- machines, devices and tools (e.g. pneumatic hammers, compressors, drills, grinders),
- a part of technological processes generating aerodynamic noise (e.g. steam dump under pressure),
- railway vehicles, planes, vessels,
- other vehicles (tractors, machinery used on site etc.),
- municipal facilities (lifts, hydrophores, transformers, fans, pumps). Industrial, types of noise are distinguished in relation to noise source and its occurrence.

- Universal character of noise sources in human surroundings exposes us to harmful noise effects practically under any circumstances: at home, at school, at work it often turns out that it constitutes a part of leisure time.

Research has confirmed that noise is harmful to man. Its long – term influence may results in nervous diseases in human organism. Man, which is under influence of noise during the period of the first several months, shows signs of visible tiredness and irritation. Human organism adapts itself to the existing acoustic conditions within the period of subsequent months and years. After this period the symptoms recur initially in the form of permanent disturbances and beside intensive nervousness and tiredness such symptoms as headache and insomnia occur. First and foremost noise has influence on quality and precision of work performed by man. This influence is all the more visible if this work requires more concentration or particular precision from man. According to the International Labour Office even weak noise is capable of decreasing job performance by 40%. Psychological reactions of organism on noise (we start to be aware of its presence or it causes awakening) occur the noise level exceeding 35 dB (A), on the other hand physiological reactions such as changes in heartbeat rate, nervous impulses, breathing rate and those causing 85 dB (A). Noise level is above all decisive as regards noise harmfulness to human hearing.

It is commonly considered that sounds which show intensity level lower than 25 – 35 dB (A) are indifferent to man sounds showing intensity level within 25 – 35 dB and 55- 65 dB (A) are bearable and those above 75 – 85 dB (A) are harmful. With the same level and duration being preserved noise is all the more harmful if it occurs in the narrower frequency range. Noise harmfulness is dependent on the occurrence of noise peak values in a given part of spectrum. Higher level of harmfulness is observed at higher frequencies. Moreover, the damaging noise influence is accumulated in time. Noise with relatively low level (in the order of 75 – 85 dB (A) but acting constantly within longer time (in the order of several or even more years) may be the cause of permanent damage of hearing. It is also to be observed that the degree of mental preparedness towards the occurrence of a given noise is decisive as regards noise harmfulness. Sudden noise is more harmful since it takes by surprise the eardrum in middle ear. Negative influence of noise and vibration manifests itself by its rare occurrence on the immediate basis and its accumulation in time.

Noise is the most common and most frequently raised issue of life in relation to people living in towns. Due to its qualities it influences a great number of groups causing strong emotions and social reactions. Noise threatens basic residential needs – calm, leisure, recuperation.

Noise encroaches upon family life, disturbs many important functions and social processes, constitutes inconveniences and very often contributes to unrest and insecurity. Noise at very high levels is relatively seldom observed (several hundred dB). It destroys the hearing organ (it damages eardrum) if it reaches the ear with high pressure. Immediate and permanent deafness follows. Long – term noise influence at the level above 85 dB causes the increasing damage to ear including deafness in extreme conditions. It is characteristic of some workplaces in industry and transport. It is to be stressed once more that the destructive high level noise influence can be understood intuitively but one should realize that lower – level sounds or even relatively low – frequency sounds are not indifferent to human organism. It is commonly considered that noise influence is insignificant in the areas where the average noise level is lower than 55 dB. As the noise level increases, the percentage of people who negatively view acoustic conditions in their places of residence also increases. Also the scale of perceived inconveniences extends.

With the values above 65 dB there is a clear intensification of irritation and emotional tensions, slowing down of psychomotoric reactions, decrease of coordination abilities, disturbances of concentration. The above – mentioned phenomena make work more difficult and mental work in particular as well as cause lower precision of its execution and the increase in number of mistakes. Noise at work is one of the most frequent factors, which are harmful and burdensome. The Institute for Labour Medicine considers that more than 600 000 employees in Poland are employed in conditions exposed to excessive noise. Every year 3000 new cases of occupational hearing damage are reported. Noise influence contributes also to many organism disturbances. People exposed to noise more often manifest the disturbance of:

a) blood circulation system (heart beating and palpitation, rapid tiredness, shortness of breath, dizziness, strokes, arterial hypertension),
b) alimentary duct,
c) internal secretion system (metabolic diseases),
d) nervous system (disturbance of emotional balance, tension and unrest, sleeplessness, nervousness, constant tiredness),

Furthermore, an essential problem is the noise influence at work (it is school for students) that can be “intensified” by acoustic conditions is one’s residence and during leisure time. Therefore, it is essential to maintain appropriate acoustic conditions at home although these are not appreciated. Man exposed to an excessive amount of noise at work has every chance to recover his good state of health when he gets back home.

Harmful influence of the above – mentioned vibrations on human organism depends on their frequency, amplitude and rapidity.

The result of vibratory influence for man is vibration disease and its advanced degree depends on intensity and duration of vibration. Human ear like eye is adapted to reception of sensations within a certain range of frequency. In such a case we talk about audible sounds. Also ultrasounds and infrasounds influence human organism. Ultrasounds are more and more frequently applied and industry, in vibrators, washing stands, flaw detectors and other devices of this kind as well as in medical diagnosis e.g. in ultrasound scanners. It is assumed that intensity in order of 0.4 W/cm^2 and higher manifest itself by harmful influence upon living tissue. The basic result of ultrasound action is the increase of tissue temperature and particularly in places situated at the border of two tissues with different properties of ultrasound conductivity. In some extreme cases ultrasounds, which are propagated in space as a disturbance with high differences of pressure, can tear a tissue or a cell. Ultrasounds of frequencies in the order of MHz are entirely absorbed by air layer a few millimeters thick, on the other hand ultrasounds of lower frequencies in the order of tens and hundreds of KHz have a bit larger scope and still sufficiently small so that only their intensive source cannot be dangerous to an average citizen – jet plane engine. Besides ultrasounds there are also infrasounds i.e. vibrations with frequency lower than audible acoustic vibration frequency consisting in propagation of elastic waves in gaseous media and above all in air. Among these infraacoustic vibrations the sources occurring outside workplace. Natural and artificial sources are distinguished. According to another classification of occurrence of infrasound sources. Rough sea, waterfalls, winds, storms, earthquakes and volcanic eruptions are rated among natural sources i.e. atmospheric and seismic phenomena as well as those connected with the movement of water masses. Eruptions, in particular nuclear and thermonuclear, exploitation of means of transport or some machines and industrial devices. Since the infraacoustic waves are longer than human body therefore they can influence his body from all sides. It is to be stated that the infraacoustic wave may have an influence e.g. on human internal organs inducing resonant vibrations, which may lead to irreversible damage. Table no. 1 presents the layout of symptoms connected with the influence of infraacoustic vibrations.

Table 1.Disease symptoms connected with the influence of infraacoustic vibrations

Frequency [Hz]	Level of acoustic pressure [dB]	Time of vibrations influence [Min]	Symptoms	According to
2-15	105		At 50% of the examined persons the time of optic reaction was extended, at 10% - balance disturbance	E. BRYAN W. TEMPEST
1-2	150		Shifting of auditory threshold, the sensation of eardrums shifting	E. BRYAN W. TEMPEST
2-15	110-120		Increase of reaction's time by 4%	H. LEWENTHALL
10	135	15	Sensation of internal organs ' whirling, feeling of eardrums vibrations, pain of middle ear, pulse acceleration, increase of arterial pressure by 20 min. Hg, acceleration of breathing by 4 and more breathes per minute, auditory threshold's shifting at 15 – 20 dB at the examination's time, and at 8-10 dB directly after finishing it	E. MALSZEV G. SKORODUMOV
7	90	35	Fall of blood pressure, loading of pulse's frequency, heart murmurs	E. BRYAN W. TEMPEST
2-22	119-144	3	Lack of heart murmurs, auditory threshold's shifting at 10 dB	E. BRYAN W. TEMPEST
1-100	154	0,4-2	Sensation of walls' rocking, headache, shortness of breathing, ears' ringing, lockjaw	E. BRYAN W. TEMPEST

Protection from noise

In the presence of common appearance of noise sources in our surrounding the protection from noise occurs extremely essential. In Poland like in another countries exist suitable norms determining maximum acceptable noise level in recreation and residential areas. Basic norms are fixed in decree of Cabinet issued in September 30, 1980 published in Dz. U. No 24 1980. In the tables 2 and 3 chosen data from this act are given.

Table 2. Acceptable sound levels penetrating into residential rooms, public utility and rooms designed for intelectual work

	Maximum acceptable equivalent sound level from all kinds of noise sources, [dB] (A)	Maximum acceptable level of installation and device noise in the building, [dB] (a)

Type of room	During the less favorable 8 hours: from 6.00a.m. to 10.00 p.m.	During the less favorable 30 min. between 10.00 p.m. and 6.00 a.m.	During the day from 6.00 a.m. to 10.00 p.m.	During the night from 10.00 p.m. to 6.00 a.m.
Residential rooms in residential buildings, dormitories and hotel rooms category S and I	40	30	35	25
Hotel rooms category II and III	45	35	40	30
Patient rooms in hospitals and sanatorium	35	30	30	25
Surgeries	35	-	30	-
Operating and post operating rooms	30	-	25	-
Classes and school laboratories, lecture halls	40	-	35	-
Auditorium, conference rooms	40	-	35	-
Rooms for intellectual and conceptual work or for another work requiring brain concentration	35	-	30	-
Administrative rooms without internal sources of noise	40-45	-	35-40	-
Reading rooms in libraries	35	-	30	-
Classes and rooms in community center, common rooms etc. depending on usage	40-50	-	30-40	-

Table 3. Acceptable noise levels

Type of area	Considered sound level [dB]		Maximum short-lived sound level [dB]
	6.00 a.m. – 22.00 p.m.	22.00 p.m. – 6.00 a.m.	
Area of health resort, landscape's park, historic districts	40	30	65

Areas surrounding sanatorium, suburban recreation areas	45	35	70
Built-up areas with a few numbers of shops and traffic up to 1000 cars per hour, research institution area, areas of permanent residence of children	50	40	75
Built-up areas with a few numbers of shops and traffic up to 2000 cars per hour, parks in the cities, recreation and sport area	55	45	80
Downtown	60	50	85
Research and scientific research institution's area and another in similar character	50	40	75
Built-up areas connected with permanent or mulithours residence of children and youth	50	40	75

Besides the law regulations another activities are taken which aim at protection from noise. But taking these activities we can only limit acoustic energy which is emitted from these sources, however it is very difficult to eliminate it completely. One of the basic method to fight against noise is to lower the intensity of tone produced by self-source. We should move away noise source, lock it in a tunnel or fence off by acoustic screens, place it in soundproof covers. The role of acoustic screens can be played by shopping pavilions, public utility buildings. A huge role at sound suppresion of noise is played by greenery which absorbs noises very effectively and therefore is often used like shield belt between buildings and the street. The noise penetrates into an apartment mainly through windows and doors. So it is necessary to do these elements right. We can always make the windows and doors this way that the noise level inside the apartment will achieve low, determined by the law regulations level. For that purpose we can apply a rubber sealing, double or even triple panes, necessarily made of glasses of different thickness, because each pane is like membrane suppresing waves strongly only at some frequency. Selecting right windowpanes we can achieve desirable suppresion of noise. Very important role play making building's walls from appropriate materials, which make possible effective insulation not only of external but also internal noises. Appropriate shaping of building's elevation has large influence on sound waves reflecting abilities (balcony, loggies, recesses). Right arrangement of buildings with respect of busy street decreasing number of these occupants, which are exposed to the most troublesome influence of noise. Also so easy solutions as locations of kitchen, bathroom, stairs from this side of building, which is display to noise influence can be helpful in improving acoustic climate of apartments. People who work at noisy places should necessarily use ear stoppers, sound – proof earmuffs or helmets in order to isolate audition organ form reigning noise at a given place.

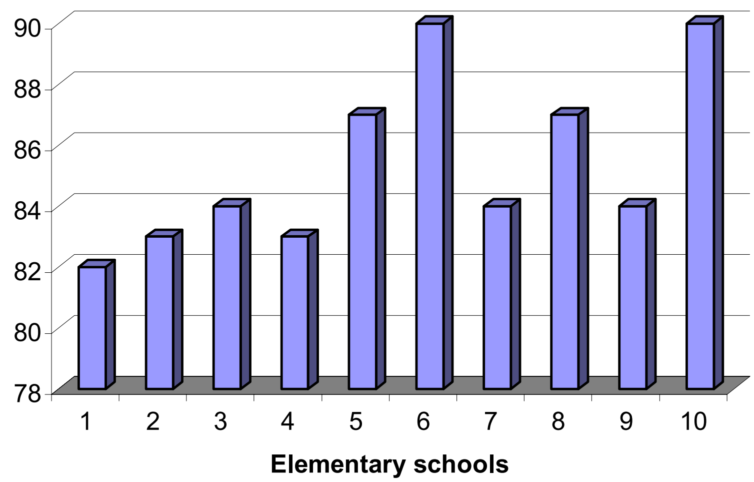
It should be remembered that the noise, especially in scopes of low frequency effects on whole human body, in connection with this application of individual protections is only half- measure. Poland like many another countries is strongly "polluted by sound". Unfortunately we do not have reliable estimation about job results of excessive noise in many Poland's regions. But we can suspect that they are serious. From closer unknown reasons, this kind of environment pollution is not within the area of interest of decision – making subjects and different organization (for example ecological ones). Therefore exist the necessity of detailed research conduction on this field and to make us aware of importance of this problem.

Description of researches conduction

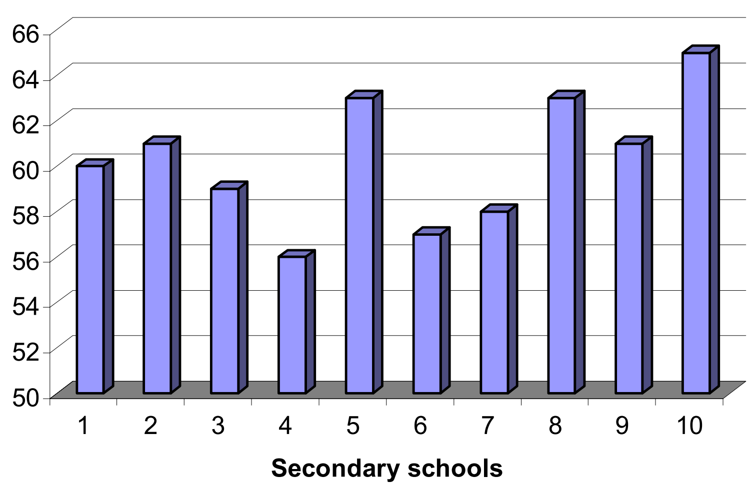
For measurement of noise level a measuring instrument (at a range of 110 dB) was used, which was made within a framework of diploma thesis at Institute of Didactic of Physics and Astronomy. During the measurement taking the microphone was placed within the distance not lesser than 1 meter from the wall or reflecting surface, 1.2 meter above the floor and 1,5 meter from the windows. The measure of noise level was carried in school corridors during the long lecture – break that is about 15 to 20 minutes. At this time as a result of measurement the maximum noise level was taken.

Researches results

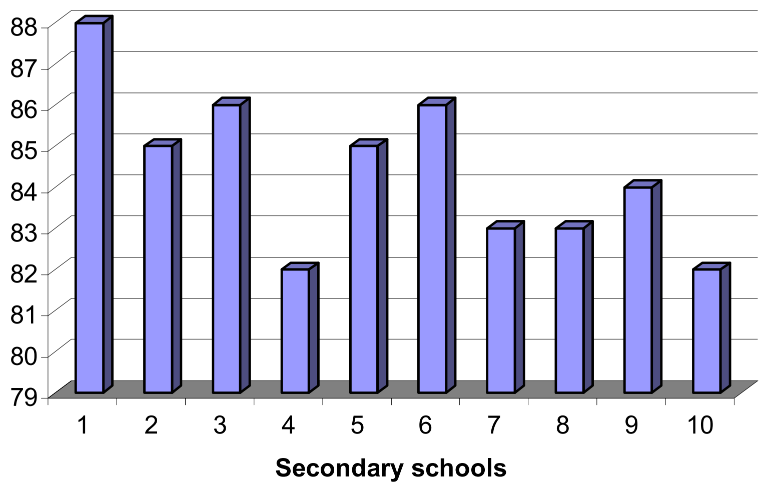
The result obtained during the researches in primary and secondary schools in Czestochowa and secondary schools in Opole are presented below on the graphes.



Graph 1. Noise level in chosen elementary schools in Częstochowa [dB]



Graph 2. Noise level in chosen secondary schools in Częstochowa [dB]



Graph 3. Noise level in chosen secondary schools in Opole [dB]

Conclusions

On the ground of article 50 of act issued on January 31, 1980 about protection and shaping natural environment on the research institutions' area and another having similar characters maximum short-lived sound level should not exceed 75 dB (A). The noise level was measured in 10 secondary schools and 10 elementary schools in Częstochowa and 10 secondary schools in Opole. The measurements showed, that the noise level was not above 75 dB (A) in no one of secondary schools. At secondary schools where among students prevail girls, the noise level do not exceed 65 dB (A). In some of secondary schools the noise level was even 56 dB (A) and 57 dB (A). A little louder is in technical collages and in school buildings, where more than one school is located. In technical colleges the noise level waved from 63 dB (A) to 73 dB (A). This result could be caused by bigger number of persons staying at school buildings. It is necessary to mention, that in many cases during the long break students didn't come out on corridor or they stayed in lecture classes, what automatically reduced the noise level on the corridor. Except this, the noise level measurement was taken in spring time, when students enjoyed beautiful weather spending the breaks outdoor, what also could cause that the noise level could be reduced. It is significantly lauder in elementary schools. Here the noise level exceeded 75 dB (A). In 60% of elementary schools the noise level waved from 80 dB (A) to 85 dB (A), in 40% of elementary schools the noise level waved from 85 dB (A) to 90 dB (A). The results of noise level's measurement are also not satisfactory in secondary schools in Opole, they exceed maximum acceptable noise level (75 dB) in all of schools tested.

As a measurement's uncertainty accepted the smallest scale: 1 dB. Measuring errors could be caused reading inaccuracy from the measurement device and external influence.

Prevention possibilities of harmful influence of noise in schools

The results of conducted test show the necessity of fighting with noise in schools, especially in primary and secondary schools. On the ground of observations conducted during the test following ways of noise level's reduction during the lectures' breaks can be suggested:

- there should be designed appropriate corridors' constructions in schools with so called boxes and with sound-absorbing doors,
- corridor walls in existing building should be finished with sound – absorbing materials
- belts of greenery should be extended around school buildings and also plants should be put in school corridors
- make students and pupils aware of the noise harmfulness on human organisms (especially students and pupils) by realization of projects, posters, contests and discussions at weekly class meeting
- organizing of different ways of resting during the lecture breaks (for example prepare "music recess", pin – pong tables)

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Physics and Brain

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Abstract:

Neuroscience is a new and exciting field that explores the brain, an extremely complicated system. In order to understand interactions between atoms and molecules in the brain, the knowledge of physical laws governing these interactions is essential. A basic knowledge of what happens at the smallest level of matter, the realm of subatomic physics, has given scientists powerful tools for studying living human brains. In this poster, macroscopic measurements of human brain activity are discussed introducing modern brain imaging techniques such as magnetoencephalography (MEG), electroencephalography (EEG), magnetic resonance imaging (MRI), near infrared spectroscopy (NIRS), transcranial magnetic stimulation (TMS), positron emission tomography (PET) and single photon computed tomography (SPECT). Some suggestions how this knowledge could be used in physics classes are also given.

Introduction

Human brain is an exceptionally complex system that contains 10^{12} neurons. Basic property of the neuron is electrical excitability that allows propagation of action potential, i.e. signal, through the brain. Every neuron is connected to 1000 neurons, which makes it impossible to follow signal transmission at the cellular level. Functional neuroimaging techniques provide macroscopic measurements of human brain activity.

Physical principles and methods are broadly used to investigate the structure and function of the human brain. Structural neuroimaging techniques, such as computed tomography (CT) and magnetic resonance imaging (MRI), attempt to examine anatomical structure of the brain and pathological structures such as tumors. Functional neuroimaging techniques are used to investigate which areas of the brain perform a particular function, the sequence of activation of those areas, and what happens to this functional organization when diseases occur.

Functional neuroimaging answers the question where and when brain activity takes place stepping up to the most intriguing question of how the brain works. Short description of some functional neuroimaging techniques is given to elicit interest of physics teachers in this very propulsive field of the interdisciplinary research.

Functional MRI (fMRI), and PET provide detailed pictures of spatial patterns of neural activation based on associated hemodynamic changes, but cannot capture the temporal dynamics of electrophysiological activation on its characteristic timescale. High temporal resolution can only be achieved by using a technique that measures the electromagnetic activity of the brain directly. MEG and EEG provide excellent temporal resolution of neural population dynamics but are limited in spatial resolution. Each technique gives important and unique insight into neural function and functional organization of the brain. Electromagnetic and hemodynamic methods are combined to derive spatiotemporal brain activation.

EEG

Electroencephalography (EEG) is the measurement of the difference in electrical potential between two areas of the head[1]. The electrodes are usually placed on the scull and referenced to a control area, usually nose or cheek (Fig. 1). The number of electrodes used can vary a lot (2-256). Impedance level should be kept fairly uniform across electrode sites.

Figure 1. EEG cap and EEG electrodes placed directly on the scull.

EEG cannot detect signals from all neurons. The source has to be a large synchronized group of neurons that is faced in a good direction so that they produce a dipole. The source generally cannot be too far from the scalp.

Whenever some sensory stimuli are presented or if a person performs a cognitive task, there are changes that occur in the brain. EEG can measure *event related potentials (ERP)* - an event locked response in the EEG waveform. As signal-to-noise ratio is very low ERP can normally be seen only after averaging multiple EEG waveforms (Fig. 2).

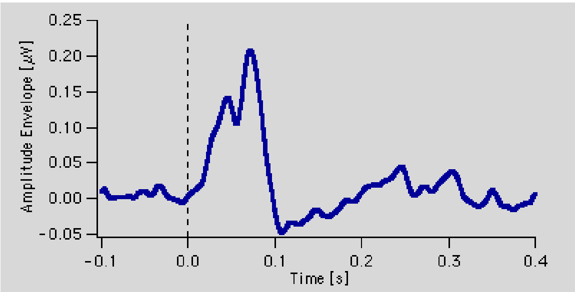

Figure 2. Averaged ERP waveform elicited by auditory stimulus.

MEG

Magnetoencephalography (MEG) is the completely non-invasive measurement of the weak magnetic fields generated by neuronal activity in the human brain[2]. By measuring the magnetic field evoked when specific sensory stimuli are presented to a subject, a map of the functional organization of the brain can be deduced with a sub-centimeter spatial resolution and a millisecond temporal resolution.

The two main difficulties in measuring MEG are that the fields are weak (fT range), and that environmental noise sources (the earth's magnetic field, cars, distant electrical equipment) produce magnetic fields much greater than those that are produced by the brain. The measurement of fT fields can be achieved using *Superconducting Quantum Interference Devices (SQUIDs)*. The basic principle of SQUID operation is that the quantum mechanical tunneling current through a weak link in a small superconducting loop is dependent on the magnetic flux through that loop. Problem of environmental noise is solved by the use of magnetically shielded rooms (Fig. 3). Such rooms have one or more layers of a high permeability alloy that give good low frequency shielding, together with a high conductivity shielding to provide eddy current shielding for higher frequency fields.

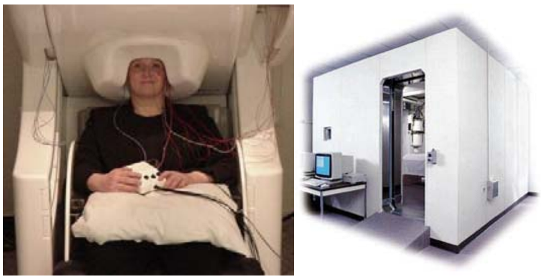

Figure 3. MEG system and magnetically shielded room.

To locate the activated area of cortex it is necessary to solve the *inverse problem* i.e. given the measured magnetic field, the generating current distribution within the brain must be calculated. Both EEG and MEG suffer from non-uniqueness, as there are many different current distributions within the head that could produce the measured field. A common model used is to assume that at any instant of time the generating distribution can be modeled as equivalent current dipoles (Fig. 4).

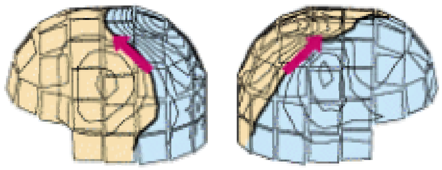

Figure 4. Magnetic field contours at the sensor's places with equivalent current dipoles.

The biggest advantage the MEG has over ERP is that magnetic fields are not distorted by the tissue that they pass through in the brain. The inverse problem is much less severe for MEG.

TMS

Transcranial magnetic stimulation (TMS) is a procedure in which electrical activity in the brain is influenced by a pulsed magnetic field[3]. The field is generated by passing current pulses through a conducting coil, held close to the scalp (Fig. 5) so that the field is focused in the cortex, passing through the skull. Magnetic induction dictates that the changing field acts on charges in the tissue it passes through, causing small local currents to flow.

Figure 5. TMS combined with EEG

TMS is the converse of magnetoencephalography. Instead of measuring the magnetic field produced by neural activation, in TMS a magnetic field is generated that induces an electric current in the desired brain area, producing neural activation. EEG can be used to locate the neuronal activity elicited by TMS, and its spread to other regions.

Integration of TMS with EEG opens new area of research as the reactivity and functional connection between different brain areas can be studied noninvasively for the first time. There are some evidences that TMS might be used in the therapy of medication-resistant depressed patients.

fMRI

Functional MRI (fMRI) is a new application of existing MRI technology (Fig. 6) that allows the study of functional activity in the brain[4,5]. fMRI is used to study changes in regional cerebral blood flow or volume in response to sensory activation or cognitive challenge.

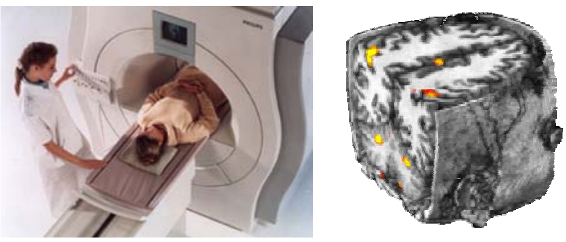

Figure 6. MRI scanner and activated regions on fMRI scans.

The principle of fMRI imaging is to take a series of low-resolution images of the brain in quick succession and to statistically analyze the images for differences among them. Activated areas are shown as colored blobs on top of the original high resolution scan (Fig 6). Two methods are usually used in fMRI:

1) A *paramagnetic contrast agent*, usually gadolinium complex Gd -DTPA, is injected into the bloodstream and becomes distributed with cerebral blood flow. It creates magnetic field gradients around blood vessels which interfere with T2* relaxation time. The change in contrast caused by Gd-DTPA is proportional to its concentration, which in turn is proportional to the blood flow in that area.

2) *Blood oxygen level dependent (BOLD)* contrast imaging is the more frequently used method. It relies on the fact that oxyhemoglobin is diamagnetic while deoxyhemoglobin is paramagnetic (hemoglobin is a molecule which transports oxygen in the blood). When a region of the brain is activated blood flow increases more than does blood volume, and extraction of oxygen increases only slightly. This means that the relative concentration of paramagnetic deoxyhemoglobin falls in the activated region. This increases T2* and so the active regions of the brain appear brighter in the image.

Other fMRI methods exploit the fact that the bulk movement of hydrogen nuclei causes changes in the MRI signal providing measure of water diffusion through tissue.

PET/SPECT

Single Photon Emission Computed Tomography (SPECT) produces images based on the detection of single gamma photons derived from the decay of a radioactive isotope with which the patient has been injected. To determine the exact source of radiation, the detectors are fitted with collimators that allow radiation from one direction only to activate the crystal of the Gamma camera (Fig. 7). This enables the computer software to construct a picture of where the gamma rays originated.

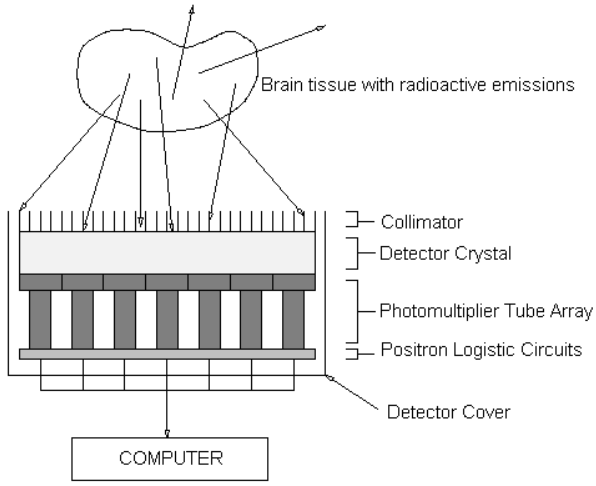

Figure 7. Gamma camera

Positron emission tomography (PET) is a technique for measuring the concentrations of positron-emitting radioisotopes within the tissue of living subjects[5]. After annihilation reaction two gamma rays are emitted 180 degrees external to each other, along a coincidence line. The emitted gamma rays interact with scintillation crystals and are converted into light photons (Fig. 7). The scanner is composed of circumferential arrays of scintillation detectors that detect coincidence events. Coincidence lines from many different angles are combined to construct a cross sectional image (Fig. 8).

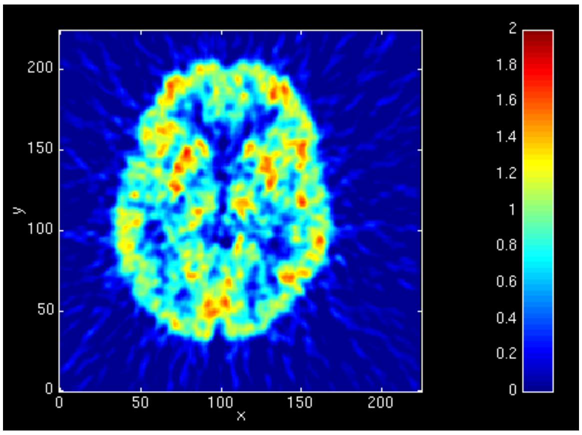

Figure 8. PET reconstructed image

Count density in the image reflects the concentration of positron tracer in the tissue. Areas of the brain that are active during a task require more blood and thus these areas accumulate more tracer than the rest of the tissue. The rate of a process in which the tracer is involved can be deduced from tracer kinetic models. Many kinds of molecules can be made radioactive or tagged so that they can be seen with PET. Using different radioisotopes PET can show blood flow, oxygen and glucose metabolism and drug concentrations in the brain tissue.

SPECT resolution (around 7 mm) is inferior to PET resolution by factor 3 or 4. SPECT tracers are more limited than PET tracers in the kinds of brain activity they can monitor. However, because SPECT tracers are longer lasting, they do not require an onsite cyclotron to produce them. While PET is more versatile than SPECT and produces more detailed images with higher resolution, particularly of deeper brain structures, SPECT is much less expensive and can address many of the same research questions that PET can.

NIRS

Near-infrared spectroscopy (NIRS) is a new technique developed for visualizing the oxygenation states of tissue, in particular the brain[6]. It is based on the discovery that human tissue has a relative transparency to infrared light in the region 700-1000nm over the highly attenuated visible spectrum. When the human body is irradiated with near-infrared light, multiple scattering occurs. Diffused light is detected at a point several centimeters from the irradiation point (Fig. 9).

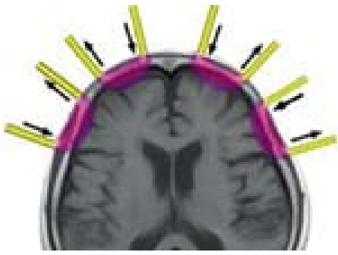

Figure 9. Numerous locations of the brain are irradiated and the diffused near infrared rays are detected.

Oxyhemoglobin and deoxyhemoglobin have different spectrums that can be individually measured (Fig.10). Consequently, blood flow change in the local cerebral cortex and the change in the level of oxygen saturation that accompany neural activity can be detected.

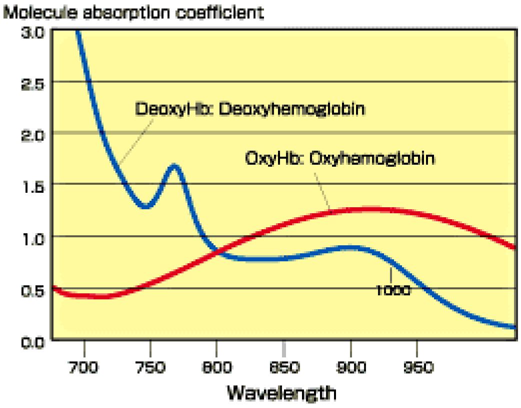

Figure 10. Spectrum changes according to hemoglobin oxygen saturation level

Conclusion

Functional neuroimaging techniques are mainly used for the research purposes but many clinical applications are developing. These techniques can help elucidate the mechanisms by which our brain works and how these processes can go awry, causing various mental illnesses.

Some of the neuroimaging techniques can be easily introduced in physics classes as applications of some basic physical laws. PET and SPECT employ radioactive decay, MEG and TMS are based on Ampere's and Faraday's laws, etc. Students are much more interested in learning physics if they can see its application in research that is more connected to everyday life.

Teaching physical principles and methods in functional neuroimaging can help create a scientifically literate public. It is also the first step in producing the next generation of researchers, innovators, and technical workers.

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"Are fine arts for children a pathway to meet Science and Physics"

or

"Can fine arts combined to physics teaching"

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Introduction

In primary and secondary education all the aspects of human personality is trying to be cultivated. For this reason teaching courses such as language, mathematics, science, history, painting and so on participate in the school program. Additionally different kind of clubs such as theatre, cinema, photography and dancing promote other trends of the students. Fine arts like ballet, painting and so on are popular among children and probably through their activity in these arts they may properly be led to find their own way to science and even to physics, which is nowadays generally requested. The possibility of finding a pathway for children to be led through these different art activities in school to learn science in general and particularly physics is exciting. At a first stage the possibility of a hidden relation of art and science is explored in this paper starting with ballet, photography and painting.

1. Motivation for learning

Learning is most effective when an individual is ready to learn, that is, when one wants to know something. Sometimes the student's readiness to learn comes with time, and the teacher has to encourage its development. Students with goals usually feel good about trying hard; they often respond to challenges with renewed effort and better performance. In school settings, students who participate in dancing, painting and photography usually want to master in these art activities. In order to achieve this goal they could learn some basic principles of physics that are useful to interpret the physical phenomena which characterise these fine arts. It is rather difficult for children to learn principles of physics while they are very young. But according to Brunner if they attend an instruction that has been adjusted to their cognitive level they may be able to learn anything. Although this view seems to be very optimistic it reinforces our aim; that is to find if fine arts are a pathway for children to meet science and physics. In this paper we analyse ballet, photography and painting as physical phenomena in order to explore this possibility.

2. Ballet and the physics of ballet

Dancing is one of the most difficult, disciplined, and beautiful art forms. Ballet is truly the foundation of all dances. But are ballerinas performing physics at its best as they dance, leap and turn across the stage? The concepts of centre of gravity, balance, projectile motion and so on are a part of physics that underlie the movements of ballet. In this section, we show a little about how steps in ballet are reliant and dependent on mechanical physics. [1]

Figure 1

The movements in the art of ballet can be interpreted by mechanical physics

2.1. Ballet and the Centre of Gravity

Dance consists of movements of the body interspersed with motionless poses. Often these poses demonstrate balance of the body over a small area of support on the floor. The balance condition will be achieved if and only if the centre of gravity lies on a vertical line passing through the area of support at the floor. If the dancer is motionless, the sum of all the forces and torque acting on the body must be zero. For example the force upward from the floor to the foot (see figure 2) will balance the force of gravity. This concept is derived from Newton's third law of motion (the action-reaction law). If the centre of gravity is not in line with these other equilibrium state forces, the dancer will be unbalanced and experience a movement (angular acceleration) towards the ground (in other words the dancer will fall). [1]

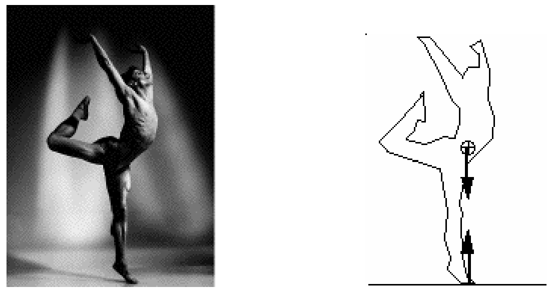


Figure 2

The centre of gravity and the forces that act on the dancer's body while he tries to balance

A dancer seldom achieves a true balance condition. If the centre of gravity is close to that "balance area" that is if the forces are almost but not perfectly vertical, the acceleration away from vertical is initially quite small and the dancer appears to be balanced. [1]

2.2. Ballet Grand Jeté and the Projectile Motion

Another classic move of ballet is the plain grand jeté, a straightforward gazellelike leap. Once the dancer leaves the floor, he is like a ballistic missile (see figure 3): His centre of gravity follows a parabolic trajectory that is totally determined by the initial conditions starting on the ground. He can't change that, but he can move parts of his body. By scissoring his legs open as he nears the top of the arc and then closing them again as he descends, he makes them take up most of his centre of gravity's vertical motion. For that instant, his head and torso can actually move horizontally. Spectators focus on those parts and think the whole body of the dancer is floating. [2]

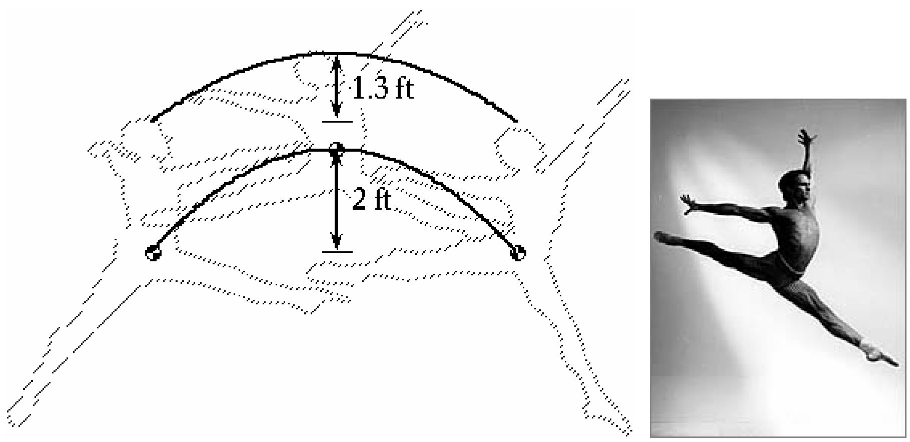


Figure 3

The projectile motion and the floating of the dancer's body during the grand jeté

2.3. Ballet Pirouette and the Rotational Mechanics

One of the most common turns in dance is the pirouette. The pirouette, in general, is a rotation where the dancer supports herself on one leg while the other leg is in retire position. [3] Any pirouette must commence with some form of preparation position followed by a torque exerted against the floor. This torque of the floor against the dancer causes the angular acceleration that produces turning motion.

To predict the angular velocity of the dancer as she rotates we have to take into account the dancer's moment of inertia. The moment of inertia depends on the mass of a body and its distribution relative to the axis of rotation. An arabesque position [4] has a larger moment of inertia (I) than a retire position (see figure 4), because the leg is now stretched out behind the dancer (larger R) rather than close to the dancer at the knee (smaller R). Therefore the retire position has greater angular velocity (ω) than the arabesque position. [1]

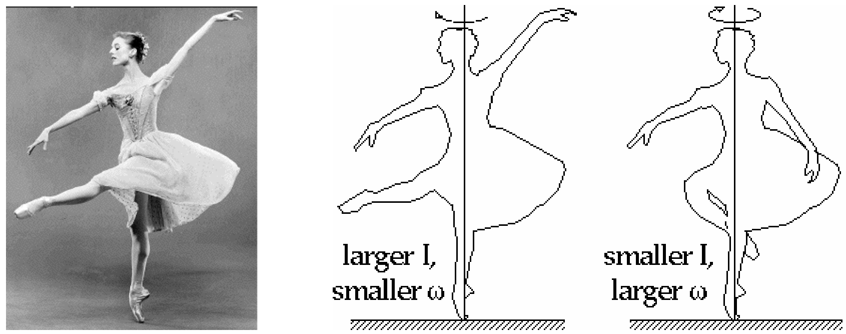


Figure 4

The moment of inertia (I) affects the dancer's angular velocity during the movement of the pirouette

2.4. Educational implications

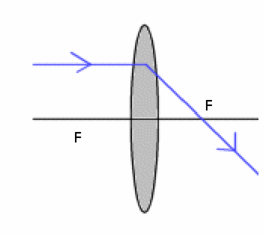
From the previous analysis we conclude that if a child realises the causes that direct his body to demonstrate the three ballet movements a) he may master in these concrete poses and simultaneously b) he may find the physical explanation quite interesting. Therefore the dance of ballet may be a motivation for a child to learn the concepts that describe and interpret the physical phenomena. We think that a young student will not be able to assimilate all the details that refer to the physical concepts. But he may acquire some primary scientific ideas about the forces, the balance, the angular velocity and so on that may prevent him from obtaining misconceptions.

3. Photography and the physics of photography

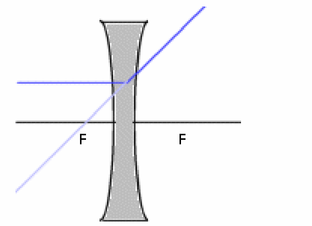
Photography is one of the fine arts that have been cultivated during the last century. Knowledge of optics in general and the function of the photo camera are very useful for students who like to take high quality photos. In this section of the paper we describe the types and the function of lenses, their application in the photo camera and the basic function of this kind of camera.

3.1. Lenses

There are two types of lenses: the double convex and the double concave. The double convex lens is a converging lens. When light waves parallel to the principal axis from an infinitely far object passes through the lens, it will converge at a focal point F on the principal axis (see figure 5.a). The distance between the focal point and the lens is the focal length. The double concave lens is a diverging lens. When light waves from an infinitely far object passes through the lens, the light waves will diverge as if it originated from a focal point F on the principal axis (see figure 5.b). We have to notice also that all images created by lenses are real images. [5]



a: converging lens



b: diverging lens

Figure 5

The trajectory of a light ray through a converging lens (a) and a diverging lens (b)

3.2. Function of the photo camera

The basic function of a photo camera is very interesting. The camera has a body that houses the film, a converging lens to focus the image, a shutter to control the exposure times, and a diaphragm to control the amount of light. There can actually be several acceptable combination settings for the same image; however, the resulting pictures will look slightly different. For example a large opening of the aperture will produce a picture focused only on objects a certain distance away while a small aperture opening will produce a picture with everything focused. In all the combination settings the lens plays the crucial role of focusing the light rays in such a way as to portray the objects of the image on the film. [6]

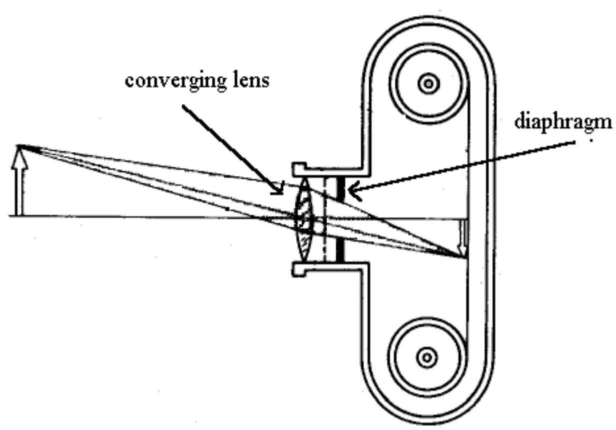


Figure 6

The converging lens focuses the image of the object in the interior of the photo camera

3.3. Educational implications

The students that participate in the school photography clubs usually wish to take good quality photos. These students are usually curious to learn the function of the photo cameras. The characteristics of lenses and the function of photo cameras may be a pathway for children to learn science in general and particularly physics. Generally we believe that this first contact of the children with optics may be a motivation for them to study physics more systematically.

4. Painting and the physics of painting

Art is perceived as the natural embodiment of imagination and painting is one of its most delightful forms. Painters usually are not conscious that they use principles of physics (optics) in order to perform their work e.g. to paint an object with its shadow. When the artists also paint on flat surfaces the result is different than that on curved surfaces because laws of reflection order the destination of the light rays. If they use paint that is firmly spread with a brush (smooth surface of colour) the result is different than that with a palette – knife (rough surface of colour). Physics underlie the colour mixing and the reflection that we present in this section of the article.

4.1. Colour mixing

The pointillists and post-impressionistic artists painted with many little tiny dots of colour. Up close, their paintings didn't appear to be anything. But if you step back and let your eye mix the dots into other colours, you would see the subject of painting. By letting the eye mix the colours, they were able to achieve a brighter and more vibrant palette. In the same way the computer or television screen also contains tiny dots, usually red, green and blue. By mixing these colours in different amounts, a large range of colours can be produced. [7] The mixing of colours provides an infinite number and variety of colours. There are two forms of colour mixing, "additional mixing" and "subtractional mixing". [8]

4.1.1. Additional colour mixing

With additional colour mixing, the colour impression is developed by the different colours of light that strike the same part of the retina of the eye. The different colours are literally added on the retina. Mixing the three primary colours can make every possible colour combination. We know that mixing red and green together make yellow. Mixing red green and blue together make white, and yellow and blue also make white. Two colours, when combined together make white and are called complementary colours. [8]

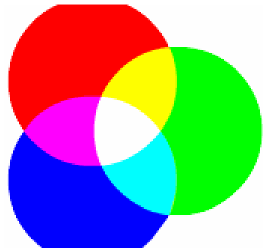


Figure 7

Additional mixing of the three primary colours

4.1.2. Subtractional colour mixing

When we mix colours and pigments, a phenomenon called subtractional colour mixing occurs. Unlike additive colour mixing, whereby the colours are "added" not until the retina, the colours sum by individual, separate absorptions. White light contains the colours green, blue and red, and the mixed colour of red and green is yellow. When we mix a yellow- and a cyan-coloured paint, we get a green mixed colour. The yellow paint absorbs the blue component, and the cyan paint absorbs the red. Red, as well as blue is now absorbed by the mixed paint (yellow and cyan). This squares with the theory and the mixing of paint is therefore an absorbent mixing process. [9]

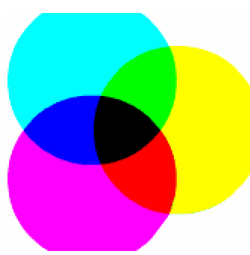


Figure 8

Subtractional mixing of the three primary colours

The three primary colours in subtractional colour mixing are thus complementary colours of the primary colours in additive colour mixing: yellow, magenta and cyan. When these three colours are mixed, unlike in additive mixing, a black mixed colour will appear. [9] An application of the above appears in the following photo (see figure 9) that presents the combination of three subtractional colours giving the final picture of a landscape.

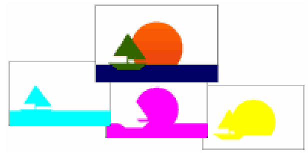


Figure 9

Combination of subtractional colours

4.2. Reflection

Reflection of light is very predictable. The law of reflection describes it simply as "the angle of incidence is equal to the angle of reflection" (see figure 10) and it works for flat surfaces.

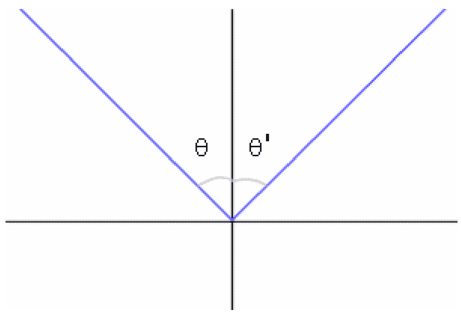
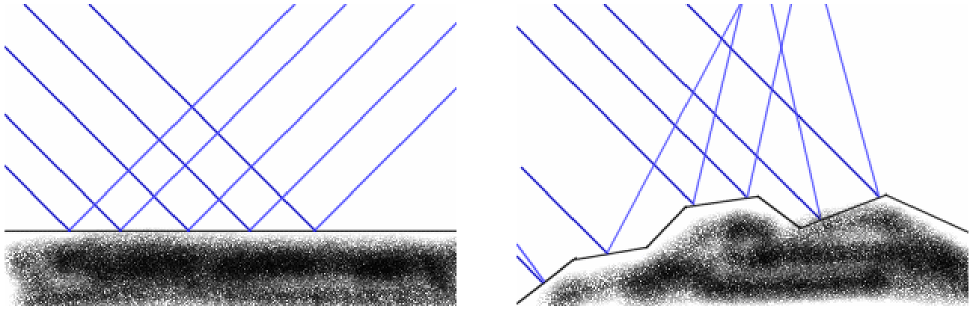


Figure 10

Reflection of light for flat surfaces

There are actually two types of reflections: specular and diffused. Specular reflection is reflection from a smooth surface. When light strikes this smooth surface, all the reflected rays are in line with each other (see figure 11.a). Diffused reflection is reflection from a rough surface (see figure 11.b). The small bumps and irregularities on a rough surface will cause each of the light rays to reflect in different directions, all following the law of reflection. The smoothness or roughness of the paint and the way that is spread on the surface settle the visual result just as happens with the printing paper of the photograph (glossy or mat).



a **b**

Figure 11

a: specular reflection of light **b: diffused reflection of light**

4.3. Educational implications

The colour mixing and the reflection of light seem to be fundamental knowledge for the young students who wish to learn painting. The scientific background that correlates to these two physical phenomena may become a motivation for young "painters" to study science and especially physics.

5. Conclusions

The previous analysis sums up to the following attestations: a) the dancers' ballet figures are interpreted through mechanics and especially rotational mechanics. b) The function of photography is interpreted very well by geometric optics. c) In painting, the painters' combination of colours and the trajectory of light rays that strike the painted surfaces are clearly described by optics.

These attestations lead us to believe that students through their activity in dancing, photography and painting art may help them to find their own way to science and even to physics. Fine arts may be a pathway for children not only to learn physics but also to choose their professional life through the systematic study of physics and science in general. Finally we believe that fine arts could contribute to the nowadays request which is the study and cultivation of science by young people.

References

[1] S., Dodge (1997). “Physics of Ballet Dancing”, PY105 - ME190. http://www.geocities. com/ CapeCanaveral/Hangar/4421/ #Center_ of_Gravity_and _Balance

[2] R., Kunzig (1999). “Spin Doctoring: Ballet can be more beautiful if you've read a little Newton”, *Discover,* vol. 20, (11).

[3] The retire position is a standing position in which one foot is at the knee of the supporting leg (also commonly called passe).

[4] Arabesque position: The dancer stands on one leg (the supporting leg) with the other leg fully extended behind the body.

[5] http://library.thinkquest.org/27356/p_lenses.htm

[6] http://library.thinkquest.org/27356/t_photography.htm

[7] http://library.thinkquest.org/27356/p_colors.htm

[8] http://library.thinkquest.org/25782/cmwdata.pl?get_file_path=informative/ sciences_of_colour /colour_mixing/additionalmixing.cmw

[9] http://library.thinkquest.org/25782/cmwdata.pl?get_file_path=informative/ sciences_of_colour /colour_mixing/subtractionalmixing.cmw

Unifying Lectures, Recitations & Laboratories as a part of the Humanized Physics Project

Vicki L. Plano Clark and Robert G. Fuller
University of Nebraska - Lincoln

As a part of our work in the *Humanized Physics Project*, we have made the content of the physics laboratories the keystone of our physics content coverage. After having selected an appropriate human application of physics for the laboratory each week, we have shaped the lecture, recitation and homework assignments to support the laboratory. Our poster will provide examples from both semesters of our general physics course.

(1) Support provided by NSF DUE grants 0088780 and 0088712.

(2) Humanized Physics Project co-PIs:
Nancy L. Beverly, Mercy College

Mark W. Plano Clark, Doane College
Beth Ann Thacker, Texas Tech University
Christopher D. Wentworth, Doane College

Rationale:

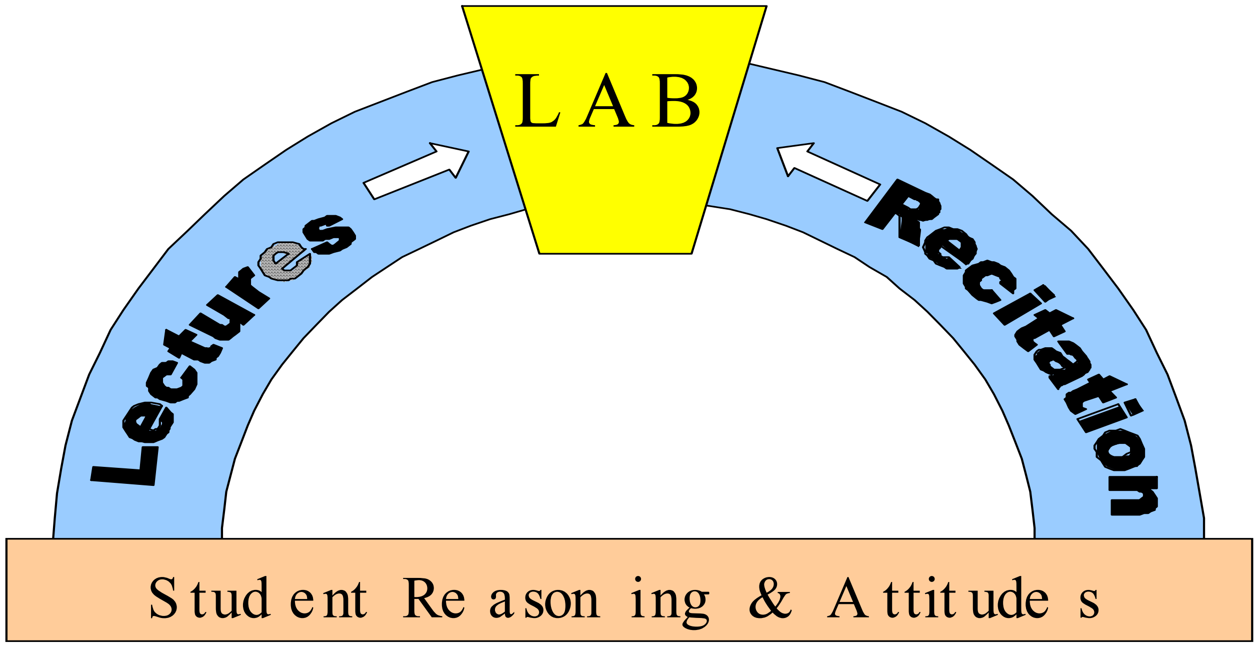
- **The students in this course are intending to have a career based on science and the students have had a college course in chemistry.**
- **The course must be responsive to the needs of students intending to have careers in biological or medical-related fields.**
- **The laboratory activities are the keystone of the course with the other course components such as lectures, recitations and examinations supporting the laboratory activities.**

Structure at UNL:

There are…

- **three 50 minute lectures per week of up to 167 students taught by a faculty member**
- **one 50 minute recitation per week in sections of not more that 32 students each taught by graduate teaching assistants**

- **one 3 hour laboratory per week in sections of not more than 18 taught by graduate, or undergraduate, teaching assistants.**


LAB
Lectures
Recitation
Student Reasoning & Attitudes

First Semester of Humanized Physics

The sequence of topics:

- **How Do We Move?**
  (Kinematics and Dynamics, 5 weeks)
- **How Do We Use Energy?**
  (Energy and Momentum, 5 weeks)
- **How Do We Transform Energy?**
  (Heat and Fluids, 3 weeks)
- **How Do We Make and Hear Sound?**
  (Waves and Sound, 2 weeks)

Second Semester of Humanized Physics

The sequence of topics:

- **How Do We Sense, Think, and Move?**
  (Electricity and Magnetism, 5 weeks)
- **How Do We See Color?**
  (Light and Optics, 6 weeks)
- **How Can We See Inside Ourselves?**
  (Radiation, 3 weeks)
- **How Can We Compare Our Senses?**
  (Overview, 1 week)

1^{st} semester lecture content example:

Poiseuille's Law

When a liquid of viscosity η flows in a tube of radius R(m) and of length L(m) with a pressure difference ΔP (Pa), the flow rate in m^3/ s may be given by:

$$\text{Flow rate} = (\pi / 8\,\eta)\,(\Delta P / L)\,R^4$$

$$\text{Flow rate} = \frac{\pi\,(P_1 - P_2)\,R^4}{8\,\eta\,L}$$

Dimensional analysis:

$$(m^3/s) = \frac{(Pa)\,m^4}{\eta\,m}$$

so η has the units of Pa•s or poise(CGS)

conversion factor 1 Pa•s = 10 poise

Recitation Class activity:
In your small group, based on Poiseuille's Law, discuss and answer the following questions:

1) **The flow of viscous blood through the human circulatory system may be constricted by a narrow portion of the system. As a person ages, the constriction may expand. Assume the diameter of the constriction increases by only 8%.**

   a) **How much does the flow rate increase?**

   b) **If the person's blood pressure is adjusted so that the flow remains constant, what happens to the person's blood pressure, assuming that it was originally 120 mm of Hg.**

2) **Assume a person with hardening of the coronary arteries can survive an effective diameter decrease of his arteries of 20%. Under these conditions, how must the blood pressure change to keep the rate of blood flow constant?**

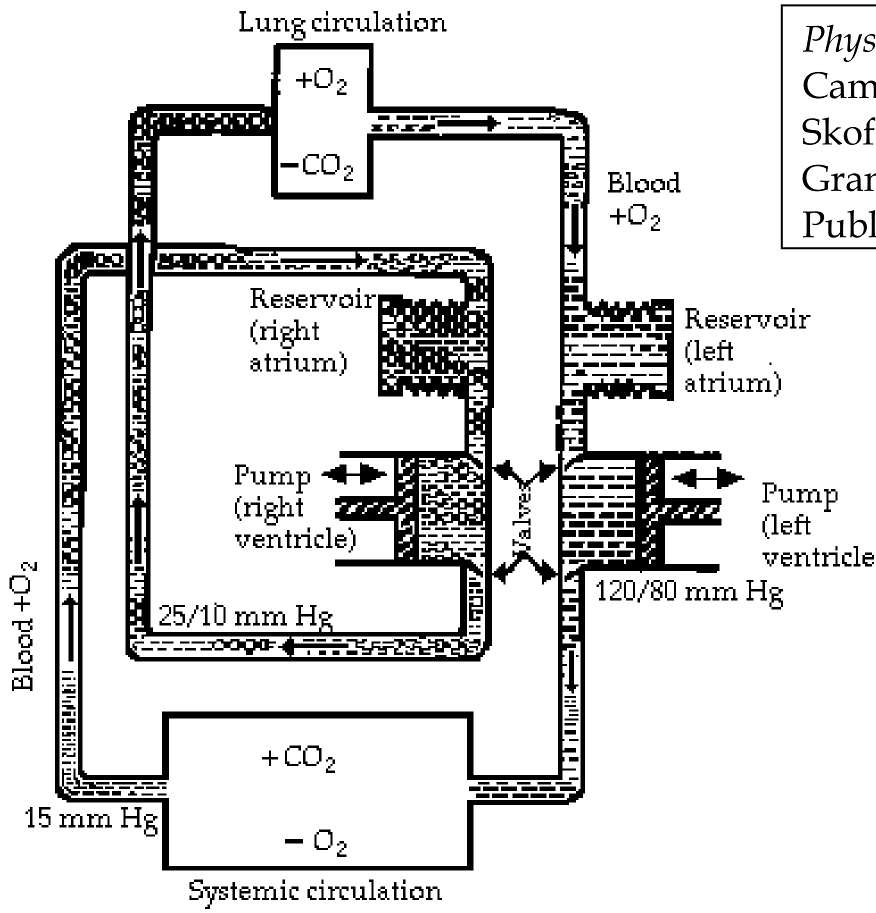
Lab - Modeling Your Circulatory System

Your Circulatory System - A Simple Model

"Blood is one of the most interesting organs in the body. It has two unique properties: it is a liquid and it is always on the move."

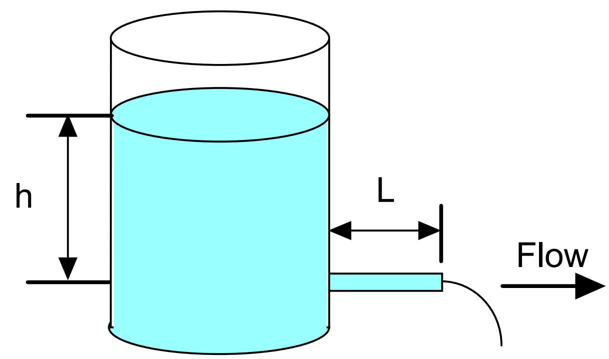
From *How the Body Works* by John Lenihan.

Here is an engineer's sketch of the blood circulation system of a human body.



Physics of the Body, J.R. Cameron, J.G. Skofronick, & R.M. Grant, Medical Physics Publishing, 1992, p. 155.

Studying Flow Rate as a Function of Pressure, Length, & Diameter



Conduct experiments to determine how the flow rate changes as a function of **pressure**, **tube length**, and **inside tube diameter**.

Data Collection:

- Keep the height of the water surface constant.
- Capture the water flowing out of the container for a set time.
- Calculate the flow rate.

Data Analysis:

(a) Determine mathematical models for each variable.

(b) Describe the physical meaning of these models.

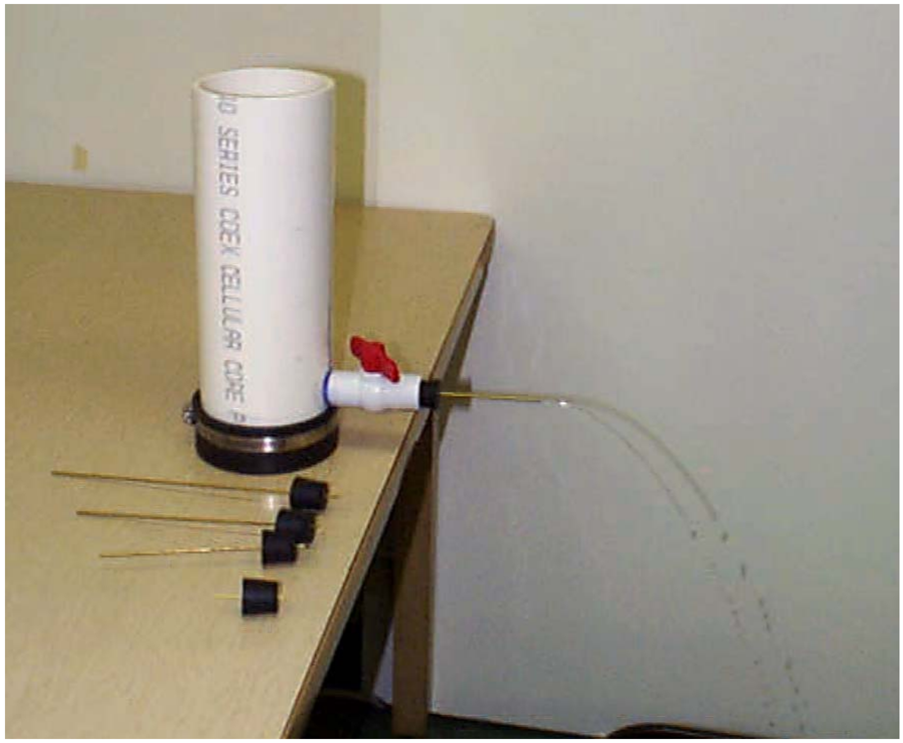
(c) Poiseuille (1799-1869) was interested in the physics of blood circulation. He found that the flow rate of a fluid undergoing laminar flow in a cylindrical tube is:

$$Flow\ rate = \frac{\pi \cdot pressure \cdot (radius)^4}{8 \cdot viscosity \cdot length}$$

Compare the class results to this predicted mathematical model.

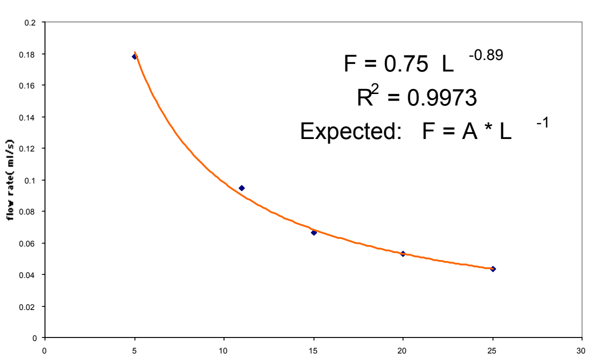
Fluid Flow Apparatus

Designed and built by Mark W. Plano Clark, Doane College

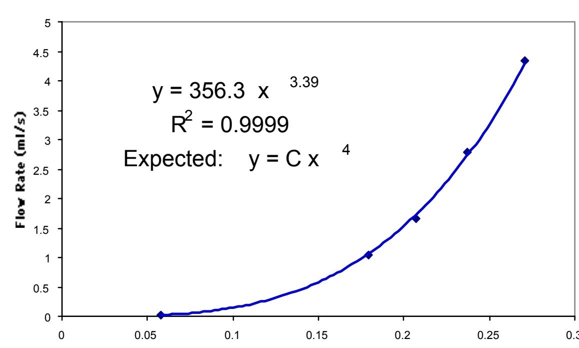


Sample Student Data

Flow Rate vs. Length



Flow Rate vs. Diameter



2^{nd} semester lecture content example:

Bouguer's Law

Absorption of light by a medium of thickness t:

$$I_x = I_0 \exp(-at) = I_0 e^{-at}$$

where t is distance (m)

and a is the absorption coefficient (m^{-1})

Beer's Law

Absorption of light by a medium with a concentration of c:

$$I_x = I_0 \exp(-bc) = I_0 e^{-bc}$$

c is concentration(g/L)

b is the absorption coefficient (L/g)

Take the logarithms (base 10) of both sides and combine:

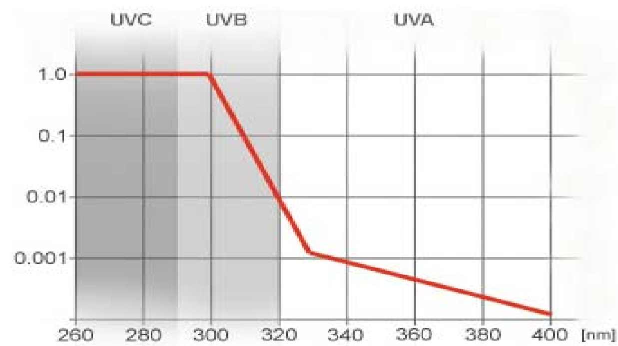
Optical Density = OD $\propto$ t c

Recitation Content

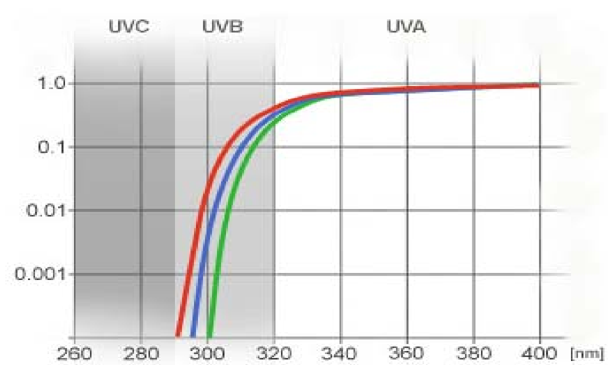
Skin Burning Intensity of Sun light

Human skin is not equally sensitive to all types of ultraviolet (UV) radiation. The Erythemal Response Spectrum is a scientific expression that describes human skin sensitivity to UV radiation.

Skin Sensitivity to Ultraviolet Radiation



UV Radiation Contained in Solar Light at the Earth's Surface for Different Ozone Thicknesses



The Effective UV Spectrum - "Skin Burning Intensity"

The Effective UV Spectrum is the mathematical product of Solar UV Spectrum and the Erythemal Response Spectrum. It can be interpreted as the "skin burning intensity" of individual wavelengths of sunlight.

1. Determine the relative "Skin Burning Intensity' as a function of UV wavelength for 2 ozone thicknesses.
2. Compare quantitatively the skin burning intensity for the two different ozone thicknesses.

Reference: www.safesun.com/scientific.html

Lab - Sunglasses and Other Optical Filters

Effect of Sunglasses as Perceived by Your Eyes

- Using your eyes as light detectors, examine how these sunglasses affect the light that passes through them.

Effect of Sunglasses as Perceived by MBL Light Sensors

- Using the MBL light sensor(s), examine how these sunglasses affect the light that passes through them. Measure the light intensity with and without the sunglasses with each sensor.

$$Absorbance = Optical\ Density = \log_{10} \frac{I_0}{I}$$

- Using your 2 different data sets, calculate the optical density of one pair of sunglasses.

Effect of Colored Filters as Perceived by Your Eyes

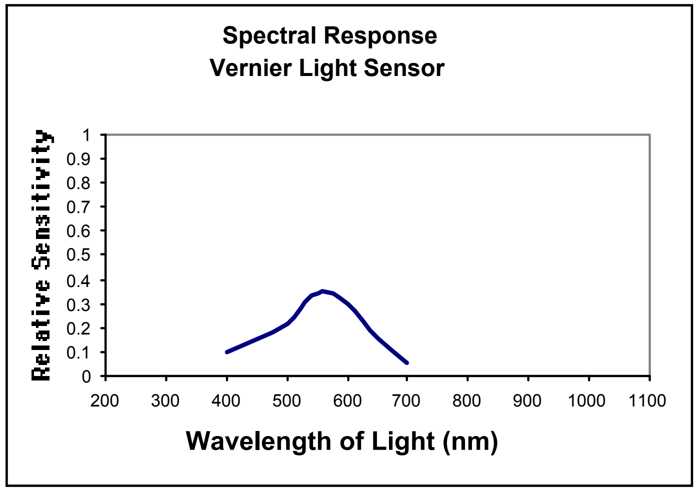
- Using your eyes as light detectors, examine how the different color filters affect the light that passes through them.

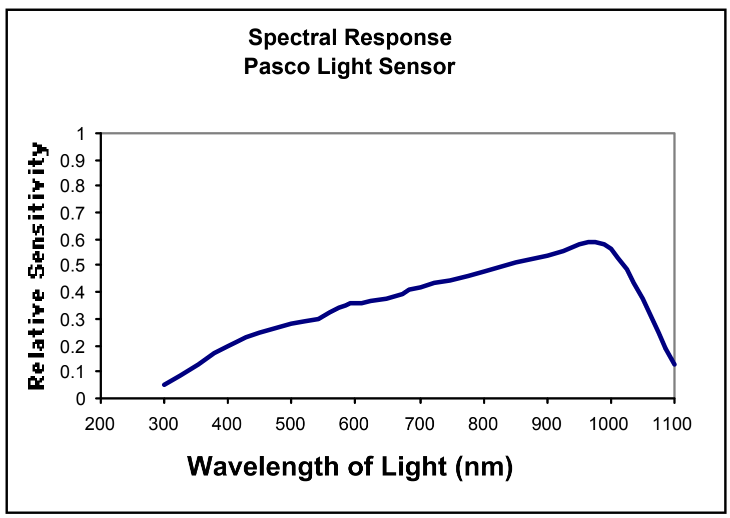
Effect of Colored Filters as Perceived by a Light Sensor

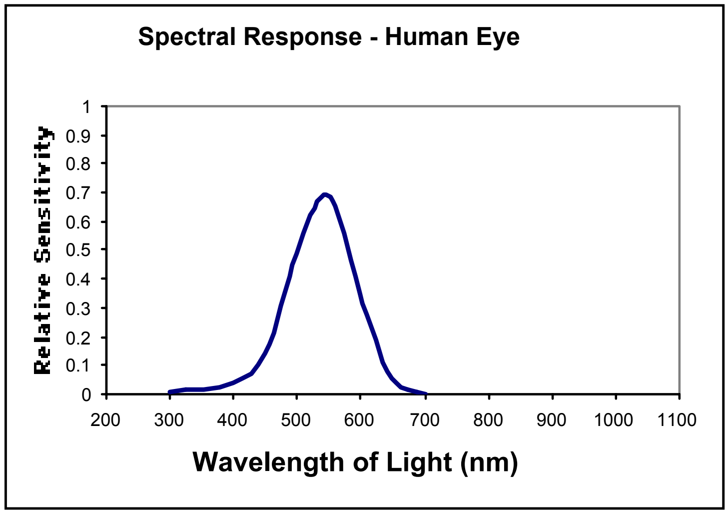
- Using the light sensor, measure the light intensity for 0 filters to 20 filters for a single color of filter.

- Create mathematical models of Percent Transmitted vs. Filter Thickness and Optical Density vs. Filter Thickness.

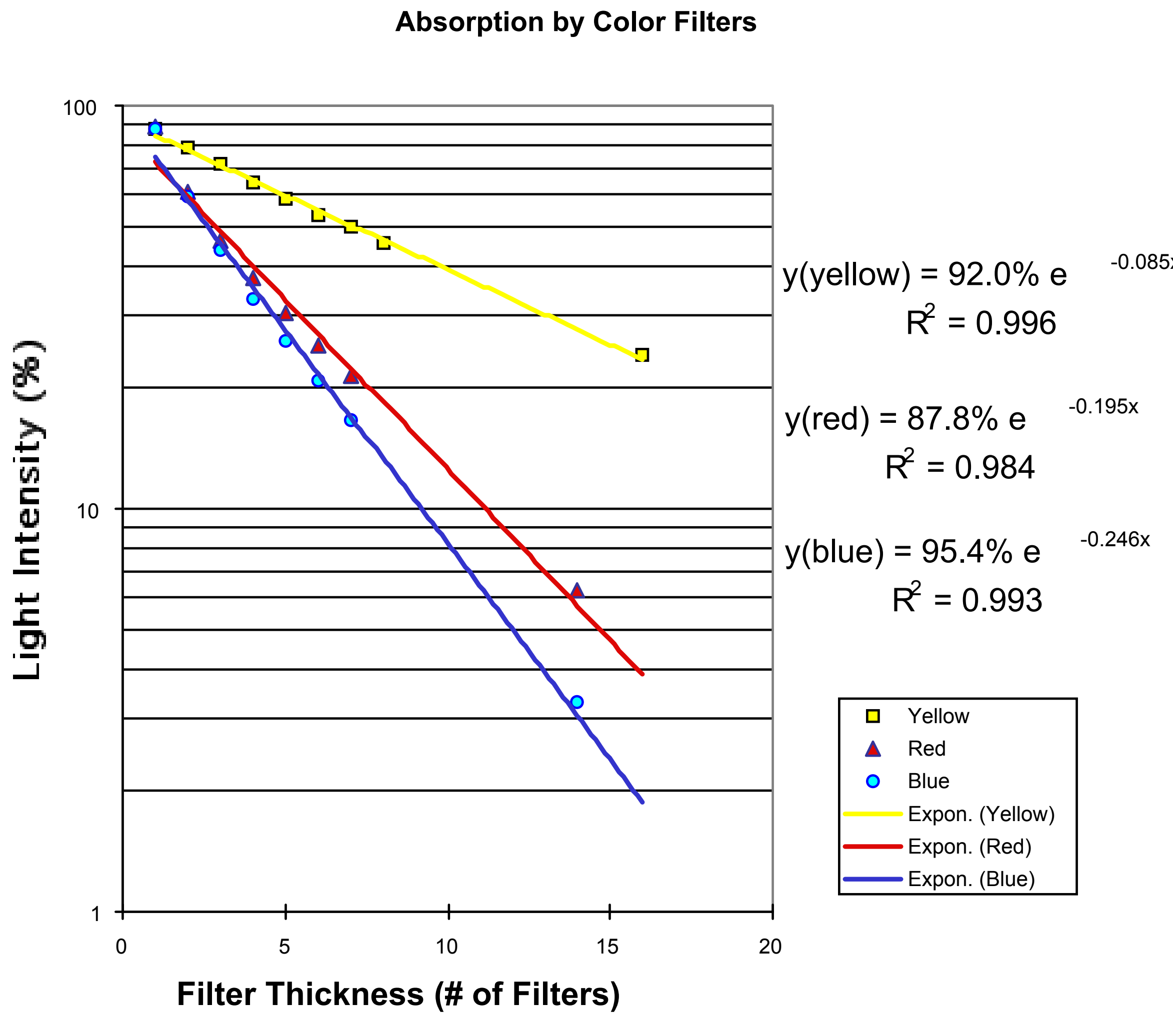
Spectral Response Curves for Different Light Detectors






Spectral Response - Human Eye
Relative Sensitivity
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
200
300
400
500
600
700
800
900
1000
1100
Wavelength of Light (nm)

Sample Data for Colored Filters



Poster Handout (One page, front and back)

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First Semester of Humanized Physics

The sequence of topics:

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The sequence of topics:

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- How Can We See Inside Ourselves? (Radiation, 3 weeks)
- How Can We Compare Our Senses? (Overview, 1 week).

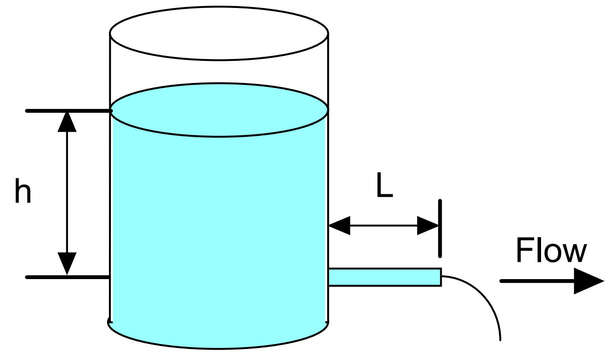
For more complete details visit our website:

http://www.doane.edu/hpp/

Sample Lab Activities

Modeling the Circulatory System

Conduct experiments to determine how the flow rate changes as a function of **pressure**, of **tube length**, and of **inside tube diameter**. Create graphical and functional models for each of these variables.



1. Poiseuille (1799-1869) was interested in the physics of blood circulation. He found that the flow rate of a fluid undergoing laminar flow in a cylindrical tube is:

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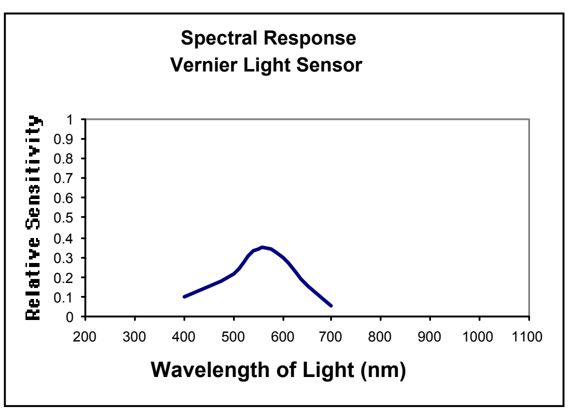
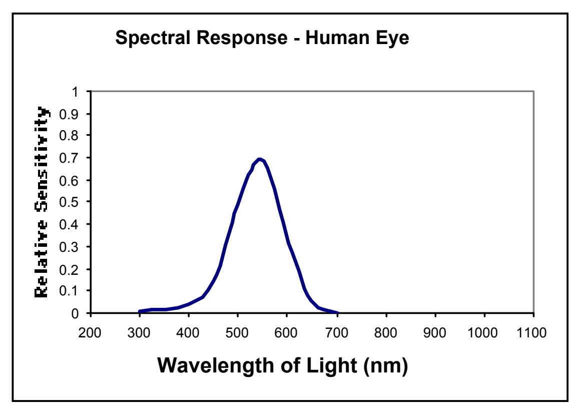
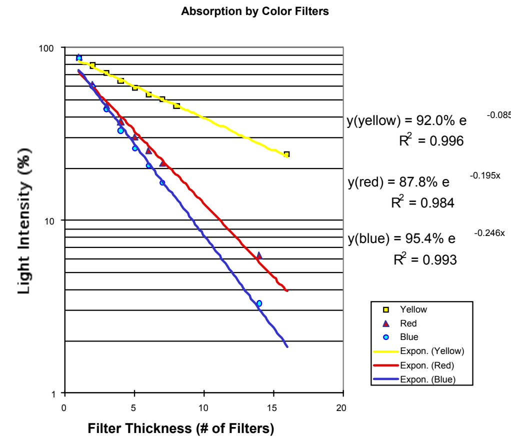
Compare the class results to this predicted mathematical model.

Sunglasses and Other Optical Filters





- Study effect of sunglasses on white light as perceived by your eyes and by the MBL light sensor.
- Study effect of different colored filters on white light as perceived by your eyes and by the MBL light sensor.
- Study the absorption of light by different thicknesses of colored filters.
- Create mathematical models for Transmission vs. # of filters and for Optical Density vs. # of filters.



A comparison of microcomputer-based and conventional methods in teaching mechanics

N P Joy Molefe, Miriam Lemmer & Jan J A Smit
School of Science, Mathematics and Technology Education, Potchefstroomse Universiteit vir CHO, Potchefstroom, South Africa

The outcomes of practical work in mechanics utilizing microcomputer-based methods were compared to those reached by conventional methods. The research reported here addressed learners' understanding of basic kinematic concepts and graphical representation of these concepts as a function of time. The results indicate that the outcomes reached by the microcomputer-based and conventional experimental methods overlap, but they also supplement each other. Microcomputer-based methods should not completely replace conventional methods.

INTRODUCTION

Thornton and Sokoloff (1990, 1998) have successfully implemented microcomputer-based interactive lecture demonstrations in introductory physics lectures since 1989. The benefits of computers in education include time-effectiveness, immediate feedback, repeatability and accessibility. Although the computer became an effective tool in physics education, it has its barriers and limitations (Lawson & Tabor, 1997; McKinney, 1997, Wellington, 1999)

The aim of the investigation reported here was to compare the learning effectiveness of a computerised experiment in comparison to a conventional experiment on kinematic graphs of constant velocity and accelerated motion. The investigation focussed on displacement versus time and velocity versus time graphs.

The drawing and interpretation of graphs is a basic skill normally taught in mechanics by means of kinematic graphs and then applied in the rest of the physics syllabus. According to McDermott *et al*. (1987) students experience difficulties in connecting kinematic graphs to physical concepts and to real world situations.

The conventional experiment used in the investigation is the trolley and ticker-tape experiment: A trolley moves along a rail while its positions are marked on a tape by a ticker-timer with a fixed frequency. The tape is then processed by the learners, the data tabulated and graphs of position, velocity and acceleration versus time plotted by hand. The learning process involves an abstraction from the motion of the trolley as depicted on the tape to the kinematic graphs.

In the microcomputer-based demonstration, the motions of walking learners and running trolleys were investigated by means of a motion detector connected to the computer. For each motion the computer instantly produces the kinematic graphs on the screen. The learners thus have to associate the specific motion with the displayed graphs.

ANALYSIS OF LEARNING OUTCOMES

When different teaching methods are compared, the outcomes reached are of primary importance. The purpose of physics laboratory work has recently been investigated by Celliers *et al*. (1999 & 2000), Lemmer *et al*. (1996) and Pedretti *et al.* (1998). While the outcomes of physics laboratory work previously concentrated on measuring and data-processing skills, the computer recently made inquiry skills easy to implement.

The outcomes stated for the experiments on kinematic graphs are that learners will be able to

(1) abstract the change in position of a moving object with time from its actual movement.
(2) conceptualise displacement, velocity and acceleration of the moving object.
(3) connect a one-dimensional change in position to a two-dimensional graphical representation.
(4) relate the velocity (or the change in velocity) of a moving object to its velocity-time graph.
(5) relate position-time and velocity-time graphs of motion.
(6) conceptualise zero and negative displacement, velocity and acceleration.
(7) apply the knowledge obtained to a variety of different motions.

Due to the different nature of the methods (conventional and computer-based) it can be expected that the experiments may satisfy the outcomes to different extents.

POPULATION

Forty grade eleven learners from Thuto-Boswa secondary school in Ventersdorp, a rural town in the North West Province of South Africa, participated in the study. The mother tongue of the teacher and the learners is Setswana. English, the medium of instruction, is their second (or even third) language.

METHOD

The learners were divided in 2 equivalent groups on grounds of their previous performances in Physical Science. Group A did the conventional ticker-timer experiment while the microcomputer-based method was used with Group B. The same teacher, a M.Ed student registered at the Potchefstroom University with 7 years of teaching experience, conducted both the conventional and microcomputer-based experiments. Three afternoon sessions were used for each experiment.

Both experiments were performed through interactive lecture demonstrations. Interactive engagement has been proven to be more effective than traditional teaching strategies (Hake, 1998). In the conventional experiment tapes produced by the running trolley were processed by small groups of learners. In the microcomputer-based experiment, the predict-observe-explain method (Sokoloff & Thornton, 1997) was used.

The same pre- and posttests were administered to both groups. These tests involved basic knowledge of the kinematic concepts (such as displacement and velocity) as well as drawing and interpretation of graphs. Some of the Thornton-Sokoloff items (Thornton & Sokoloff, 1990) were included for comparison. The other items were typical Grade 12 examination questions.

RESULTS

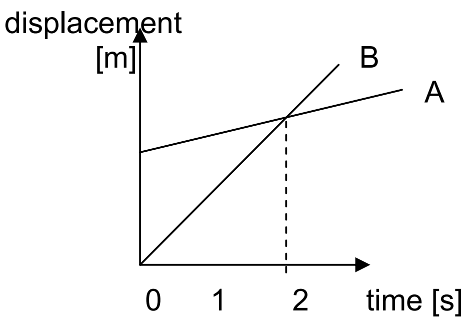
On average, the percentages obtained by the conventional group increased from 31,5 % in the pretest to 45,3 % in the posttest, i.e. with a gain <g> of 0,2. The gain of the microcomputer-based group is also <g> = 0,2 as their averages changed from 30,8 % to 43,8 % in the pre- and posttest respectively. Statistically these two groups performed similarly with an effect size of only 0,07. (For a description of the gain and effect size refer to Hake (2002).)

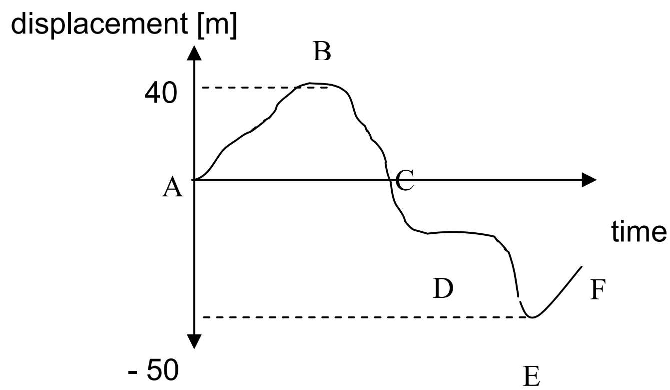
Although the averages obtained by the two groups in the tests are similar, in some individual questions the one group outperformed the other significantly. The conventional experiment group outperformed the group who did the microcomputer-based experiment with medium to large effect-size (d-values $\geq$ 0,35) in questions 1(c) and (d), 3.1, 9.1 and in some of the Thornton-Sokoloff items (question 13) (See Table 1). On the other hand, the microcomputer-based group performed statistically better than the conventional group in questions 11, 12 and the other items of question 13. The effect size is given by the d-values which are calculated as the mean difference between the pre- and posttests of both groups, divided by the standard deviation (Hake, 2002).

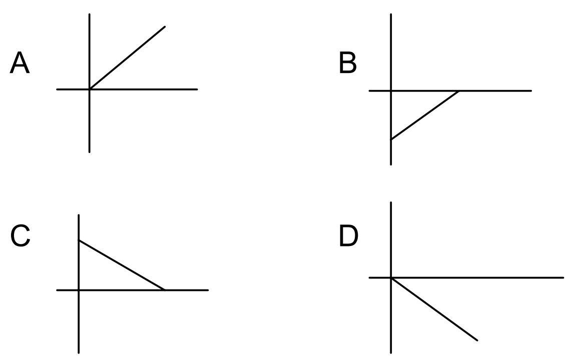
No significant differences in performance between the two groups were obtained in questions on definitions of distance and displacement, relations between distance, speed and time, relative motion, vectors, the plotting of graphs and simple interpretation of graphs.

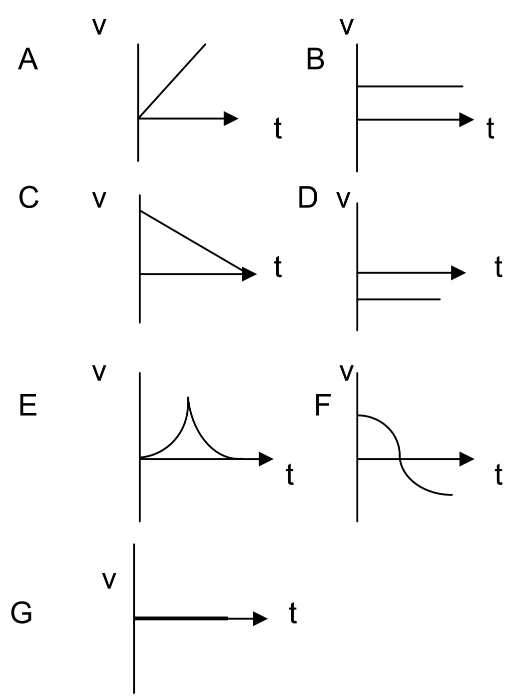
Small, but significant negative results (i.e. a decrease in performance after the experiment) were obtained in some items by both groups. The conventional group only showed a negative result in question 12 (d), while the performance of the microcomputer-based group dropped in questions 3.1, 13.1 and 13.3.

Table 1: The questions in which the of the effect size of the gains obtained by the two groups were medium to large ($d \geq 3.5$).

Item	**Largest gain in**	**d-value**
1. Define the following concepts. Illustrate each concept by means of a sketch or example. (c) speed (d) velocity	Conventional experiment	0,50 0,35
3.1 Two cars A and B travel from Ventersdorp to Potchefstroom. Car A leaves before car B. Both cars reach potchefstroom at the same time. How do the distances traveled by the two cars compare?	Conventional experiment	0,55
9.1 Two cars A and B move on a straight road. Use the displacement-time graph below to choose the correct answer to the question. At the instant t = 2 s, the speed of car A is (a) greater than the speed of car B. (b) less than the speed of car B. (c) equal to the speed of car B.  	Conventional experiment	0,42

11. Answer the following questions using the displacement time graph of the motion of an object. 		
(a) Where is the object furthest from its original posision?	Computer-based	0,31
(b) Describe its position relative to the origin (place where it started) at point C.	Computer-based	0,50
(c) Where is it standing still?	Computer-based	0,61

12. Consider the following graphs and write down the letter or letters (A, B, etc.) of those with a negative gradient . 	Computer-based	0,35

13. An object can move in either direction along the + distance axis. Choose the correct velocity - time graph for each of the following questions. Which graph shows the object		
13.1 moving away from the origin at a steady (constant) velocity	Conventional experiment	0,84
13.2 standing still	Computer-based	0,50
13.3 moving towards the origin with a constant velocity	Conventional	0,51
13.4 reversing direction	Computer-based	0,23
13.5 increasing its speed at a constant rate	Conventional experiment	0,32
		

DISCUSSION OF RESULTS

When interpreting this result it must be taken into account that both the teacher and learners were inexperienced in working with computers. The majority (71 %) of the learners have never worked on a computer before. Most admitted that they were fascinated by it (and therefore possibly distracted). This inexperience and fascination could have contributed to a gain lower than that reported in other studies (Hake, 1998; Redish *et al.* 1997).

Although no group outperformed the other on average, the learning effectiveness of the two methods differs for specific items. This result can be explained in terms of the learning outcomes that are favoured in the two experiments. The conventional experiment was more successful in satisfying learning outcomes 1 and 2 stated above. The learners can "see" the change of the trolley's position with equal time intervals when analysing the spacing of the dots on the ticker-tape. They measure the displacements and calculate differences in displacement with time (i.e. velocity). Graphs are plotted point by point, the gradients determined and meaning attached to it. On the other hand, the microcomputer-based experiment enhanced understanding of aspects that cannot easily be taught with the conventional apparatus such as "standing still" and "reversing direction" situations (learning outcome 6). By immediate feedback for a variety of different types of motion, the microcomputer-based method is ideal to enhance understanding by repetition (learning outcome 7). The remaining learning outcomes (3, 4 and 5) were satisfied to an equal amount in both methods.

The negative results obtained in some questions in both experiments may be ascribed to the overwelming of learners with information, especially when they do not have the proper basic knowledge and understanding of the concepts and graphs. Without the basic knowledge and understanding the variety of different types of motion displayed by the computer can lead to confusion. On the other hand, students with a proper basic knowledge can enhance their knowledge in the microcomputer experiments.

CONCLUSIONS

The conventional ticker-timer experiment was more successful in satisfying the first learning outcomes which are prerequisites for achievement of the later outcomes which can be better achieved by the microcomputer-based experiment. It is therefore recommended that the conventional experiment is done first, followed by the microcomputer-based experiment.

This recommendation is consistent with the results obtained by Lemmer *et al*. (2000), which shows that there is synergism of the two methods. The combined effect is larger than the sum of the individual effects. Lemmer *et al*. (2000) reports an increase of 6,8 % (<g> = 0,1) with the Thornton-Sokoloff questions after the conventional ticker-timer experiment, followed by an increase of 15,8 % (<g> = 0,3) after the computer-based experiment was done. This enlarged gain shows the enlarged learning effectiveness with students who obtained a proper basic knowledge in the first experiment.

These results are in agreement with teaching theories according to which a proper understanding of the basic concepts and principles is needed before a variety of physics problems can be solved effectively (e.g. Rosenquist & McDermott, 1987). The same principle holds for kinematic graphs. A proper understanding of the basics of concepts and graphs are necessary before a variety of motions can be investigated effectively.

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THERMODYNAMIC CYCLES:
What one can learn from the stepwise approach

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Abstract
This paper aims at clarifying how the work performed by the gas is related to the changes in the sand distribution, (i.e. changes in the potential energy of the sand.) A stepwise thermodynamic cycle is performed by means of N small weights, (here called *dw's*), which are first added and then removed from the piston of the vessel containing the gas. The size of the *dw's* affects the Entropy production and the Lost Work. The work performed by the gas can be found as increase of the potential energy of the dw's. We identify each single dw and thus evaluate its raising i.e. its increase in potential energy. In such a way we find how the energy output of the cycle is distributed among the dw's. We can see (for a given size) that some dw's go down, one reaches the maximum height etc. Analysis of such individual and size-dependent behaviours for Carnot, Stirling and Circular cycles allows to obtain the known[12-13] collective properties but at same time gives a deeper insight in the ideal gas heat engines.

INTRODUCTION

In the past ten years there has been renewed interest in thermodynamics of heat engines. Many papers address the issues of maximum power, maximum efficiency and entropy production by heat engines both from practical and theoretical point of view [1-10]. An effort to clarify the main features of the ideal gas heat engines is acknowledged as useful as many students find it difficult to grasp what work has been effectively done [11] by an ideal gas heat engine (i.e. Carnot-engine, Stirling, Otto-engine etc).

This paper presents (after the earlier paper by H. J. Leff [12] and the recent paper by M. J. Nolan [13]) a way to address such a difficulty and, hopefully, allows a deeper understanding of such ideal gas engines. The main strategy is the "stepwise approach" [14] i.e. all processes in the cycle are performed step by step; such approach allows a mathematically simple treatment, suitable also for an undergraduate level.

In order to perform an ideal gas stepwise cycle we need a heat source, a heat sink, a vessel with a free piston and a large number (N) of small "driving weights" to increase or decrease slowly, step by step, the external pressure *P*.

If the steps are infinitesimally small the cycle is "reversible".

In order to determine the work performed by the ideal gas during the cycle, the displacements of the small driving weights (dw's) must be done carefully. We let them to move on and off the piston only horizontally. To this end we assume that the handle of the piston is endowed with so many shelves that we can move each dw horizontally (and without friction) from (or to) the corresponding fixed shelf , which belongs to the dw's Reservoir. (The dw's Reservoir is a vertical sequence of horizontal shelves on which the dw's are initially located). Such an ideal device is shown schematically in Fig. 1.

A cycle as the Carnot or Stirling cycles, in which there are no isobaric steps, can be performed through Z=2N steps. In each of the first N steps one dw *is added* on the piston and removed from the Reservoir from its initial height h_0. In each of the following N steps one dw *is removed* from the piston and brought back to the Reservoir at its final height, say h_f.

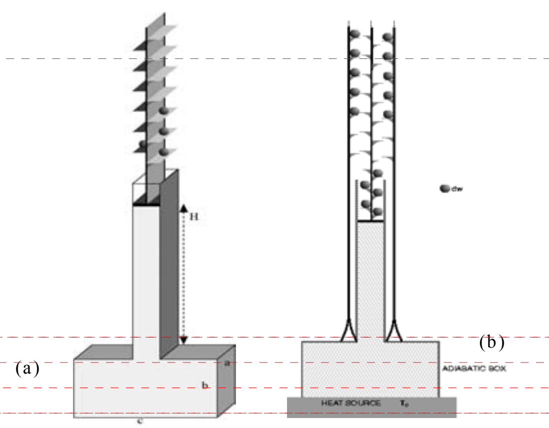

Figure 1 a) The adiabatic vessel with some dw's on the piston. b) Cross section view of the vessel showing two supports for the dw's (the dw's Reservoir)

The *k-th* dw is the dw that has been added on the piston at the *k-th* step during the compression. Therefore at the end of the cycle the overall raising on the dw's Reservoir, of the *k-th* dw from its initial height ($h_{k,0}$) to the final one ($h_{k,f}$) is

$$h_k = h_{kf} - h_{k0} \qquad (1)$$

Notice that by way of the shelves on the handle of the piston, $h_{k,0}$ is not strictly related to the height of the piston at the *k-th* step.

Since a no friction process is assumed, at the end of the cycle, the vertical motion of the dw's is only due to the gas and the total work (W) performed by the ideal gas can be found as increase of potential energy of the dw's,[10] i.e.

$$W = \sum_{i=1}^{Z} P_i \Delta V_i = mg \sum_{k=1}^{N} h_k \qquad (2)$$

Where P_i is the external pressure at step *i*, $\Delta V_i = V_i - V_{i-1}$, is the volume variation from step $(i-1)$ to step *i* and *mg* is the weight of the generic dw. In the following we will consider also the case in which some of the dw's have different masses.

For those cycles that contain isobaric steps relation (2) still holds, but Z>2N and (Z-2N) is the number of isobaric steps;

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we prove in Section 2 that relation (2) is true for whatever cycle. Section 1 is devoted to the Carnot-cycle, to the raisings of the dw's for this engine and to the main features of the stepwise approach. Section 2 is a little bit technical as some algebra is required to prove relation (2). In Section 3 the results obtained for the Carnot-cycle are extended to the Stirling–engine and to the Circular-engine also for dw's of different masses. Finally Section 4 is devoted to examination of what happens in the dw's Reservoir at the end of a cycle (see also Ref. [12] and Ref. [13]).

SEC.1- THE RAISINGS OF THE DW'S FOR A STEPWISE CARNOT CYCLE

During the thermodynamic classes I held at the University of Naples I have adopted the stepwise approach to illustrate the behaviour of the heat engines and particularly of the Carnot-engine.

Sometimes in these last three decades it happened that *some* clever student claimed: "*I have thought about it a lot, and it seems to me that the dw's go down*". My answer has been always: *"You should think about it more, because the work performed by the gas must necessarily increase the potential energy of the dw's "*.

Here we show that the clever student was not totally wrong and that, as matter of fact, at the end of the Carnot-cycle, some of the dw's will have moved downward (Negative raising), while the majority of them will have moved upward (Positive raising).

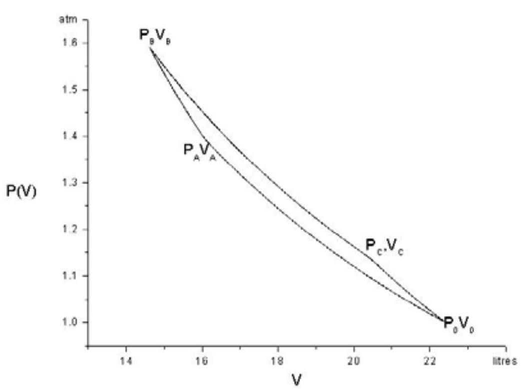

Figure 2 The step-wise Carnot cycle with very small steps.

The cycle we consider is reported in Figure 2. The steps are too small to be seen. The chosen values of P and V are easily available in the ordinary conditions. In the first N steps the dw's are *added* on the piston to perform first an isothermal compression (O→A) and then an adiabatic compression (A→B). In the remaining N steps the dw's are *removed* from the piston in order to return to the initial state (B → C → O). The working fluid is the ideal gas and the free piston is massless. We neglect gravitational effects in the gas itself. The vertical vessel's walls are heat insulating and the vessel's diathermal floor is made adiabatic when needed. The values in Figure 2 are P_0=1 at, V_0 =22.4 *l*, T_0 =273.15° K, γ= 1.4, P_A =1.3969 at, V_A=16.034 *l*, P_C =1.1385 at, V_C =20.416 *l*, T_C = 283.47°K.

We have considered here N=610 dw's and therefore 2N=1220 steps. The mass of each dw is *m*=0.1Kg. The surface of the piston is *S*=100 cm^2 so that at each step in the compression the pressure increase is $\Delta P=mg/S=Po/1033$, i.e.

$$P_i = P_0 + i\Delta P \quad for\ i \in [1, N] \qquad (3a)$$

And for each step in the expansion the pressure decreases of ΔP i.e.

$$P_{N+l} = P_0 + (N-l)\Delta P \quad for\ l \in [1, N] \qquad (3b)$$

Observe moreover that $V_{2N} = V_0$ and $V_N = V_B$ i.e. the volume at step 2N is the initial volume and the volume at step N is the smallest volume in the cycle.

Keeping in mind how we perform the Carnot cycle, let us take a closer look at the last dw. It is clear that its raising in the Reservoir is negative: when it leaves the Reservoir and is added on the piston, it (together with the piston and the previous dw's) moves downward; afterwards, at the step N+1, during the expansion, it is removed and goes at rest on the fixed shelf of the Reservoir in front of it. It stays on the piston for one step only! i.e.

$$h_N = (V_N - V_{N-1})/S .$$

Similarly the last but one dw moves downward for two steps and moves upward for one step. It performs two "negative" steps and one "positive" step

$$h_{N-1} = (V_{N+1} - V_{N-2})/S = (V_{2N-(N-1)} - V_{(N-1)-1})/S$$

Therefore for the *k-th* dw

$$h_k = (V_{2N-k} - V_{k-1})/S \qquad (4)$$

And $h_1 = (V_{2N-1} - V_0)/S$: The first dw moves downward for N steps and moves upward for N-1 steps.

Is this behaviour of the dw's that may explain the clever student's remark. The point, however, is the relative magnitude of the positive and negative displacements, *i. e* of the positive or negative raising of the piston.

Let Hi be the height of the piston at step i and $\Delta H_i = H_i - H_{i-1}$ the related piston raising.

In the first N steps the piston moves downward, $\Delta H<0$. In the second N steps it moves upward, $\Delta H>0$.

In Fig. 3 the raisings of the piston for our step-wise Carnot cycle are reported. As expected there are strong discontinuities when one goes from the isothermal to the adiabatic process and *vice-versa.*

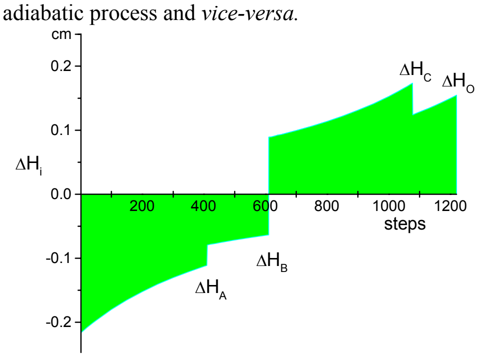

Figure 3. Raising of the piston step by step. The total shaded area is zero since the piston at the end of the cycle come back to its initial position.

By means of relations (4), we can calculate, [15] the overall raising of each of the N dw's on the Reservoir i.e. the h_k's.

We can also evaluate the h_k's by means of the plot in Fig. 3. For example the 300-th dw , it is added on the piston at the step 300-th, it stays there during the following steps until the step 2N-300 and then it is removed; therefore it, together with the piston, first moves downward and then upward. Its raising is given by the net shaded area enclosed in the big box of Fig.4

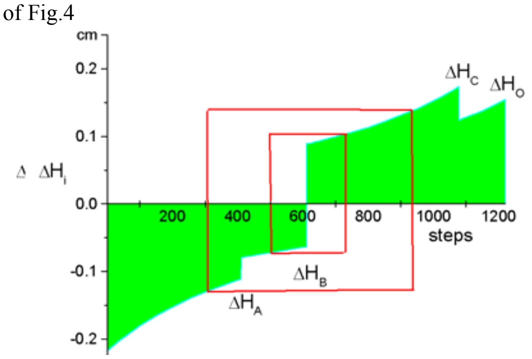

Figure 4. The net shaded area in the big box gives h_{300}, the raising of the 300-th dw. The net shaded area in the small box gives h_{500}

The overall raisings are reported in Fig.5. The inserts in the upper part of Fig. 5 show that the first dw's and the last ones have negative raisings, it is clear that the negative raising disappear only for the « reversible cycle » i.e. in the limit N→∞ (and therefore $\Delta P \to 0$, $m \to 0$). In such limit the work performed by the gas is:

$$W = R\ln\left(\frac{V_c}{V_B}\right)\left(1-\frac{T_C}{T_0}\right) \quad (5)$$

where R *is* the Universal gas constant

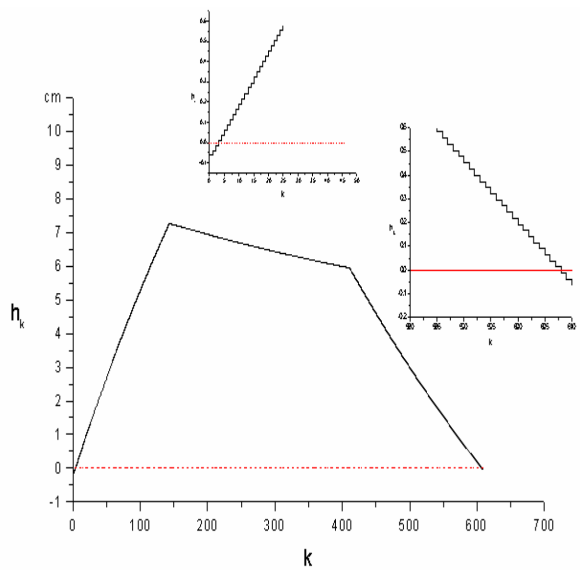

Figure 5 overall raising on the Reservoir for each dw, with zooms of the extremities of the graph, where one can see that the first dw's and the last ones have negative raisings

Remarks

1) The raising h_k depends on the removing process we choose (these processes are N!) [15-16]. We call the removing process used here (which starts with the last dw and ends with the first dw). the Simplest Process as opposed to the remaining N!-1 processes which we call Complex Processes [16] .

2) Relation (4) proves to be very useful since it enables us to evaluate the raising of the dw directly from the *PV* diagram of the cycle. We need only to observe that V_{2N-k} is the volume at the step *2N-k* i.e. the volume occupied by the gas during *the expansion* when the pressure

$P_{2N-k} = P_{N+N-k} = P_0 + [N-(N-k)]\Delta P = Po + k\Delta P$ (6a)

and that V_{k-1} is the volume in the *compression* when the pressure is $P_{k-1} = P_0 + (k-1)\Delta P$. (6b)

Therefore to evaluate the total raising of the *k-th* dw (h_k) from the *PV* diagram of the cycle one must firstly evaluate the pressure on the gas after that this dw has been added on the piston, then register the volume in the *expansion* corresponding to that pressure and from that volume, subtract the volume in the *compression* at the slightly smaller pressure of previous step. The difference must be divided by the surface of the piston.

3) One may observe that in the cycle there has been an Entropy production: It has been shown [15-16] that in the isothermal steps

$$\Delta S_{iU} = \Delta S_{i\,Sys} + \Delta S_{i\,Env} \cong R\left(\frac{\Delta P}{P_i}\right)^2 \quad (7a)$$

and that in the adiabatic steps

$$\Delta S_{iU} = \Delta S_{i\,Sys} \cong \frac{R}{\gamma}\left(\frac{\Delta P}{P_i}\right)^2 \quad (7b)$$

The cycle therefore is not reversible [17].

Obviously for ΔP→0 the cycle become reversible

4) An useful exercise for the students is to have them draw a cycle in the *PV* plane and derive from it a plot of H_i, the eight of the piston step by step and *vice-versa;* then them have decide the suitable number N of the dw's to perform the cycle (i.e. the magnitude of ΔP) and finally report in a plot the raising of the dw's on the dw's Reservoir. At that point it is instructive to compare the area of this last plot with that of the representation of the cycle in the *PV* plane.

SECTION 2-THE WORK PERFORMED DURING THE CYCLE.

Here we prove relation (2) first for Z=2N, i.e. in absence of isobaric steps, and then for Z>2N.

Observe that in both cases the value of the initial pressure P_0 is inessential, in fact it is

$$\sum_{k=1}^{Z} P_0 \Delta V_k = 0 \quad . \quad (9)$$

In the first case (for Z=2N), using relations (6) and (9), we can write the left hand side of relation (2) as

$$\sum_{i=1}^{2N} P_i \Delta V_i = \sum_{i=1}^{N} P_i \Delta V_i + \sum_{i=1}^{N} P_{N+i} \Delta V_{N+i} = \\ = \sum_{i=1}^{N} (i\Delta P)\Delta V_i + \sum_{i=1}^{N} (N-i)\Delta P \Delta V_{N+i} \quad (10)$$

Moreover observe that

$$\sum_{i=1}^{N}(i\Delta P)\Delta V_i=\sum_{i=1}^{N}(i\Delta P)(V_i-V_{i-1})= \qquad (11)$$
$$=N\,\Delta P\,V_N-\sum_{i=0}^{N-1}V_i\Delta P$$

And that

$$\sum_{i=1}^{N}(N-i)\Delta P\Delta V_{N+i}=$$
$$=\Delta P\sum_{i=1}^{N-1}(N-i)(V_{N+i}-V_{N+i-1})= \qquad (12)$$
$$=\Delta P\sum_{i=0}^{N-1}V_{N+i}-\Delta PNV_N$$

Therefore it follows

$$\sum_{i=1}^{2N}P_i\Delta V_i=\Delta P\left[\sum_{i=0}^{N-1}V_{N+i}-\sum_{i=0}^{N-1}V_i\right]$$

and reversing the first sum

$$\sum_{i=1}^{2N}P_i\Delta V_i=\Delta P\sum_{i=1}^{N}(V_{2N-i}-V_{i-1})$$

then , using relation (4), we have

$$\Delta PS\sum_{i=1}^{N}h_i=mg\sum_{k=1}^{N}h_k$$

Let now prove relation (2) for a cycle including isobaric steps, where $Z > 2N$.

To fix the ideas let us look at an isobaric version of the Stirling-Cycle reported in Fig.6.

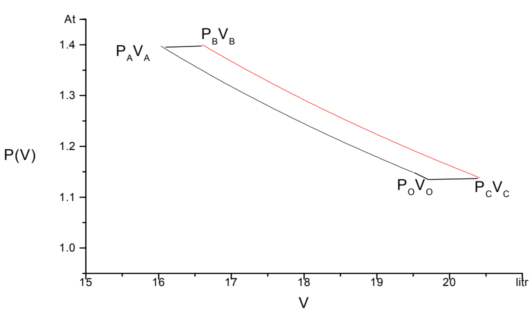

Figure 6 The isobaric version of the Stirling-Cycle

The isotherm O→A is performed in N steps, the isobar A→B in α steps, the second isotherm B→C in N steps and finally the isobar C→O in β steps. Therefore Z=2N+α+β.

Using relations (6) and (9) we can write the left hand side of relation (2) simply as

$$\sum_{i=1}^{Z}P_i\Delta V_i=\sum_{i=1}^{N}(i\Delta P)\Delta V_i+\sum_{i=1}^{a}(N\Delta P)\Delta V_{N+i}+ \qquad (13)$$
$$+\sum_{i=1}^{N}(N-i)\Delta P\,\Delta V_{N+a+i}$$

since the last term, $\sum_{i=1}^{B}P_0\Delta V_{2N+a+i}$

is eliminated by means of relation (9).

Since A→B is isobaric we have

$$\sum_{i=1}^{A}(N\Delta P)\Delta V_{N+i}=N\Delta P(V_B-V_A)$$

where V_A and V_B indicate respectively the volume of the state A and B.

Using relation (11) and (12) we have

$$\sum_{i=1}^{N}(i\Delta P)\Delta V_i=N\Delta PV_A-\sum_{i=0}^{N-1}V_i\Delta P$$

and

$$\sum_{i=1}^{N}(N-i)\Delta P\Delta V_{N+a+i}=$$
$$\Delta P\sum_{i=0}^{N-1}V_{N+a+i}-N\Delta PV_B$$

In conclusion, reversing this last sum we have

$$\sum_{i=1}^{Z}P\Delta V=\Delta P\sum_{i=1}^{N}(V_{2N+a-i}-V_{i-1})$$

but in the present case

$$h_N=\frac{1}{S}(V_{N+a}-V_{N-1})\ \ i.e. \qquad (14)$$
$$h_k=\frac{1}{S}(V_{2N+a-k}-V_{k-1})$$

and relation (2) is proved.

This proof is general. It does not depend on the particular cycle.

Remark

If some of the dw's has a different mass, say m_n*=10 m* relation (2) becomes

$$\sum_{1}^{Z}P_i\Delta V_i=g\sum_{k=1}^{N}m_kh_k \qquad (15)$$

where $m_k=m$ for $k\neq n$

Moreover since $g\frac{m_k}{S}=P_k-P_{k-1}=\Delta P_k$ (16)

using relation (4) for the raisings, i.e.

$h_k=(V_{2N-k}-V_{k-1})/S$, we can write

$$g\sum_{k=1}^{N}m_kh_k=S\sum_{k=1}^{N}h_k\Delta P_k=\sum_{k=1}^{N}(V_{2N-k}-V_{k-1})\Delta P_k \qquad (17)$$

For infinitesimally small steps, namely for a "reversible cycle" relation (4) becomes

$$h(P)=\frac{1}{S}[V_-(P)-V_+(P)] \qquad (18)$$

where $V_-(P)$ and $V_+(P)$ are the volumes at the pressure P respectively in the *expansion* and in the *compression* and *h(P)* is the raising of the infinitesimal dw which brings the pressure on the piston at value P .

Therefore from relations (15),(16), (17) and (18) it follows

$$\oint PdV=S\int_{P0}^{PMax}h(P)dP=\int_{P0}^{PMax}[V_-(P)-V_+(P)]dP= \qquad (19)$$
$$=-\int_{P0}^{PMax}V_+(P)dP-\int_{PMax}^{P0}V_-(P)dP=-\oint V(P)dP$$

where P_0 is the initial pressure and P_{Max} the pressure when all the infinitesimal dw's have been added on the piston.

Relation (19) is also given in [12] and [13]

Using relation (18) we can easily find analytically *h(P)* for a "reversible" Carnot-cycle.

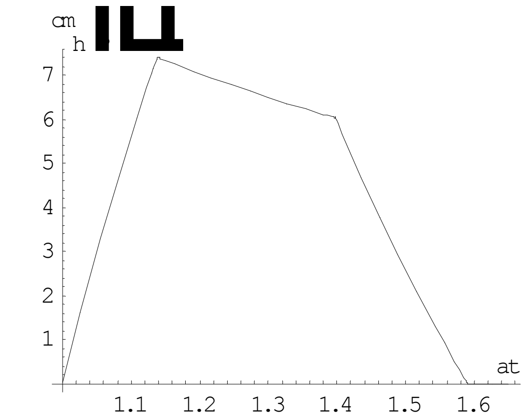

Figure 7. Plot of h(P), the raising of the infinitesimal dw which brings the pressure on the piston at value P, for a "reversible" Carnot-cycle

This plot *can be regarded* as the plot of h_k for the stepwise Carnot-cycle reported in Fig. 2 performed with the ideal device reported in Fig.1 and with a very large number (N) of dw's all of mass *m* such that

$N\,\Delta P = Nmg/S = P_{Max} - P_0$

For example for $N=6100$, the mass has to be $m=10\ g$.

N has to be very large to perform a "reversible" cycle.

SEC.3 TWO MORE HEAT ENGINES AND THE LOST WORK IN THE STEPWISE APPROACH.

Carnot cycle is the most popular cycle. Less attention is usually devoted in the textbooks to other ideal gas heat engines as the Otto, Diesel, Joule-Brayton, Atkinson, Stirling and Circular cycle.

Here we report on the behaviour of the dw's for the Stirling cycle and the Circular cycle. Results for the others are reported elsewhere [18].

A Stirling ideal gas heat engine is reported in Fig.8

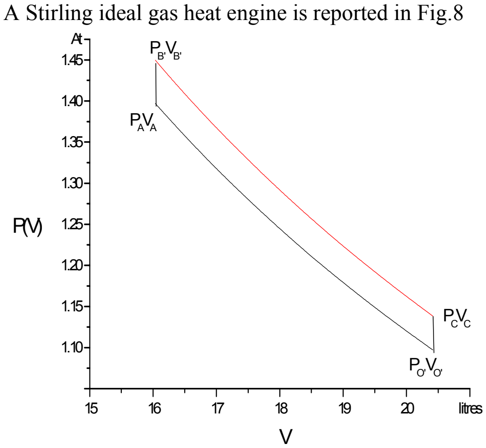

Figure 8. The Stirling-cycle

It consists of two isothermal processes (at T_A and T_B of the previous Carnot cycle) and two isochoric processes. The *isochoric compression,* starts from the state A at T_A=273.15°K, and reaches the state B* ($V_{B*} = V_A$, P_{B*}=1.4497at, T_{B*}=283.47°K). The *isochoric expansion* reaches the state O* ($V_{O*} = V_C$, P_{O*} =1.0971at, T_{0*}=273.15°K).

This cycle can be performed by means of the ideal device reported in Fig.1 with N=364 dw's all of mass *m=0.1 Kg* and therefore in 2N=728 steps; here too the steps are too small to be seen. In Fig 9 are reported the raisings of the dw's for a "reversible" ideal gas Stirling engine. As before this can be regarded as the result of a stepwise Stirling Cycle made up of a very large number of dw's, for example N=3640 dw's of mass *m=10g*.

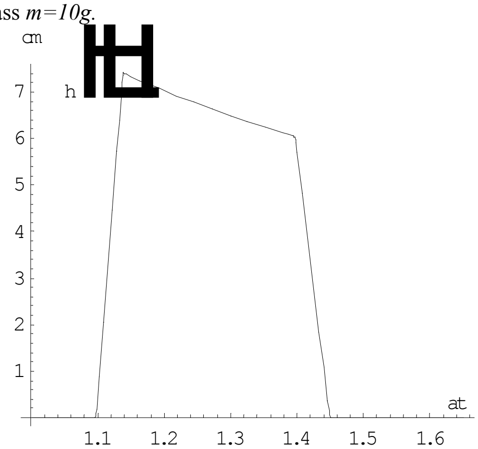

Figure 9. Plot of the Raisings h(P) for a reversible Stirling cycle

Another cycle, easy to draw in the PV plane, but difficult to carry out is the Circular Cycle reported in Fig.10.

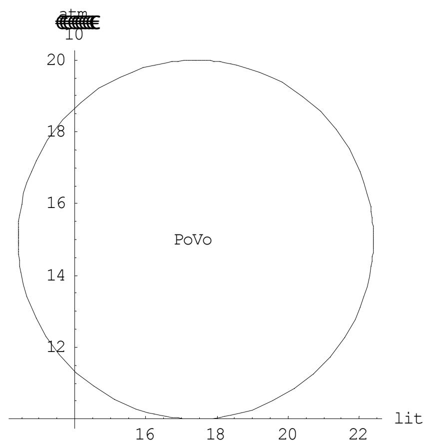

Figure 10 Circular cycle centered into P_0 =*15•10^{-1}at* and *V_0=15 l*

It is described in the *PV* plane by the relation

$$\left(\frac{P-P_0}{\Delta P}\right)^2 + \left(\frac{V-V_0}{\Delta V}\right)^2 = 1 \qquad (20)$$

where $P_0 = 15\ 10^{-1}\ at$, $V_0 = 17.4\ l$, $\Delta V = 5\ l$ and $\Delta P = 5\ 10^{-1}\ at.$

For $\Delta P \neq \Delta V$ one has elliptic cycles. This ideal gas engine was firstly discussed by Leff [12] and afterwards by Nolan [13]. Recently it has received a lot of attention [19-21].

For a reversible Circular Cycle that starts from V_0 *=17.4 l* and P^* *=10 10 -1 at=1 at,* the raisings *h(P)* are easily given from relations (18) and (20*)*

$h(P)=\frac{2}{5}\left[\Delta V^2-(P-P_0)^2\right]^{1/2}$, whose values are reported in Fig 11.

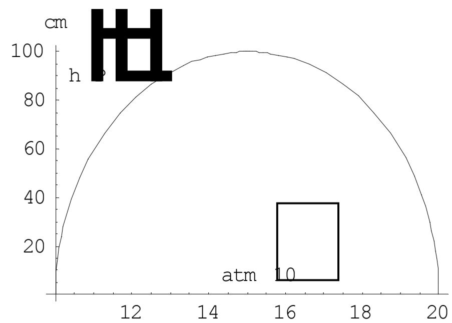

Figure 11. Plot of the Raisings h(P) for the reversible circular cycle

As pointed out in Remark 3) of Sect.1, the stepwise cycles are not reversible, there is some Lost Work and some Entropy production, related to the amplitude of the steps. The Lost Work can be easily seen in the energy output of an *anomalous* stepwise Carnot-cycle i.e. a Carnot-cycle in which one dw is bigger than the others.

In fact let us suppose that to perform the Carnot cycle of Sec.1 instead of N=610 dw's of mass *m=0.1Kg* one has only N=551 dw's; one of mass *m*=6Kg* and the remaining 550 of mass *m=0.1Kg* as before.

When the dw with mass *m** is added on the piston at the step 250 (in the isothermal branch O→A) and removed at step 2N-250 (in the isothermal branch B→C) the raisings are those reported in Fig.12, where one can easily understand that the bigger the mass *m**, the more is the Lost Work i. e. the missed area under the graph.

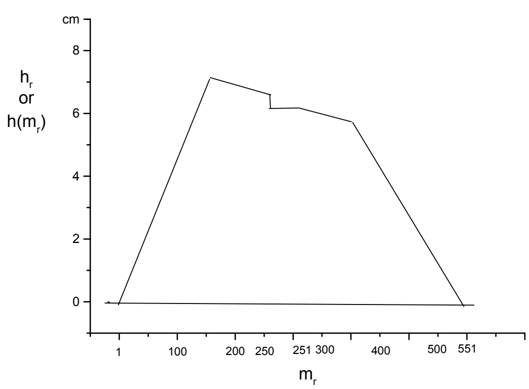

Figure 12. Raising for the *anomalous* Carnot-cycle, in which the 250-th dw has mass *m*=60 m.* The missed area is the Lost Work

The Lost Work is much more evident in Fig.13, where are reported the raisings h (P) for a stepwise circular cycle made with N=91 dw's, one with mass *m*=1Kg* and the remaining with mass *m=0.1 Kg*,

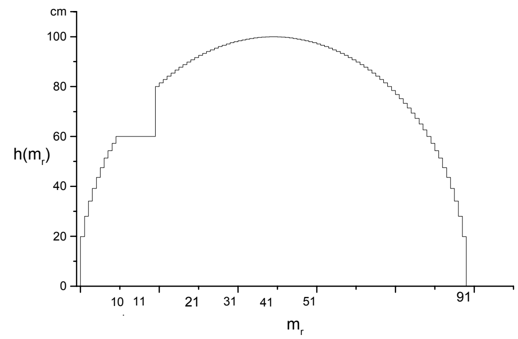

Figure 13. Raising for the *anomalous* Circular cycle,in which the 11-th dw has mass *=10m.*The missed area is the Lost Work

SEC.4 CHANGE IN THE DISTRIBUTION OF THE DW'S ON THE RESERVOIR

In the previous Sections we have analysed the raisings of the dw's on the Reservoir and their relationships to the work performed by the gas. Clearly at the end of the cycle the Reservoir of the dw's turns out to be in a new configuration: on many of its shelves there has been a depletion of mass that has reached a new height.

In this section we focus on the variation of the mass distribution on the Reservoir after a cycle. It is clear that at the end of the cycle there is a change in the distribution of the small weights on the Reservoir and this change is related to the total work performed by the gas in the cycle. Both this two aspects of the ideal gas heat engines have been extensively and accurately investigated originally by Leff [12] in 1978 and recently, in 1995, by Nolan[13]

In the present approach the estimate of the mass variation is easy. Remember that during the cycle the piston height runs from H_{Min} to H_{Max} (respectively related to the smallest volume, V_{Min} , and the largest volume, V_{Max} , in the cycle). For the Carnot-cycle given in the previous Sections, H_{Max} is just the starting height H_0 and $H_{Min} \equiv y_0$ is the height reached in the state B; for the circular-cycle reported in Fig.10, V_{Max}= *22.4l* and V_{Min}*=12.4 l*, but the starting height $H_0 \neq H_{Max}$

The height of the piston at each step, is equal to the height on the Reservoir from which the *k-th* dw is removed i.e. $H_k=h_{k0}$ if the stepwise cycles are performed under the following two hypotheses, as in [12,13],:

.a) The *adding* process is such that each dw added on the piston is removed from the shelf that is (apart from a constant [12]) at the same eight of the piston [22].

b) The *removing* process is the Simplest Process

The full range of the piston heights, H_k (and the full range of the Reservoir's heights) can be divided in *p* intervals of equal amplitude $\Delta y=(H_{Max} - H_{Min})/p$.

Let us call $y_1=y_0+\Delta y$; $y_2=y_1+\Delta y = y_0+2\Delta y$; $\dots y_s = y_0+s\Delta y$ the related Reservoir's heights and $\Delta m(s)$ the net mass-balance on the Reservoir in the *s-th* height interval (y_{s-1}, y_s) , $s=1\dots p$.

To find $\Delta m(s)$ we have only to compute, for the *s-th* height interval, the total mass of the incoming *dw's* and subtract the total mass of the outgoing *dw's*. For dw's of equal mass *(m)* this computation will give an integer number n_s (positive, negative or null) therefore

$$\Delta m\,(s)= m\cdot n_s \quad (21)$$

For dw's with different masses we will proceed similarly.

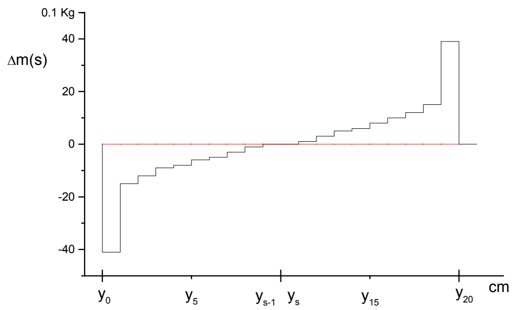

Figure 14. Net mass balance on the Reservoir versus height intervals, for the circular cycle reported in Fig.11.

In Figure 14 are given the $\Delta m(s)$ versus the height intervals for the stepwise circular cycle reported in Fig.9 made (under the a) and b) hypotheses) by means of N=100 dw's of equal mass $m=0.1$ *Kg*. We have chosen $p=20$

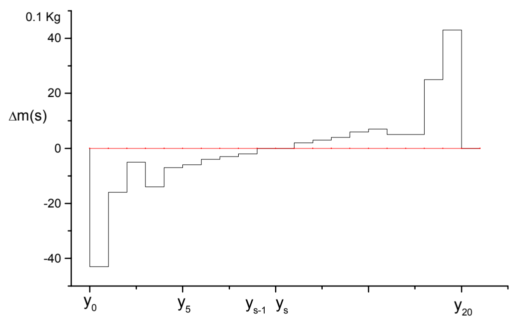

Figure15. Net mass balance on the Reservoir versus height intervals, for the *anomalous* circular cycle reported in Fig. 13.

In Fig.15 are given, still for $p=20,$ the mass increments for the same cycle made with N= 91 dw's one of which (the *11-th*) has mass $m^*=1kg$ and the other 90 the mass as before. Notice the differences

Obviously it is expected and is extensively shown in [12-13] that

$$\sum_{1}^{2N} P_i \Delta V_i = mg \sum_{k=1}^{N} h_k \cong \sum_{s=1}^{p} y_s \Delta m(s)$$

Remark that for removing processes that do not fulfil hypotheses a) i.e. $H_k \neq h_{k0}$. *or* b) (for example the Complex Processes) the plot of the mass increment will be completely different. A mass increment analysis for the Otto, Joule-Brayton etc ideal-gas heat-engines are given elsewhere [18]

Conclusion

The detailed analysis of the classical cycle followed here shows a fruitful complexity in the behavior of the raisings of the small driving weights.

It would moreover be useful to actually perform the step-wise Carnot engine. In such a case the pattern of the overall raisings of the dw's would be preserved in spite of the energy loss due to friction between the piston and the vessel and the dw's and the shelves.

We believe that a stepwise analysis of the entropy production (i.e. of the entropic gain of the Universe) (ΔS_{Ui}) and of the lost Work $T_i\ \Delta S_{Ui}$ step by step may give a deeper insight into the properties of such engines.

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14 The stepwise approach although implicit in the Carnot, Clausius and Kelvin papers is explicitily used by A Sommerfield, " Thermodynamics and Statistical Mechanics" *Lectures on Theoretical Physics. Vol. V. Academic Press (1964)* and by Andresen , R S Berry , A Nitzan and P Salamon: "Thermodynamics in finite time. I. The step-Carnot Cycle" *Phys. Rev*. **A 15**, 2086 (1977) where it is also shown that the best performance is obtained with equal pressure steps .

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22- There may be some practical difficulties in the fulfillment of the hypothesis b). For the device in Figure1 the dw's have to be added on a particular chosen shelf, for example the highest one. The scale pad in [12] is another solution.

NEW PRINCIPLES OF EDUCATIONAL TEXTS CREATION

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ABSTRACT

In many countries one of the tendencies of modern education is the reduction of pupil's interest to such subjects as physics and astronomy. Many teachers explain it by artificial distance between these subjects and life round us. In order to increase pupil's motivation to learn these subjects, it is offered to use in training some game elements, entertaining experiences or to try to explain cultural (historical, architectural) aspects by means of physic's laws.

Thus, it is necessary to include demonstrations of practical orientation, and some scientific knowledge, as a part of historical of culture, in educational material. We consider that it is convenient to apply the methods of semiotics on construction the educational materials. Semiotics (from Greek word meaning "sign") is the science, which object of investigation is the sphere of sign dialogue. These ideas are widely developed in works of Russian philologist Yu. Lotman. It is also useful to apply the methods of neuro-linguistic programming, the methods of communication rapidly developing now, in construction of the computer teaching sites. All the methods of training are aimed at making the understanding of the subject easier and to improve the learning process. It can be achieved by special organization of the material. To promote better learning, we can construct a set of semiotic pairs:

1. "Already known"→ "new knowledge".
2. "Already known"→ "a cultural code".
3. "A cultural code"→ "new knowledge".

Using the methods of neuro-linguistic programming we can make computer to contact with the pupil in his style (language), adopted to his level of knowledge, and then to give him more information in proper way according to the pupil's personal character. The server containing educational material is constructed using the above-stated ideas. The server training functions are based on the methods of neuro-linguistic programming.

TEXT FUNCTIONS

The philologists distinguish several functions of text. It is necessary to know them to organize educational material in proper way to achieve best results in educational process.

One of text functions is the transfer of ***information***, available already in it (rational text component). The majority of the people think that it is the only text function. They consider text only to be storage of information. As the consequence, in training prevails learning by hart the information, numbers e. t. c. frequently. The information storing only is not good for educational process, and for the majority of schoolboys it is short-lived, they forget every thing in some very short time, as it has no connections in their mind with something else. The material does not communicate by associations and consequently it is quickly forgotten. It is the psychological question of education, the question of our mind nature, of its organization. How to organize educational material for better learning.

The text is ***condenser of cultural memory***. Using the text symbols men can reconstruct the proper value incorporated by many generations (archetypes). It is irrational component of the text. Such interaction of text and cultural memory of people results in creation of new knowledge.

During all mankind history people used to look, to observe heavenly stars. The most ancient texts are already connected with the subject, which contemporary astronomy investigates. That is why the astronomical knowledge makes a part of cultural environment of society. The process of learning astronomy is the contribution to further development of culture.

The text serves the ***generator of the new information,*** new knowledge which cannot be deduced unequivocally from already available knowledge. It is the creative function of the text.

BASIC SEMIOTIC PRINCIPLES

For skilful use of these texts, combination them with popular scientific material, it is necessary to know how the diverse texts cooperate. Let's consider scientific lecture and myths as two different sign systems.

1. The minimally thinking system should include, as a minimum, two differently organized subsystems, exchanging by information. One system operates with discrete coding system, which basic unit is segment (mark), and their chain (text) is secondary. Another system has continuum character, when the text, being the carrier of sense, is primary.
2. There is no oneness translation between systems.
3. Pair of mutually non-comparable meaningful elements with established adequacy relations, within the framework of some context, forms semantic track. The semantic track makes essence of creative thinking.

So, it is important to compare them, in order to receive a semiotic pair. In this case myths and lecture have to tell about the same things, in our case about any concrete constellation. Then, in first approximation, it is possible to say that these texts are about the same, but in different unequivocally not compared sign systems. By concentration on information, the pupil will admire irrational myths component, so the semantic tracks will be formed.

By forming databank and by describing properties of diverse fragments of the text on various ideas, it is possible to make an educational lecture (lesson) productively. And the construction of lecture (lesson) can be entrusted even to the computer. Building the material from such "stones" it is possible to use it for the popular books and textbooks and Internet sites.

EDUCATIONAL TEXT CONSTRUCTION

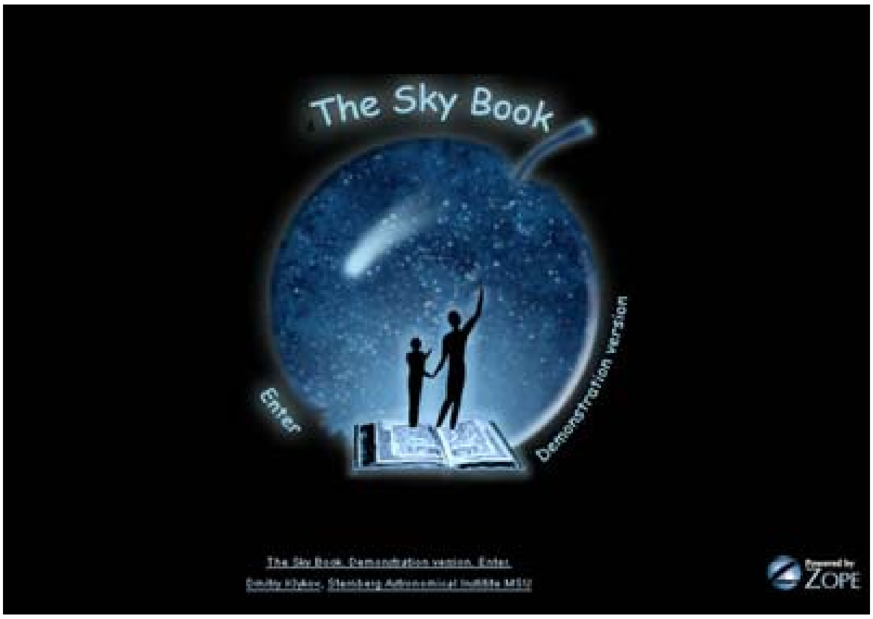
The artificial inclusion of semiotic structures is applied on site "Sky Book" (http://uranometria.sai.msu.ru), made with the help of server system Zope. The information on the screen is submitted as book with different kinds of information on pages. For example, verses, myths, picture are put on the left page and the popular scientific text, connected with them on sense, is put on the right page. Together these texts form original game in pupil's mind, resulting in new semantic forms, appearing on the basis of available ones. In this way we achieve intellectual, mental and cultural development of pupils.

Under the text both on the left, and on the right page, there are references to the following pages concerning the appropriate items. The user chooses (and it also a semantic pair!), whether he will press on the left page and will read, for example, myths, or will press on the right page, continuing to read scientific information. The server accumulates the information on preferences, and also according to the level of the reader using the elements of neuro-linguistic programming, and, if necessary, corrects teaching process.

The ideal is to use neuro-emmulators in construction of teaching programs.

It is one of information representation variants, huge amount of variants are possible.

The work of different schools in different countries on their servers is very interesting for constructing texts from such “stones”. Thus it is important to adjust, except for mutual working communications, the exchange of these texts by means of Global Net. Such "inclusions" of other culture texts Yu. Lotman calls "... an important factors provoking culture development. It is connected with the fact, that the text, like a grain containing the program of future development, creates a fundament for its future development under the influence of new contexts".


The Sky Book
Enter
Demonstration version


The Night

Sky's attraction is so strange and deep
Like magnet that's acting to compass.
There is something of relationship
Between abyss of the stars and us.

Many ways we have for separation
To extract Important elements.
But to estimate the perfection
It is better use no Instruments.

Then cascade of values will be end
And destroyed heavy arch of heaven
And unite In deep of firmament
Mankind and the Nature for ever.

Yu.S. Ephremov, 1992

Next page: Pictures from gottorpsky globus

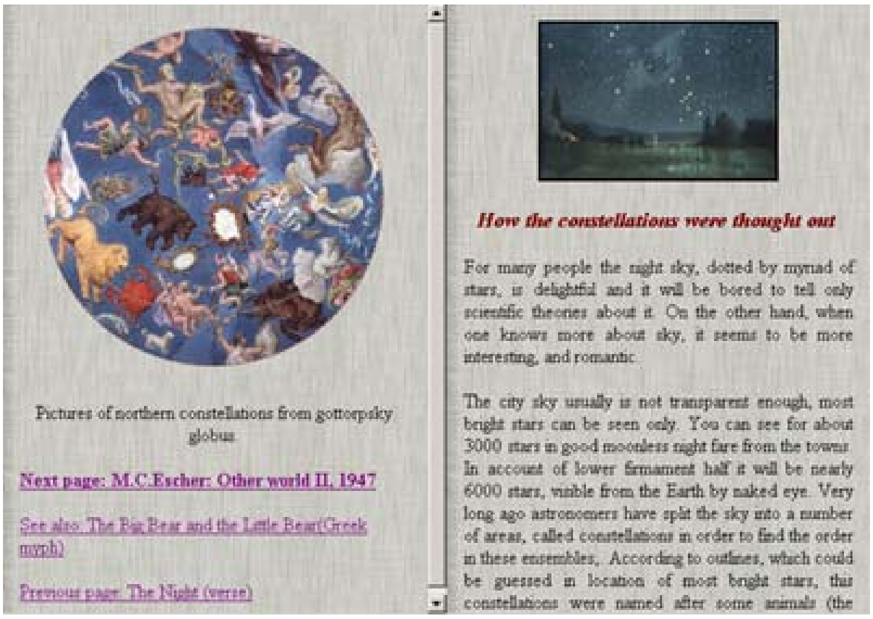
See also: M.C.Escher: Other world II 1947
See also: The Big Bear and the Little Bear (Greek myph)

(c) A.Yufereev

This page is about that is constantly above us. It is enough to raise your head in clear evening see at the sky above you and wonder. To wonder, that you have known so little about all these before.

Next page: How the constellations were thought out

See also: Where is North?
See also: The Constellations on north side of horizon


Pictures of northern constellations from gottorpsky globus

Next page: M.C.Escher: Other world II, 1947

See also: The Big Bear and the Little Bear(Greek myph)

Previous page: The Night (verse)

How the constellations were thought out

For many people the night sky, dotted by myriad of stars, is delightful and it will be bored to tell only scientific theories about it. On the other hand, when one knows more about sky, it seems to be more interesting, and romantic.

The city sky usually is not transparent enough, most bright stars can be seen only. You can see for about 3000 stars in good moonless night fare from the towns. In account of lower firmament half it will be nearly 6000 stars, visible from the Earth by naked eye. Very long ago astronomers have split the sky into a number of areas, called constellations in order to find the order in these ensembles;. According to outlines, which could be guessed in location of most bright stars, this constellations were named after some animals (the

MODELING ENVIRONMENTS: TWO EXAMPLES INVOLVING DIFFERENT LEARNING STRATEGIES

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Abstract

The objectives of innovative science education involve that students can give a scientific meaning to physical world where they live by using mathematics to build a predictive model. Many research studies, based on the representational nature of human knowledge and describing how people construct their knowledge about the world, focus on strategies of modelling, i.e. a facilitating process for the construction of adequate mental models that will help the understanding of physical models.

We report examples where learning of physics follows the same steps than the learning of a new language: as it happens in the case of a new language, the learning of semantic precedes the learning of syntax, that is, mathematical representations. Teaching strategies are implemented that take into account that the students already have the basic tools to generate mental models, which are the same they use to interpret the world: to make analogies, idealizations and abstractions.

The reported examples use two different kinds of modelling environments: the first one belonging to the category of the so-called "aggregate" modelling engines (STELLA) and the second one belonging to the category of "object-based" modelling languages (NET LOGO).

Introduction

It is widely accepted that pedagogical approaches based on modelling strategies can make Physics more understandable to pupils, helping them to simplify and classify complex phenomena, to predict trends and to explain mechanisms and processes. Actually, many research studies [1, 2] have pointed out that model building can be a formative pedagogical activity, also because it allows pupils to better understand many content areas, enabling them to see similarities and differences among apparently different phenomena. As a consequence, a teaching approach focusing on modelling procedures can contribute to construct a unitary view of physics as well as to unify the scientific approach to many problems [3]. However, many pedagogical questions, concerning methods and strategies making the modelling approach teachable and/or learnable, are to be deepened.

In this paper, we present some pedagogical strategies and tools, based o the use of Information Technologies (such as microcomputer based laboratory, multimedia, simulation programs etc.), giving pupils the possibility to formalise a problem following well defined steps tailored to identify relevant elements of a given observation, define the associated variables, predict relationships among them and check predictions using tools scaffolding the process of personal knowledge construction. The reported examples are aimed to students in 16-18 year range and have been experimented in courses for pre-service teacher preparation.

"Aggregate" modelling engines: STELLA

STELLA is a simulation environment developed to communicate models generally produced by the process of "thinking" [4]; its main advantage is to eliminate the need to manipulate symbols and to make complex mathematics understandable and easily manageable.

STELLA represents the changing dynamics of a variable by a *stock* that can fill or drain through incoming or outcoming *flows*. Its main graphic interface makes available the basic elements assigned to the model building. These are:

- *Stocks* containing amount of the variable changing in time,
- *Flows* representing the action to fill or drain stocks,
- *Converters* additional objects used to complete the logic sentence,
- *Connectors* used to link objects together and define their relationships.

In natural language a mental model is generally associated to a verbal description; STELLA allows the users to translate the verbal model of the system under scrutiny into a symbolic scheme, by representing carefully all the elements of the idea describing its evolution. The program automatically generates a code describing the scheme built by users and simulates the time evolution of the system, representing it through graphs, tables etc.

Modelling becomes a "translation" from verbal descriptions to iconic representations; STELLA, then, "translates the specific iconic language to mathematical equations.

Very often high school pupils, as well as many undergraduate students, have a inadequate comprehension of the mathematical symbology and, what is surely worse, they do not know when and why mathematical formalization becomes necessary in order to solve problems. In this context, modelling activities using a iconic language can help students to develop competencies in translating different descriptions of real world into each other. The use of the STELLA environment, with its components allowing to easily visualize physical objects and processes, makes possible the construction of operative thinking forms that can be easily translated in mathematical formal ones .

Let's now see some examples involving a use of STELLA that can make clearer a typically misunderstood mathematical concept: the time rate of variation of a variable. We develop this by building models of some real world relevant situations and considering the formal representation generated by the program as the result of the iconic model constructed starting from the verbal description of every situation.

Some examples with STELLA

1. Decay of pollution: the lake purification

Consider a lake, of constant volume, V_L, contaminated by some kind of substance. If the lake is well mixed, we can assume that the contaminant concentration is uniform. Assuming that at time $t=0$ we start to decontaminate the lake by making flow in clean water at rate R and allowing that at the same rate R water containing the polluter flows out, we can begin with a simple verbal description of the phenomenon in order to model the process of the lake purification and calculate the time dependence of the contaminant volume, $V_C(t)$. A possible one can be the following: *The volume of the contaminant must decrease, due to both the outflow of polluted water and the inflow of clean water. The clean water volume consequently increases until it reaches the (constant) volume of the lake.*

Now, how can we try to schematise the relevant variables and all the logic links between them influencing the process of lake purification?

A possible STELLA iconic representation of the lake purification is shown in figure 1.

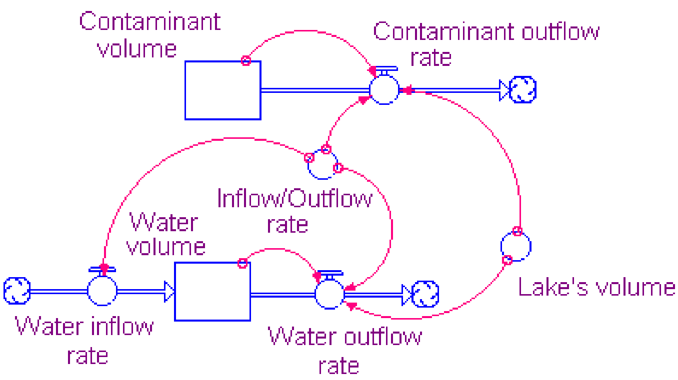


Fig. 1. STELLA iconic model for the process of a contaminated lake purification.

The figure shows that the model is built by using two stocks, three flows, two converters and some connectors. The relevant variable, the contaminant volume, V_C, is represented by the first stock and the other stock does represent the volume of clean water in the lake, V_W. One of the converters indicates the lake volume, V_L , equal to $V_C + V_W$ and constant by definition. The other converter represents the rate of inflow of clean water into the lake and, at the same time, the rate of outflow of polluted water from the lake, equal because of the constant lake's volume.

The flow marked "Contaminant outflow rate" represents the rate of decrease of the contaminant volume. It must obviously depend from the lake's volume, V_L , the contaminant volume, V_C , itself and from the Inflow/Outflow rate and is linked to them by connectors. The two flows connected to the water stock indicate the two ways the clean water volume has to vary; the "Water inflow rate" flow represents the constant inflow of clean water into the lake and is linked (or, better, equal) to the "Inflow/Outflow rate" converter; the "Water outflow rate" flow, on the other hand, must depend from the Inflow/Outflow rate, the lake's volume and the clean water volume. Note that the links between The "Contaminant volume" stock and the "Contaminant outflow rate" flow and the "Water volume" stock and the "Water outflow rate" flow actually give two feedback loops, indicating that these flows must take into account the instantaneous value of the variable represented by the stocks. As a consequence the two rates "Contaminant outflow rate" and "Water outflow rate" are not constant, but depending from the instant values of the volumes.

The equations lying behind the model are:

$$\frac{d}{dt}\left[V_C(t)\right] = -\frac{R}{V_L} V_C(t)$$

$$\frac{d}{dt}\left[V_W(t)\right] = R - \frac{R}{V_L} V_W(t)$$

Their solutions should exhibit exponential time dependences. In figure 2 are reported the results of the STELLA simulation, with $V_L = 10^8$ m^3, $V_C(0) = 10^4$ m^3, $R = 0{,}5$ m^3/s.

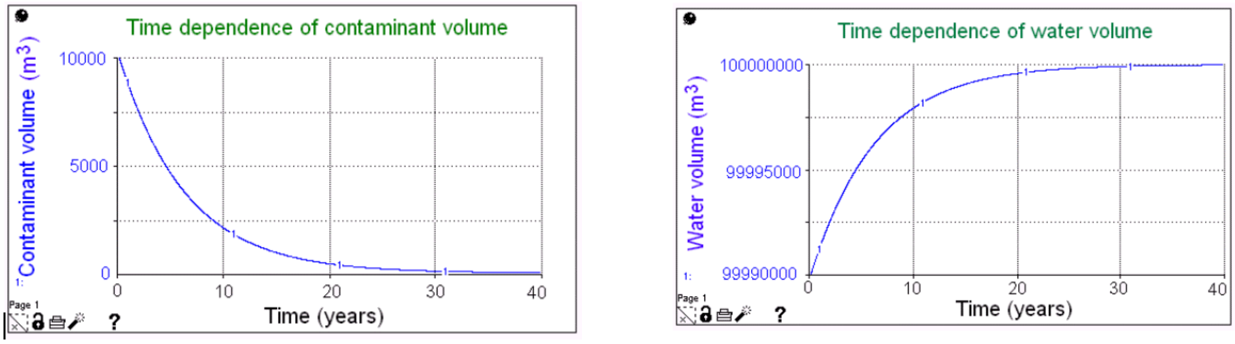


Fig. 2. Results for the lake purification STELLA simulation

It is worth noting that the first equation contains all the necessary information to solve the problem if we make a more adequate choice of the variable describing the evolution of phenomenon: i.e. the concentration of the contaminant in the lake, *c(t)*, (the mass of contaminant per cubic meter of water). The equation behind the model is very similar to the one for the contaminant volume:

$$\frac{d}{dt}[V \cdot c(t)] = -Rc(t)$$

In this case the STELLA model is simpler, mainly because we need not to take into account the water volume time dependence (see figure 3). The solution shown in figure 4 is obtained with $V_L = 10^8$ m^3, $c(0) = 0.1$gr/m^3 and $R = 0{,}5$ m^3/s.

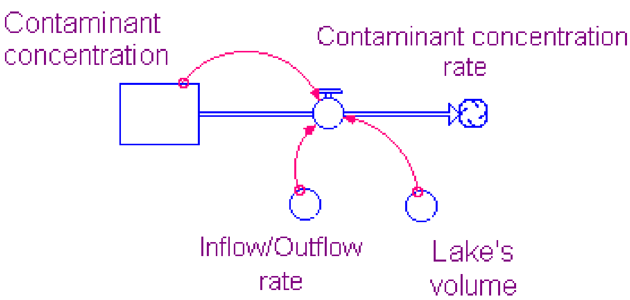


Fig. 3. Alternative model for the lake purification process

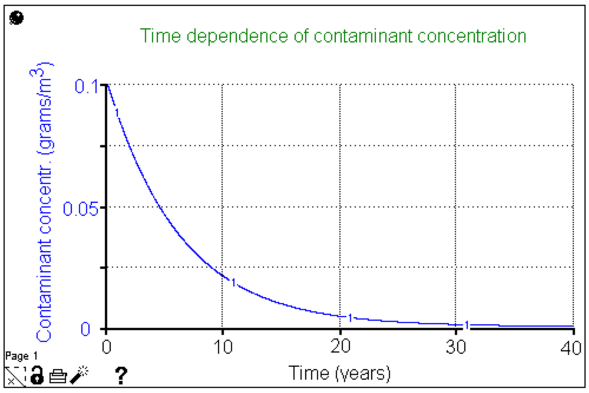


Fig. 4. Results of the alternative model

1.1 The equilibrium concentration of contaminant in a lake

Let's now analyse a slightly more complex situation. We consider the lake of the previous example, of constant volume V_L , and suppose that the water flowing into the lake is not clean. It contains some contaminant making the pollution concentration in the lake increase at a rate P_{in}. We call R the total (clean water plus contaminant) output flow rate and consider that at $t = 0$ the concentration of contaminant is $c(0) = c_0$ (gr/m^3). We calculate the contaminant equilibrium concentration.

We start by considering that, if an equilibrium concentration of the contaminant, c_{eq}, is to be reached, the contaminant mass outflow must balance its inflow. So, $Rc_{eq} / V_L = P_{in}$. However, with respect to the first case, the input source of pollution can significantly modify the time dependence of the contaminant concentration.

A verbal description of the phenomenon of this lake purification model can be the following: *the concentration of the contaminant is proportional on the outflow-rate of water, that makes it decreasing, as well as on the input-rate of contaminant, that works in the opposite direction.*

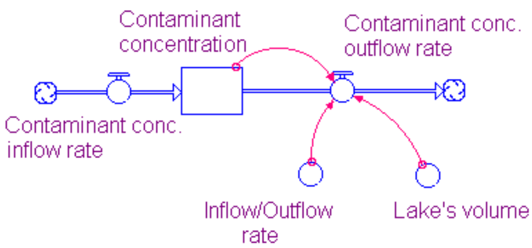


Fig. 5. STELLA iconic model for the reaching of an equilibrium contaminant concentration in a lake.

The STELLA representation of the relevant variables and the logic links between them are very similar to the first lake purification problem, with the significant exception of the constant pollution input rate. In fact, the rate of variation of the total contaminant mass in the lake is due to both the output and the input of polluted water.

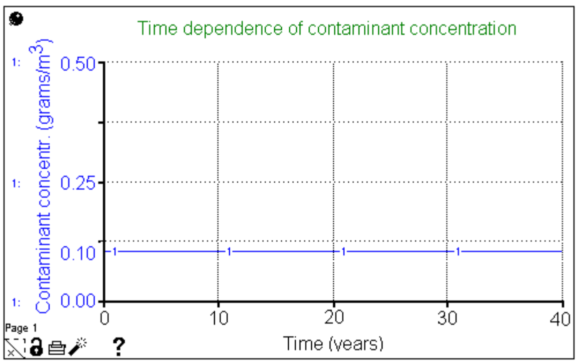
The mathematical formalization of the model is:

$$\frac{d}{dt}\left[V_L \cdot c(t)\right] = V_L P_{in} - Rc(t)$$

and its solution is the following:

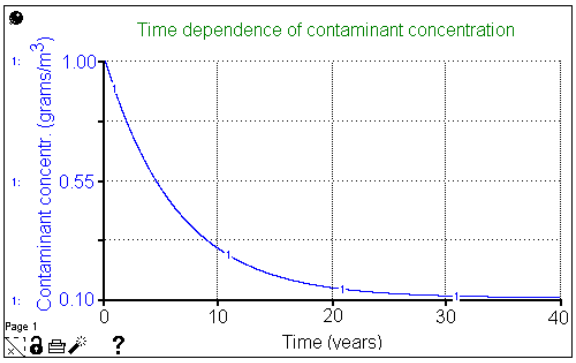
$$c(t) = \frac{V_L P_{in}}{R} + \left[c(0) - \frac{V_L P_{in}}{R}\right] \cdot e^{-\frac{R}{V_L}t}$$

The value of the rate of contaminant concentration inflow, P_{in}, with respect to the initial concentration of contaminant, *c(0)*, plays an important role in the time dependence of the concentration. In fact, if $c(0) = V_L P_{in}/R$, the inflow of new polluter makes no difference, i.e. the concentration remains at the initial value, *c(0)*. On the other hand, if $c(0) > V_L P_{in}/R$, the pollution will decrease, converging to the equilibrium value, c_{eq}, at $t \to \infty$. Finally, if $c(0) < V_L P_{in}/R$, the pollution will increase, converging to the equilibrium value, c_{eq}, at $t \to \infty$. These behaviours are shown in figures 6.



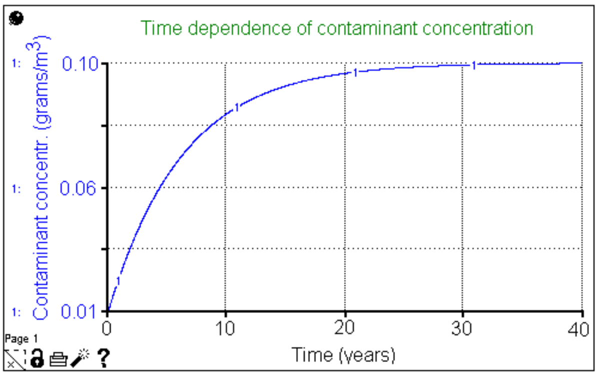
$c(0) = 0.1$ g/m^3

$V_L P_{in}/R = 0.1$ g/m^3



$c(0) = 1$ g/m^3

$V_L P_{in}/R = 0.1$ g/m^3



$$c(0) = 0.01 \text{ g/m}^3$$

$$V_L P_{in}/R = 0.1 \text{ g/m}^3$$

Fig. 6. Results of the simulation for different values of relevant parameters

2. Cooling a substance in an environment at constant temperature

We now analyse and model a classical physical problem showing behaviours similar to those analysed in the previous paragraph.

We consider a container with a given mass of water at temperature T_W set in an environment at a lower constant temperature T_E. The process of water-cooling is easily observed as well as the fact that the cooling rate is not constant. The appropriate variable to describe the phenomenon is the temperature difference between water and the environment, $T(t)= T_W(t)-T_E$. It decrease as a consequence of the heat flow from the system to the environment. If we call K the cooling coefficient, depending from the physical parameters of the system (liquid and container)[1], we can hypothesize a dependence of the cooling rate dT/dt from the instantaneous value of T.

The STELLA iconic representation of water cooling model is very similar to the lake's purification model (see figures 7-8) and consequently to its results.

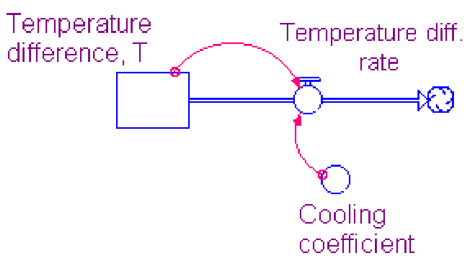


Fig. 7. STELLA iconic model for the cooling process

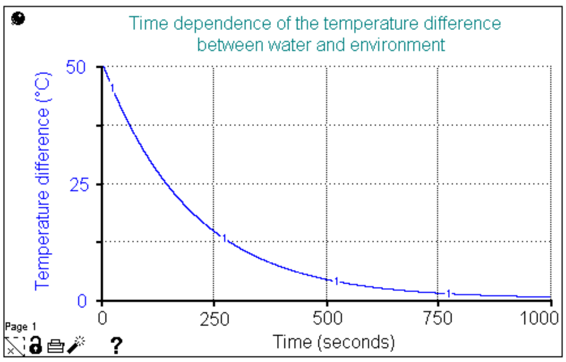


Fig. 8. Results of the simulation

Heating a room: the equilibrium temperature

[1] From the Newton's cooling law, the cooling coefficient, K, is equal to hS/C, were h is the "external conductivity coefficient", S is the thermal contact surface between water and the environment and C is the thermal capacity of the sample of water

We consider a room, containing air at initial temperature *T(0)*. The room's walls are thermally insulated but heat can flow by a window in thermal contact with a cooler environment. A heater system supplying a constant heating power *P*, is, then, switched on.

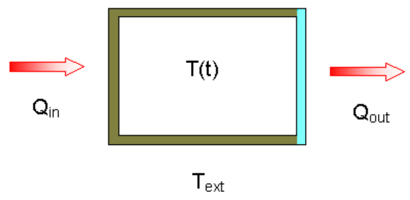


Fig. 9. Scheme of the system

The STELLA representation of the model is similar to the previous one (see figure 10).

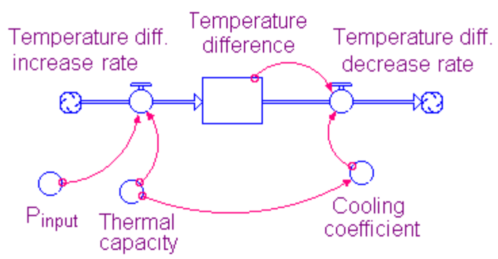


Figure 10. STELLA iconic model of the heating-cooling process

To find the mathematical model behind the iconic representation, we have to consider the rate of heat inflow as well as the rate of heat outflow. By defining $T'(t) = T(t) - T_{ext}$ (the temperature difference between the air inside the room and the external environment), its rate of change will depend by the heating power and by the cooling conducting effect. The mathematical formalization of the model can be written:

$$\frac{dT'(t)}{dt} = \frac{P}{C} - \frac{K}{C}T'(t)$$

where *P* indicates the heating power, *C* the thermal capacity of the mass of air and the constant *K* is defined by the Fourier law, *K = hS/d* (with, *h* the thermal conductivity of the window material and *S* and ,, respectively, the surface and the thickness of the conducting window).

The analytical solution of the equation is:

$$T'(t) = \frac{P}{K} + \left[T'(0) - \frac{P}{K} \right] e^{-\frac{t}{\tau}}$$

with $\tau = C/K$.

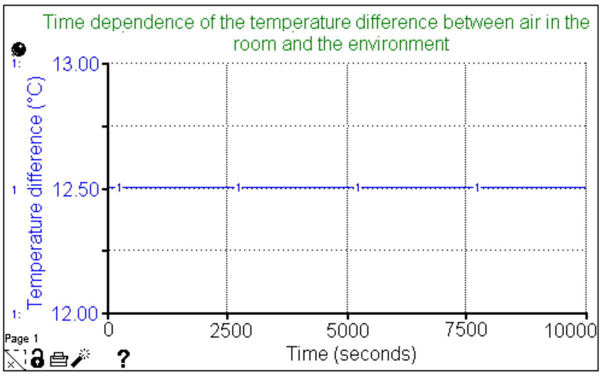
The solution shows that the system reaches an equilibrium temperature difference given by:

$$T_{eq} = \frac{P}{K} = \frac{Pd}{hS}$$

As in the case of the equilibrium concentration of contaminant in a lake, the relevant parameters of our system, with respect to the initial difference of temperature, can make a great difference in the time dependence of the difference of temperature:

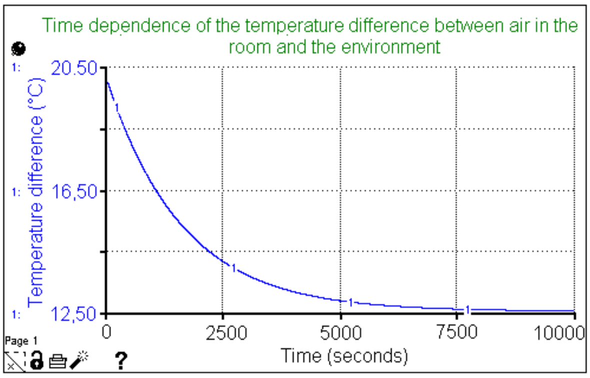
- If $T'(0) = Pd/hS$, the difference of temperature remains constant at the initial value, $T'(0)$.
- If $T'(0) > Pd/hS$, the temperature difference will decrease, converging to the equilibrium value, T_{eq}, at $t \rightarrow \infty$.
- Finally, if $T'(0) < Pd/hS$, the temperature difference will increase, converging to the equilibrium value, T_{eq}, at $t \rightarrow \infty$.

Figure 11 shows the results of STELLA simulation in a typical case: a room with a 1000W heat source and a normal glass window ($S = 1m^2$, $h = 0.8\ W/m°C$, $d = 0,01\ m$) and, as a consequence, with a equilibrium temperature $T_{eq} = Pd/hS = 12.5\ °C$.



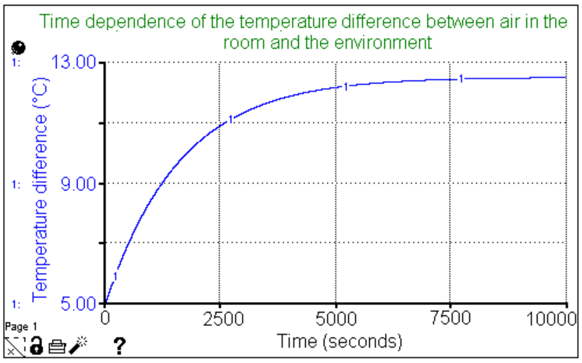
$T(0) = 12.5$ °C

$P\Delta x/hS = 12.5$ °C



$T(0) = 20$ °C

$P\Delta x/hS = 12.5$ °C



$T(0) = 5$ °C

$P\Delta x/hS = 12.5$ °C

Fig. 11. Results of the simulation for different values of relevant parameters

The NetLogo modelling environment

NetLogo (6) is a programmable modelling environment for simulating natural and social phenomena. It is particularly well suited for modelling complex systems developing over time. Modellers can give instructions to hundreds or thousands of independent "agents" all operating in parallel. This makes possible to explore the connection between the micro-level behaviour of individuals and the macro-level patterns that emerge from the interaction of many individuals. The agents can represent animals, cells, trees,….., that is individual elements interacting and consequently also molecules of a substance cooling in an environment at low temperature (see figure 12).

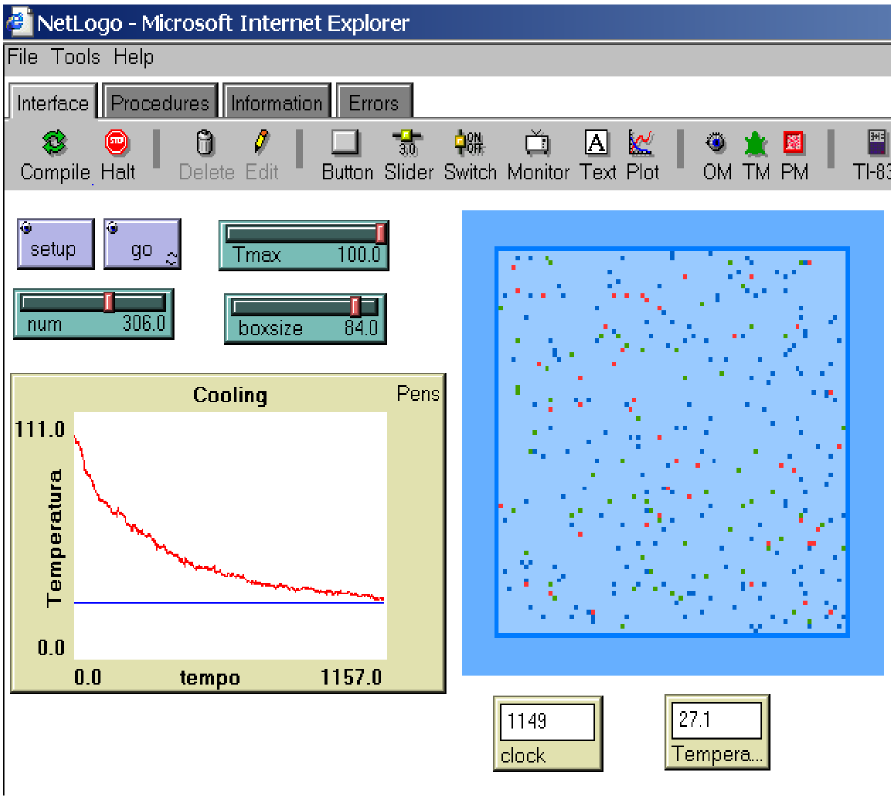


Fig. 12. NetLogo interface reporting results of a model for the cooling of a gas in a box in thermal contact with the environment at low temperature

The figure shows the NetLogo interface representing a given number of gas molecules, at a given temperature, contained in a box in thermal contact with the environment at low temperature. The cooling of the gas is represented using different colours for molecules with different energies. A graphical display of the gas temperature as a function of time is also represented. Data fittings of the cooling curve can be performed and its mathematical characteristics pointed out.

NetLogo lets students open simulations and "play" with them, exploring their behaviour under various conditions. It is also an "authoring tool" which enables students, teachers and curriculum developers to modify models and/or create their own models. NetLogo is simple enough to allow students and teachers to easily run simulations or even build their own. And, it is advanced enough to serve as a powerful tool for researchers in many fields.

Many real systems are usually so complex that a description and interpretation at macroscopic level requires mathematical competencies usually not mastered by high school pupils. Their analysis at level of their constituents can, some times, simplify understanding by making pupils enable to construct causal explanations of a wide range of phenomena, and provide them with a framework that is useful across a wide range of disciplines.

Conclusion

The approach, here described, has been tested in courses for pre-service teacher preparation, in order to make prospective teachers aware of the power of informatics tools in facilitating the construction of mental models adequate to help the understanding of physical models as well as the formalism of differential equations. Several parts of the modelling approach have also been tested in some high school classrooms.

The STELLA approach offers real advantages in helping users to construct models and to eliminate the need to manipulate symbols, making complex mathematics more understandable. Student teachers, graduated in mathematics or physics, at the beginning encountered some difficulties in switching the symbolic perspective: they have studied differential equations in their degree courses and were familiar with their formalism. They began to appreciate the new representational formalism in approaching more complex systems to model: they understood the power of the iconic formalism and showed to appreciate its pedagogical impact. Some teachers, introduced to STELLA during a in-service teacher training course, recognized the advantage of using it in the teaching of science, but showed the need to have a well performed didactic guide introducing to the language. An introductory guide is in preparation.

NETLOGO uses a different approach that allows users to model systems directly at the level of their individual constituent elements. Using it, students can learn to think about actions and interactions of individual objects and to describe complex system properties as the result of individual actions.

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Constructing a “didactical mirror” for science student teachers

A study of prospective teachers’ explanations of physical phenomena to a hypothetical Grade 7 pupil

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Paper for GIREP 2002

1. Introduction

An important professional skill that prospective science teachers should develop during their university studies is to learn to explain things to pupils. We assume that this ability to explain comprehensibly to another person is explicitly and implicitly formed in teacher education. Also that communication skills of teachers reflect their professional competence.

Adopting a sociocultural perspective on human activities is helpful in discussing importance of developing communication skills in science teacher education. A key aspect of this paper is that student teachers’ professional knowledge development is based on, and reflected in, their communication.

As a means of investigating this, small research project was designed to illuminate student teachers’ pedagogical skills in giving written explanations in science. The study was conducted simultaneously in teacher education in Petrozavodsk (Russia) and Umeå (Sweden)[1].

Our research interest was on prospective science teachers command of options in “delivering” information on science topics. We focused on the following questions:

- What kind of communication tools (concepts, drawings, symbols, analogies, etc.) did student teachers spontaneously choose when communicating in writing with a school pupil?
- Was the content scientifically correct?
- Did the students provide relevant background information to facilitate understanding of the phenomena?
- Were there differences between Russian and Swedish students in their way of presenting explanations? And if so, what were they?

2. Sociocultural perspective

The main reason for choosing to adopt a sociocultural perspective (SCP) as a theoretical framework of analysis, was our search for understanding relations between communication, learning and the sociocultural context.

Lev Vygotsky can be considered as one of the founding fathers of the sociocultural analytical approach. A central assumption of a sociocultural perspective is that mind and culture co-constitute each other and develop in close interrelationship. Student teachers’ minds are formed by their education and also within a broader sociocultural context.

[1] The study was supported by a grant from the Visby cooperation programme, the Swedish Institute

According to Vygotsky (1987), personal development is conditioned by learning. To learn and to develop means to appropriate and master artefacts within meaningful social activities. The nature of cultural artefacts and its appropriation is not uniform across cultures and societies. Sociocultural context influences why, what kind of and how cultural artefacts were developed, selected and used. Communication tools are probably the most important cultural artefacts that mediate our perceptions of, and actions in, the world.

Humans tend to learn through communication rather than by discovery. Think only about looking for answers to such kind of questions as how to cure a sick child, what mushrooms are eatable, or how to make a best buy on the stock exchange. “Try and error” way of answering these questions would not be the best one. The better way would be to consult an expert in the field.

Communication is the teacher’s main pedagogical tool, used for mediating his/her relations with pupils. During initial teacher education, students should acquire basic skills in using a variety of mediation artefacts, such as oral, written and graphical communication tools. Nowadays, they also need to master different kind of multimedia equipment. In our project, we chose to study student teachers’ pedagogical skills by looking at the mediating instruments of their communication - written texts presented to an hypothetical pupil.

3. Research instrument

School culture is based mainly on written language; it is a text-based culture. Mastery and practice of proper forms of communication emerge as significant activities per se within the school. In the school context, pupils learn to *read the world* through and with a text. Knowledge is presented as print (Säljö, 2000, 219). Therefore, our questionnaire was focused on written communication.

The following problem situation was presented to student teachers: a hypothetical Grade 7 pupil could not attend a school because of illness and the pupil asked them to explain by letter two physical phenomena: how and why the shadow from a tree appears (a sketch of a tree and a street lamp was presented) and why the bulb lights in a torch (see Appendix 1).

We tried to formulate simple questions that could allow student teachers’ to show their skills of didactical reasoning and written communication.

4. Description of the sample

Our questionnaire was completed by students specialising in science in the Faculty of Teacher Education in Umeå and students from the Faculty of Physics and Mathematics at Karelian State Pedagogical University. The students were all trained to teach science/physics in Grade 7. The questionnaire was completed by 200 students in Sweden and Russia. 185 responses were selected as valid for analysis: 110 in Russia and 75 in Sweden.

Concerning gender representation, number of female and male students in the sample reflect general gender trends in the corresponding institutions in the two countries. In Russia, there were 70% female and 30% male students, while in Sweden, the corresponding figures were 55% and 45%.

The mean age of Russian students was 19 years and the Swedish, 30 years, i.e. Swedish students were in average ten years older than Russians. This can be explained by the following: in Russia, people enter to university at age 17, directly after finishing secondary school (after 10 years and now 11 years of compulsory schooling), while in Sweden, students finish gymnasium at age 19 and often work a couple of years before going to university. The Swedish part of the sample also included a group of distance education students, some of whom were over 40 years old.

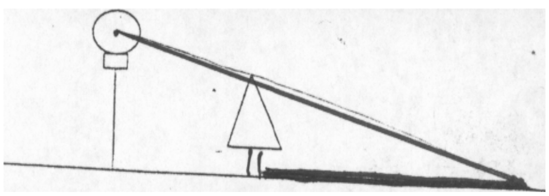
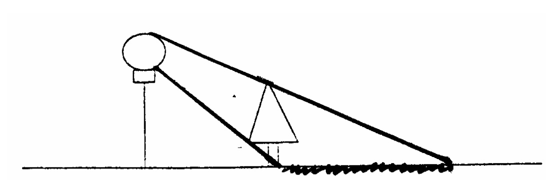
5. Some findings and brief discussions of the results

Written explanations provided by student teachers to a hypothetical Grade 7 pupil reflected, on the one hand, their own (mis)understandings of the phenomena, and on the other hand traditions of teaching/learning in the two countries. As Ambrose *et al* (1999) points out “It is often difficult to distinguish difficulties with concepts from difficulties with representations. The two are intertwined.” In the following text, we will try to shed light on typical use of representations (mediating artefacts) by student teachers that we assume reflect their scientific and pedagogical knowledge. In the analysis, we have divided every answer into two parts: *picture* (symbols and illustrations) and *text* (concepts, analogies and suggested experiments and activities). Therefore, our discussions will concentrate around both visual images and written explanations.

5.1. Explanations about shadow

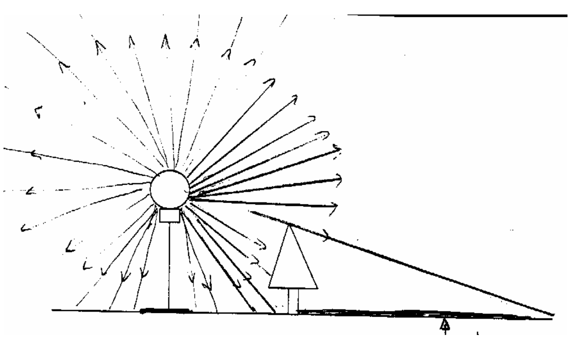
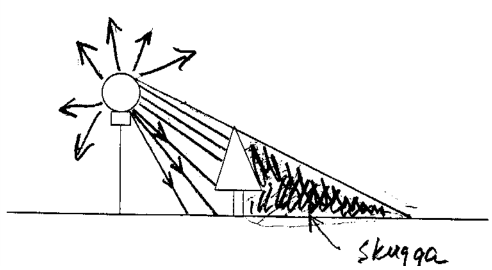
Russian students explained shadow construction in a more formalised way, using a kind of geometrical optics approach. More than half of them (53%) drew light rays only in the direction of the tree (so called construction rays) and marked shadow as a place on the ground (64%) as it shown on the diagram 1 below:

Diagram 1. Typical rays construction made by Russian students.

In Sweden, most of the students used common a more sense approach that, in our opinion, aided their pedagogical method in, thinking about age of the target group of pupils. The majority of them drew rays in all directions from the lamp (57%) (see diagram 2). However, they made less articulated illustration (drawing) of the shadow: 34% draw shadow as flat, 24% as volume and almost 40% did not draw it at all.

Diagram 2. Typical rays construction made by Swedish students

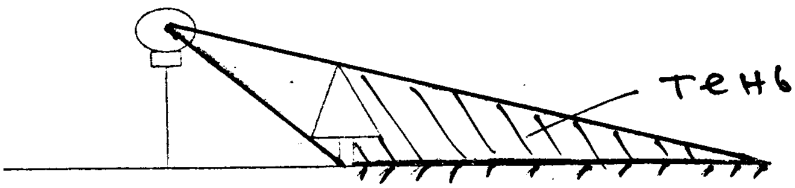



Nevertheless, 85% Swedish students presented description of the shadow in words (as compared to 75% of Russian students).

5.1.1. Space or flat shadow

We could distinguish between scientific and everyday understandings of shadow. Those students who presented a volume/space form of shadow either in a drawing (see diagram 3) or in a text were considered as students who could communicate scientific understanding of shadow. This was attributable to 27% of Swedish and 18% of Russian students.

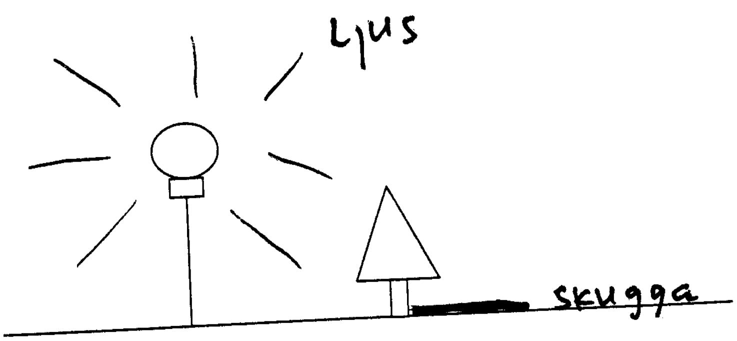
Diagram 3. Example of drawing a volume/space form of shadow by a Russian student.



As was mentioned earlier, 64% of Russians and 34% of Swedes drew a flat shadow on the ground, according to their everyday perception of shadow.

There were several students in both countries who drew a shadow but not light rays (see example in diagram 4).

Diagram 4. Drawing of shadow without marking construction rays



This could be interpreted as an observable phenomenon at the everyday level of understanding – what we can see. We do not see light rays, we see just shadows. However, these students did not use the scientific tools of explanation (light rays model) to explain how shadows that we see appear.

Many students in both countries revealed having problems in making presentations of meaning that had clear language. As a consequence pupils may construct vague ideas about the essence of physical phenomenon. For example, 31% Swedes and 43% Russians described shadow as darkness behind the tree, without pointing out whether this darkness is located on the ground or in a space where direct lamplight does not reach. Such presentations may lead pupils to different interpretations of the teacher's words.

5.1.2. Ideas relevant for preventing learners' misunderstandings:

Providing the learner with additional information about the context of the problem can facilitate understanding. Two Swedish student teachers pointed out that it should be dark on the street to see a shadow of the tree created by the street lamp.

Six Swedish respondents also explained that shadow does not mean complete darkness but rather less light.

Only 25% of Swedish and 17% of Russian students clearly presented in the text an important idea that light goes straight.

5.2. Explanations about a flashlight

We could expect the following steps in the explanation:

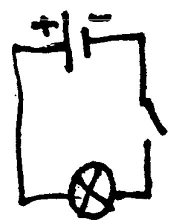
1.Presentation of the importance of an electric circuit, 2.Electric current caused by the voltage of battery, 3. In the bulb the current meets a high resistance of the bulb filament, 4.In the filament, electric energy turns into thermal energy and 5) The bulb filament gets very hot and starts to shine and emit light.

However, just a few students in both countries could highlight these points in their explanations.

5.2.1. Drawing of electric scheme and illustrations on structure of torch

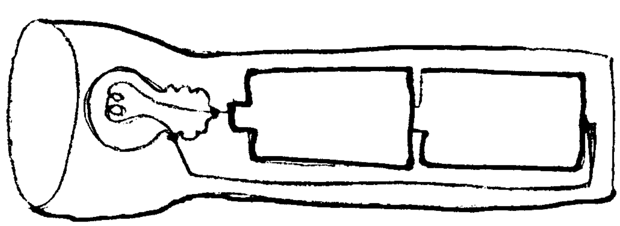
Russian students explained flashlight functioning also in a more formalized academic way than Swedish students. For example, 33% of Russians drew a conventional schema of an electric circuit while only 15% of Swedish students did so. Russian students used schematic presentation of batteries '-**1**1-' and a lamp ⊗ as it is practised in physics classes (see diagram 5 below)

Diagram 5. Schematic presentation of an electric circuit



Swedish students relied more in their answers on everyday experience. About a quarter drew a picture of flashlight construction with the electric circuit clearly marked (see diagram 6), and 18% drew such a picture but without a marked circuit.

Diagram 6. A flashlight construction with the electric circuit clearly marked.

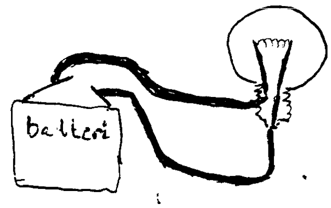


In contrast 12% of Russian students drew flashlight construction with a circuit and 23% without a circuit. Students who did not draw a circuit in the pictogram of the torch were likely to be unaware about pupils difficulties with understanding of this concept.

5.2.2. Separate drawing of bulb and battery

Instead of or in addition to the flashlight construction 42% of Swedish and 13% of Russian students drew the bulb and battery forming the circuit (see diagram 7 below). It was used as a didactical tool for explaining a circuit.

Diagram 7. Separate drawing of the bulb and battery forming the circuit



5.2.3. Role of filament in the bulb

72% of Swedish students showed the bulb with its inner structure and 12% drew the bulb without its inner structure. Russian students drew the bulb with an inner structure in 32% of cases, and in 23%, without inner structure.

5.2.4. Concept of circuit explained in the text

Swedish students used more practical ways of explaining the principles of flashlight function. 67% of Swedish students explained how electric current circulates inside the flashlight compared to 32% of Russian students.

How the bulb emits light was explained by 58% of Swedish students against 32% of the Russians.

5.3. Use of analogies and suggestion of activities

The table below presents respondents' suggestions for illustrating their explanations with analogies and pupils' activities.

	Shadow (%)		Flashlight (%)	
	analogy	*activity*	*analogy*	*activity*
Sweden	24,2	22,4	30,3	7,6
Russia	2,7	5,5	14,5	0

There were mainly two kind of analogies used:

Analogies related to qualities of human/living beings:

Active electrons *(piga elekroner*[2])

Queuing people rash through an open door into a dance hall,

Electrons *forcing themselves* to go through the lamp

Analogies related to different everyday phenomena/objects:

Sport: "start (-) and finish (+)", a running race (*löparbana*)

Battery as equivalent to a pump

Electrons as equivalent to domino pieces (*elektroner agerar som brickor i domino när batteri puttar på de*)

5.4. Contradictions between different forms of explanations

---

[2] We provide in brackets *in italic* examples of original sentences/expressions in Swedish or Russian.

Students had problems connecting visual images with written explanations. In some cases, text and illustrations enhanced and confirmed each other; in other cases, students presented description in the text that did not correspond to their drawing.

Usually, a picture is easier for many children to remember than a message in the text. Therefore, what is not reflected in a drawing can be more easily forgotten, or even not noticed within text. For example, some Swedish students drew rays only in the direction of the tree but wrote that the light from a lamp spreads in all directions.

In several cases, the meaning derived from pictures was opposite or contrary to the meanings of sentences and concepts used in the text. For example, the following erroneous texts was presented after correct drawings of the shadow:

- Light goes straight, that is why when light meets an object, it bends around it. (*Свет распространяется прямолинейно, поэтому, встретив на своём пути препятствие, огибает его*).
- We can explain the appearance of shadow by the property of light to bend the objects. Light rays meet the tree, bend round it and then spread in different directions. (*Зная такое свойство света огибать препятствия, можно объяснить появление тени. Лучи света, доходя до дерева, огибают его, распространяясь в разные стороны.)*

Here we can see a contradiction between the straight propagation of light and its bending! 11% of Russian students stated that light can bend round the obstacle and tried to explain a phenomenon using ideas drawn from properties of diffraction. These students misinterpreted the limits of using diffraction phenomena.

A couple of Swedish students marked “short circuit” in the battery in a schematic drawing of a torch but their explanations in text were correct.

In our opinion, student teachers should get more training in producing and deciphering descriptions and presentation of images as it is not a simple task to use visualisation as a mediating tool for communicating ideas.

5.5. Some examples of misconceptions presented in the explanations of Swedish students

We will give below some examples of wrong physics ideas from the student teachers explanations that we organise around few categories.

Relativism/egocentrism

The shadow is an image of the tree. The form of the shadow depends on the observer’s position. *(Skuggan är bilden av trädet. Beroende på var du står faller skuggan olika.)*

Electrons and current:

Electrons move from the battery’s minus pole towards the plus pole. They move against the current and therefore, the electric tension is built up and this tension warms up metal wire (wolfram) in the bulb so it lights up. *(Elektroner vandrar från batteriets minus till dess plus sida, de går i motsats riktning mot strömmen, & då bildas en spänning, & spänningen värmer upp metalltråden (wolfram) in glödlampan & den lyser.)*

Current as a wave

The electric current is like a wave of small particles. These particles are charged and it is this charge that makes the bulb light up. When the bulb receives the charge wave, the bulb becomes also charged and can therefore emit light. *(Ordet elektricitet kan man förstå som “en* *våg av små partiklar". Dessa partiklar är laddade och det ät denna speciella laddningen som gör att lampan lyser. När lampan tar emot vågen blir den också laddad och kan därför lysa.)*

Battery and electric current

Battery contains current (*batterier innehåller ström = elektroner som rör sig. Batteri kan alstra elektrisk ström*.)

Ideas about electrons

Electrons are minus charged atoms *(elektorner är minus laddade atomer)*.

Electrons move at such a high speed that they emit light (*elektroner rör sig så fort att det blir ljus).*

Electrons are small charged "things" that leave their charges in the bulb (*elektroner är små laddade "saker" som "lämnar" av sina laddningar till glödlampan)*

A bulb filament and gas in the bulb

Low resistance in the bulb filament. (*motståndet är liten i glödtråden*)

Copper wire in the bulb (*Koppar tråd i lampan*)

Because of the gas, the bulb emits more light (*gas i lampan är för att åstadkomma mer glöden – ljus*)

Gas lights (*Gas "antänds"*)

Light comes from the gas in a bulb (*Det blir ljus eftersom det är gas i lampan*).

There is a vacuum in the lamp.

5.6. Some examples of misconceptions presented in the explanations of Russian students

Light interference

Branches of the tree are non transparent for light quanta thus interference is taking place. Light decomposes and, as a result, only a black color of light can go through the branches to form a shadow. (*Ветви дерева становятся препятствием на пути квантов света, в результате происходит интерференция света и свет разлагается, в результате чего сквозь ветви дерева проходит только чёрный цвет света, он и образует тень*)

Hot charges

Charges get hot and emit heat so the bulb gives off light. (*Заряды нагреваюстя, выделяют тепло и лампочка загорается.)*

Antimateria?

The filament inside the bulb getting warmer because incompatible substances meet there. (*Нить накаливания нагревается, так как вспречаются несовместимые вещества.)*

Charge interaction

The bulb receives both the positive and the negatives charges; because of this it gives off light. (*Лампочка получает и положительные и отрицательные заряды, за счёт них она и горит.*)

5.7. Importance of different communication skills according to student teachers

The respondents also had an opportunity to express their opinion on relative importance of different skills/knowledge for "good communication in science education". We made coding on a scale 1 to 3, where 1 is very important and 3 is not important. In the table below is presented a mean value, where the smaller number represents the bigger importance, according to the students' judgements.

	To adjust explanation to pupils' level of understanding	To anticipate and prevent students' misunderstandings	To have relevant subject knowledge	To use correct scientific symbols	To create a good layout of the text
Sweden	1.03	1,25	1,15	1.94	2,07
Russia	1.15	1.35	1.21	1,99	2,00

We assume, that student teachers' attitudes and values reflect school and university teachers' attitudes and values. Misconceptions (misunderstandings) and adjustment to pupils level of understanding (to start where pupils are) is a strong didactical issue in the West, but does not have the same value in Russia. Thus, the questionnaire (students' answers) provides a "didactical mirror" for us as teacher educators to see our own professional values, attitudes and errors.

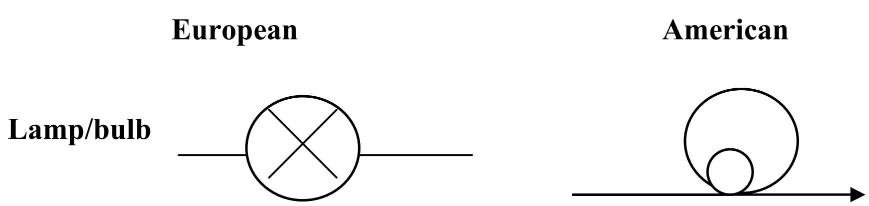
5.8. Common difficulties/problems in Sweden and Russia:

Use of illustrations

Student teachers appear unaware of pupils' difficulties with simple illustrations. They do not appear to possess clear knowledge about visualisation conventions neither do they value them. For example, quite a few students indicated light rays by waved lines and not by lines with arrows. Some students used dashed lines for this purpose. Maybe we need more clear conventions about how a light ray should be indicated.

When students drew shadows, many had problems with stereometrical / 3-dimentional presentation of shadow (how and where shadow is placed, how to draw it).

An important idea in the explanation of how a flashlight works is that the current should go through the bulb – but this was often (too often) missing. The role of the bulb in a circuit seemed unclear, i.e. how a current goes through the bulb. We suggest that the American way of presenting a bulb in a circuit is more pedagogical than European. In American pictogram of a bulb there is clear indication of a current's way through the bulb.



A number of students openly admitted that they lacked a vocabulary to express their ideas. ("I know but can not express my knowledge"). A few expressed self-criticism and wrote that their presentation would not be appropriate for grade 7 pupils.

6. Conclusions

According to Vygotsky, learning is impossible to describe as a general phenomenon but as a phenomenon in a context, related to *what* one is expected to learn. The aim of sociocultural practices as realised in teacher education is socialisation in the teaching profession and introduction into the professional discourses relevant for schools. There thus needs to be a special focus on educating future teachers to use different communicative tools for transmitting meaning to other people, and to prepare them to teach their pupils about using different forms of mediation for effective learning in school to take place.

Our experience as described in this paper shows that communication genre – a way of giving or getting meaning – at university science departments is not oriented towards the teaching profession. We carried out a number of interviews with students coming from these departments to our pedagogical courses. Many interviewees openly recognised that they have problems in expressing knowledge in written form and in pictures. Many Swedish students before they come to a teacher education had not drawn a simple picture since childhood. To create a simple drawing thus is a big problem for many of them. Their minds and hands have somehow forgotten how to draw.

Future teachers during their training, need to change their perspective on school activity. They need to gradually shift from the student's view towards the teacher's view on teaching and learning. In practice, this means, for example, getting a metacognitive awareness not only about personal understanding of natural phenomena and possession of scientific skills, but also about the ability to introduce such skills and knowledge to children.

In both Sweden and Russia, student teachers of science have poorly developed communication skills. It seems, that teacher educators underestimate importance of students' practising in explaining and communicating knowledge. Development of communicative skills we suggest should be one of the main foci in teacher education, as language grows through function.

Ability to explain things in oral, written and visual form and especially in a combination of these communicative forms characterises teacher's professional competence. Students have problems to "convert" images into words, to verbalise images. In our view, future teachers should be explicitly trained to visualise linguistic communication and to translate visual representations into natural language statements and questions. This allows for multiplicity of meaning.

Our analysis shows that Russian student teachers had more problems with seeing themselves in the role of teacher than Swedish students. Many Russian students tried to answer the questions as students in a physics course. Their explanations tended to be more academic and formalised than is appropriate for a Grade 7 pupil. This reflects the formalised teaching / learning style of Russian teacher education currently.

This provides a contrast to the situation in Swedish teacher education, where students frequently work in small groups, often practising presentations at the children's level. They generally feel quite comfortable in acting out different social roles and responsibilities. This reflects the conviction of Swedish teacher educators that learning about science should reflect a participatory and collaborative way in which knowledge is generated. Thus, science education should be a participatory activity in which teachers and learners share responsibility for learning.

The dominant form of communication in teacher education thus varies between countries. In Sweden, there is a richer multi-way communication based on group work. This differs from Russia where the one-way – lecturing form is still dominant.

The pedagogical traditions and communication cultures which exist in the corresponding teacher training institutions are probably the main factors explaining the different forms and qualities of explanations presented by the prospective science teachers involved in this study.

According to well known pedagogical saying "people teach as they were taught", student teachers used their experience which included good and bad examples of ‘teacher communication’ in responding to the questionnaire. In that sense, their answers reflected the teaching culture that students were exposed to.

We found in our discussions with students that the research instrument developed in this study also serves as a “didactical mirror”, helping the students to gain a reflection of their pedagogical skills of giving written explanations in science. This encourages us to use similar instruments in the future in the education of our science student teachers.

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Appendix 1. Questionnaire

Sex: F ☐ M ☐

Age: ______

Program: ________________________________

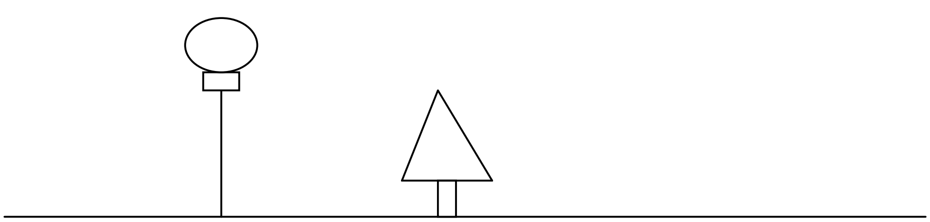
Term: __________________

The target group for communication is grade 7 students (12-13 years old students). We suggest that you think of following situation: “A grade 7 student cannot attend classes (e g because of sickness) and you have been asked to give her an explanation of certain phenomena in the form of a letter”.

I agree that my answers can be tested with grade 7 pupils.

Yes ☐ No ☐

1) In grade 7, pupils start to work with light phenomena. A pupil has drawn a sketch of a tree and a street lamp and asked you to explain how and why the tree’s shadow appears as it does.



2) Pupils often have difficulty in understanding the physics behind simple technical things, for example, how a flashlight works. Using words, pictures, models and/or analogies, explain for a grade 7 pupil, why a bulb lights in a flashlight.

What does "good communication in science education" mean for you?

Signifies a good communication	Very important	Rather important	Not important
To use comprehensive scientific symbols	☐	☐	☐
To find good analogies and metaphors	☐	☐	☐
To use correct language	☐	☐	☐
To adjust explanation to a target group's level of understanding	☐	☐	☐
To illustrate text with tables, graphs, diagrams and drawings	☐	☐	☐
To create a good layout of the text	☐	☐	☐
To anticipate and prevent students' misunderstandings	☐	☐	☐
To have relevant subject knowledge	☐	☐	☐
To suggest and creatively use thought models and experiments	☐	☐	☐

How was it to answer this questionnaire?

Very difficult ☐ difficult ☐ neither / or ☐ easy ☐ very easy ☐

School Measurement Studio controlled by LabVIEW

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Abstract:

We have developed a School Measurement Studio consisting of tools for measuring and demonstration of school physical experiments using a computer, electronical signal conditioning and analysis. For the development we have used the LabVIEW software, formerly aimed to laboratory measurement and automation.

The usage of full LabVIEW in schools is impossible and wouldn't be of much use, but the prepared applications may be useful. The advantage of our approach is that you don't have to know, how to work with LabVIEW, but you may use some of the functions contained in its rich libraries for signal measurement and analysis. Some of these examples are the "FFT Analyzer" or the "AC/DC volt/ampere meter with memory."

Our software is working with the hardware called ISES, commonly used in Czech schools, but there's no obstacle in using it with any other ADDA converter supported with LabVIEW drivers.

1. Introduction

As a reaction to the number of computers came out before some time the idea to use them for teaching Physics. These ways have been developed many systems based on the principle of sensors, ADDA converter and controlling software. Some of them are Leybold CASSY, IP-COACH, Phywe COBRA, Philip Harris "First Sense" or the ISES. Each of them has its unique controlling software incompatible with other systems. For the older systems it was common that each single experiment had had its own control program, modern conceptions tend to universality.

Many of Czech schools have nowadays uxually at least one computer with the ISES system installed, with its standard measuring software. It should be mentioned that there are schools owning a whole ISES equipped classroom or laboratory. The idea of our work was to support ISES users with extra measurement software, which would work in a more "open" way. This means working with another hardware systems and possibly sharing the measurement control or results on the Internet. This is the set of tools for ISES – **The School Measurement Studio**.

2. ISES and LabVIEW

The ISES (Intelligent School Experimental Systém – more info at www.ises.info) mentioned above consists of an ADDA converter (Axiom AX5411), a set of sensors for measuring various physical, biological and chemical quantities and the measurement software. The system is able to measure with up to four sensors and two output (control) channels connected at one time. One of its interesting features is the capability of sensor autodetection.

For our studio's development we have used the LabVIEW environment. LabVIEW is a graphical programming environment designed for industrial and laboratory measurement and automation. It would be very expensive and also useless for schools to purchase the full development environment. That's why we decided to create single applications and compile them to an executable format.

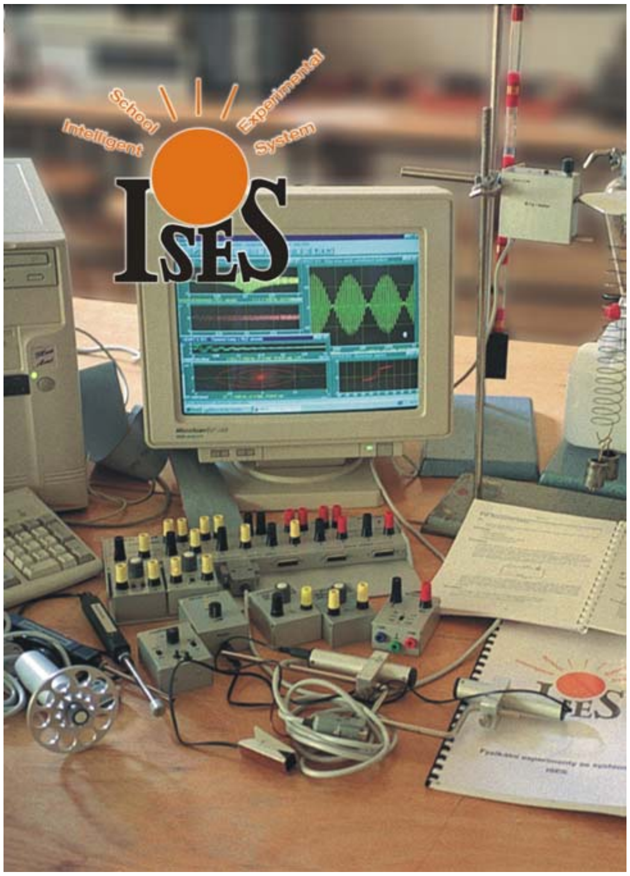

Figure 1 – The ISES System

It was crucial for entire development that there exist LabVIEW drivers for the AX5411 converter. As their upgrade we could have designed the LabVIEW drivers for ISES. And here we find the way to create an open system. If any other measurement system has proper LabVIEW driver, it is possible to create a similar upgrade and use our studio with it.

The LabVIEW gives us a great number of benefits, for example rich signal conditioning libraries, quick front panel creation or easy Internet presentation. It should be also mentioned, that LabVIEW is a standard in many real laboratories and students have an opportunity to learn things useful for their life.

3. The ISES Drivers for LabVIEW

As mentioned, one part of our work was creation of LabVIEW drivers for ISES. This means a set of VIs (Virtual Instrument – A program or sub-code in LabVIEW) that may have its significance for application creators (teachers). This presumes a school equipped by both ISES and LabVIEW, in Czech Republic these are mainly Universities. With the help of such drivers a teacher may develop his own applications and instruments suitable for his lessons and possibly place them on the Internet.

4. The School Measurement Studio

The standard software included in the ISES works mostly as a recorder with the capability of drawing time-based graphs or dependence between quantities. It is also able to make some post-measurement analysis such as differentiation, integral or approximation. This software is totally universal (for all kinds of sensors) which has both its pros and cons. The *Studio* is created other way, as a set of independent tools for each kind of measurement. It consists from the tools like Volt-Ampere Characteristics Measurement Tool, Frequency Analyzer, Universal Multimeter etc.

4.1. VA Characteristics Measurement Tool

The least complicated tool of the whole set is this application. It is able to measure and draw the VA characteristics of any connected element. For the measurement a voltmeter, amperemeter and one output (control) channel are used. After the measurement time is over, it is possible to read values from graph and export them to a standard text format. This Tool is meant mostly as a learning task. Student finds here out how a virtual instrument looks like, how it behaves and how it is controlled. A simplified version of this task with online measurement is available on the address http://kdt-17.karlov.mff.cuni.cz/multitask.htm, however only Czech version is available now.

4.2. Frequency Analysis Tool

The tool for frequency measurements is the most complex tool of all. It is capable of measuring with any sensor from the ISES set, possibly also without a sensor directly on the converter input. When the measurement session is over, it is possible to analyze the signal, edit it, compare to a clean generated signal (sine, triangle, sawtooth) and of course save and load, mix, read values from it etc.

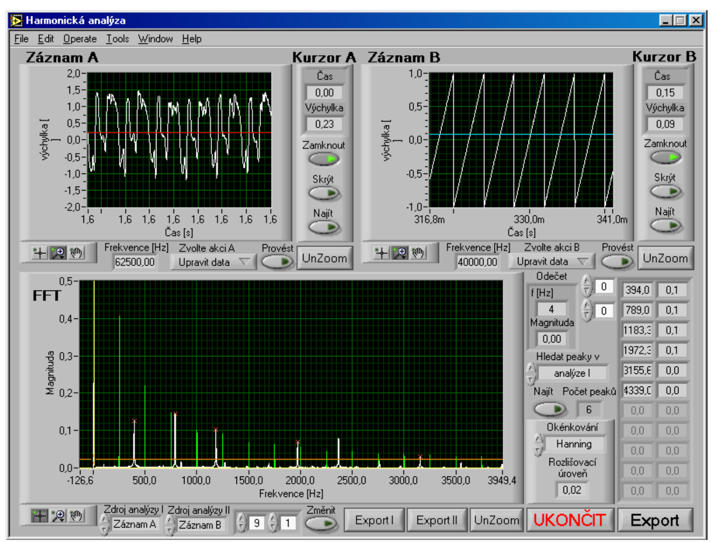

Figure 2. – The Frequency Analysis Tool's front panel

4.3. Universal Multimeter

The Multimeter Tool is not fully working now. It will be a complex instrument aimed to simple one-channel measurements. In the first phase the program detects the sensor and according to it selects proper measurement environment. For example, if the program finds the voltmeter, it opens a window where actual values will be written to a graph (similar to oscilloscope). The digital display will be showing the actual value, RMS and peak value of the voltage. The user has only to set the measurement frequency. While measuring the capacity only the value will be shown. The heart pulse meter will show the graph (similar to EKG) and count the number of heartbeats per minute.

4.4. AC Volt/Amperemeter

As mentioned, the original ISES software is capable of making good signal analysis but everytimes it is the post-processing. It is not possible to count online the RMS value from measured values while measuring when using it. When we were creating this tool we have used the LabVIEW libraries, mainly the statistical functions. The result is a tool measuring both effective and peak value of electric voltage and current. What is more, it also finds the phase shift between signals. This is a capability we haven't found by any other system than our Studio. The periodic signal may look anyhow but the reliability is best with harmonic signals

5. Web – publishing

From version 6.1 the LabVIEW enables user to publish an experiment on the Internet. The technology is called Remote Panel Sharing. To use it, it is necessary to own the full LabVIEW development system. For this reason this form is not available for our Studio's common user. However, on the web is placed one task running online in our laboratory in Prague. The address is http://kdt-17.karlov.mff.cuni.cz/multitask.htm. It is possible to remotely measure the VA characteristics of a semiconductor diode, make a spiral with weigh move (by resonance with magnetic force) or light a bulb. These tasks are very simple but it is a way to distance learning. This is the possibility how to show an experiment running on an apparatus not owned by school. It only requires, that there is a laboratory with an online experiment. For the measurement you don't need then anything else than the free LabVIEW Run-Time Engine and a kind of explorer.

6. Conclusion

We have developed a set of ISES drivers for LabVIEW and on their base built our School Measurement Studio.

For the school laboratories equipped with ISES system this is a complement to standard software, a new toolkit filling the gaps between ISES possibilities and common usage. Without new investments it is giving an opportunity to show new experiments, for example from acoustics or alternating currents (RLC circuits etc.), with existing hardware.

Finally, in every institution, where both ISES and LabVIEW are installed, it is possible to connect these systems. It is for example possible also to publish the measurement running on the Internet.

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Miniprojects in physics give the students initiative and ownership to their learning.

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Keywords : small groups, miniproject, electromagnetic radiation, science education research, experimental problems, holistic learning, context-rich problems, PBL

Abstract

We will report from a pilot study where miniprojects were implemented instead of traditional laborations in two different physics courses at Mälardalen University in Västerås, Sweden. The students worked in small groups with a problem they have chosen from a list of proposed miniprojects or with a problem they have created themselves. The miniprojects should be experimentally solved or investigated during a laboratory period of three hours, and finally reported to the whole student group after two weeks. The students were asked to make portfolio notes during project, and to write final reports and Power-Point presentations. The miniprojects have been designed with variations in context and with different degrees of ownership. The concept ownership describes to what extent the students "own" their project: For example what freedom do they have in formulation of questions and designing procedures to solve the task. It was also possible for the students to choose with whom they wanted to collaborate with, which attributes to the differences in group size (1-4 persons). The student body in one of the courses consisted of students with a non-science background attending a bridging course in physics. Students in the other course where in their final year of a bachelors program in computer science, electro engineering or environmental engineering, studying together in an environmental physics course. Both groups have been working with miniprojects in the content area of electromagnetic radiation. For evaluation purposes the students took a Swedish translation of MPEX (E.F.Redish 1998), a questionnaire of electromagnetic radiation concepts, and an attitude test. They were videotaped during their laboratory work, which give possibilities to analyse the laboratory work from different perspectives. Interviews were made with some of the students. Instrument for a study will be developed on bases of this pilot study, and that investigation will take place in year 2003 in other content areas as well. We will report on some of our preliminary results. The teachers have found it to be very stimulating to tutor these miniprojects. The miniprojects gives the teacher an opportunity to come closer the students and their learning process. The miniprojects have not only facilitated a high degree of student and teacher interaction but also a very high degree of student-to-student interaction. This has fostered a very nice, open and rewarding atmosphere in the classroom.

Background

When students of non-science background attend a bridging course in physics it means that physics from level of the Upper secondary schools is studied in one year. As the student's backgrounds are non-science, they study mathematics, physics and chemistry in parallel during these forty weeks. The students afterwards continue their university studies in a bachelors program in computer science, electro engineering or environmental engineering. The physics courses have been divided in lessons of one session of four hours a week and one laboratory session of four hours every second week. This year three different teachers have been involved in the course. The students are in the age of 19 to 45 years old. The speeds in courses are high, and they have lessons in the three subjects almost 8.15 - 17.00 Monday to Friday. About 75 percent of the students pass the course and continue to university studies. The challenge to teach physics in these classes is to invite these socially mature students into the discourse of physics, which could be very special to them. Some have long experience from technical work, in for instance electronics, others like to change life and change profession fundamentally. These students are motivated, but have difficulties to reach the result of understanding the physics course. They usually work in groups of four in all courses, and these groups often persist through the physics course, and even longer. The teachers' intentions are very much to help these students to a reasonable level of problem solving and to be able to do a lot of exercising of "end of chapters problems" in the groups. We introduced Miniprojects in electromagnetic radiation into these students groups but also to a group of students studying together in an environmental physics course in year three of their university education.

Why Miniprojects?

Miniprojects as laboratory problems were introduced into Swedish physics course literature after the new curriculum for Upper secondary school in 1994. They were called Experimental tasks (Alphonce R. 1998), or Activities (Ölme A. 1996) or Miniprojects (Ekstig 1997)These signals inspired physics teachers to invite their students into a lot more activity not only during lab sessions but also under ordinary lessons. We like to explore if Miniprojects defined as experiment problems give possibilities to increase student ownership to the physics studies, and to increase problem solving skills, critical thinking, and development of creativity and to realize this within the curriculum stated. As part of a study in physics education research we wanted to design research in this field. The differences and similarities from problem-based learning, project-based learning, case-methodology, inquiry-based education and other types of experience and experimental based learning will be reviewed in a separate article, but will be commented here.(Tabachnich 1991; Heller 1992; van Heuvelen 1993; Botti 1995; Duch 1995; van Heuvelen 1995; Nagel 1996; Krajcik 1998; Leach 1999; Hult 2000)
The theoretical base for these teaching strategies or instructional settings are John Dewey's pragmatism, or a social constructivism that include situated learning or situated cognition (Heller; Dewey 1897, 1998; Dewey 1938; Brown J.S. 1989; Lemke 1993; Bredo 1994; Krugly-Smolska 1996; Sternberg 1997; Dewey 1997,1910; Carlgren 1999; Niedderer 2000; Säljö 2000; Brickhouse 2001).This raise a question about the subject matter of physics related to learning and participation (Sfard 1998).
Miniprojects could be a way to combine what Sfard calls the "Acquisition metaphor" and the "Participation metaphor"- to be in the core of the subject matter of physics but also offer the student possibility to development by participating in the project-group-work.

Collaborative learning.

In "Collaborative Learning Enhances Critical Thinking " by A. Gokhale she says:
"According to Vygotsky (1978), students are capable of performing at higher intellectual levels when asked to work in collaborative situations than when asked to work individually. Group diversity in terms of knowledge and experience contributes positively to the learning process. Bruner (1985) contends that cooperative learning methods improve problem- solving strategies because the students are confronted with different interpretations of the given situation. The peer support system makes it possible for the learner to internalize both external knowledge and critical thinking skills and to convert them into tools for intellectual functioning."(Gokhale 1995) In her investigation she found positive effects of critical-thinking-and problem-solving skills.

Inquiry-based education

The purpose with Inquiry-based education is to engage students in finding solutions to important and meaningful questions through investigations and collaboration with others.

The Inquiry Page http://www.inquiry.uiuc.edu/ is about teachers sharing their successes and their collective expertise. Dr. Chip Bruce, Professor of Education and Library and Information Science, University of Illinois, Urbana stand behind the website.
"Based on John Dewey's philosophy that education begins with the curiosity of the learner, we use a

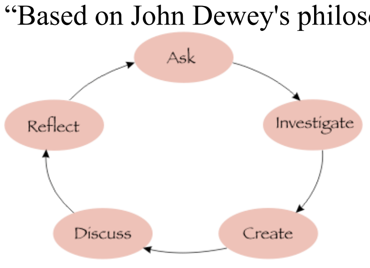


Fig 1. The five steps in Inquiry-based education

spiral path of inquiry: asking questions, investigating solutions, creating new knowledge as we gather information, discussing our discoveries and experiences, and reflecting on our new-found knowledge." Another example on resources concerning Inquiry base pedagogy is the Collaboratory Visualization (CoVis) project website. http://www.covis.northwestern.edu/

Project-based and problem-based learning

Project-based learning is well established as a teaching strategy, and are sometimes referred to and mixed with Problem-based learning, originally from medical educational cash-study learning. Both are referred to as PBL. In "A Newsletter of the Center for Teaching Effectiveness January 1995" Barbara J. Duch describe PBL like this:

"What is Problem-Based Learning?

Problem-based learning (PBL), at its most fundamental level, is an instructional method characterized by the use of "real world" problems as a context for students to learn critical thinking and problem solving skills, and acquire knowledge of the essential concepts of the course. Using PBL, students acquire life long learning skills, which include the ability, to find and use appropriate learning resources. The process used in PBL is the following:

1.Students are presented with a problem (case, research paper, video tape, for example). Students (in groups) organize their ideas and previous knowledge related to the problem, and attempt to define the broad nature of the problem.

2.Throughout discussion, students pose questions, called "learning issues," on aspects of the problem that they do not understand. The group records these learning issues. Students are continually encouraged to define what they know - and more importantly - what they don't know.

3.Students rank, in order of importance, the learning issues generated in the session. They decide which questions will be followed up by the whole group, and which issues can be assigned to individuals, who later teach the rest of the group. Students and instructor also discuss what resources will be needed in order to research the learning issues, and where they could be found.

4.When students reconvene, they explore the previous learning issues, integrating their new knowledge into the context of the problem. Students are also encouraged to summarize their knowledge and connect new concepts to old ones. They continue to define new learning issues as they progress through the problem. Students soon see that learning is an ongoing process, and that there will always be (even for the teacher) learning issues to be explored." (Duch 1995)

Experiment Problems

"Experiment Problems are problems that involve apparatus and the performance of an experiment. To solve an experiment problem, students must do one or more of the following

- add definition to the problem,
- plan a solution before solving the problem,
- divide the problem in parts, solve the parts, and reassemble the parts to answer the big question,
- decide what the important quantities are and measure these quantities,
- justify approximations and make estimates,
- design an experiment, and/or
- figure out how something works. " says Alan van Heuvelen, The Ohio State University.

Alan van Heuvelen,, introduced Case Study Physics (van Heuvelen 1993; Gautreau 1997) problem based tasks that was reported very positively from a class-room perspective.(Gautreau 1997).

Miniproject in international literature

A more advanced form with investigative project work in periods up to 8 months for University students in their last year are reported by Ryder an Leach.(Leach 1999). They describe "learning through a guided introduction into a culture of professional practice", what by Brown-Collins-Duguid are called "cognitive apprenticeship"(Brown J.S. 1989). Miniprojects here refer to research-like tasks given to undergraduate students in their third year at university as preparation for future research.

Context–Rich problems.

Cooperative group problem solving are reported from the University of Minnesota Department of Physics. http://groups.physics.umn.edu/physed/Research/CRP/crintro.html
They describe Context-rich problems like this:
"The problems need to be challenging enough that a single student cannot solve it, but not so challenging that a group cannot solve it.
The problems need to be structured so that the groups can make decisions on how to proceed with the solution. The problems should be relevant to the lives of the students.
The problems cannot depend on students knowing a trick nor can they be mathematically tedious."
Teaching materials and Context-rich problems are available at their website (Heller 1992).

Miniprojects in this investigation.

Miniproject in physics as described in this investigation are most similar to inquiry-based learning or experiment problems. They include a given or self formulated problem, that should be prepared and analysed, investigated (often experimentally) and reported in a seminar or/and with an Power-Point presentation. The result could be an answer to the given problem as well as a description on a real-world problem context that are related to physics. The end product is a report from the group that has done the collaborative learning. They could be used within the curriculum in every course and will take about two weeks from first formulating the problem to the final report. The MP can be used as a complement to ordinary teaching or to ordinary labsessions, but as the other teaching strategies mentioned here they intend to integrate theory and practice instead of different it in special sessions for theory and different for experimental sessions as often are the situation in university physics courses in Sweden.

Purpose of the pilot study.

The pilot study will give a broad introduction to this research questions:
A1) to create miniprojects in different content areas
A2) to explore, in the work in small groups with miniprojects, how students' **motivation** changes over time
A3) to explore, in the work in small groups with miniprojects, how knowledge changes over time
A4) to study if the work in small groups with miniprojects **gives special effects** to report.
A5) to study if the effects of **environmental physics included into physics** contribute to holistic views by offering interesting contexts.

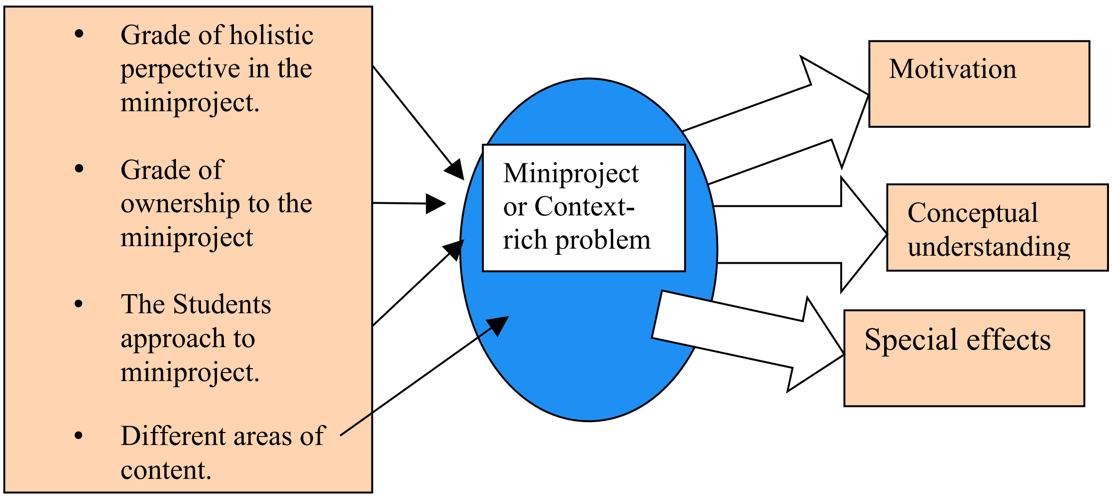


Fig. 2. Strategy of research questions implementation.

The questions of the pilot-study.
How do student choose among the miniprojects in electromagnetic radiation in aspects of context, level of starting point and group work? Is it possible to get a broad image of the attitudes in a course group by using existing instruments used by earlier research? How do this student groups understand the fundamentals of electromagnetic radiation? Are there some special effects with miniprojects we can notice? Can the pilot-study help us to build a research strategy for a larger investigation?

Design and Methods

Guide-lines

A purpose with this pilot study was to investigate and develop some instruments to measure different aspects of the learners abilities, some determined by personality and character, other determined by knowledge and understanding of physics as well as ability to show initiative and problem solving ability. We also have ambitions to either collect from literature or develop ourselves experimental problems, miniproject, that can be used as complement to other physics teaching performance. The study of miniprojects in the field of electromagnetic radiation were designed like this: Two groups of students from bridging courses and one group of students from the third year were given information about the study by a personal meeting in class-room. They were informed and we discussed the ethical aspects of how we should handle the information they gave to us. If they wanted to be anonymous that was all right. They were given a paper with examples of possible miniproject to choose from. They also got the opportunity to choose an alternative of a totally own design. They were asked to choose miniprojects before groups were chosen.
The miniprojects were graded in three levels of freedom concerning student ownership in design. The students discussed two by two the pre-test with ten questions concerning understanding of the concept of electromagnetic radiations. The MPEX survey were given individually and so the Perry-test. Their choices of miniproject were noted and their wishes of group size and as well. They were some days later informed if they could go on with their chosen miniproject. They were asked to give portfolio notations over their work. One-week/two weeks later we met in the laboratory session. They were very engaged and almost excited to start, and they were informed about to give a ten-minute presentation over the miniproject two weeks later. We videotaped their work and took pictures with digital-camera so that they could use the images in their power-point presentation of the project later on.

Principles of a “Miniproject:”

The miniproject is an experimental problem chosen in purpose to obtain clarity of the connection of physics concepts included in the specific context. The context is preferable related to a real world problem. Small group work includes 1 – 4 students. After choosing and preparing for the project, the group will have one ordinary lab session to make the practical part of the project. Later they will make an account for the investigation, preferable as a power-point-presentation for 10-15 minutes.

Holistic perspective in the miniproject.

Nagel reports that in purpose to o make physics meaningful to student it is important to begin to study questions of interest for the community and for the students themselves (Nagel 1996). But what makes a problem holistic and meaningful in this sense? There are several aspects to consider. A technical problem can be meaningful to one person but not to the next. An environmental physics problem can be really broad and holistic to some persons. We will investigate if environmental physics problems could contribute to make physics meaningful to students.

Grade of holistic perspectives.

To categorize the miniprojects we used these categories for different grades of holistic perspective.

Grade Hol1: Physics problem with no to specific context.
Grade Hol2: Question related to technical problems.
Grade Hol3: Physics problem applicable to related areas.
Grade Hol4: Question related to environmental physics.

Ownership to the miniproject

Our students are experienced and mature people, and can be expected to have ability to and to appreciate to deciding their own way of learning. The ownership to the miniproject will become an opportunity to use what they have learned before in other learning environment, and to complement with a new type of knowledge that other can inspire them into.

Grade of ownership to the project.

To categorize the miniprojects we used these categories for different grades of ownership.

Grade Own1: The Miniproject are defined and given by the students. The teacher looks over the ideas so it could be done with equipment in laboratory.
Grade Own2: The Miniproject are defined and given by the teacher .The student chooses method, design and the student carry through the investigation and hand in an account for the results.
Grade Own3: The Miniproject are defined and given by the teacher.
The teacher decides title, purpose and design and method.

Result 1 The Students approach/attitude to miniprojects.

To evaluate the students' attitudes towards physics we used MPEX -The Maryland Physics Expectations survey(E.F.Redish 1998; Edward F. Redish 1999).
We also developed a questionnaire based on a Perry´s scheme of Intellectual and Ethical Development, to study level of attitude towards learning development. The Perry´s scheme Describe development in stages :

- Dualism (all knowledge is known, right and wrong answers exist for everything)
- Multiplicity (diversity of opinion and uncertainty with respect to knowledge become legitimate)
- Relativism (all knowledge must be viewed in context, students see themselves as makers of meaning)
- Commitment within Relativism (for life to have meaning commitment must be made in a relativistic world) (Fitch 1984).

Instrument of our own : The “Perry”-test

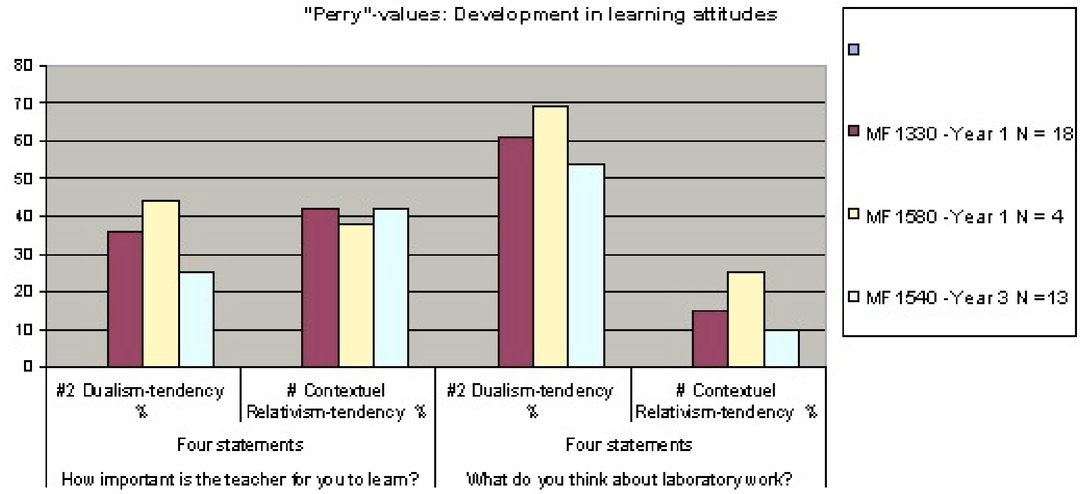


Fig. 3. Differences in level of development of learning attitude in two different questions.

We ranked answers to our questionnaire in tendency to dualism (Immature view) and tendency to Contextual-Relativism (Mature view).
The result for the four statements concerning ”How important is the teacher for you to learn?” Showed that year 3 to be more mature than year 1, which was not so surprising. More interesting was that the result for the four statements concerning “What to you think about laboratory work in physics)?” , showing a high overweight to immature thinking. The groups were mature students That showed in general social relations in the teacher-student relation but despite this when it came to physics, one was backing another view.

MPEX-swedish version

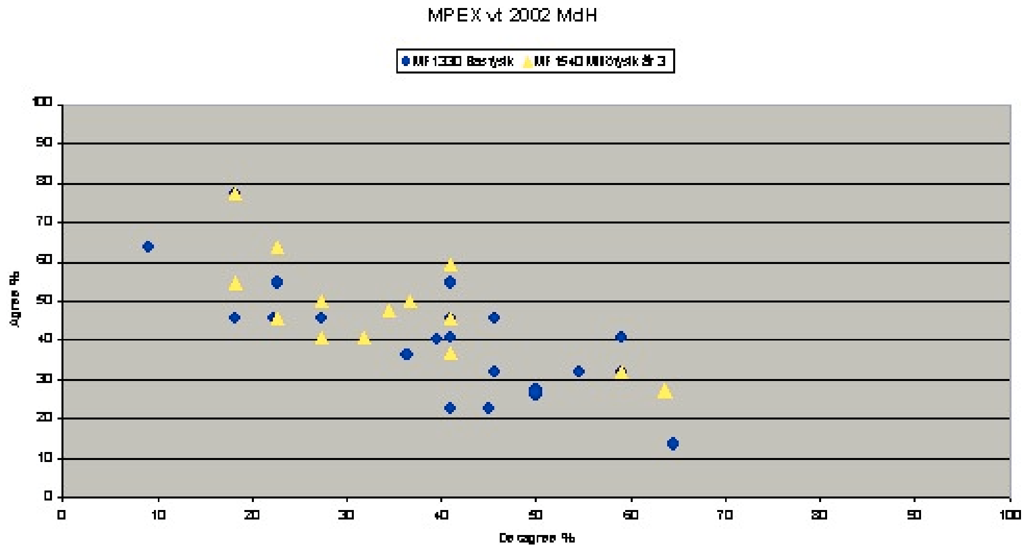


Fig 4 .MPEX-survey on students with a non-science background attending a bridging course in physics compared with students in their final year of a bachelors program in computer science, electro engineering or environmental engineering.

The MPEX survey show attitudes compared to expert-attitude to physics studies. (100,0) will be the similarity to an physics expert like an advanced university researcher and teacher.

Result 2 Conceptual understanding

The choice of miniproject

How do student choose among the miniprojects in electromagnetic radiation in aspects of context and level of starting point? The answers given by students were **interest**, but they continued to work in their old groups with only few exceptions. The strong relations inside the groups were confirmed in interviews as well. The first year students had high preference for the miniproject "How many tracks have a CD?" most preferable. That miniproject has a high degree of ownership, but with the problem formulated by the teacher. (Grade Own2). That miniproject was a question related to technical applications.(Grade Hol 2).
The students of year 3, (that were together in a course in environmental physics (!), choose preferable the miniproject UV-radiation. That miniproject has a high degree of ownership but with the problem formulated by the teacher. (Grade Hol 4, Own 2)
The tendency in both student groups are to choose a miniproject that have a high degree of ownership but with the problem formulated by the teacher.

Miniproject	**Grades**	**Why did they choose as they did?**	*	**
The Bulb –decide melting point for the wire inside 6/35	 *Hol2* *Own 3*	Interest No specific reason. Difficult to decide.	2 2	 2
Polarisation of light 3/35	*Hol3,* *Own 3*	What do polarisation do for our eyes?	3	
Decide how many tracks there are on a CD 15/35	*Hol 2,* *Own2*	Interest of the CD –want to learn more about the CD. Fascinating. I have an idea how to solve the problem already.	10 1 1	2 1
UV-radiation 10/35	*Hol 4,* *Own 2*	-Because you everyday are explored to it. Interesting. -Interesting . Important before holiday It concern me as a human being. -Because it inside the area of my education(environment) -Because I am interested in methods of measuring	4	 2 2 2
Own choice- **The microwave oven 1/35**	***Hol2,*** ***Own 1***	Interesting to know how it works-not many people do.	1	

Fig 5. Students choice of miniprojects. * Year 1 MF1330/MF1580 N=24 **Year3 MF1540 N=11

The understanding of the concept electromagnetic radiation

How do this student groups understand the fundamentals of electromagnetic radiation?
The concept electromagnetic radiation are not clear to the students, and they were unsure if one can see, feel and /or hear electromagnetic radiation in pre-test, but showed better understanding in post-test.

The pre-test consisted of ten questions of qualitative kind to discuss with the person next to you, and to give a written answer to.
The question *" Can you see, near and /or see electromagnetic radiation?"* had remarkable answers in both groups:

MF 1330 First year	**YES**	**NO**	**NO ANS**	*	**Other answers from students**	
Pre-test (N=20)		10	5	1	Hear and feel You can feel it	1 1
Post-test (N=16)	8		1	2	Yes, some wave-lengths No, you can see and feel light but that is not electromagnetic radiation No, not without instruments Yes, radio waves you can hear and laser you can feel and see You can hear it , see and feel you have to measure with instruments. If you walk under a high voltage cable than you can hear it, but to see and feel you need equipment	1 1 1 1 1 1 1

Fig 6. MF 1330 First year students answers to question *" Can you see, near and /or see electromagnetic radiation?"* ***You can see, feel but not hear electromagnetic radiation (correct answer)**

The question *" Can you see, near and /or see electromagnetic radiation?"* had remarkable answers in both groups:

MF 1540 Third year	**YES**	**NO**	**NO ANS.**	*	**Other answers from students**	
Pre-test (N=14)	1	7	1	0	Electric allergic persons can feel it You can hear the sound from electric circuits Maybe hear? Some persons state that they become ill from it If big enough you can feel it, like James Bond in" Golden Eye"	2 1 1 1
Post-test (N=14)	6	0	0	1	Yes, as heat Yes, as heat and visible light Yes, indirectly Yes, for example radio wave Electric allergic persons can feel it. Yes, depends on wave length	2 1 1 1 1 1

Fig 7. MF 1540 Third year students answers to question *" Can you see, near and /or see electromagnetic radiation?"* * "You can see, feel but not hear electromagnetic radiation"

It seems that students do not pay attention to the fact that light is an electromagnetic radiation, and that the heat radiation is electromagnetic radiation with just another wavelength. The model of light coming from excited electrons going back to ordinary state is familiar to the students, but the model of electromagnetic radiation as created by electrons in acceleration are not even mentioned in answering the questionnaires. The course literature present these models separately, causing that electromagnetic radiation from electrons in acceleration is seen only in connection to the theory of the antenna.

Result 3   Ownership to the project and holistic perspective.

Four of the seven proposed miniprojects were chosen, and there was one own project suggestion.
The tendency in both student groups are to choose a miniproject that have a high degree of ownership but with the problem formulated by the teacher.

Grade of student ownership to the project:	**Miniproject title chosen by students. Student choice in percent.**	**Grade of holistic perspective in the project:**
Own 1: The Miniproject are defined and given by the students. The teacher look over the ideas so it could be done with equipment in laboratory.	• Own choice- The microwave oven 1/35 =3,0 %	Hol 2: Question related to technical applications..
Own2: The Miniproject are defined and given by the teacher .The student chooses method, design and the student carry through the investigation and hand in an account for the results.	• How many tracks on a CD? 15/35=44 % • UV-radiation. 10/35=29 %	Hol 2:Question related to technical applications. Hol 4: Question related to environmental physics.
Own3: The Miniproject are defined and given by the teacher. The teacher decides title, purpose and design and method.	• The Bulb. (Decide melting point on the wire.) 6/35= 17% • The polarisation of light. 3/35=9 %	Hol 2: Question related to technical applications. Hol 3:Physics problem applicable to closely related areas.

Fig 7. Grade of ownership and holistic perspective in chosen project.

Result 4   The Interviews

The interview manual.

In purpose to categorise positive and negative effects with miniprojects as a complementary topic in physics teaching, some exploring questions were formulated which were the base for interview.

B1   *Can the student get empowerment to lead his/her own learning process in away that is effective and nice by taking charge of the students' personal qualifications to solve a laboratory problem?*

1. What initiative will the student show, and what approach to solve the laboratory problem in the miniproject?
2. How important is it for the student to have the possibility to choose his/her own project?
3. What personal qualifications do the student use in the small group work with the miniproject?
4. How do the student act within the group?

B2   *Can miniprojects as a complementary topic in physics give students freedom to begin in his/her own level of knowledge in aspect of facts and understanding in the content area?*

1. Do you decide yourself the level of difficulty and the level of ambition?
2. Do you compensate your own lack of qualification with other people's abilities? Does that mean that you develop yourself or does it mean that they all get stuck in a position?

B3 *Can miniprojects give possibilities to introducing problems and tasks with a more holistic approach than that of pure physics, in purpose to increase the students possibilities to recognise physics in different contexts?*

What do the student find as an holistic approach contra atomistic in the field of

1. electromagnetic radiation?
2. electrodynamics ?
3. and in mechanics?

B4 *Are elements of environmental physics into ordinary physics coursers in Upper Secondary Schools or introductory physics course something that in itself increase interest and motivation by giving a holistic perspective? Why/Why not do students choose miniprojects with environmental character?*

Three transcribed interviews high-light that students find it demanding but interesting and valuable to work with miniprojects.

David about miniprojects:

Interviewer: If you work like this in miniproject how do you think that will act upon learning?

David: *I feel as if it gives narrower knowledge but I think it's better. If one look at the autumn, it was theory, exercises (in the book) and some lab work, but now one has almost forgotten everything already. But this with the miniproject, that's still there. Why you did do it, you did it for a longer time, you prepared your speech about it, you made the power-point presentation…you worked on it more and under longer time and in more occasions than you do usually. That means that you remember it better. But you make it more narrow, if you take two chapters in the book and make miniprojects from that area, than it will be really tight to manage in time, it have to be a balance there. It should definitively be valuable to have each period. Miniproject is much better than "quiz"the "small tests". One does not take them seriously.*

To Hanna stress the importance of grasping the meaning of the given problem. She will come back to this several times in the interview.

Hanna about laboratory sessions:

Interviewer: What is positive and negative working in the laboratory compared to theoretical problem solving?

Hanna: *That is good in the cases you know what you are up to. But sometimes you only get a formula thrown up on the black board and you think …where did that come from…? Than it is no good with it being lab work. No, the most important is to know what you are doing. There are some calculations and so in lab work too. I want to know what I am doing.*

In answering next question she express the same feeling, not really having control of the situation, and not belonging to the discourse.

Hanna about using different personal abilities in the studies:

Interviewer: Did you discover things about yourself you had not thought of before (when studying physics…)?

Hanna: *What I saw when it come to science and so* ***was that I do not have that kind of thinking naturally, but others do have that****. It only says "smack - smack" so there it is, but for me I do not have that thinking at all, It takes a long time before (I understand) it is there. But in other subject I can pick up things very rapidly!*

Interviewer: What is it than that others have but you don't?

Hanna: It could be interest. It could be. ***But on the other hand…***

Interviewer: Hmmm? Could it have something to do with if you are able to relate it to a context you are familiar to?

Hanna: Yes, it could. I see no coherence in this. No I do not. The others think those things are obvious. Maybe it comes with how things were around you. When you were a child and so…

It is interesting to notice different kind of answers to the question *"How do the sun influence our lives?"* As a physics teacher making an interview about electromagnetic radiation of course some students answer that all energy comes from the the sun . But Hanna do not think like that at all.

Hanna about the sun:

Interviewer: How do the sun influence our lives?
Hanna : How do the sun influence our lives….??????
Interviewer: Mmmm. How do you look upon the sun? What would it be without the sun? Cold would it not be?
Hanna : Yes, it would be cold, and nothing could grow either. If it just comes clouds than it makes you feel no good. You need the vitamins C and D or which they are…
Interviewer: So when you think of the sun, you first think of it in relation to yourself, that you will get vitamins and so…
Hanna : Laugh! Yes, I am an ego. Yes, I think of myself.

The conversation with Hanna made it obvious to me that the discourse of physics is closed to some students. They are unsure what the purpose is, and how to make it meaningful to them.
This is reported and discussed frequently in the literature (Lemke 1993; Säljö 2000).

Discussion

The aim of this pilot study was to address broad questions to students in some different ways and to find successful methods and design for a larger investigation based on these headlines of research questions.

MINI-PROJECTS Experimentally problems within different content areas	MOTIVATION Approach to studies —changes in approach over time	KNOWLEDGE Individual level in starting point– changes over time	SPECIAL EFFECTS WITH MINIPROJECTS Holistic view – different contexts to different students	ENVIRON-MENTAL PHYSICS into physics

Fig 8. The research question headlines in the full investigation.

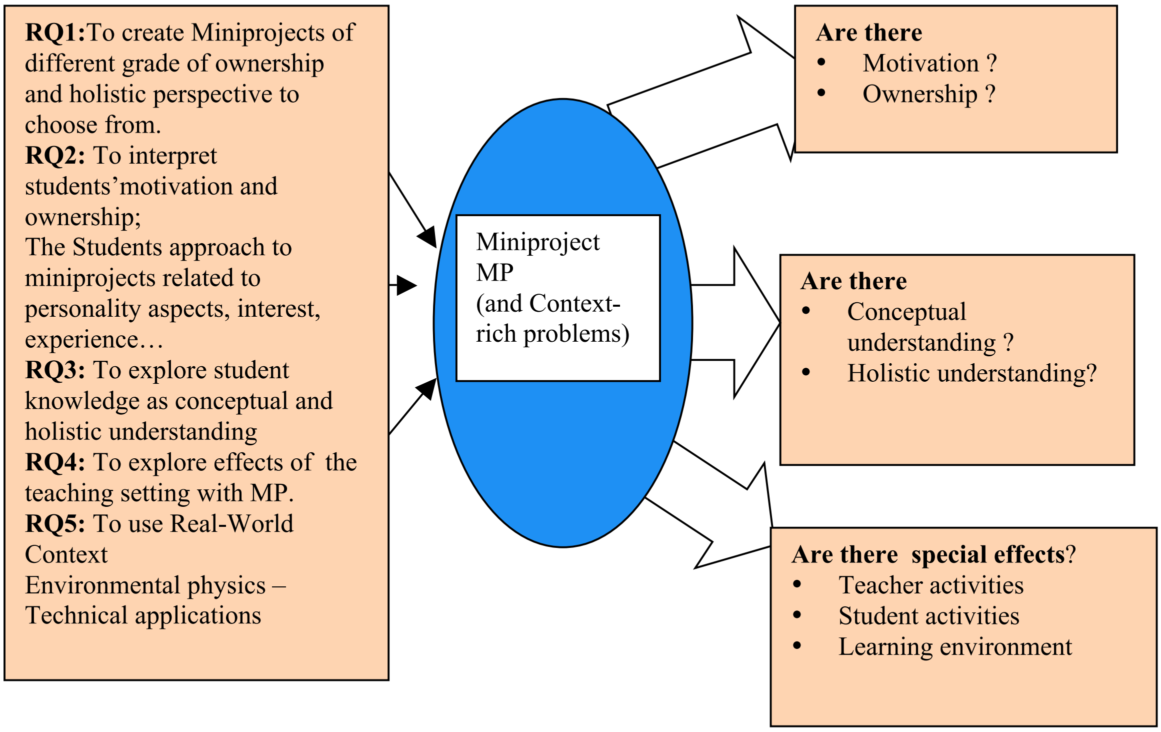
In this study we used instruments to get an over-view of attitudes to physics learning and an impression of the students understanding of fundamentals of electromagnetic radiation (Upper secondary school level). We have got some preliminary results that can help us go further with the investigation. The human personality is a very complex base of our human nature, hidden to everyone, and maybe a life project to explore to oneself. The psychological researchers do large statistical inventories, where multivariable analysis are used to step by step find clusters with categories, that are not specific to a special person, but still relevant to give a picture that an individual are described by at least partly. One started early to study processes and development of student abilities instead of the personality itself (Westlund 2001). But the Perry study about the student development in attitude towards learning is probably an instrument that is useful in science education research even in 2002.(Perry 1970; Fitch 1984).

From this pilot study we can report some observations.

- The MPEX survey *measure differences in student attitudes* concerning to physics studies. The third year students had attitudes more expert-like than the students from the bridging-course, but the differences inside the groups were surprisingly high. The students with the highest score were best in result in the end of the course. Even if we notice that the test cannot reliably indicate such a connection individually, the test gives an informative picture of the group members' attitudes to physics studies.
- Both student groups showed low scores in "Perry-value", that means that concerning attitude to learning development they were oriented towards a dualistic view. (Right and wrong, there is a correct answer to everything.)
- There was a notable difference in "Perry-value" scores concerning the view of the teacher compared to the view of physics lab work. These students have a longer personal development in relationship and general group work, but as physics is a new area to them. It is obvious that you can show different development of learning attitudes in different learning situations.
- The Perry-test showed that a third of the group members wished to be leaders of the groups they were involved in. The student did not take the possibility to change group in favour of choosing their own project. To continue to work with the same group members were most important.
- The pre-test indicated low understanding of the concept electromagnetic radiation. Students did not realize light to be an electromagnetic radiation, and did not recognise that you can feel and see electromagnetic radiation but not hear it.
- The interactive work in miniprojects helped students to better understanding. The post-test gave good results in both groups but still students had difficulties to "feel and see" electromagnetic radiation A reason to this could be course literature that did not explicit define light as electromagnetic radiation, and had a chapter called "Light" and another called "Electromagnetic radiation" concerning radiation from charged particles in acceleration, explaining the antenna. The student taking the course in environmental physics showed high improvement in post-test. This is probably an effect of both teaching and miniprojects.
- Three interviews are transcribed. One interview highlight how the science discourse can be experienced as closed to a girl with no earlier experience from physics. This girl felt that she never got into the game of physics. She had good results in her tests, but nevertheless she this girl took a non-science university program instead. I think miniprojects more similar to the background of girls like Hanna could be developed to help them feel more comfortable within the physics classroom discourse.
- The study indicate that student prefer miniprojects with high degree of freedom to design and problem-solving, but with miniprojects proposed from the teacher to choose among.
- The teachers have found it to be very stimulating to tutor these miniprojects. The miniprojects gives the teacher an opportunity to come closer the students and their learning process. The miniprojects have not only facilitated a high degree of student and teacher interaction but also a very high degree of student-to-student interaction. This has fostered a very nice, open and rewarding atmosphere in the classroom.

Implications for further research

To continue the investigation we have found all the instruments used to be measuring and to be useful also in the next investigation. In the next step the research question will be formulated slightly differently, to focus on the students **experienced** motivation, ownership and **experienced** holistic perspective. We will further develop MP with a core of physics concepts so comparison regarding holistic perspectives can be made. We will also develop categories for exploring video sequences, and use Category Based Analysis of Videotapes (Niedderer 2002)



RQ1:	To create Miniprojects of different grade of ownership and holistic perspective to choose from.
RQ2:	To interpret students' motivation and ownership; The Students approach/attitude to MP related to personality aspects, interest, experience…
RQ3:	To explore student knowledge as conceptual and holistic understanding
RQ4:	To explore special effects of the teaching setting with MP for example how teacher activities and student activities change and how the learning environment change.
RQ5:	To explore how using Real-World Context in the MP from Environmental physics and Technical applications effect students' motivation, ownership and holistic perspective.

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Context-led Physics Teaching and Learning: The Salters Horners Advanced Physics project

Summary

The Salters Horners Advanced Physics project (SHAP) is a new context-led physics course developed in the UK for school students aged 16-19. Up-to-date contexts and applications provide the starting-point for the study of physics concepts and principles and lead to a wide range of practical and computer-based work. SHAP was evaluated as a pilot in 1998-2000 and is now used in some 200 schools in the UK and overseas. Students are responding positively to the new approach, and there is evidence that more are being inspired to study physics and related subjects at university.

Introduction

In the 1990s, there was mounting concern amongst UK physicists – as in many other countries – about the decline in numbers of young people choosing to study physics. This was linked to a concern that physics courses then available to UK students aged 16-19 were overdue for improvement and updating. Students perceived that physics was dull, difficult, and did not lead to interesting careers or further study.

Traditionally, science students have first been introduced to scientific principles, such as Newton's law of motion, then worked through various exercises before eventually reaching a pay-off in the form of some interesting applications such as the launching of satellites, or improving athletic performance. Many students find this approach dry and un-motivating. They would question 'why are we doing this?', and lose motivation long before reaching the interesting parts, thus reinforcing their negative views of physics.

At the University of York, UK, the Science Education Group has pioneered a novel approach to science education, in which the teaching and learning are 'context-led'. In contrast to the traditional approach, students begin by exploring a situation (a 'context' or 'story') that they can relate to, and then learn the associated science. The first courses to use this approach were in chemistry, notably the Salters Advanced Chemistry course [1, 2], and in general science. Following their successful implementation, a project was set up in the mid 1990s to apply the same method to the teaching of physics.

With the financial backing of the Salters and Horners companies (formerly mediaeval trade guilds, now charitable organisations) and a consortium of industrial sponsors, the project was named the Salters Horners Advanced Physics project. A large number of school physics teachers, industrialists and university physicists took part in the development, ensuring that the course would appeal to students and that the contexts and content were up to date and rigorous [3].

SHAP is one of six AS and A-level physics courses available to students in England aged 16-19. The courses all meet the same national criteria but each has its own examination, all of which qualify young people to enter university.

SHAP has its own course publications. Two student books contain contextual material along with the appropriate physics explanations, and include many examples and questions along with mathematical support. Each book is accompanied by a comprehensive resource pack for teachers and technicians, giving guidance on teaching and assembling apparatus, and providing additional materials for use at the teacher's discretion. [4, 5]

The SHAP course

It is important to state the SHAP is first and foremost a *physics* course. The contextual material is a vehicle for studying physics and a means of providing interest and rationale, rather than being an end in itself. At the end of the course, it is the concepts and principles of physics that students are tested on in examinations, not their knowledge of the contexts in which the physics has been learnt.

The two-year SHAP course is built around eleven context-led units. The unit contexts are designed to appeal to students and to lead to their learning physics of an appropriate standard. Some of the contexts build on students' own personal and leisure interests, such as sport and music, some have a more industrial/careers bias (for example the food, telecommunications and space technology industries) whereas others focus on fundamental research in areas such as astronomy.

The physics content of each unit is carefully planned so that students are introduced to key topics in one context then review and extend their understanding in different contexts as they progress through the course. There is thus some preferred order for teaching, though there is also flexibility for teachers to design their own programmes.

The course contents and contexts, and the assessment structure, are described in detail on the SHAP website:

www.york.ac.uk/org/seg/salters/physics

However, one example can serve to illustrate how the course design works. The unit called 'The Sound of Music' comes near the beginning of the course and is generally taught during the first autumn term. There are two main parts to the unit. One focuses musical instruments, giving students opportunities to play their own instruments and explore the sounds they make. Basic ideas about travelling waves are introduced, along with the idea of phase, and students use oscilloscopes and an interactive CD-ROM to display and study simple waveforms. The principle of superposition leads into a study of standing waves which in turn helps explain the operation of stringed and wind instruments. The other part of the unit is based around the workings of a CD player. The optical scanning of the CD again brings in basic wave physics and superposition: here a simple CD model using 3 cm microwave apparatus illustrates the principle. By considering the operation of the laser, students have a first introduction to photons and atomic energy levels, and in the context of focussing and splitting the beam they encounter the physics of refraction and lenses.

Many of the physics principles introduced in 'The Sound of Music' are revisited later in the course. Waves are encountered in the 'Spare Part Surgery' unit (in the context of ultrasound scanning) and 'Build or Bust' (where SHM and resonance are taught in the context of earthquake-resistant buildings). Refraction and lens optics come into 'Good Enough to Eat' (refractometry of sugar solutions) and 'The Medium is the Message' (fibre optics) and 'Spare Part Surgery' (eyesight and lenses). Photons and atomic energy levels feature in 'Digging up the Past' (thermoluminescent dating), 'Reach for the Stars' (spectra) and 'Probing the Heart of Matter' (subatomic particles). Students thus have ample opportunity to develop, apply and test their understanding.

Student activities

Each unit incorporates a variety of activities so that students may develop their practical and ICT skills. Teachers are able to select from a large number of activities and choose those which best suit their own circumstances and those of their students.

Many of the activities have been developed specifically for the SHAP course, arising naturally from the context and sometimes using novel apparatus. For example, the unit 'Technology in Space' uses small sections of photovoltaic panel in place of conventional dry cells for dc circuit work. In 'Good Enough to Eat' students measure the viscosity of honey and syrup and carry out mechanical tests (of hardness and elastic modulus) on sweets and biscuits. 'The Medium is the Message' includes a model CCD imager and 'Build or Bust?' incorporates a model earthquake table to illustrate simple harmonic motion and resonance.

In addition to laboratory-based practical work, SHAP students make an out-of-school visit during the first year of the course to report on 'physics at work'. The choice of location depends on the teacher and students. Some choose to visit an industrial venue, or a research establishment, while others have found physics behind the scenes at a cinema or supermarket. Teachers and students find that the visit really does bring physics to life and can also give students ideas for careers or areas of future study [6, 7].

In the second year, students undertake an extended practical project. Students choose a topic that interests them, with guidance from their teacher, carry out some preliminary research then spend about ten hours of laboratory time investigating their chosen subject. The project gives students an opportunity to follow their own interests and to put into practice some of the physics that they have been studying. While the project can be challenging, students generally find it a very rewarding part of their course.

Implementation and evaluation

The course was first introduced as a pilot in September 1998, in anticipation of a revision to the whole post-16 examination system in England and Wales. Teachers and students participated in the trial with enthusiasm [8] and provided valuable feedback to the project team. The trial was also the subject of an extensive research project which looked at, among other things, the effectiveness of the context-based approach to physics teaching and students' and teachers' responses to the visit [7, 9].

A survey of the two cohorts of pilot students, who gained their A-level qualifications in Summer 2000 and 2001, showed that 11-13 % of students gaining their physics A-level with SHAP went on to study for physics degrees while about 20-25% go into engineering. This compares favourably with the national picture, where only about 9% of UK A-level physics students continue with the subject at university.

Following the successful pilot, the course was then made publicly available from September 2000, and this brought about a large increase in the number of schools and colleges using the course. More centres adopted the course in 2001 and there are currently about 200 schools and colleges following the SHAP course. These will be joined by yet more in 2002.

It is impossible in this short article to give more than a brief overview of the SHAP project and the effect that it is having on the teaching and learning of physics. For further information, or to be put in touch with a school using the course, please contact the project director:

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Building an European Virtual University
A Thematic Network Approach

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Abstract:
This paper presents the first steps taken by several European universities grouped in a Thematic Network Project to study various features of the implementation of a virtual university. The European Commission under the Socrates- Thematic Networks Programme funded this project. The overall goal of this TN is to convert the traditional approach of learning:

- *Lecture, Laboratory, Library*

into a European Distance Learning concept using the Internet.

1. Introduction

In 1998, in the Sorbonne meeting and in 1999,in the Bologna convention some European countries adopted a declaration for a common effort to obtain a curricular harmonisation to promote convergence between educational systems.
The proposal commonly referred as the "**3-5-8 Model"** contemplates two main common levels, Bachelor and Master, corresponding more or less to the classical "undergraduate" and "post graduate" degrees used in most countries in the world. The Bologna meeting also adopted a common regime of credits, designated by ECTS (European Credit Transfer System).
The implementation of this document is not easy given the different levels and curricular structures of higher education in Europe.
New forms of practice must be devised to prepare students to compete in an open market where information and communication technologies are key features. The association of teachers and researchers in wide networks where exchange of practices and information can take place is an essential step towards better teaching praxis and to curricula harmonisation.

2. The Theiere Thematic Network

The THEIERE *(Thematic Harmonisation in Electrical and Information EngineeRing in Europe)* Thematic Network began in 2000 as the result of converging interests between the EAEEIE (European Association for Education in Electrical and Information Engineering), an European association which aims at promoting better engineering teaching practices and develop common curricula in EIE, and the European Commission, through DG "Education and Culture" which started the Thematic Networks programme in 1996.

The main objective is the co-operation between the partner institutions in order to contribute to the harmonisation of curricula at an European level, with the contribution of 65 European universities and some observers: Bogazici University in Istanbul (Turkey), University of Mariupol (Ukraine), and University Abdelmalek Saadi from Tangiers (Morocco).

The aims of this new thematic network, which is expected to run between 2000 to 2003, are:

- a survey concerning the available curricula in EIE (Electrical and Information Engineering) throughout Europe,
- To enable a curricula comparison that will facilitate the transfer of knowledge between higher education institutions.
- a reflection on the best practices of high engineering education in the specific field of Electrical and Information Engineering in a European perspective,
- A development of pieces of curriculum and pedagogical tools available through the Internet as pre-requisites to help students for mobility exchange programmes (ex: ECTS). The aim is to allow the student to prepare him/herself before going in a foreign country by:
    - Acquiring the basic level,
    - Beginning to learn in the foreign language and with the foreign approach the academic content of one particular course.

The whole aim is to get a harmonisation of the curricula in EIE throughout Europe in order to facilitate the exchanges of knowledge, students and teachers. This harmonisation will make also possible the establishment of common accreditation, crediting and certification procedures.
Due to the size of the Network 84 European institutions are partners, including some observers: Bogazici University in Istanbul (Turkey), University of Mariupol (Ukraine), University Abdelmalek Saadi from Tangiers (Morocco), an enterprise Giunti Labs from Genoa, Italy, and a European Association EAEEIE.

Due to the wide accessibility of the Internet, a possible way to assure convergence is the following:

A- In a short term, in the design and implementation of Internet-based modules, whose content is defined by a group of partners of the same speciality working in close co-operation.
B- In a long term perspective by disseminating and assessing these modules in Europe.

Based on the interest and expertise of active participating members, six major areas in Electrical and Information Engineering were selected to be the targets of TN activities: Computers, Communication, Electronics, Power Systems, Sensors and Theoretical Electrical Engineering. For each major topic a 'Lead Site' was selected which was supposed to co-ordinate the development work within the topic.

TABLE I
ORGANIZATION OF DEVELOPMENT

Topic of Package	Lead Site
Electronics	Université de Rennes 1, France, Universidad de Cantabria, Spain
Telecommunications	Universität Ulm, Deutschland
Computers	Oulun yliopisto, Oulu, Finland

Power systems and EMC	Instituto Superior Técnico, Lisboa, Portugal
Instrumentation and Sensors	Université Henri Poincaré Nancy 1, France, University Rzeszow, Poland
Internet Services and Applications	Univ. Ilmenau, Germany, Univ. Vigo, Spain
Virtual Labs	Univ. Rousse, Bulgaria, KdG, Antwerp, Belgium
Fundamental Concepts	University Riga, Latvia, Univ. Bratislava Slovakia

Another objective is thus to design pedagogical modules, installed on a web-server to be used by teachers and students in this field, thus paving the way to the emergence of a European virtual university, with a common syllabus.
The interconnection of these modules will allow the end users (teachers and students) to get a wide view about educational resources that are normally sparse.
As far as the teachers are concerned it will allow the retrieval of a special module that can be used in conjunction with the normal curriculum to enhance some aspects of the presentation in the class while avoiding the burden of developing specific software themselves.
For the students these pieces of curriculum and pedagogical tools developed in several universities in Europe, easily available through the Internet will act as pre-requisites allowing the student to prepare him/herself to mobility exchange programmes. The modules are available both in English and in some cases also in the native mother tongue.

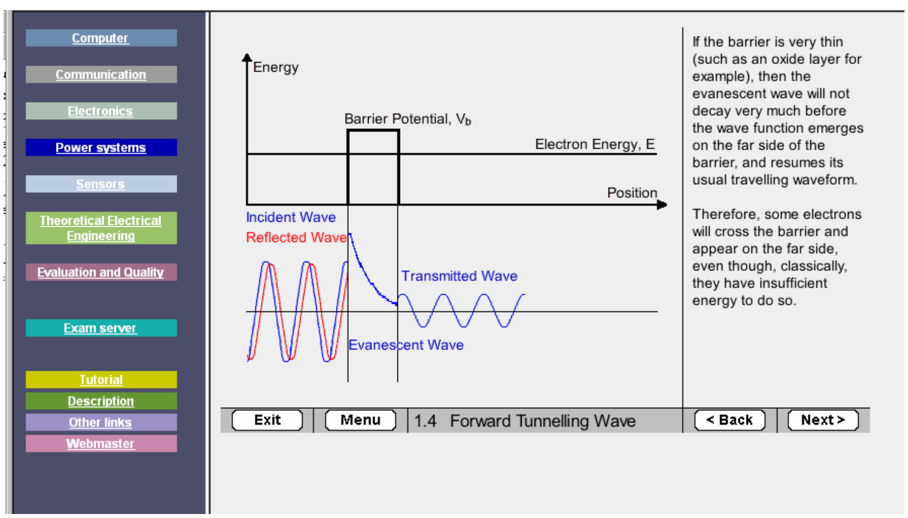

Fig. 1- *An interactive showing the influence of the width of the barrier potential.*

Other important objectives are:

- To provide tools for dialogues and exchanges (mail, newsgroups, and databases) between teachers themselves and also between teachers and learners, which should allow an improvement of the courses and a comparison of various pedagogical experiences.

▪ to allow a global assessment, which could help partners to compare students levels, in order also to get a whole view of the teaching in Europe in this domain

The various pieces of curriculum and pedagogical tools available are proposed in a web server located at http://www.eaeeie.org/theiere/

As an example of pedagogical resources where students have contributed, a Java applet is shown in Fig. 2 [13]. It demonstrates the influence of a proper choice of parameters for sampling a time-domain signal and its regeneration from the sampled values. The student is able to select some types of signals to be analysed and to choose parameters as for instance the sampling frequency. The applet then show the original signal together with the reconstructed signal thus demonstrating aliasing effects. By actively setting good and bad parameters

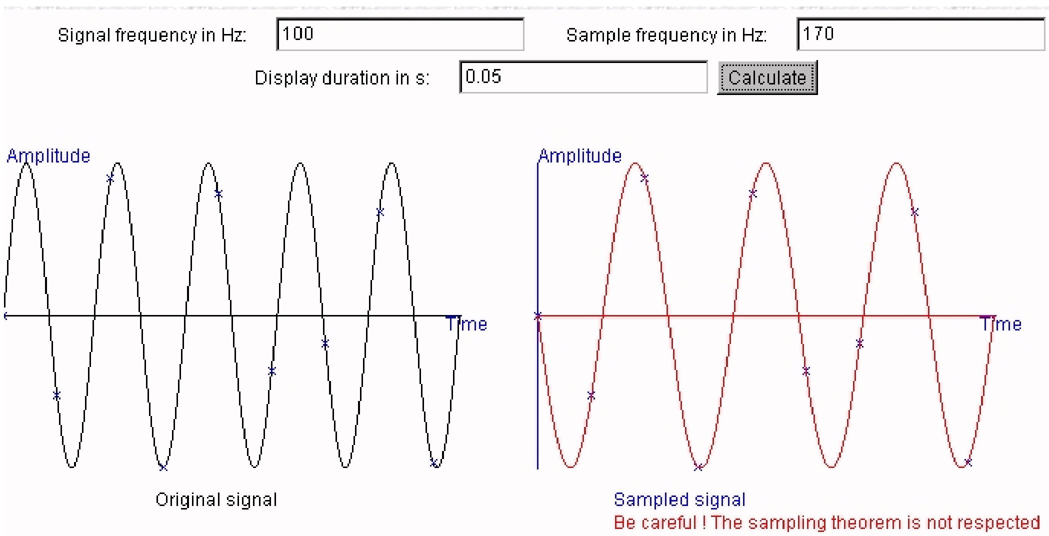

Fig. 2- *A Java applet is showing the influence of the choice of parameters for sampling a time-domain signal and its regeneration from the sampled values.*

Important points of our strategy are:

- Exercises are assigned with interactive contact between the student and the teacher. Questions and answers are delivered using email facilities,
- Simulations of some lengthy, critical thought processes are available to the students through internet,
- Access to a remote laboratory process is provided. No local resources are needed apart from access to Internet and appropriate computing facilities.

Apart from web communication, face-to-face meetings were organised two times a year to discuss common aspects of material implementation. Training of web material production was organised in the early phase of the project as well.

3. Evaluation and dissemination of results

The home page of our site proposes some help available in six languages (Portuguese, English, French, Spanish, German, and Esperanto).
The structure of the server is distributed, the tools are proposed on the site where they were developed however some are also proposed in the native mother tongue. Others in English to facilitate international assessment

A questionnaire was distributed to the students concerning the following aspects:

- facility to use (ergonomics),
- problems of connection,
- interests and difficulties of the courses in HTML,
- role of simulations,
- difficulties in using the English language,
- Suggestions for improvements.

The remarks of the students were as follows:

- They are mostly in favour of using internet-based tools as a complement to classical lectures, either in a deductive or in an inductive manner,
- Concerning the text by itself, some mentioned the difficulty to read on a screen rather than on paper.
- 28% mentioned some difficulties for the connection (availability of machines within their institution, configurations of machines, problems of connection),
- Concerning the use of the English language, the students behave generally positively, arguing that it is interesting in the frame of their education and their future job to know the vocabulary in English.

4. Conclusions

The work developed in Task 1 will be a useful tool to adapt our curricula to the 3-5-8 format recommended by the European country ministers for education. The survey will help to understand the differences and can provide guidelines to achieve a harmonisation of curricula in EIE.

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Physics Through the Medium of Sport

Introduction:

Many science students on both pre-university and undergraduate courses see Physics as a 3D subject, that is Dull, Dry and Difficult! Often the cause of this is the mathematics but it is also often due to the content being so far removed from any situation of interest to the student. This paper presents two topics, the Magnus Effect and Coefficient of Restitution, through the medium of football (soccer) and tennis respectively.
Work with post-graduate students wishing to become teachers of either Science or Physical Education has shown that this approach can address their initial apprehension of that thing called Physics!

The Physics of Football

When the likes of David Beckham or Roberto Carlos swing a football around and/or over a defensive wall they make instinctive use of the Magnus effect. The Magnus or Lift force acting on the ball is related to both its linear velocity and its rate of rotation by:

$F_L = C_L \rho D^3 fv$, where

C_L is the 'lift coefficient'
ρ is the density of the air
D is the diameter of the ball
F is the rate of 'spin'
V is the velocity of the ball

The direction of the Magnus force is as shown in figure1.

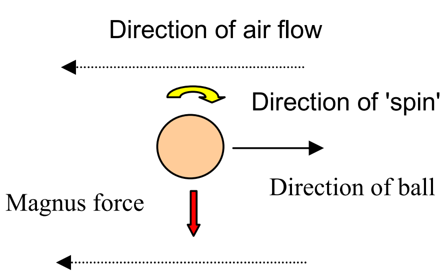

Figure1 - The Magnus effect on a spinning ball.

If the magnitude of the Magnus force is considered to be constant during its flight then, by reference to figure 2, we have:

$y = vt$ $\qquad y \propto t$

$x = ½at^2$ $\qquad x \propto t^2$

hence $x \propto y^2$ which is the equation of a parabola.

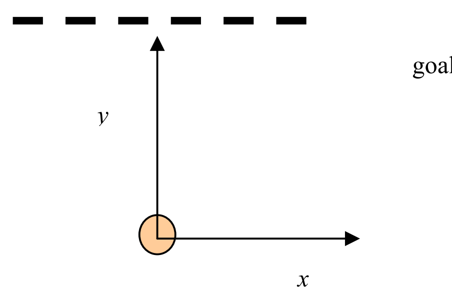

Figure 2 - constant Magnus force results in a parabolic motion

Wesson (2002) suggests the total displacement sideways, *D*, is related to the distance from the goal, *L*, by:

$D/L = kn$ where *n* is the number of rotations during the flight.

The suggestion, based on work with balls other than footballs, is that k is of the order of 0.01.

Consider now a ball kicked at $25ms^{-1}$ at a distance of 25m from the goal. Assuming a spin rate of 10 revolutions per second and time of flight of 1 second:

D/L = k*n* gives a sideways deflection of 2.5m.

However calculations by Ireson (2001), using $s = ut + ½at^2$, gives a deflection of 4.57m. It is also evident, from video footage, that some kicks bend with very little spin.

If we consider the assumption of constant Magnus force to be unsafe then perhaps we have a partial answer. Since when drag acts on the ball it reduces its velocity it can be shown that the variation in drag force, F_d, varies with velocity as shown in figure 3 taken from Ireson (2001).

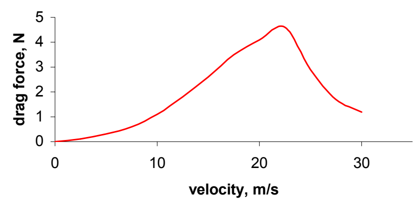

Figure 3 - variation of drag force with velocity.

This analysis can be modelled as a 7th order polynomial but it is based on a treatment of a soccer ball as a 'smooth sphere'. Wesson (2002) challenges this assumption and suggests that a simpler square relationship may be closer.

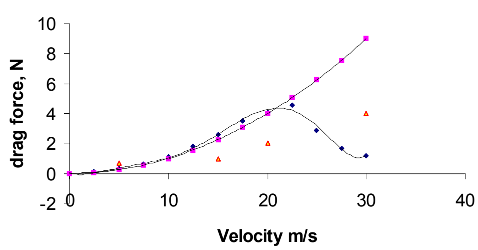

Figure 4- drag force versus velocity using a polynomial, square and 'experimental' data.

Obviously this is an area for further research which may lead to the solving of dr/dt where r is the position vector, r ≡ (*x, y, z*), taking *x, y, z* as the normal spatial co-ordinates.

The Physics of Tennis

Anyone who has ever hit a ball with a tennis racket will, at some time, have felt the effect of hitting it in the 'wrong place'. The 'right place' causes no vibration to be felt in the hand and racket manufacturers refer to this as the S*weet Spot.* However the physics of why this should be so is not obvious and further investigation reveals that it may be more useful to talk out of one but four sweetspots.

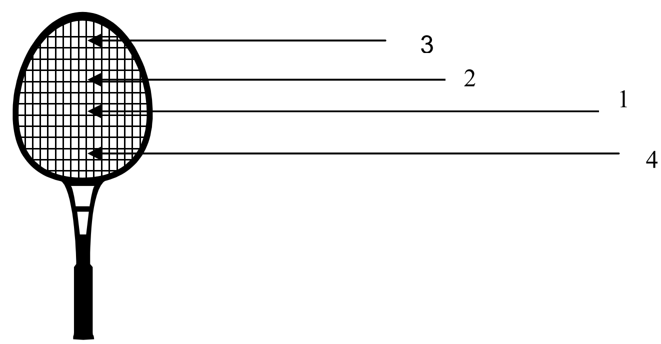

Figure 4- approximate position of the 4 sweet spots.

Imagine a tennis racket balanced on the end of its handle. If a ball impacts on the racket at its centre of mass then the motion of the racket would be purely translational.
If the ball strikes a point other than the centre of mass then a translation will be needed to conserve linear momentum and a rotation will be needed to conserve angular momentum.
A point on the racket face exists where the distance the tip of the handle moves to the right under translation is equal to the distance moved to the left under rotation - this is **'sweet spot 1'** and is know as the centre of percussion. Striking the ball here causes minimum force on the forearm of the player. On a typical racket the centre of percussion will be of the order of 5.0cm above the centre of the strings.
Unfortunately limiting the force on the forearm by striking the ball at the centre of percussion will, inevitably, cause the racket to vibrate. The fundamental mode for a racket varies between 100Hz and 150Hz with one node being near the centre of the strings and the other in the handle. Striking the ball at a node, **'sweet spot 2'**, will result in no vibration. The lack of vibration affords greater racket control which can, in turn, result in lower levels of muscle fatigue in the forearm.

Imagine a racket clamped by the handle and balls then being dropped onto the strings along a line from the handle to the tip. If the rebound height is recorded the coefficient of restitution can be found;

The coefficient of restitution is defined to be the ratio of the rebound speed, v_r, to the incident speed, v_i.

Using $\Delta mgh = \Delta \frac{1}{2} mv^2$ it is easy to show that coefficient of restitution, e, is given by;

$e = \sqrt{h_r / h_i}$ as shown below.

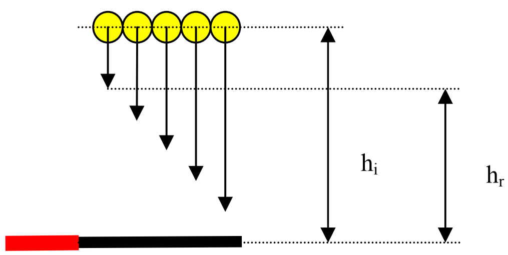

Figure 5 - coefficient of restitution.

This gives us **'sweet spot 3'**, the dead spot, where the coefficient of restitution is minimum and **'sweet spot 4'**, the lively spot, where the coefficient of restitution is maximum. At the dead spot minimum energy is returned to the ball from the stationary racket. Similarly if a stationary ball is hit by a moving, for example rotating, racket then all of the rotational energy will be given to the ball - this is obviously the best place to strike the ball for a fast serve. However to return a ball with pace the best place to strike the ball is at the lively point since this will return maximum energy to the ball.

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Co-operative teacher education: ”Physical Methods in Biological Research”- an advanced course for senior high-school students at the University of Turku

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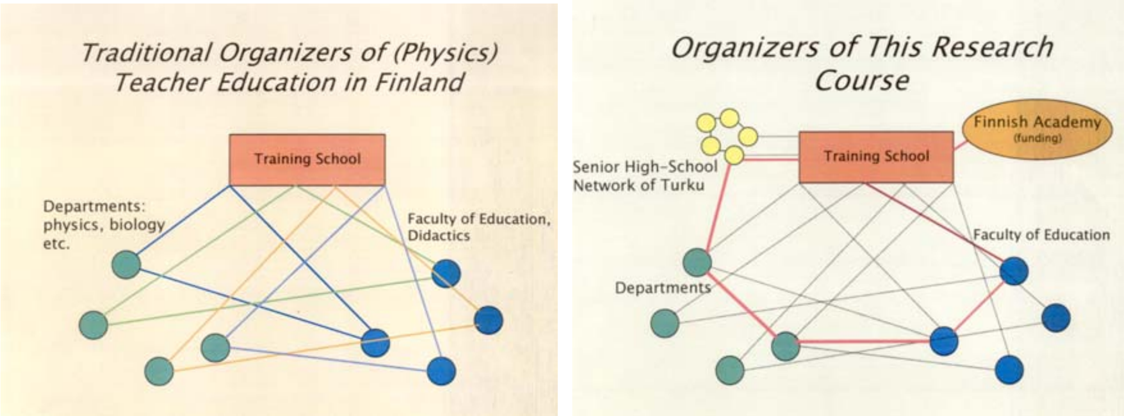
TRANSLATED TO ENGLISH BY MISS HANNA ISOTALO TO WHOM THE WRITER IS GRATEFUL.

”I am also going to apply for the University of Turku to study biology even though I don’t even know what job opportunities they graduate there for.”, The Regional Newspaper Turun Sanomat, 13.5.2002, abiturient Anna Hupponen. Impressions like that are unfortunately quite common among potential students regardless of the field of natural science concerned. At the University of Turku we wanted to find a solution to the matter and when Turku Teacher Trainig School contacted us and wanted to collaborate with us, the idea of applied course about physical methods in biological research was born. There was also consortium consisting of about twenty senior high schools from Turku (Senior High-School Network of Turku) and even Institution of Teacher Education of Turku as co-operatives. Academy of Finland granted an encouraging bonus to Turku Teacher Training School for participating the science-competition Viksu. That made it financially possible to carry the project through. During the course twenty students got familiar with not only the research made at the department of animal physiology at the University of Turku but also the physical principals applied in the research and the phenomenal surroundings involved. We tried consciously to give physics a status of a expedient, not a status of end in itself. Twenty students from four different senior high schools divided in four separated groups took part in the course arranged spring 2002.

The idea of integrating subjects is old, but it should be obvious for the students all the time, that all their knowledge from different subjects really support each other. Nowadays, in the education of teachers at the University of Turku, this integration of different subjects happens far too rarely. In reality all the subjects function totally separately in the triangle formed by departments of subjects, Institution of Teacher Education and Turku Teacher Training School.



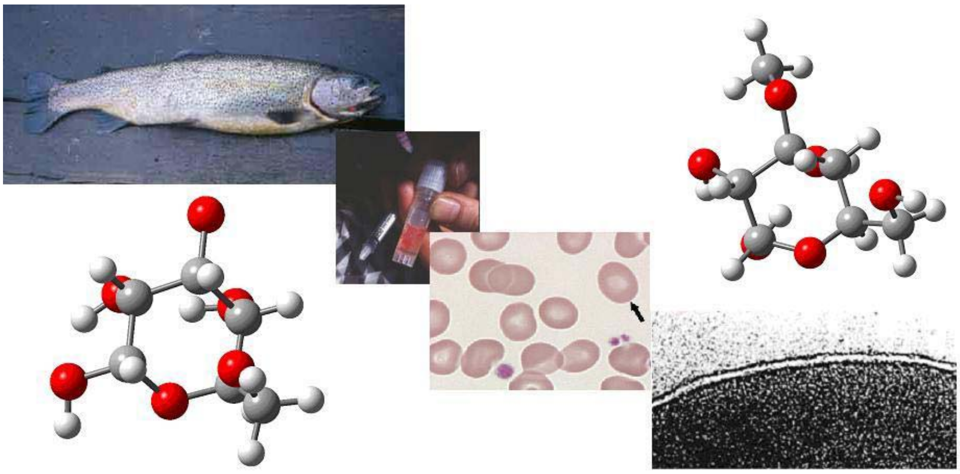
Picture 1. *The triangle of traditional Teacher Education in Finland and all the organizers of this course.*

The recruitment of students to the university is also regarded as a problem which needs to be solved immediately. It has became obvious also that all the information concerning studies at a university or the life of a student in general comes in handy. The students should know what they are entering into. Besides of getting the students to work a bit at the university, there aren't too many ways to have an effect on the students.

Senior-high School Network of Turku as a channel of co-operation

Turku Normal School took the initiative of co-operational course which was to be organized by the University of Turku and the senior high school. In the year 2000 the students of the Turku Normal School had been taken part in great numbers in a science competition Viksu organized by the Academy of Finland and even the work that won was amongst them. That is why the Academy of Finland granted a special encouraging bonus for the Turku Teacher Training School. The principal, Marjut Kleemola, canalized this entire amount of money to the teaching of natural sciences. In addition Turku Teacher Trainign School is a part of The Senior High School Network of Turku, which is a co-operative project between senior high schools in the Turku area and Institution of Professions of Turku. *The main goal of the project is to increase co-operation between different schools. The students in daytime senior high schools will get more and more variability in their supply of different courses. Students from the accompanying senior high schools are going to produce a course in which the methods of distance learning are applied. In the network senior high school students can choose any course they like which, for what comes to teaching, is based on normal contact teaching and teachers guidance and for what comes to material, is based on existing material in the network and on material produced by the teacher. The teachers will outline* *the curriculum, basis of evaluation of the students and common modes of action for the netcourse. Network courses will be accepted in the curriculum in the participating senior high schools .*[1]

At first Turku Normal School started to look for appropriate co-operatives and as a result the Department of Physics[2] and the Department of Biology at the University of Turku participated. In the beginning it was also agreed that the students who study to become teachers should take part in outlining the course and also carrying it through. As participants in the group which outlined the course there were *Katri Sarlund*, teacher of biology from Turku Normal School; *Riitta Rajala*, teacher of physics; *Ensio Laine*, professor of physics; *Mikko Nikinmaa*, professor of biology and *Kalle Ojanen*, assistant of physics. The outlining started from finding a proper subject for the research in biology. That kind of subject was easily found in the laboratory of animal physiology. For the miniresearch to be performed the drifting of glucose through cell membranes was chosen. The methods to be used in the research are a lot similar to the methods used in a research publication by Nikinmaa et al. in 1995[4] about cells of carp.



Picture 2. *The events in biological research: from the blood sample of the rainbow trout all the way to inside the cell membrane.*

Two students of biology were given a task of planning the equipment for the experiment and putting it into practice so that it would make a suitable entirety for senior high school students and the data could easily be processed. The physicists part was determined to be getting the students to become familiar with the methods of measurement and the phenomena studied, that is the possible mechanisms of transportation of matter in cells.

Contents of the course and producing of the material

Before the course even started it was well known that the students should be given more material to study before the research. Because beforehand it was clear that during this course the amount of contact teaching would grow far beyond the usual in network courses, the free material already existing in the internet was utilized as much as possible. The homepage founded specially for that course was used as a channel for distribution of material[5]. The homepage will be maintained at least until the following course begins, and after that the new homepage will include a link to the old material.

Glucose passive diffusive drifting through cell membranes as a function of time was studied at the laboratory of biology. For observing the amount of 3-O-methylglucose drifted, the glucose was marked with carbon 14- isotope, so that it would be possible to observe the concentration of glucose with the beta-counter at all times. The drifting of glucose starts from the plasma surrounding of the blood cell, and so it could have been possible to observe spectrophotometrically the amount of glucose in the plasma and then measure the decrease of glucose in plasma during the drifting process. The practical part of the research showed to the students the different levels of the study and how important it is to be very precise during the whole process. The students did not have knowledge of radioactivity from the last course in the senior high school physics, so the radio-tracer techniques were teached starting from the ground zero. Working team came up with a decision to produce some new material for teaching physics including some problems to solve.

The preparation of the students for the research in laboratory

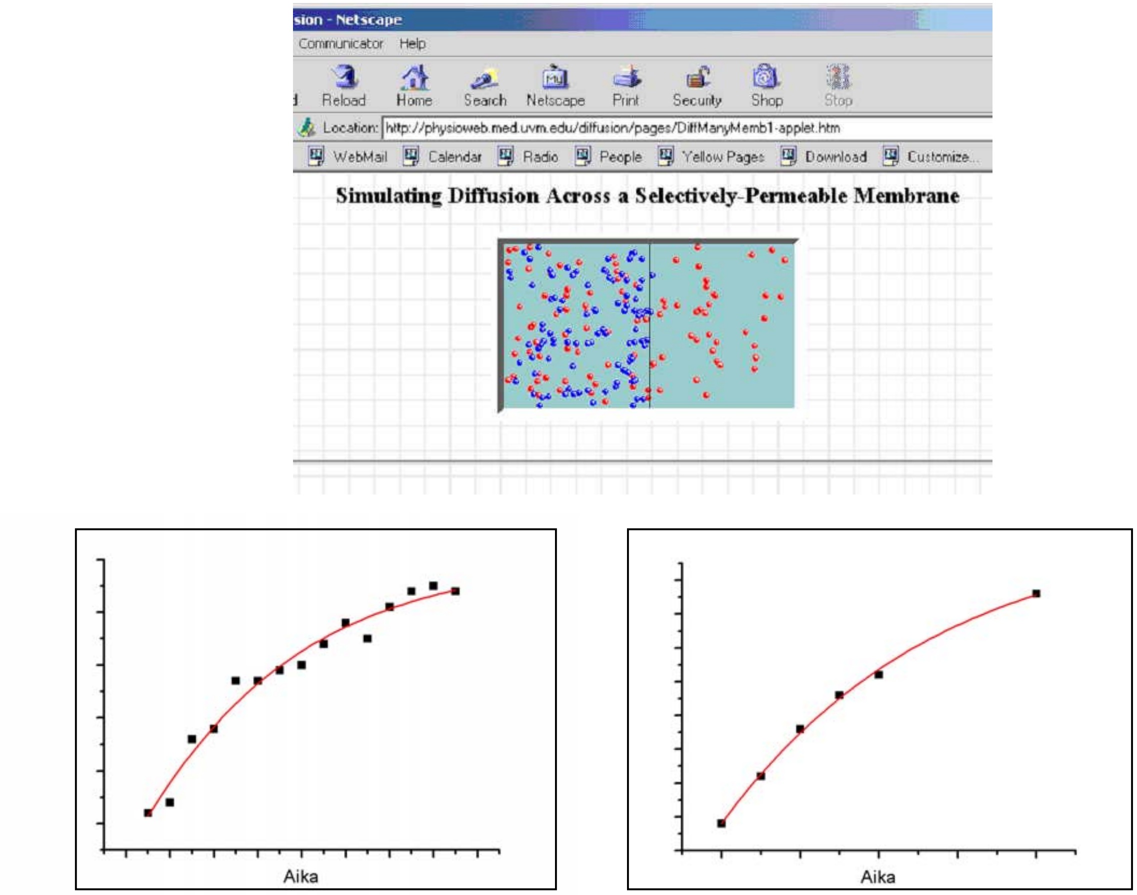
The material distributed in advance was divided into three components- fundamentals of graphic presentation of the data from the research, the working part of physics and the material of biology. The fundamentals of graphic presentation were considered needful because graphic presentation is a important tool in scientific research and it seems that even for students starting their studies at university the meaning and principals of graphic presentation are not clear. The graphic presentations are introduced in the senior high school with slender grounds and students often experience graphic presentations to be hard to form. In transforming the measurement data from numerical form to graphic form, the actual point is often missed. The material explains to the student why the graphic presentation is important including few exercises to ease up the actual process of making graphic presentations during the research project. The use of graphic presentation is argued with five main reasons: 1. To express relationships or laws, 2. To observe qualification requirements to make the law functional, 3. Observing phenomenona based on measured data, 4. The exclusion of truly false data points, 5. To evaluate the inner accuracy of the measurement and the possibility to repeat it exactly the same way. In the end of the material some instructions are given for producing graphic presentations with a computer and some bits of information concerning the expected forms of graphs in biological research are presented.

In the laboratory of physics- background of the phenomena and methods of measuring

The working part of physics included the foundations of radiation physics and the principals of simulating diffusion and radioactive decay with computer. The realisation of the working part of physics based on programmed teaching- like instructions, which included six kinds of exercises: 1. Measurement or experiment, 2. To become familiar with the material, 3. Drawing exercise, 4. Calculation, 5. Exercise with a computer, 6. Brainstorming exercise. It finally came to this mode of action, because of the lack of time, even though some consider it slightly out-of-date. In addition there was only one assistant guiding the groups of students. The instructions were not all straightforward but there were also exercises that required some thinking, for example how is it possible to determine different kinds of radiation from the overall activity of the sample, if the sample is alpha-, beta- and gamma- active at the same time. Before the brainstorm exercises instructions of what different kinds of stages the working process includes were given. The innovative discovering as a part of a physicists job is often mentioned in series of physics books of senior high school in the very end of obligatory courses, but maybe it is due lack of time that it is rarely used a working method in schools. This mode of action was new to the students and they seemed to be enthusiastic about it.

The computer simulations of diffusion and radioactive decay were performed with the help of material obtained from the internet, some of which were presented even in foreign languages. Used this way the internet facilitates the work of teachers. It was rarely recognised among the participants that computer simulations are a remarkable part of making theoretical physics and that in programming in general knowledge of physics is needed. The fact that the information from the net is often visually impressive and the availability of fresh information adds extra value to the use of the internet, for example one might find out what is the national PET- centre in Turku currently using the radio water for.

The measurements consisted of simple research on diffusion with even naive methods, the only target was to make all the students understand how the concentrations were about to balance. In computer simulations balls presenting different compounds penetrated through a membrane dividing two different spaces. The students calculated the amount of balls penetrating the membrane as a function of time and drew a graph to get a preconception of what kind of a presentation comes out when the phenomenon of diffusion is observed as a function of time.



Picture 3. *Simulation:* *http://physioweb.med.uvm.edu/diffusion/pages/DiffManyMemb1-applet.htm*
On the left: a graphic presentation based on a simulation. On the right: Graphic presentation based on average results of diffusion of glucose drifting through membranes.

Observing the quantity weighed for analysis with tracer method was studied with durable preparates and with a neutronwell activated sample of indium. The transmittance of different kinds of radiation was studied and also elements with different half- lives were studied with computer simulations. Also the amount of background radiation, the source of background radiation and its influences on health were estimated. In the very beginning one main target was set; to eliminate prejudices of the students concerning practical applications of radioactive compounds. With the information from the website of STUK - Radiation and Nuclear Safety Authority of Finland, the scale in which radioactive material can be dangerous was made clear.

As soon as the sample of indium was activated, the specific activity of the sample was determined. Beforehand the term ‘specific activity’ used in tracer techniques was strange quantity to the students. Observations of durable preparate (Sr-90, $T_{1/2}$=28,5 a)- and artificially activated indium – 116 ($T_{1/2}$=54 min.)- samples were made by turns. Some differences were observed from the graphic presentations drawn from these observations as a function of time. A difficult brainstorm- like exercise to be solved graphically followed the discussion of applications of differences in half-life times. In the exercise it was determined how it is possible to observe two matters with completely different diffusion times within only one measurement. Finally, at the end of working part of physics, the received amount of radiation and the source where it all came, were evaluated.

In the laboratory of biology- applications of methods and handling living objects of research

In the working part of biology the students got to adapt their knowledge to practical use. The group visiting the lab the day before had already taken a blood sample out of a rainbow trout which they treated with specific step-by-step- instructions by adding first some 3-OMG marked with radiocarbon to the sample.


Pictures 5, 6. *Participants in the aquarium room preparing to catch the trout. (Photo 5: Mr. Henrik Jussila, Turku University Communication and Public Affairs)*

After that the students took at equal time intervals smaller samples from the original blood sample for the research. The sample was then centrifuged and the plasma was sucked away. Intracellular fluids were released by breaking up the remaining blood cells with perclhorid eacid. This made it possible to measure the activity. Measuring the activity was made with a pulse counter and with the activity measured it was possible to calculate the amount of glucose drifting through cell membranes through diffusion. In some cases the results differed quite a lot from ideals, but this was partly the intention, because with this as an example it was easy to emphasise how important it is to be careful and exact in laboratory work.

Finally the students got to anesthetize a rainbow trout, take a blood sample out of it and then restore it to consciousness again all by themselves. In the opinion of he students especially restoring the consciousness of the trout was very impressive and the whole project did not leave faulty image of inhuman animal tests in nobody’s mind.

Performances of the students and evaluation of the course

The actual mark of the course composed of a research report made by the whole group, a personally made diary of the course and the final exam. The group was clearly divided in two in what came to the marks, the intermediate results were weakly represented. A university- like course obviously fits some people but not all. The course could be utilised in all senior high schools as an extra course of biology or physics.

In advance it was well recognised that majority of the participants were orientated in biology. That is why during the course the meaning of physics as a beneficial tool in other sciences was consciously emphasised. Both in advance and after the course, partially same questions were asked where for example the attitude towards a scientists´ profession was measured. The whole evaluation of the course can be read in Finnish on the website of the course. In the inquiry surveying the operation of the distant senior high school in whole, open questions were asked. The most significant results of the inquiry were: 1. All participants chose the course because the contents or the research itself were interesting. 2. Becoming familiar with studying at the university was according to the participants good preview for the future. 3. Making the final report of the research was experienced as a difficult task and more guidance was needed. 4. The participant wished also for more time to work and more independent search for the material.

Future measures- courses for years to come

Organising courses of research at the university is a very expensive way to organise teaching if all starting from the equipment has to be provided for the particular purpose of the course. That is why it is reasonable to utilise resources existing already. Applying the resources properly it is possible to arrange something else than just solving the basic university laboratory exercises in advance. Producing materials and payment for the research assistants took the majority of the 3500 euro budget. In addition a few practically free lessons by a university lecturer were given. However by utilising the existing instruments and free material from the web, ten times the money of the budget was saved.

The course will be arranged also next year. Intention is to tie the working part of the physics more tightly to biological research. By doing this it should get clearer how widely it is possible to apply physics. Also the regional development of bio- sciences in the economic life of Turku is still not utilised.

Websites and more information

[1] **http://www.tkukoulu.fi/˜iltal/etarengas/**

[2] **http://www.physics.utu.fi/opiskelu/opettajat/**

[3] **http://www.utu.fi/ml/biologia/fysiologia/**

[4] Tiihonen, K., Nikinmaa, M., Lappivaara, J., *Glucose transport in carp erythrocytes: individual variation and effects of osmotic swelling, extracellular pH and catecholamines*, The Journal of Experimental Biology, *198*, 577-583 (1995)

[5] **http://www.physics.utu.fi/opiskelu/kurssit/fysbio**

REACHING NEW STUDENTS IN THE NORTH WEST PROVINCE, SOUTH AFRICA

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1. INTRODUCTION

The Third International Mathematics and Science Study TIMSS (1996) ranked the performance of South African children in science as amongst the lowest in 50 participating countries (Howie, 1997). It is also a matter of concern that Physical Science (a combination of physics and chemistry) is unpopular in schools and a few learners enroll for the subject in Grades 10 – 12. In 1998 a new outcomes-based curriculum (Curriculum 2005) was introduced in SA schools (National Department of Education, 1997). This new curriculum is structured on presently accepted educational principles and is aimed at bringing South Africa at the same level as other industrialised countries. The challenge is to upgrade educators to teach the new curriculum with confidence. It needs to be mentioned that the qualifications of South African science educators are in general not adequate to teach modern science effectively.

Staff at the Potchefstroom University in cooperation with officials of the North West Department of Education responded to the challenge to upgrade science educators in the North West province, one of the nine provinces of South Africa. Financial resources are obtained from the private sector.

2. THE SEDIBA PROGRAMME

2.1 Baseline investigation

The Sediba programme focussing on the science educator was started in 1995. The first phase of the programme was a baseline investigation conducted by Smit *et al*. (1997). This extended investigation probed educators' qualifications, deficiencies in training, needs, expectations of further training and revealed demographic information on all science educators teaching at high schools in the North West province. It was established that 1218 educators taught science to Grades 6 – 12 learners in 1997. Of this population 31% was not academically and/or professional competent to teach science as they had little or no training in physics or chemistry. Of the *qualified* science educators almost 50% possessed only a 3-year teachers' diploma (UDE or STD).

2.2 Pilot Project

Based on the results of the baseline investigation it was decided to target the group with only a 3-year diploma. In a pilot project sponsored by the parastatal arms corporation NASCHEM/DENEL, 39 science educators were enrolled in January 1996 for a two-year part-time Higher Education Diploma (HED) in the Sediba Project (Sediba means a water-well in Tswana). The educators enrolled for *Physics, Chemistry, Methods of Teaching Science, Computer Literacy* and *Education.*

The profile of the pilot group of 39 educators is: average age 29 years, teaching experience 5 years. All educators had a three-year educators' diploma with specialisation in science and taught physical science in high schools in the North West province.

Tuition was scheduled in quarterly contact sessions on campus (16 weeks in total over the two years during school holidays). In term time educators worked on assignments at home. Four well-qualified lecturers were appointed. All of them were successful and experienced educators. Students could visit or phone the lecturers between contact sessions. Further contact was through a regular newsletter, *Sediba News,* edited by one of the staff members.

2.3 Reasons why educators enroll in Sediba

All educators applying for study in Sediba are annually asked to indicate on a comprehensive questionnaire to state why they want to study for the HED.

The four main reasons given are (in order of priority)

- To improve their teaching abilities
- Their desire for knowledge
- To earn a higher salary
- To improve their chances for promotion.

2.4 Partnerships

As was mentioned in paragraph 2.2 the arms corporation NASCHEM/DENEL initially financed and still support the project. The North West Department of Education seconded two science educators to assist in teaching.

Research by Smit *et al.* (1998) revealed that success with in-service training of science and mathematics educators in Southern Africa (Botswana, Lesotho, Swaziland, South Africa, Namibia and Zimbabwe) depends to a large extent on financial support from outside the government sector.

At present, more than ten partners contribute financially to Sediba.

2.5 Assessment

The pilot project was continuously assessed. At the end of the first year, the sponsor (NASCHEM/DENEL) decided to call it a programme and to extend it to include mathematics. Annual enrolments of up to 50 new science and 50 new mathematics educators were approved. The programme is continuously assessed. Quarterly reports are issued to sponsors and the North West Department of Education.

2.6 Enrolment and pass-rates

Table 1 gives the enrolment and pass-rates for 1996 – 2001.

It needs to be remarked that the average pass-rate is above 80%.

TABLE 1

Year	1996	1997	1998	1999	2000	2001	2002
Enrollment	39	80	108	104	80	71	80
Pass rate (%)	92	88	81	75	80	81	-

2.7 Research

Research associated with the programme is classified in two categories:

- research related to demographic and organizational issues and
- research on the academic and professional components of the courses.

Special methods of teaching the Sedibas and apparatus to support teaching were developed and researched (For example: Smit, 1998, Smit, 1998b and Wesi, 1998).

2.8 Further studies

The Sediba HED gives access to BEd/BEd(Hons) and these educators may ultimately acquire a PhD.

Until December 2001, a total of 21 Sediba alumni completed the BEdHons(Science Education) and 23 more are in the first and second years of study.

Five Sediba alumni are at present enrolled for MEd.

Lecturers in the Sediba programme have the opportunity to study for higher degrees. To date one acquired a PhD and three masters degrees.

2.10 Impact of Sediba

The impact of Sediba is remarkable. More learners enroll for science in the North West Province, the matric pass rates and average mark for science in the North West Province increase (For example the average mark in the matric paper in 2001 was about 15 % higher than in the years before 2000).

Specific success indicators are

- More than 50 000 science learners are at present exposed to Sedibas and Sediba Alumni.
- Sediba educators teach in the Ikateleng (Saturday school) project, with annual enrollment of about 2 000 Grade 12 learners.
- Sediba was thrice nominated in the past two years for national awards by two instances.
- Sediba alumni are in demand by other universities and NGO's.
- Materials produced in Sediba are widely used in SA schools.
- On average about 25 Sedibas mark final Grade 12 papers (North West) annually.
- Sedibas are motivated for post-graduate studies (See 2.9).
- The programme is so popular that annual applications exceed the number that can be accommodated in the programme by far.

3. Conclusions

The success of the Sediba Programme can be attributed to the following key factors:

- The situation analysis that clearly revealed the great need for dedicated physical science teachers in the North West Province of the Republic of South Africa and which identified the target group.
- The sound research basis of the programme. Through continuous research, academic and professional needs and expectations of the target group are revealed and addressed.

- Maintaining close co-operation and liaison between the North West Department of Education, the Potchefstroom University and the sponsors.
- Addressing the real needs of the educators.
- Employing devoted, well-trained and experienced staff.
- Promoting continuous interaction between the Sediba educators and staff.
- Teachers develop an awareness of the importance to improve their teaching skills.
- Input by teacher representatives toward the management of Project Sediba making management aware of educators' needs and ambitions.
- Rewarding the teachers for their efforts. The university awards a NQF recognized qualification and the North West Education Department a monetary award.

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Learning Mechanics in the Context of *Biomechanics*

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This is part of the ***Humanizing Physics*** Project
Robert Fuller and Vicki Plano-Clark, University of Nebraska-Lincoln
Mark Plano-Clark and Chris Wentworth, Doane College
BethAnn Thacker, Texas Tech University

The students who predominantly populate the algebra-based introductory physics course are typically preparing for careers in the health or life sciences. These students have needs, interests and attitudes that are considerably different from those of physics/engineering students. The ***Humanizing Physics*** project attempts to make explicit connections of physics principles to other sciences, particularly related to human functioning which is innately interesting to all students.

The purpose of this approach is not for students to learn biomechanics per say but to learn physics principles and problem solving through biomechanics as a conduit.
Engagement of students, necessary for a successful active learning curriculum, is enhanced when the material is perceived as being relevant.

Initial Exploration of Concept – Body Directed
Students' own Bodies **-** Movement/Sensation
Students Predict phenomenal behavior - Can student articulate ***"why"*** **?**

Analysis of Concepts with Body Directed Computer Technology

- Graphical Analysis
- Mathematical Modeling

Use of sensors directed at or on ***Students' own Bodies***

Increase Scope of Concept
Human functioning on different Scales (eg. related to molecular/ cellular functioning)
Applications to non-biomechanical Topics

Initial Exploration of Concepts – Body Directed

Students' Own Bodies - Students are introduced to concepts through their own body movements and sensations

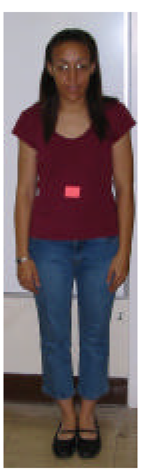
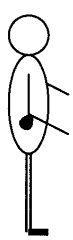
- Body-active introduction activities
    - Commiserate with future applications
        - Techniques for optimizing human motion *sports, skill activities*
        - Minimizing damage to body tissues
            - Impact or sudden injuries
            - Chronic overuse injuries
    - Additional sensory input helps incorporation of concepts
    - Students' own bodies are an accessible, non-intimidating (non-technical) piece of equipment
    - Physics concepts reinforcement possible during daily activities

- Human Bodies instead of Blocks
  A) Human as point object - Dot on human cm - *passive locomotion, self locomotion*
  B) Human moves object *hit, push, throw*
  C) Extended body - Human Body parts *limb rotation*

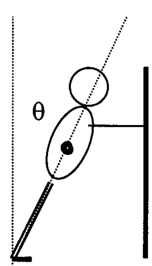
A) Dynamics of Human CM DOT – watch the "Dot" - how, why does that "Dot" move?
Examples:

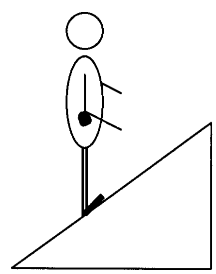
Not Moving - Force and Torque Equilibrium

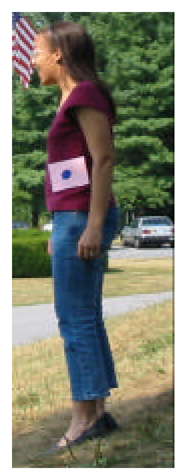
1D Equilibrium

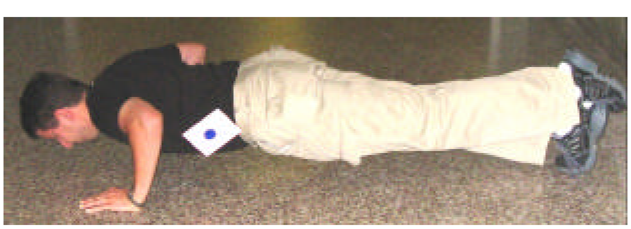
2D Equilibrium







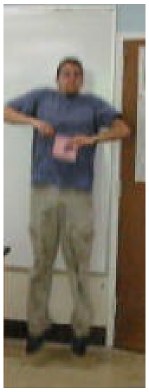
Torque Equilibrium

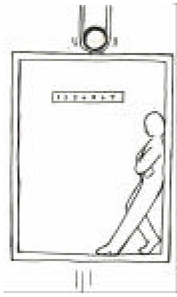


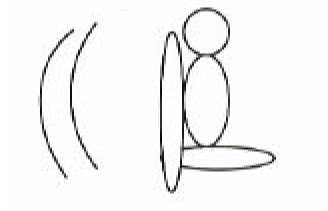
Passive Locomtion

1D Motion/Forces

1D Motion/2D Forces







falling/landing

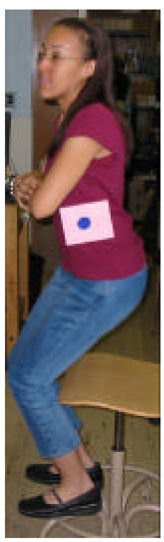
elevator

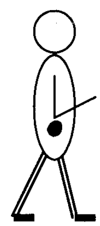
vehicular transport

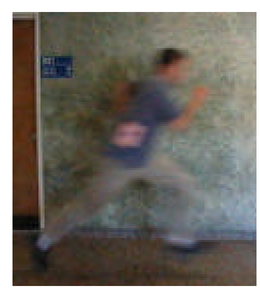
Self Locomotion

1D Motion/Forces

2D Motion/Forces







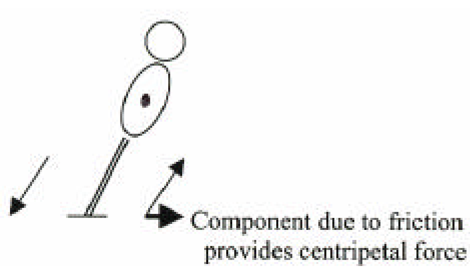
Vertical Jumping

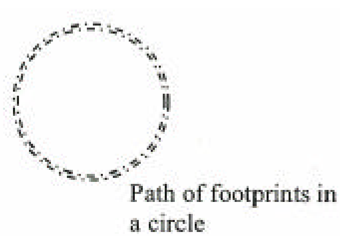
Sitting Getting up out of Chair

Climbing Stairs

Walking

Running

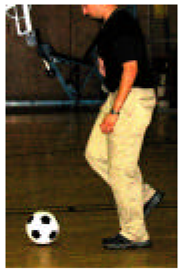
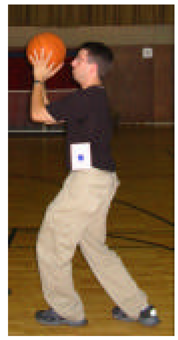
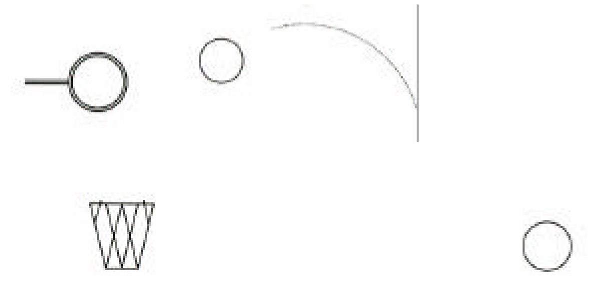




B) Human moves object - connection between body and object's forces and motion

1D Dynamics
- Vertical Throwing
- Horizontal Pushing, Hitting

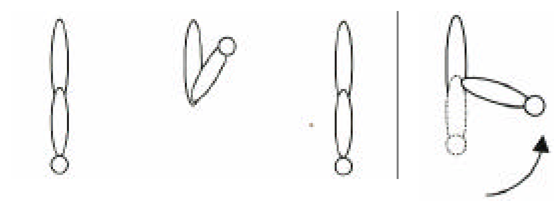
2D Dynamics
Aiming – Projectile Motion

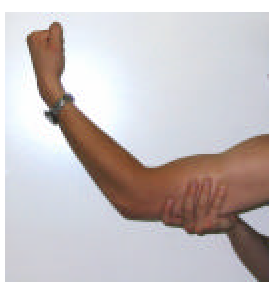
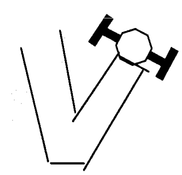
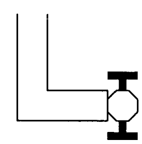
C) Human Body parts - *Rotation of Limbs*

Torque Equilibrium - Muscle forces

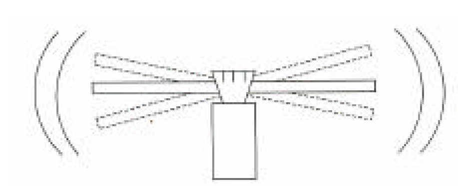

Rotational Kinematics



Torque non-equilibrium – Muscle forces

Rotational Inertia
Angular Momentum
Oscillations/Resonance
- Arms/Legs in walking

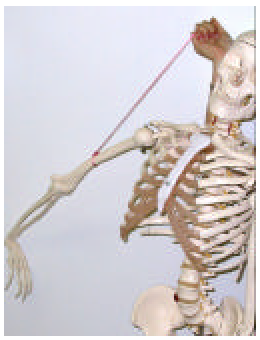


C) Models of Body Parts

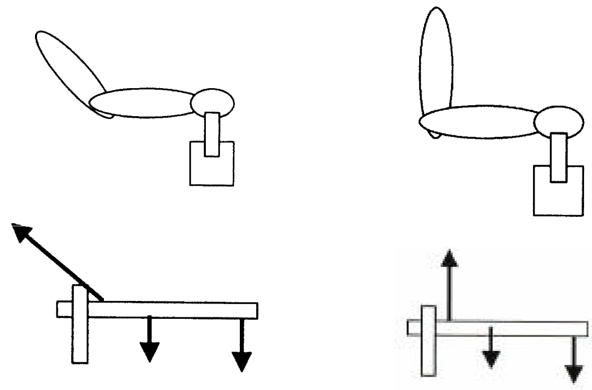
Skeletal parts

Students get kinesthetic sense of magnitude of muscle force by pulling on “muscle” string

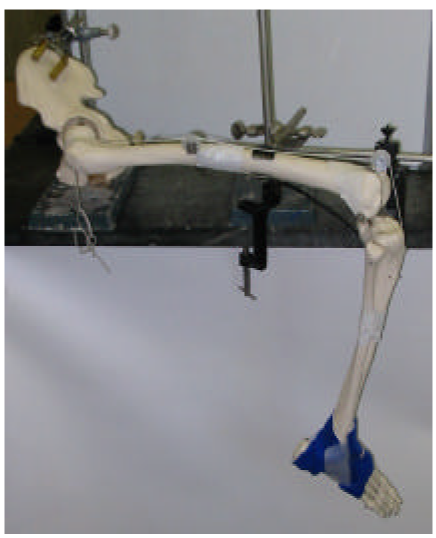
Components



Torque/Torque Equilibrium



Torque non-equilibrium



Oscillations/Resonance

Human Tissue Models

Hair, Collagen based gummi worms

Hooke’s Law, Stress/Strain

Analysis of Concepts with Body Directed Computer Technology

Body Attached Sensors
- Rotary Motion Sensors
- 1D, 2D, 3D Accelerometers

Body Directed Sensors
- Force Platform
- Motion Sensor
- Force sensors

Sensors attached to skeletal parts
- Rotary Motion of Limb
- Force of Muscle
- Force of Floor/Table, etc. on Extremity

Video Analysis Software

- Sensors allow students to relate bodily sensations to graphical representation. Natural progression to graphical analysis and mathematical modeling of body dynamics

- Exposure to aspects of real modeling of complex biological systems involving approximations and simplifications

Students can predict dominant features of graphs and reconcile measurement results with prediction. Data from students' own bodies can be used for individual application

New physics for this audience – true <u>2D dynamics</u>
2D motion w/2D forces - *walking, running, climbing stairs, getting up out of chair*
using: 2D &3D accelerometers on students' bodies, video analysis
- can relate to forces exerted on person during human movement

old - ordinarily limited to - 1D motion with 2D forces (eg motion on an incline)
or 2D motion with 1D force (projectile motion)

Increased emphasis on **rotational dynamics**
- Use of rotary motion sensor to monitor limb rotational dynamics
- Reinforcement of previous translational concepts
- Connections between of translational and rotational
- Kinesiology typically does not go beyond static - missing out on dynamic

Body Attached Sensors

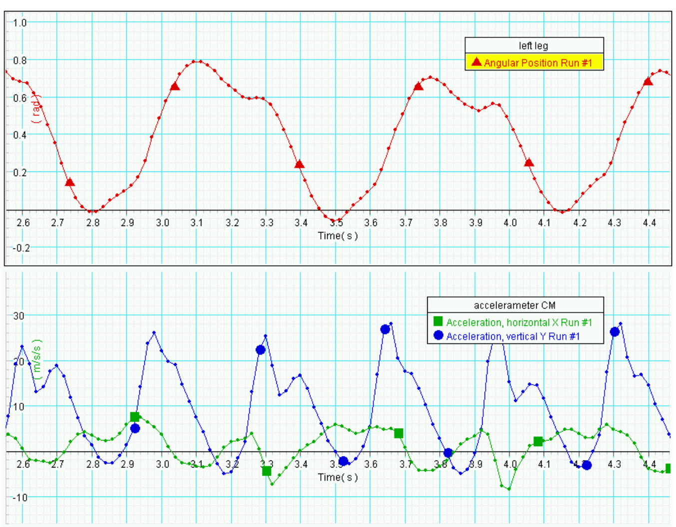
- 2D Linear Dynamics
- Rotational Dynamics
- Relation between 2D Linear and Rotational Dynamics

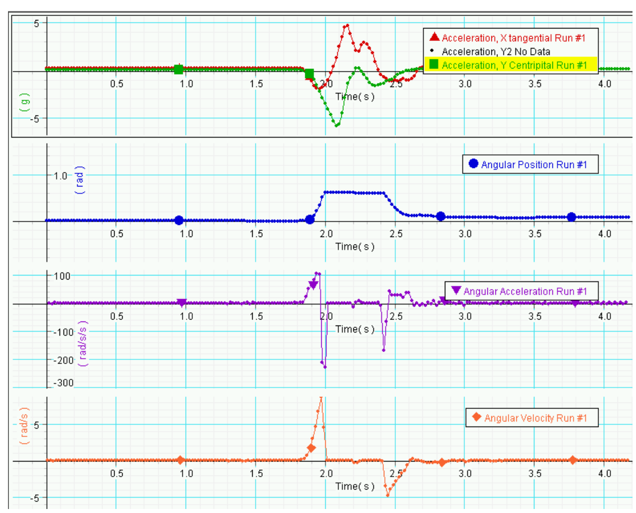
Rotary Motion on Hip
2D accelerometer on Foot

Rotary Motion on Hip
Rotary Motion on Knee

2D accelerometer on Foot

Rotary Motion on Elbow
2D accelerometer on Hand





Walking

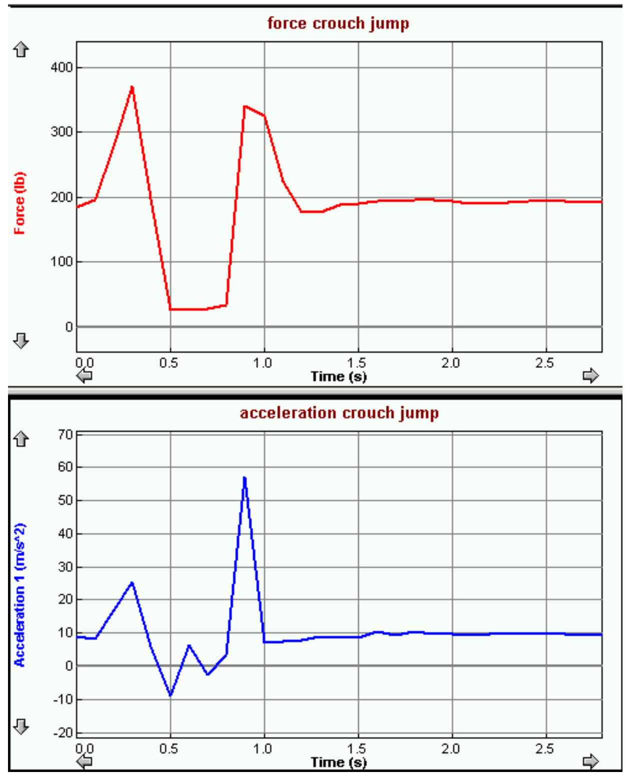
– **Angular Position vs. time**
- **Vertical Acceleration vs. time**
- **Horizontal Acceleration vs. time**

Lifting forearm/hand up and back down

- **Centripetal acceleration of hand**
- **Angular position of forearm**
- **Angular acceleration of forearm**
- **Angular velocity of forearm**

Body Directed Sensors

- 1D Dynamics



Force Plate

Force Plate with 1D Accelerometer

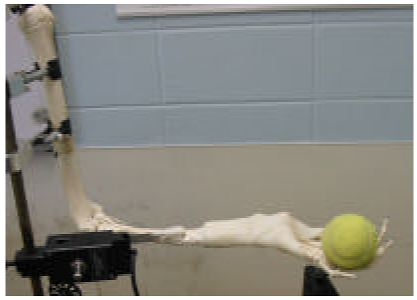
Vertical Jump - Force of “floor vs. time
- acceleration of CM

Motion Sensor

Sensors attached to skeletal parts

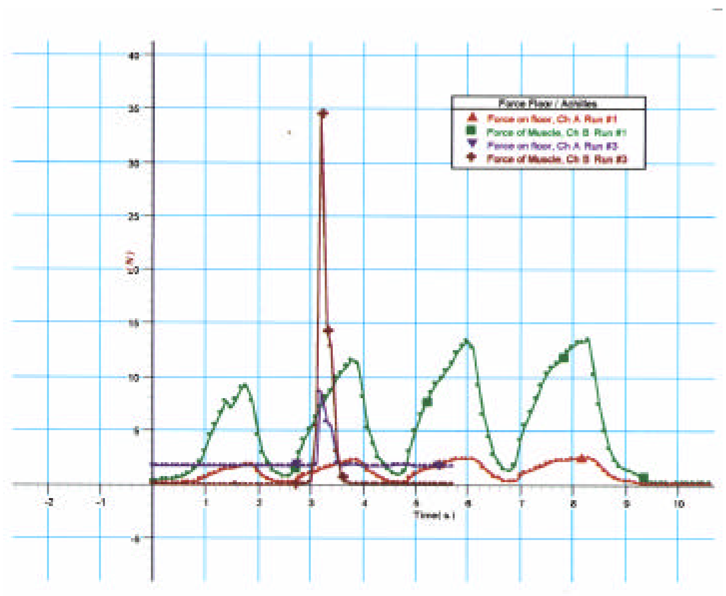
Rotary Dynamics of Limb
Force of Muscle
Force of Floor/Table, Bal l, etc. on Extremity

Jumping
Force Sensor underneath ball of foot
Force sensor on string/Achilles tendon



Throwing a Ball
Rotary Motion on Elbow
Force sensor on String/Biceps muscle

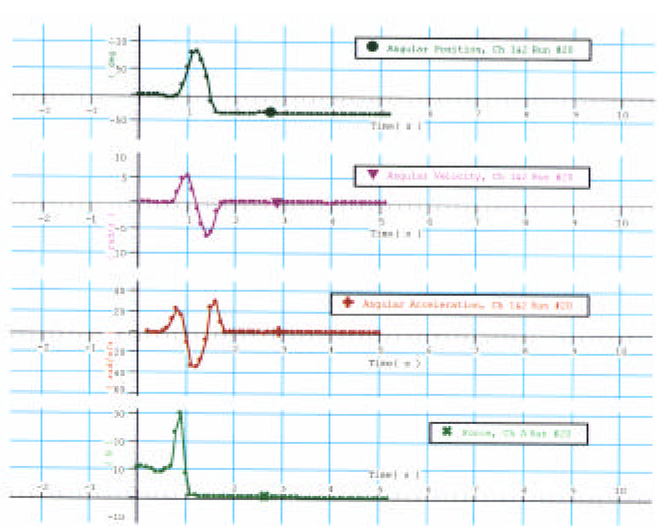
Kicking a Ball
Rotary motion on knee
Force sensor on string/quadriceps



Foot –

Standing Still - tiptoe
- Red – Force of floor on ball of foot
- Green – Force on Achilles tendon

Jumping
- Purple – Force of floor on toe of foot
- Brown – Force on Achilles tendon



Throwing Ball
- Angular position of forearm
- Angular ve locity of forearm
- Angular acceleration of forearm
- Force of Biceps Muscle

LIVING ORGANISMS IN THE EYE OF A PHYSICIST

Magdalena Staszel, Andrzej Majhofer and **Paweł Olasek**
Institute of Experimental Physics, Warsaw University, Poland

Life sciences seem easier and are more appealing to young people than physics. This is also reflected in the very full high school biology curricula and the large numbers of hours allotted. We can turn this into our advantage if we look for reflection of fundamental physical processes in the way Nature solves her problems. In the vast diversity of living organisms one can follow regularities that are connected to fundamental physical laws. To show how physics influences and limits biological designs it is worth while to discuss a selection of examples, of varying degree of depth and complexity.

SIZE MATTERS

When we look at living organisms the first thing that strikes us is their diversity. However, it is to some extent a matter of body size - it varies over 21 orders of magnitude. In order to be able to see through this variation, the allometric scaling laws have been introduced to biology. It seems Galileo was the first to notice and discuss the scaling of animal bones [1]. A recent review of papers on scaling laws appeared as a Resource Letter [2]. Simple examples of scaling involved in various modes of locomotion can be found in [3]; more typically biological regularities are summed up and discussed in [4].

The intriguing exponent

In the 1930s physiologist Max Kleiber showed that an animal's metabolism rate is proportional to its body mass to the power of 3/4 [5]. This holds for living organisms from bacteria to blue whales and giant redwoods. The diagram demonstrating the so-called Kleiber's law is shown in Fig.1.

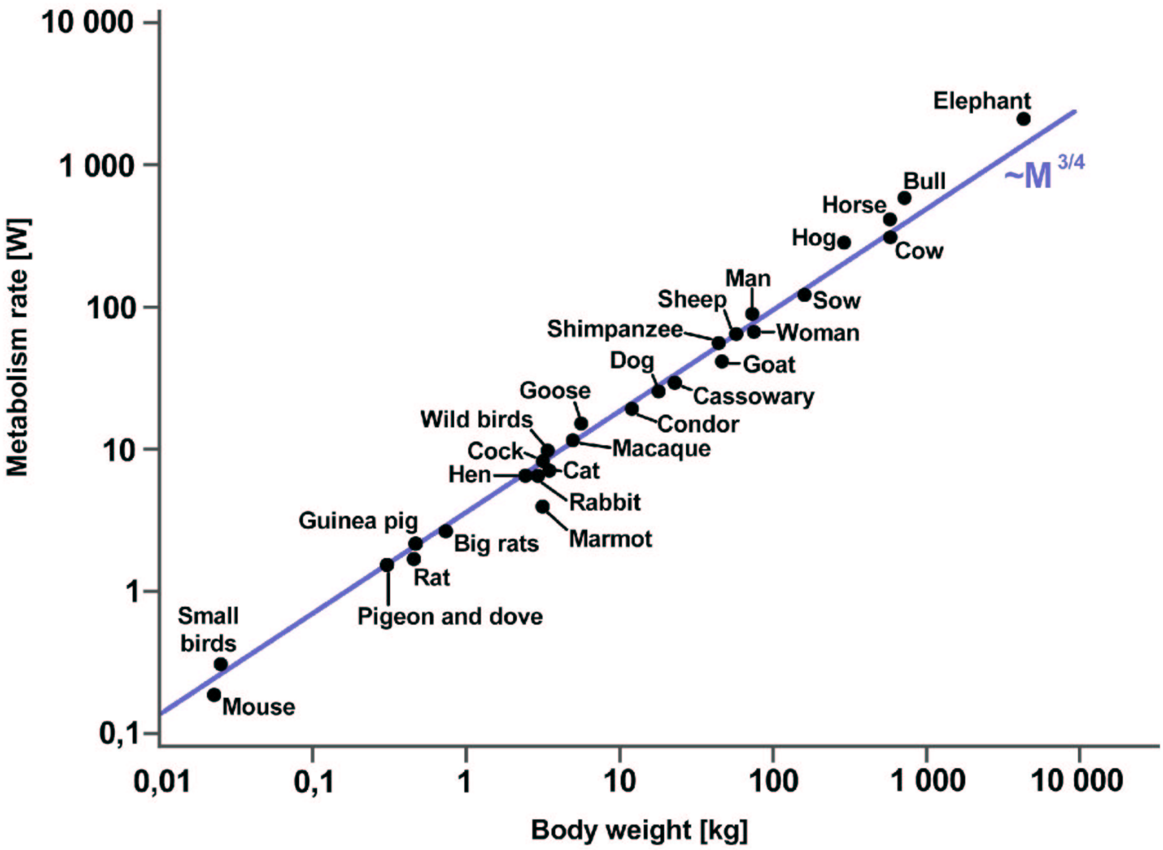


Fig.1. Kleiber's law (adapted from [4]).

Scaling laws with exponents being a multiple of 1/4 apply to many other biological variables: times of blood circulation, embryonic growth and development and lifespan scale as $M^{1/4}$, while rates of cellular metabolism, heartbeat and maximal population growth scale as $M^{-1/4}$. The exponent has puzzled biologists for a long time. Organisms are 3-dimensional, so one would expect rather 1/3 than 1/4 in biological scaling laws. One would expect metabolic rates to scale as 2/3 power of the body mass; this is how body surface area, where metabolic heat is lost, scales with its volume, which determines how much metabolic heat a given organism can produce.

In the late 1990s a hypothesis has been formed [6] that behind the scaling exponent lies the dynamics of organisms' internal transport of nutrients and other resources. The scaling problem is then considered in terms of resource-distribution networks, such as mammalian blood vessels and bronchial trees, the xylem that transports water through plants and the tracheal tubes that carry oxygen to an insect's tissues. The model was developed with three assumptions: 1) in order for the network to supply the whole volume of the organism, a space-filling fractal-like branching pattern is required (Fig.2); 2) the final branch of the network is size-invariant; 3) the energy required to distribute resources is minimized. Scaling laws arise from the interplay between physical and geometric constraints in these assumptions [7].

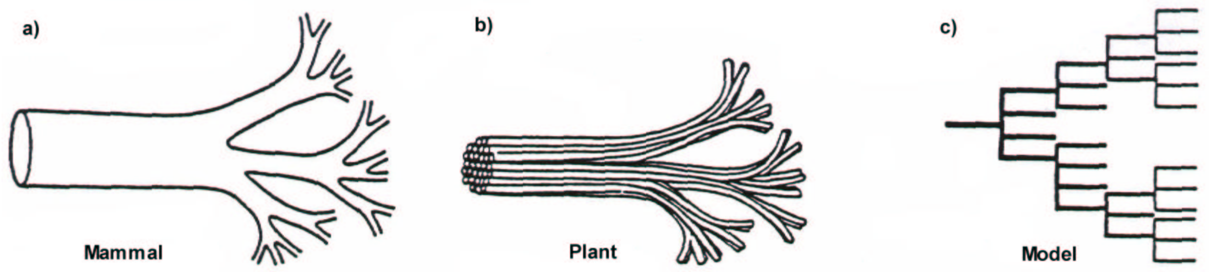


Fig.2. Biological distribution networks: a) mammalian circulatory and respiratatory systems; b) plant vessel-bundle vascular system; c) topological representation of such networks (adapted from [6]).

Too large, too small?

All the terrestrial organisms live in the Earth' gravitational field, and most of them move in air, in water or across the border of the two. There is a limit to mountain height, related to the strength of rocks. The height of living trees is also limited, but not because of simple gravitational loading , but rather because of difficulty of transporting water and nutrients all the way up. A nice study of mechanical properties of biological materials has appeared recently [8]. Looking for physical reasons like hydrostatic pressure, osmotic pressure, surface tension in many biological situations makes a fascinating and enlightening reading [9]. Why do we sink in water, while some insects walk on it, and for other, smaller creatures surface tension can create a deadly trap?

Locomotion of microorganisms

How do very small organisms swim? A delightful paper by E.Purcell [10] gives us much food for thought. One invokes here the Reynolds number, R, which is the ratio of inertial forces to viscous forces ($R=av\rho/\eta$). When the Reynolds number is small, the viscous forces dominate. Besides, small Reynolds number means small absolute force. For a man swimming in water $R = 10^4$; for a goldfish it can go down to 10^2. For microscopic animals it is 10^{-4} -10^{-5}. Their size is of the order of micrometer. In water they move with a typical speed of 30 μm/s. Inertia plays no role whatsoever and the fluid world through which they swim is quite Aristotelean. Swimming means being in liquid and being able to deform one's body somehow. Not all types of motion result in change of location (a motion with one degree of freedom in the configuration space does not take one anywhere). But there exist in nature at least two solutions allowing to swim at low Reynolds numbers: one - a „flexible oar”, the second - a „corkscrew”. An example of the second one can be found in *E.coli* - it has a flagellum. Based on observations and experiments a conclusion was formed that *E.coli* swims by rotating its flagellum, not waving it, and that it has a rotary joint. The efficiency of such propulsion has been found very small (1%), but this is not important as the overall power output in this motion is very small (0.5W/kg). *E.coli* feeds on molecules that reach it by means of diffusion, and motion only serves to shift to the regions where the nutrient density is larger.

COLOR.......

Colors in the living world

According to an exhaustive book by Kurt Nassau [11], the colors in biological systems come from four main sources: pigments, scattering, interference and diffraction, so there is a lot of physics in the way they are generated.

The majority of irridescent colors in biological systems originate in thin film interference. Colors derived from a single film occur e.g. in thin transparent wings of flies, but they are rare; most interference colors are based on multiple film interference. In bird feathers the coloration usually occurs on the surface of the barbules - overlapping members between the barbs - the lateral structure feather components extending on either side of the main shaft of the feather (see Fig.3). The peacock and blue jay owe their colors to this mechanism.

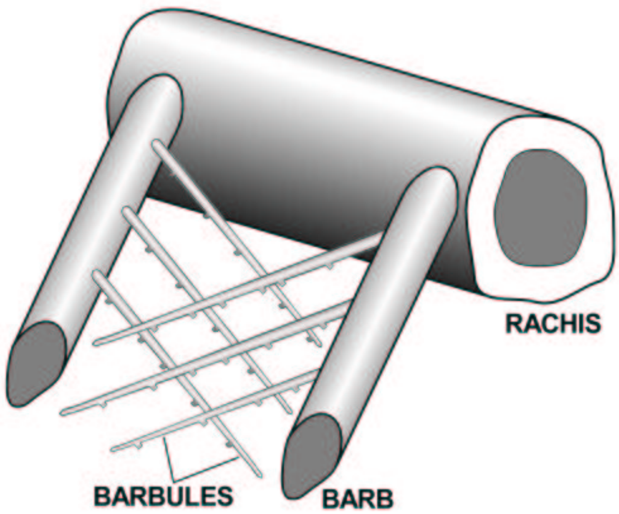


Fig.3. Color-generating structure of a feather (adapted from [11]).

....AND VISION

Nature has produced many optical visual systems. A review of animal senses, including the number of eyes of various species and their spectral sensitivity, is presented on the www site [12]. We have a „normal" refractive human eye with a single lens. We think this is a good eye.

There are many excellent materials on the anatomy and working of a mammalian (especially human) retina, e.g. [13, 14]. Nature invented (and improved) the same design again; the giant squid has the eye with the same optical structure as ours, but with better retina configuration, resulting in no blind spot. The eye is huge - 20-30 cm in diameter, but the creature itself is huge.

For small organisms a compound eye seems to be a better solution - e.g. for insects and butterflies. The bee's eye has been studied deeply and both its structure and vision range is well known. A description and a nice teaching simulation of how the bee's eye sees the world can be found on www site [15].

The Nature's compromise

Feynman [16] has considered the resolving power of a bee's eye. The eye is made up of many conical cells - *ommatidia* - arranged in a hexagonal array on the roughly spherical surface on the outer side of bee's head. On top of each cell there is a lenslet, and each ommatidium has its own optical nerve. What is the resolution of this eye? One can estimate the diameter δ of a facet on a surface of a sphere of radius r (the head, see Fig.4a) assuming that evolution did a good job. If the facet is too large, the resolution is poor. Too large opening angle, $\Delta\Theta_g = \delta/r$, spoils the sharpness of vision. The reason the bee does not have very small facets is the existence of diffraction limit; the eyelet gathers the light from an angle $\Delta\Theta_d = \lambda/\delta$. One looks for the minimum of the total influence of the two factors (Fig.4b), which occurs for $\delta=(\lambda r)^{1/2}$. Assuming r=3 mm, λ=4000 Å, the estimated diameter is 35 μm, which is close to measured 30 μm. The world seen with bee's eye is not very sharp anyway. For a human type eye, however, the bee is too small. The eye would either submit to overwhelming diffractive effects or take up the whole head volume. For a bee the existing solution is optimal.

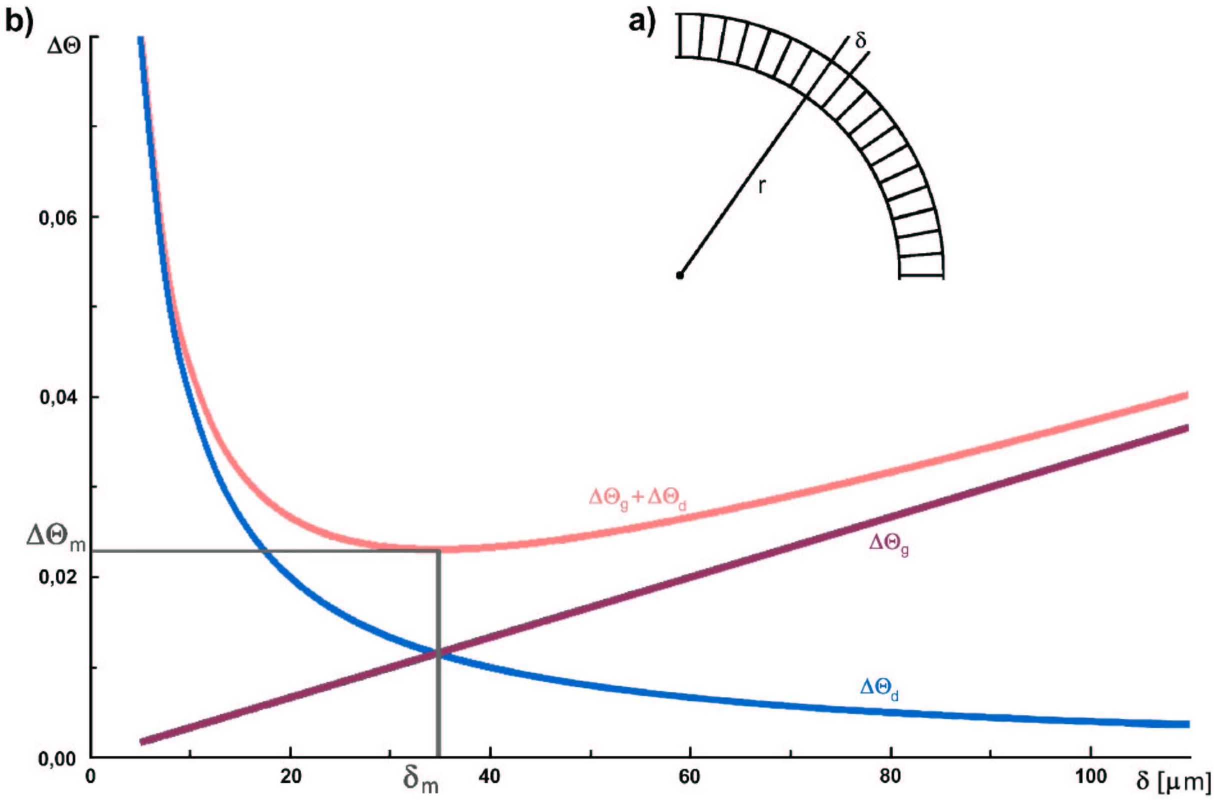


Fig.4. a) The arrangement of facets in bee's eye; b)δ_m is the optimal facet size (cf. [16]).

The mirrors in your eyes

Nature invented and used thin films aeons before man learned to apply consciously antireflective coating. Not only to create a visible effect (animal eyes shining in reflected light- see the photograph below, coloured wing or skin surfaces), but also to make a good sensory apparatus. Below we shall quote some examples of the eye structure that involve thin films as mirrors.

It has been thought for a long time that all the „geometric optics” functions of the eye are fulfilled by lenses. By an unanimous agreement living organisms were not supposed to produce mirrors. However, an organic reflecting surface can be formed with thin films. Multiple layers of alternating high and low refractive index materials yield a mirror surface. Each layer of the stack must have a thickness of 1/4 of a wavelength of the illuminating light, so the light is reflected in phase from all the interfaces of the stack. Because only one wavelength is reflected, the mirror is brightly colored. The high and low refractive index can come e.g. from chitin (1.56) and air (1.00), respectively.

Why do some animals need mirrors? To see better, of course. It turned out that there are three main types of compound eye (Fig.5) [17].

a) Apposition eyes - made up of a hexagonal array of lenslets, each of which has its own set of photoreceptor cells. Such eyes have diurnal insects, e.g. our bee.
b) Superposition eyes, in which each lenslet has a radial gradient of refractive index and bends the light continuously so as to focus the multiple rays entering the array at the single spot on the retina; such eyes have nocturnal insects.
c) Superposition eyes, consisting of a square array of mirror-lined plugs, which superpose light on a single spot on a retina. Such eyes belong to lobsters, shrimps and crayfish. The mirrors help then to focus the light on the single spot on the retina, because the lens itself is not very efficient.

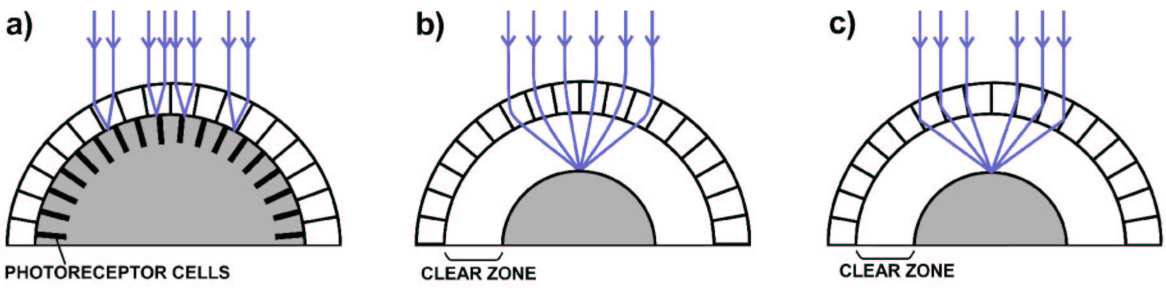


Fig.5. Three types of compound eye (adapted from [17]).

Several other imaging systems based on a superposition eye have also been found [18].

♦

This is only a sample of topics that can be pleasurably and profitably introduced into teaching, without the stigma of „physics, rather inhuman, besides being boring and incomprehensible” or „biology, so we have to count leaves and petals”. All the truly „real-life” problems are more complex than somewhat sterile „pure physics” problems. However, they can wake scientific curiosity and make young people aware of the fact that a multitude of very diverse phenomena are based on relatively few physics laws. It is a signal that a lot of biological facts, the nature designs, are of physical origin. We think this has not been exposed enough in education.

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