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International Conference on World View on Physics Education

In celebration of the International Year of Physics 2005, a Conference on **World View on Physics Education 2005: Focusing on Change** will be held in New Delhi, India on 21-26 August 2005. The sponsors of the conference include International Commission on Physics Education (ICPE), International Union for Pure and Applied Physics (IUPAP) and the United Nations Educational, Scientific and Cultural Organization (UNESCO).

The conference has the following themes: (1) Changes in the ways of teaching-learning of physics, (2) Changes in the understanding of the teaching-learning process, (3) Changes in the content of physics as a discipline and (4) Changes in the context of physics teaching.

Noble Laureate Prof. Horst Stormer of Columbia University, USA and Lucent Technologies will deliver the Inaugural Plenary.

Some selected proceedings would be telecast via EDUSAT, India's indigenous Educational Satellite which would transmission and interactive linkage to any part of India.

The main thrust of deliberations would be Undergraduate and Senior Secondary Physics Teaching. Only glimpses of physics at other levels shall be provided through special exhibitions, poster sessions, *etc.*

Two special sessions - *Nurturing Women in Physics* and *Physics and Sustainable Development* - are planned.

See page 3

In this issue

PHYSICS AND SUSTAINABLE DEVELOPMENT

On October 31 to November 2, 2005, the **World Conference on Physics and Sustainable Development** will be held in Durban, South Africa in celebration of the World Year of Physics. The Conference will offer a unique opportunity for the international physics community to come together and formulate a plan for tackling some of the large problems facing the world. In the past physics has made tremendous contributions to the health and welfare of people and nations. Think of the contributions that physics has made to the world economy in areas such as electronics, materials, and computer technology, and to health through x-rays, magnetic resonance imaging and nuclear medicine. These contributions are ongoing and should be celebrated during the World Year of Physics and at this Conference. However, many of these contributions have

See page 3

ICPE Chair's Corner

We have now spent a few months of the *World Year of Physics*, or the *International Year of Physics* as the United Nations liked to call it. As probably most of you know, the idea was born in the year 2000 during the celebration of the Max Planck centenary in Berlin. Martial Ducloy of France, later to become President of the European Physical Society (EPS), started reminding us of the splendid opportunity to celebrate the centenary of the miraculous 1905 year of Einstein, and make it into a really global year of physics. EPS accepted the idea.

All major international organizations with physics or science interests joined, like IUPAP and UNESCO, and finally the UN General Assembly passed a resolution last June to the same effect. In January of this year, a Launch Conference was arranged at the UNESCO headquarters in Paris. The meeting had the suitable title *Physics for Tomorrow*. Not only was it attended by several very distinguished speakers, some of whom were Nobel laureates, but also by several hundreds of young people from all over the world. All of us who attended this conference were duly impressed by the presence of these (hopefully) future scientists.

For ICPE the main event will be the conference arranged by our member Pratibha Jolly and her collaborators in New Delhi in August of this year.

The title "World View on Physics Education in 2005: Focusing on Change" is a challenge to all of us in the community to think of the future of physics in schools and universities. The string of international physics education conferences supported by ICPE and IUPAP in 2003, 2004 and 2005 in Cuba, South Africa and India, respectively, sets up an extremely valuable complement to others arranged in countries with longer traditions in this respect.

In October 2005, Durban is again hosting a conference, sponsored by UNESCO, IUPAP, International Centre for Theoretical Physics (Trieste) and the South African Institute of Physics. The dates are October 31 to November 2 and the title *World Conference on Physics and Sustainable Development*.

Physics Education is one of the four themes chosen for the agenda; the others are *Physics and Economic Development*, *Physics and Health*, and *Energy and the Environment*.

However important these international manifestations are, it is probably promoting the cause of physics even more if things happen locally, with activities initiated by us individual physicists in our surroundings.

In this way one can, for instance, strengthen the contacts between schools and university physics: invite school pupils to come and see your laboratories. If you are working at a university, you can go out to the schools and meet teachers and pupils in their daily environment, arrange exhibits, give public lectures, get in touch with media and use the opportunities for comments on physics events in the research community. An excellent tool for keeping up with news is subscribing at http://physicsweb.org.

At the end of this year, the IUPAP Council meets in Cape Town to prepare the agenda for the IUPAP General Assembly. One of the major tasks of the Assembly is to decide about the future officers and Commissions. This implies that for some of us our next ICPE annual meeting in New Delhi will be the last. Fortunately, some members will stay for another three-year term, to secure the continuity. My own farewell can wait until our next issue of the Newsletter.

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World Year of PHYSICS 2005

Coinciding with 100th anniversary of Albert Einstein's "Miraculous Year", the events of the World Year of Physics 2005 aim to raise the worldwide public awareness for physics and more generally for physical sciences.

http://www.wyp2005.org

FUNDAMENTAL PRINCIPLES IN INTRODUCTORY PHYSICS

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The goal of the contemporary physics enterprise is to explain a broad range of phenomena using only a very small number of powerful fundamental principles. Although instructors and textbook authors may see the enterprise this way, this is not the view typically acquired by students in the calculus-based introductory course. The result of conventional instruction is to reinforce the student's belief that there exists a separate formula for every situation, and that the student's task is to figure out which of these formulas to use. Students may even believe that it is the responsibility of the teacher or the textbook to tell them which formula to use! We have developed a new, modern, curriculum, *Matter & Interactions*, which emphasizes the power of fundamental principles, and guides students through the process of starting from these principles in analyzing physical systems, on both the macroscopic and the microscopic level. The continual emphasis on the application of fundamental principles and on the atomic nature of matter makes possible the integration of topics that are traditionally taught as disconnected: mechanics and thermal physics are intertwined, as are electrostatics and circuits. For additional information, see http://www4.ncsu.edu/~rwchabay/mi.

Continue to next page

INTERNATIONAL... *from page 1*

Specially designed Satellite Events would be open to senior school and college students to enable them to interact with eminent physicists and educators participating in the conference.

A special first day registration is likely to enable the larger community of physicists, physics teachers and other stakeholders to participate. The program would then give a preview of the conference. The remaining days would tend to be more technical.

Registration for the conference opens on 13 January 2005. Last day for early registration will end 8 June 2005. Abstracts may be accepted until 11 April 2005 and confirmation of their acceptance will be given on 23 May 2005.

Source: http://www.icpe2005.net/index.html
http://www.icpe2005.net/html/program.htm

PHYSICS... *from page 1*

benefited people in the developed world more than those in the developing world. The World Conference will give the physics community the chance to begin to focus on how we can work with colleagues in the developing world to bring more benefits to their world.

As part of the celebration of the *International (World) Year of Physics*, *UNESCO*, the *Abdus Salam International Centre for Theoretical Physics* (ICTP), the *International Union of Pure and Applied Physics* (IUPAP), and the *South African Institute of Physics* (SAIP) have joined together to sponsor the World Conference. It is expected that 500-600 physicists from around the world as well as representatives of physics organizations and the private sector will participate. With the help of many organizations, funds will be available to help support at least 250 physicists from the developing countries and Eastern Europe.

Four themes have been chosen for the conference. These are *Energy and Environment*, *Physics and Health*, *Physics Education* and *Physics and Economic Development*.

For each theme, an international Program Committee will develop a program that that will allow participants to formulate an action plan for the future. It is hoped that the Conference will encourage the broad physics community to initiate new mechanisms of cooperation to carry out its plan of action. The Conference will also provide an international forum to develop closer communications, partnerships and networks among physicists, industrialists and policy makers from developed and developing countries.

The Conference is planned for three days. The first day, a plenary session, will be used to introduce the four Conference themes and the contributions of physics toward each. Day one will end with a reception and poster session, to which all participants are invited to contribute. The second day will be spent primarily in smaller group meetings for each theme to develop the action-oriented outcomes. There will be a banquet on the evening of day two. The final day, again plenary, will be used to hear reports from the theme-oriented discussion groups and decide on final Conference outcomes and action items.

Email updates regarding accommodations, registration and other information may be received by visiting the web site *http://www.wcpsd2005.org.za/email.asp* to place your name on the mailing list.

Source: http://www.wcpsd.org/objectives.cfm

FUNDAMENTAL... *from page 3*

Introduction

Physics is characterized by the search for deep, fundamental principles. The power of physics is based on the idea that from a small number of fundamental principles it is possible to predict and explain a broad range of phenomena. However, despite the intent of physics instructors and textbook authors, many students perceive the calculus-based introductory physics course to consist of a large number of special-case formulas, each specific to a very narrow range of situations. In the typical course students are not asked to analyse novel situations but rather to make small changes to previously solved problems. The emphasis is on specific solution patterns rather than on reasoning from powerful, universal principles.

We have created a new curriculum and accompanying textbook, *Matter & Interactions* (Chabay and Sherwood, 2002), which is structured to make clear to students that there is a small number of fundamental principles, which the students themselves can employ to analyse a broad range of phenomena. In mechanics, these are the momentum principle, the energy principle, the angular momentum principle, and the fundamental assumption of statistical mechanics. In electricity and magnetism, we add conservation of charge and the field concept, as expressed in Maxwell's equations. This emphasis on fundamentals permits the integration of topics that have traditionally been kept completely separate. For example, mechanics and thermal physics are intertwined, and both electrostatic and circuit phenomena are analysed using the same concepts and principles. Students are continually asked to analyse new situations, different from ones they have seen before, by starting from these fundamental principles.

In addition to its emphasis on starting from fundamentals, the *Matter & Interactions* (M&I) curriculum is modern throughout. From the beginning, it emphasizes the atomic nature of matter, and does not relegate atoms to a final chapter that no one has time for. Students themselves engage in building physical models of messy real-world phenomena, including making idealizations, simplifying assumptions, approximations, and estimates, instead of solving only sanitized problems in which all such modelling has been done silently by the textbook author. As a part of this process, students write computer programs to model and visualize mechanical systems and fields in 3D using VPython (http://vpython.org) as an introduction to computational physics, which has become an equal partner to theory and experiment in the contemporary physics enterprise. Details of the mechanics course are described in Chabay and Sherwood (2004); aspects of the integration of mechanics and thermal physics are described in Chabay and Sherwood (1999). For additional information about the textbooks and curriculum, see http://www4.ncsu.edu/~rwchabay/mi.

Fundamental principles

Students who have completed the introductory calculus-based physics course should see clearly that a small number of fundamental principles can explain a very wide range of phenomena; this should be a central goal of the course. Students should learn to feel capable of applying principles to new problems. They should see the place of classical physics in the larger physics framework (including the atomic nature of matter, quantum mechanics, and relativity), and they should have experience with semiclassical analyses. In contrast, the typical rationale given for introductory physics is to learn systematic problem solving, to learn to separate the world into system and surroundings, and to practice applying mathematics. Little attention is given to the larger goal of bringing students to see the unity of physics and the power of a small number of fundamental principles.

> **The traditional calculus-based introductory physics course has been unchanged for 50 years and is all classical, all macroscopic, with anonymous, featureless objects of mass *m* and charge *q*.**

The theory expounded in lecture is often disconnected from the experiments done in the lab. There is no computational physics, despite the fact that contemporary physics is now characterized as the interplay not only of theory and experiment but also of computation. A serious failing is that the traditional course does not connect to contemporary topics such as materials science, biological physics, nanoscience, astrophysics and cosmology, nonlinear dynamics, quantum computing, condensed matter physics, particle physics, or computational physics.

In the traditional calculus-based introductory physics course the fundamental concepts are introduced quite late, and consequently are not seen by the student as having central importance. In a typical introductory textbook force is introduced in chapter 5, energy in chapter 7, momentum in chapter 9, and angular momentum in chapter 12. Consequently, what students see as the most fundamental principle in all of physics is $x = (1/2)at^2$, the formula they have used the most.

Traditional instruction focuses on solutions to classes of problems (constant acceleration, circular motion at constant speed, static equilibrium, etc.) rather than on reasoning from fundamental principles. There is a nearly exclusive emphasis on deducing unknown forces from known motion (or lack of motion), with no opportunity for students to experience the power of the Newtonian synthesis, in which motion is predicted from initial conditions and a force law. As a result of this emphasis, students in the traditional course do not see clearly that a small number of fundamental principles can explain a very wide range of phenomena. Rather what comes across to the students is that each situation has its own formula.

During the past 20 years there has been significant research on the learning and teaching of physics, conducted by researchers within the university physics community. One of the central results of this research has been the finding that effective teaching and learning does not come easily, and requires a significant investment of effort and time on the part of both instructors and students. Physics education researchers have developed a variety of improved pedagogical approaches which do in fact improve students' learning of the traditional introductory physics topics.

We argue that it is time to ask a different question: what educational goals are worth such an investment of time and effort? What should students learn in the introductory course? A clear set of educational goals (not just a list of physics topics) needs to be articulated. The goal of the M&I curriculum is to engage students in the contemporary physics enterprise, by emphasizing:

- A small number of fundamental principles, from which students start analyses
- The atomic nature of matter, and macro/micro connections

See next page

FUNDAMENTAL...*from page 4*

- Unification of topics, facilitated by the atomic view of matter
- Modeling physical systems, including computational modeling

As an example, in mechanics the fundamental principles are introduced much earlier than has traditionally been the case. The momentum principle is introduced in chapter 1 and used from then on; the energy principle is introduced in chapter 4, the angular momentum principle in chapter 9, and the fundamental assumption of statistical mechanics in chapter 10. This in itself makes the fundamental concepts and associated principles stand out as truly central to the enterprise.

In the traditional curriculum, the momentum principle (Newton's second law) is not actually central. In its general form, it is introduced very late in the course. In *Matter & Interactions* it is introduced immediately in chapter 1 in the form $\vec{p}_f = \vec{p}_i + \vec{F}_{net}\Delta t$, where $\vec{p} = m\vec{v}/\sqrt{1-v^2/c^2}$. The concept of momentum, and the idea that for a known force law the motion of objects can be predicted into the future in an open-ended fashion, is central to the entire mechanics course. We introduce the Newtonian Synthesis: initial conditions plus the momentum principle plus a force law make possible an iterative update of momentum and position, showing the time-evolution character of the momentum principle. (This picture constrasts with the understandable perception of students that $F = ma$ is essentially an algebraic statement of proportionality, with no sense of time evolution.) Students carry out one or two steps of the Newtonian Synthesis on paper, then write computer programs to study planetary orbits, spring-mass oscillators, and scattering. We place less emphasis on deducing forces from known motion, such as deducing the support force of an inclined plane on a sliding block.

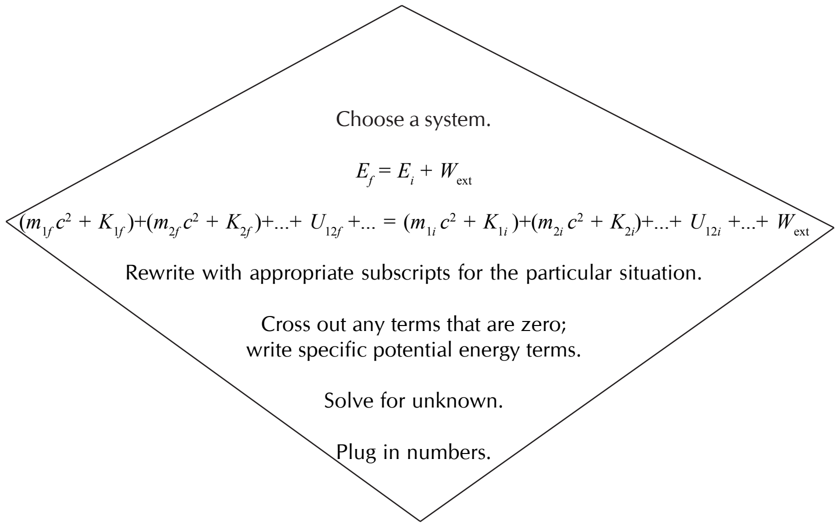
Teaching students to start from fundamentals

It is important that students be able to approach problems of a kind they've never seen before. This requires starting from a fundamental principle rather than using a solution from some previously solved problem or grabbing a tertiary formula.

> **The idea of starting every analysis from a fundamental principle is a new one to most students, whose previous schooling has stressed memorizing formulas to be used in particular kinds of problems.**

To these students, it is not obvious how they will obtain a solution (the desired quantity) by starting with an equation that may not explicitly contain that quantity at all. Thus, part of the instruction and acculturation necessarily involves explicit teaching of what it means to start from a fundamental principle, and how to move from the general statement of the principle to a detailed analysis using information particular to a specific situation.

One useful representation was developed by an undergraduate teaching assistant, who himself had taken the course only a year previously (Alex Schriber, personal communication, April 2004). He envisioned the problem solution process as a diamond-shaped flow, first expanding from a fundamental principle, then contracting to a final solution. Many students found this graphic device extremely helpful in clarifying what was meant by starting from a fundamental principle, and indeed were able to apply it to the solution of problems which



they had previously found intractable. Here is an example of his "diamond" approach, starting with the energy principle:

Without this visual guide to the problem solving process, students had typically focused only on the last step: plug numbers into some formula.

Examples of large problems involving modeling

Here are some examples of novel situations which we assign students to analyze as homework problems. Applications of the momentum principle:

- Running students collide (find the force of one student on the other)
- NEAR spacecraft encounters Mathilde asteroid (a detailed statement follows below)
- Finding dark matter (how Vera Rubin discovered this in galaxies)
- Black hole at galactic center (find the mass from the orbits of nearby stars)

Applications of the momentum principle plus the atomic nature of matter:

- Ball-and-spring model of solid
- Macro-micro connection: Young's modulus yields interatomic spring constant k_s
- Model propagation of sound in a solid; determine speed of sound
- Diatomic molecule vibration: estimate the frequency from interatomic k_s

Quantum statistical mechanics of the Einstein solid at the end of the mechanics course: students fit data for the low-temperature heat capacity using k_s obtained from Young's modulus.

Here is the problem statement concerning the NEAR spacecraft mission:

> In 1997 the NEAR spacecraft passed within 1200 km of the asteroid Mathilde at a speed of 10 km/s relative to the asteroid (http://near.jhuapl.edu). Photos transmitted by the spacecraft show Mathilde's dimensions to be about

See page 6

FUNDAMENTAL...*from page 5*

> 70 km by 50 km by 50 km. It is presumably composed of rock; rock on Earth has an average density of about 3000 kg/m^3. The mass of the NEAR spacecraft is 805 kg.
> A) Sketch qualitatively the path of the spacecraft:
> B) Make a rough estimate of the change in momentum of the spacecraft resulting from the encounter. Explain how you made your estimate.
> C) Estimate the deflection (in meters) of the spacecraft's trajectory from its original straight-line path, one day after the encounter.
> D) From actual observations of the position of the spacecraft one day after encountering Mathilde, scientists concluded that Mathilde is a loose arrangement of rocks, with lots of empty space inside. What about the observations must have led them to this conclusion?

These homework problems deliberately transcend the traditional narrow restrictions of introductory mechanics. Classical mechanics taught in isolation is sterile, and can lead to wrong physics. Classical mechanics needs to be embedded in the larger context of thermal physics, relativity, and quantum physics to be authentic to contemporary physics, which is often semiclassical. After a traditional mechanics course, a math major in our E&M course said, "Last semester they presented mechanics as a closed axiomatic system. I thought I had learned something of universal validity, and I felt betrayed when I found that wasn't true. I appreciate an axiomatic treatment in math courses, but that's not appropriate in a physics course."

Students' perception of fundamentals

Do students studying the M&I curriculum in fact see and understand the power of fundamental principles in physics? One source of information is students' own reflections. Students were asked to write a paragraph to answer a question such as, "In your opinion, what was the most important concept in chapter 3?" Here is an example of a student reflection:

> In my opinion, the central idea in this chapter was to learn that atoms bonded to each other can be thought of as two balls connected to one another with a spring. Once we understood this concept, we could apply the models of springs from the macroscopic world to the atomic level, which gave us a general idea of how things work at the atomic level. Understanding that gave us the ability to predict vibrational frequencies of diatomic molecules and sound propagation in a solid. It is absolutely amazing how we can use very simple concepts and ideas such as momentum and spring motion to derive all kinds of stuff from it. I truly like that about this course.

A second measurement of students' view of fundamentals was made in a problem-solving study.

How students use their knowledge reflects the nature and organization of the knowledge.

In a protocol study very difficult, novel problems were posed to volunteer students from a traditional course and to students from an M&I course at the same institution. A striking difference in the two populations was that students from a traditional course tried to map each problem onto a problem whose solution they knew, and/or looked fruitlessly for a formula for the particular situation. In these difficult problems this mapping was inappropriate; for example, students tried to use results from uniform circular motion in analysing an elliptical orbit, or to use constant acceleration results to describe air resistance forces (Chabay, Kohlmyer, & Sherwood, 2002). In contrast, even if they were not able to complete the difficult analysis, all M&I students started from a fundamental principle (Kohlmyer, Chabay, and Sherwood, 2002).

Integration

The emphasis on starting from fundamental principles, and the stress on an atomic view of matter, makes possible the integration of topics which traditionally are presented as disconnected subjects. In this section we discuss two examples of such integration: the integration of mechanics and thermal physics (Chabay & Sherwood, 1999), and the integration of electrostatics and circuits. Like other topics in the course, these subjects are presented in such a way that the limitations of the purely classical treatments are clear, and the articulation of classical physics with quantum and relativistic physics is exposed.

Macro-micro connections and the integration of mechanics and thermal physics

It is a peculiar feature of the traditional introductory curriculum that classical mechanics and thermal physics are taught as separate subjects. The first law of thermodynamics, for example, is often presented as though it were completely separate from the energy principle encountered in mechanics. However, classical mechanics alone, without the addition of thermal physics, cannot explain various common everyday phenomena. For example, if you drag a block across the table at constant speed, it would seem that no net work is done on the block, yet the block's temperature rises, and evidently there is an increase in the internal energy of the block (Sherwood & Bernard, 1984). Does this mean that the energy principle applies only to situations where thermal effects are negligible? Or is it a powerful fundamental principle that applies to all situations?

The M&I curriculum intertwines mechanics and thermal physics, by taking a viewpoint that emphasizes the atomic nature of matter. The ball and spring model of a solid is introduced early in the mechanics course. Students hang weights from the end of a long thin wire and measure Young's modulus, then interpret this phenomenon in terms of the ball and spring model of a solid metal. Through a semiclassical macro-micro argument we obtain from Young's modulus the effective stiffness of the spring-like interatomic bond.

Students measure the spring stiffness and period of a macroscopic spring-mass system, then write a computer program to carry out a numerical integration of the momentum principle applied to this system, using their measured mass and spring stiffness. They find good agreement between the period of the computer model and the period they measured. Students also study the analytical solution for the motion. From there, we consider a microscopic model of an aluminium wire, considered as a chain of aluminium atoms connected by interatomic "springs", whose stiffness the students previously determined from Young's modulus for aluminium. By displacing an atom and observing the propagation of the disturbance through the chain of atoms in the model, it is possible to obtain a numerical prediction for the speed of sound, which agrees quite well with the measured speed of sound in aluminium. This analysis is repeated to find the much smaller speed of sound in lead. It is a striking example of the power of the fundamental principles of physics, plus a simple model for the atomic nature of matter,

Continue to next page

FUNDAMENTAL...*from page 6*

that hanging weights on the end of a wire leads to predicting the speed of sound!

As a result of this experience with the ball and spring model of a solid, when the energy principle is introduced it is easy to include the thermal energy of a macroscopic object, which is simply energy associated with the microscopic kinetic and potential energy of the atomic balls and springs making up the solid. Thermal energy is always considered along with other energy terms in the application of the energy principle to macroscopic systems.

Since students have previously encountered the idea of discrete electronic energy levels in their chemistry courses, it is an easy step to discussing quantised electronic, vibrational, and rotational energy levels, and photon absorption and emission, in a variety of atomic systems. No attempt at this stage is made to discuss wave functions, superposition, or the relation of wavelength to photon energy. We state that the quantised harmonic oscillator has evenly spaced energy levels, and students work through several exercises and problems that deal with this system.

With this preparation, students in the introductory course find quite accessible a quantum statistical mechanics analysis (Moore and Schroeder, 1997) of the Einstein solid, a ball and spring model in which each atom is modelled as three independent quantised oscillators. Students write computer programs to calculate the entropy, temperature, and heat capacity of nanoparticles of aluminium and lead. They are asked to fit their curves for heat capacity as a function of temperature to actual experimental data for aluminium and lead, by adjusting one parameter, the effective stiffness of the interatomic "spring". When a stiffness that is consistent with the value of Young's modulus is used, the curves fit the experimental data quite well.

This climax to the mechanics portion of the course is a striking illustration of the power of fundamental physics principles and atomic models of matter. The students see that from measuring the stretch of a wire due to hanging weights, they gain sufficient information to predict both the speed of sound and the temperature dependence of the heat capacity of the metal, two properties that initially look totally unrelated to the original measurement.

Macro-micro connections and the integration of electrostatics and circuits

In the traditional E&M curriculum electrostatics and circuits are treated as almost completely separate topics. Electrostatic phenomena are analysed in terms of charge and field, but circuits are analysed in terms of current and potential, and the connection between these two sets of concepts is not made salient. This dissociation undermines the claim that physics can analyse a wide range of phenomena starting from a small number of powerful fundamental principles. Pedagogically, it also removes the concept of electric field from the student's view, so that by the end of the course students have often forgotten most of what they learned about this concept in the beginning.

In the M&I curriculum both DC and RC circuits are analysed from a microscopic point of view directly in terms of electric field and the microscopic properties of conductors. The key to this microscopic analysis is the surface-charge model of circuits. This model has appeared in the physics literature for many years but has rarely been mentioned in introductory textbooks (Preyer, 2000). Haertel (1987) brought the explanatory power of this model to our attention and stimulated us to explore ways to make this analysis accessible to students in the introductory calculus-based course. The scheme now works well, and students acquire a deep sense of mechanism for circuit behaviour, including the transient in which the steady state is established through feedback. The subsequent connection of this model to the traditional macroscopic analysis of circuits allows students to reinforce connections between field and potential difference, and to see the microscopic components of macroscopic quantities such as resistance.

Classical physics in the larger context

Since so many contemporary applications of science and technology are based on 20th century physics, it is important that students completing an introductory physics course, whether or not they will continue to study physics, see the relationship of classical physics to modern physics.

In the M&I curriculum the principles of mechanics and E&M are not narrowly restricted to their limited classical formulations but are obviously embedded in a larger physics context.

Momentum and energy are treated relativistically from the start. Students work homework problems on fission and fusion in which the rest masses change. Quantised energy is introduced to help students link the nature of energy at the macroscopic level to the behaviour of energy in the world of atoms. The reality of electric field is made manifest through discussions of retardation effects, in which the field of a remote positron and electron can affect matter for a while even after the remote source charges have annihilated each other. Retardation also plays a role in the transient that leads to the steady state in a simple circuit. A thought experiment involving the mutual repulsion of two protons, viewed from two different reference frames, shows that time must run at different rates in the two frames. All of these discussions serve to situate E&M in a larger context than would otherwise be the case.

Use of the M & I Curriculum

The *Matter & Interactions* curriculum is currently in use with students at a variety of institutions within the United States, including small private universities, large state engineering and science universities, four-year liberal arts colleges, and two-year community colleges. Extensive resources are available for instructors who wish to implement this curriculum. For more information, see http://www4.ncsu.edu/~rwchabay/mi.

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Continue to page 8

Physical Science Educators' Perceptions of the Inclusion of Astronomy and Their Conceptions in Astronomy with Regard to the New FET Physical Sciences Curriculum in S.A.

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Introduction

Exciting and innovative additions to the new FET physical science curriculum (D.O.E., 2003) for example, astronomy, particle physics, astrophysics pose major challenges to physical sciences educators. They have to make decisions about the depths of themes and select effective teaching strategies with regards to the Outcome-Based Education (OBE). The new curriculum is expected to create greater interest in Physical Sciences and seeks to provide alternate career pathways in science. Teacher's content knowledge and pedagogical content knowledge especially in astronomy education have hardly been researched in SA. A literature survey in basic astronomy and earth related concepts amongst students (Trumper, 2000) suggests that the alternative concepts in astronomy are widespread and are not easy to change. Such data is necessary for curriculum planning and effective teaching and learning in the new themes. The aim of this research was two-fold: Firstly to determine the perceptions of high school physics teachers of inclusion of astronomy education in the FET Physical Sciences curriculum and secondly to categorize their conceptual understandings of basic astronomical concepts viz. day and night, seasons, phases of the moon and planets and stars.

Physics Education links with Astronomy Education

Astronomy is one of the oldest sciences but only recently introduced in school science curriculum in SA. South Africa is one of the leaders in astronomy research and with its new project, Southern Africa's Large Telescope (SALT), astronomy education is bound to grow. Reports of introduction of astronomy education in Northern Ireland found that learners found it interesting, different and 'related to everyday life' (Jarman & McAleese, 2000). Johansson, Nilsson, Engstedt & Sandqvist (2001) states that exposing students to modern physics which includes astronomy, particle physics and cosmology with scientific data and the right tools, students could explore fundamental processes in nature that they thought were only accessible to scientists.

An excellent reason for learning physics with astronomy is not only to comprehend the fundamantal laws of nature but learning is immediate and relevant to one's curiosity about the nature of the universe. The physics concepts are clearly applicable in numerous examples in astronomy, for example "What keeps the planets revolving around the Sun?" involves both a study of mechanics and basic astronomy. Another reason relates to the use, costs and impact of technical instruments in astronomy. The new FET Physical Sciences curriculum to be implemented in 2006 features several links with astronomical concepts : Grade 10 and 11 Mechanics includes planets and their movements, astronomy and cosmology; Waves, Sound and Light includes astronomical instruments, starlight and sunlight; and Grade 12 Matter & Materials covers Astrophysics.

Methodology

The methods of data collection included a Multiple Choice Questionnaire (MCQ) and individual and group focussed interviews. Fourteen high school teachers were first given the MCQ based on alternative conceptions in Astronomy. The questionnaire covered daily observational astronomy, day and night , seasons, phases of the moon and planets and stars. There were almost an equal number of females and males with ages ranging from 22-50 year-olds. The individual and focussed group interviews were conducted immediately after the MCQ was completed. Most teachers completed a diploma in education at one of the ex-colleges of education and a few had degrees in pure sciences. The teachers taught either Physical Sciences only and/or Biology or Maths. The average teaching experience ranging from 3 years to 25 years.

A question on teacher's confidence on a scale 1-5 was included to guage teacher attitude towards teaching astronomy. The data from the MCQ were analysed for high frequency choices. The data from both individual and focus group interviews were recorded, transcribed and analysed using the phenomenographic method-a complex "hermeneutic " procedure (Marton, 1981). The object of phenomenographic research is to identify the variation in ways of experiencing something or a concept. Phenomenography describes the phenomena in the world as others see them, and in reporting and describing the variation therein, especially in an educational context. Phenomenographers are also interested in exploring "changing in capabilites" (or how concepts can be changed) which can be hierarchically ordered for understanding particular phenomena. Some capabilites are more complex then others and differences between the concepts are educationally crucial to learning. Phenomenography therefore provides a well researched theoretical foundation to construct an explanatory framework of teacher's conceptions in Astronomy and has already found applications in Physics Education (Govender N, 1999).

Results

Teachers attitude during interviews were positive towards astronomy education as they felt that everyday questions can be now understoon by learners. One teacher who wanted to switch to Technology teaching now said that she will remain as a Physical Science teacher. Teachers generally felt that they needed workshops to upgrade their knowledge and the more confident teachers that they can teach by consulting textbooks. The data from the confidence scale and scores obtained suggests that teachers were over confident of their conceptual understandings in astronomy education. Probing physical sciences teachers' understandings of basic astronomical concepts i.e., day/night, seasons, phases of the moon and planets and stars through the MCQ's and interviews confirmed most of the alternative concepts experienced by school children (Baxter, 1985), university students (Trumper, 2000) and primary school teachers (Parker & Heywood, 1998) as reported in international literature. The results are reported under the following categories.

Continue to next page

FUNDAMENTAL... *from page 7*

Moore, T. & Schroeder, D. (1997). A different approach to introducing statistical mecanics. *American Journal of Physics* , *65*, 26-36.

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PHYSICAL... *from page 8*

1. Observational Astronomy

Data from MCQ

1. The sun always follows the same path through the sky in SA.

	a. True	b. False	c. Not sure	d. Don't know
Responses	5	6	2	1

2. The sun is directly overhead at midday in SA.

	a. Always	b. Sometimes	c. Never	d. Not sure	e. Don't know
Responses	5	6	2	1	

3. The moon is only visible at night.

	a. True	b. False	c. Not sure	d. Don't know
Responses	5	6	2	1

Analysis and discussion of observational astronomy

The majority of the sample did not know that the Sun's path changes over days in the sky. A large percentage indicated that the Sun is always or sometimes directly overhead at midday. At least two teachers did not know that the Moon can be visible during the day. Trumper (2000) noted that university students performed poorly on this aspect as well. The Sun's position at specific times of the day and during seasons, low in altitude in Winter and high in Summer were not observed over time suggests a lack of general observation and inquiry although skills expected of science teachers.

2. Day and Night

Data from MCQ

4. The sun goes around the earth once in 24 hours.

	a. True	b. False	c. Not sure	d. Don't know
Responses	3	7	2	1

5. The earth turns around on a line from the north to the south pole once in 24 hours.

	a. True	b. False	c. Not sure	d. Don't know
Responses	9	4	1	0

6. The moon plays a role for the occurrence of day and night.

	a. True	b. False	c. Not sure	d. Don't know
Responses	3	8	2	1

7. The earth moves around the sun once in 24 hours.

	a. True	b. False	c. Not sure	d. Don't know
Responses	4	6	3	1

Data from analysis of interviews

Category of Conceptions of Day and Night
Sun is stationary - Earth is rotating

Table 1: Categories of Conceptions of Day and Night

Analysis and discussion of conceptions of Day and Night

Both question 5 and 7 confirms that some teachers still hold the geocentric view instead of the heliocentric view of the Solar System. They confused rotation of the earth on its axis once in 24 hours with revolution of the earth, one a year around the Sun, evident in Trumper's (2000) study with students as well. Question 5 revealed that some teachers did not know that the earth rotates on its axis from west to east once in 24 hours as they chose the rotation of the earth along a line from North Pole to South Pole. There is a uncer-tainty arising with regard to the use of terminologies em-ployed by science teachers where words such as rotation, revolve and spin are used inter-changeably. Parker & Heywood (1998) also found that primary school teachers descriptive language was embedded in everyday language with words such as goes around,moves about, turns being employed interchangeably in describing orbit and spin.

Although teachers do not elaborate on the sphericity and opaqueness of the earth, they are aware that due to the rotation of the earth, exposure of light by the sun onto half of the earth results in day and night. Most university students (Trumper, 2000) and high school students (Lightman and Sadler, 1993) also hold the correct view of day/night. Baxter (1985) provides four conceptions about children's ideas about why it gets dark at night viz., conceptions of the animate sun, covering the sun, astro-nomical move-ments and orbits, and rota-tion of the earth. A pos-sibilty exist that some teachers may hold con-ceptions as pointed out by Baxter as five teachers in Question 6 answered that the moon has something to do with the reason for day and night. A promi-nent and con-sistent concept that emerged during inter-views is teachers belief that the sun is absolutely stationary. This suggest a limited understanding of the relative motion of the Sun with respect to other galaxies.

3. Seasons

Data from MCQ

8. In summer in South Africa the earth's south pole is slanted toward the sun.

	a. True	b. False	c. Not sure	d. Don't know
Responses	6	0	4	2

9. In winter it is colder because the heat from the sun is more spread out.

	a. True	b. False	c. Not sure	d. Don't know
Responses	5	6	3	0

Analysis and discussion of Seasons

The Sun is closer to the Earth for Summer and further away from the Earth for Winter.
The N-pole is closer to the Sun for Summer and S-pole is further away for Winter.
The earth is tilted and revolves and the tilt changes resulting in the different seasons.
The earth is tilted and revolves. Only Summer and Winter can be explained.
The earth is tilted and revolves resulting in the different seasons. All seasons can be explained.

Table 2: Categories of Conceptions for Seasons

With regard to the earth's tilt, 33% were unsure about the position of the South Pole in Summer in SA. 27% indicated it slanted towards the Sun and 21% said it slanted away from the Sun. The categories of conceptions for Seasons (Table 2) obtained after interviews and phenomenographic analysis revealed five distinct concepts to explain seasons. Seasons are a yearly occurrence and although a general description of the change in seasons can be furnished, few teachers provided a complete scientific explanation of seasons. Trumper (2000) found that in three MCQ questions on seasons, only about 30% of students answered all correctly and Atwood & Atwood (1996) found only one answered fully out of forty-four preservice elementary teachers. The scientific conception that was required for seasons was based on the following : The earth rotates on its axis as it revolves around the sun. "*The inclination of the earth's axis causes variations in the length of the day and the angle at which the Sun's rays strike the Earth's surface. These two factors affect the amount of heat the Earth's surface receive during the day and radiates away at night and it is these variations that causes seasons"* (Dilley & Rijsdijk, 2000, p. 42).

The most common explanation for seasons cited and demonstrated in this study and others (Atwood & Atwood, 1996) is the movement of the Sun closer to the Earth for Summer and further away from the Earth for Winter. Children

See page 10

PHYSICAL... *from page 9*

(Baxter, 1989) at ages 13-16 year olds gave the same reason for seasons which was the commonest followed by tilt of the earth's axis. During interviews, the sequence of cycles of seasons could be stated but only Summer and Winter could be explained, either with the variable distance of Sun to Earth or the tilt of the revolving Earth. Autumn and Spring posed a significant hurdle for teachers to explain. Teachers thus hold most of the alternative conceptions that 12-16 olds still hold about Seasons as evidenced from the categories of conceptions for Seasons (Table 2).

4. Conceptions of Phases of the Moon and Eclipses

Data from analysis of interviews of Phases of the Moon

The earth casts a shadow on the moon. The earth blocks the moon. The relative position of the Sun, Earth and Moon.

Table 3: Categories of Conceptions for Phases of the Moon

Analysis of conceptions of Phases of the Moon

MCQ in this study showed that 57 % chose the correct option whereas 30 % were unsure that the proportion of the Moon seen on the Earth depends on relative position of the Sun , Moon and Earth.

In this study three distinct explanations were given:

i)The earth casts a shadow on the moon causing the different phases of the moon: One possible reason for holding this concept maybe related to teachers understanding of eclipses and phases of moon being the result of the same phenomena.In solar eclipses, the moon's shadow falls on the region of the earth causing total and partial eclipse giving light and dark areas. These light and dark areas maybe linked with the changing phases of the moon. This is the most common conception in this and other studies, Trumper (2000) with students and Baxter (1985) with 16 year-olds high school learners.

ii)The earth blocks the moon: The earth blocks the moon from the Sun accounts for teachers incorrect explanation of new and full moon-a commonly held alternative concept. For new moon, the Sun-Earth and Moon are in a line and teachers explained that no light from the Sun goes to the moon, as the earth is on the way and the moon appears dark. For full moon, Sun-Moon and Earth are in a line and light from the Sun shines on the Moon which then reflects onto Earth.

iii) The relative position of the Sun, Earth and Moon results in the different phases of the moon: The full scientific explanation for phases of the moon are caused by reflected sunlight was given by only three teachers in this study and 30%-40% other studies with university students (Trumper, 2000; Zelik et al, 1998; Bisard, et al., 1994). Physical science teachers in this study had difficulty representing the correct lunar phase for a given-earth –moon model.

Baxter (1989) noted that children developed five different ideas of phases of moon including the science view. These were from clouds cover the moon,planets cast a shadow on the moon, shadow of sun falls on moon, shadow of earth falls on moon to the scientific view relative position of the Sun-Moon –Earth and reflected light of the moon. Physical science teachers hold at least three of these concepts.

5. Planets and Stars

Data from MCQ

12. Stars are the same as planets but are out of the solar system.

	a. True	b. False	c. Not sure	d. Don't know
Response	3	6	2	3

14. Stars give out heat and light and planets don't.

	a. True	b. False	c. Not sure	d. Don't know
Response	4	4	1	2

15. Stars go around planets.

	a. True	b. False	c. Not sure	d. Don't know
Response	4	5	2	2

16. Stars are a long away from the solar system.

	a. True	b. False	c. Not sure	d. Don't know
Response	6	2	3	2

17. Some stars are nearer and some stars are further away from the earth than the planets.

	a. True	b. False	c. Not sure	d. Don't know
Response	3	6	0	3

18. The Sun is a star.

	a. True	b. False	c. Not sure	d. Don't know
Response	8	2	2	1

Data from analysis of interview

Sun is the central source of all light. Sun is not a star. Sun is bigger than stars. Sun has hydrogen and helium gases.	Sun is a ball of fire and limited lifespan. Sun is a star. Stars bigger than the Sun.

Table 4: Categories of Conceptions of Planets and Stars

Analysis and discussion of conceptions of Planets, Sun and stars

The MCQ and interview analysis suggests that there is poor understanding of the distance of the Sun to Earth, size of Sun in relation to other stars,composition of the Sun and distance of stars. Some thought that planets and stars are the same and some the planets give off light. Possible reason is that visible planets like Mars, Venus and Jupiter are seen to be shining and are viewed as not reflecting light but as a source of light. Stars are also thought to be found within our Solar System. A significant percentage of teachers did not know that the Sun is just another average middle-aged star. There are seven different conceptions related to the stars and the Sun (Table 4). The Sun being a ball of fire is a common naïve conception as one would think of a coal fire. There is evidence of knowledge of the composition of the gases in the Sun but this is not related of nuclear fusion. Another common naïve conception is that the Sun reflects light onto the stars; stars themselves are not sources of light analogous to moonlight.

Conclusions and Educational Implications

The categories of description obtained provides crucial information to construct an explanatory framework of teachers' understandings of difficult concepts in the theme Earth & Beyond. Without an intervention process, teachers most likely will teach what they know about seasons and entrench incorrect conceptions in learners. In resolving teacher's dilimma's there are two major issues for teacher education. Firstly teachers need to resolve their own concepts (declarative knowledge) and understand the phenomena they are to teach and secondly teachers need to know how to present astronomical phenomena at an appropriate at a particular level.i.e their pedagogical content knowledge is also significant. Teachers therefore must be aware of the alternative conceptions that they themselves hold and undergo conceptual change. The categories of conceptions obtained in this and other studies provides us with this information. They must also be informed of their learners conception at that particular age or school phase level and how to resolve them. If both issues are not firmly resolved, then conceptual confusion will occur at both teacher and learner level.- a serious issue for teacher education. The subsequent question to ask is what kind of strategies assist

Continue to next page

PHYSICAL... *from page 10*

teachers in resolving their conceptual dilemma's and their learners as well.

At the teacher level, appropriate interventions should result in conceptual change and a deep and scientific understanding of essential astronomical concepts. This should include teachers discussion of alternative concepts through active learning (Comins, 2000), interactive groupwork,use of interactive CD's and video's, modelling- torches, spheres of different sizes and scaling of solar system as well using three-dimensional models. A multiple of strategies must be employed at appropriate times and there must be a time – delay of interventions engagement workshops supported by information obtained through a variety of assessment strategies to effect significant changes in conceptual understanding for teachers declarative knowledge to evolve into scientifically accurate concepts. Since teacher's conceptual knowledge influences the way learners perceive and make sense of knowledge (Appleton, 1992), it is imperative that educational authorities and institutions involved in teacher education focus on teachers' declarative knowledge as well as pedagogic content knowledge. This study thus contributes to the initial understanding of astronomical concepts of teachers and cognizance must be taken of this and other studies with regard to curriculum development in the Physical Sciences.

Acknowledgement

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Some International Projects for the World Year of Physics 2005

- **"International Launch Event of the World Year of Physics"**

Contact: Johannes Orphal and Martial Ducloy
Event place: UNESCO, Paris, France
Dates: January 13-15, 2005 (closed).
The Launch Conference of the World year of Physics 2005 was a great success! We had over 1200 participants; over half of them were students. 25 percent of the students were young women. There were also students on an individual basis, so the overall number of countries represented by STUDENTS was 70 (exactly). A nice short report (BLOG) for each day of the conference is from APS journalist Ernie Tretkoff, see: www.physics2005.org/wypblog/#010305#010305

- **"Beyond Einstein - Physics for the 21st Century"**

Contact person: Ophélia Fornari
Event place: Bern, Switzerland
Dates: 11 - 15 July 2005
Description: The 13th General Meeting of the European Physical Society will take place in Bern, and is expected to become a high point of the World Year of Physics , WYP2005, i.e., the centennial celebration of the annus mirabilis 1905 of Albert Einstein, which he spent working at the Swiss Patent Office in Bern.

- **"Physics Talent Search"**

Contact: Beverly Hartline
Event place: Various countries
Dates: Entire year
Description: A Physics Talent Search is be organised within the framework of the World year of Physics. Its goal is to create enthusiasm, interest, and participation in physics among young people (and their families). Participating countries will identify physics-talented girls and boys who will be rewarded for the excellence in physics.

- **"Stories in Physics"**

Contact: Fred Hartline
Event place: Various countries
Date: entire year
Description: Well told stories are a compelling way to reach students and adults, and stories about physics can do much to make physicists and their work better understood, and to convey the excitement of real scientific research. This project will challenge scientists and science educators world-wide to share their best stories with students and teachers of all cultures and nationalities.

- **"International Poster Contest"**

Contact: Caitlin Watson
Event Place: Launch of the poster competition at ASE**,** U.K.
Dates: The launch in January 2005
Description: It is a proposal for physics poster competition. The Deadline for posters May 2005 - Long listing of enties, June/July 2005 - Final judging and announcement October 2005
improvements in the surrounding where education is being realized. The school buildings are the nearest surroundings. www.designshare.com/awards/

- **"Quantum Diaries"**

Contact person: Mrs Bellevin Katherine
Event place: to come...
Dates: to come...
Description: Quantum Diaries is a collaborative blogging project where 32 particle physicists from around the world are blogging their professional and personal lives as part of the World Year of Physics. Involved in this effort are CERN, SLAC, Fermilab, KEK, NIKEF, JINR, and many other physics labs around the world. All details are on the site: www.quantumdiaries.org

Source: http://www.wyp2005.org/activities.html

Physics Activities Around the World

In celebration of the International Year of Physics 2005, several activities have been organized in countries around the world. Some of these are the following:

AFRICA
South Africa
- **IT and Electronics Expo & Conference** (3-5 Feb)
- **Symposium on "The Science Case for Extremely Large Telescopes"** (14-18 Nov)

ASIA
India
- **Mobile Science Exhibition** to move weekly to different schools and colleges (throughout the year)
- **International Cosmic Ray Conference** (2-10 Aug)
- **Conference on Women in Physics** (Oct)

Philippines
- **PhysikLaban** - an amazing race of Physics (28 Feb - 5 Mar)
- **Physics Caravan** (5 Apr)
- **Public Lecture - Who is Einstein for you?** (Nov)

OCEANIA
Australia
- **Talking Einstein in the Shops** - to questions on and off the air about Einstein, the universe and everything through ABC Radio (14 Apr)
- **SCINEMA** - a festival of Science Film (6-23 Aug)

EUROPE
Italy
- **Physics on Train:** a travelling exhibition on trains which will stop for at least 10 days in various Italian stations
- **International Conference on "Spacetime in action: 100 years of relativity"** held in Pavia (March 29-April 2, 2005)
- **Exhibition: "Radioactivity, a FACET of nature"** - to be held at, Palazzo Renata di Francia, Ferrara (26 Apr - 6 May)

France
- **Physics and the Arts: A New Inspiration**
- **International Colloquim of Research** (18-23 July)

NORTH AMERICA
Canada
- **Physics Balsa Bridge Building Contest** (1 Jan - 31 Dec)
- **Holo-tent** - Inside the holo-tent, students of all ages, families and visitors can make a hologram to keep, see the inside of a laser, and experience amazing physics in action. (30 Apr)
- **"Einstein: A Stage Portrait"** - an award-winning play on the life of Einstein (13 & 14 May)

United States of America
- **Physics Across the World: International Poster Competition** for students aged 10-16. Students can create their own colourful posters to show how physics applications makes their lives better and has a positive impact on their everyday lives.
- **PhysicsQuest**
- **Measure the Earth with Shadows**

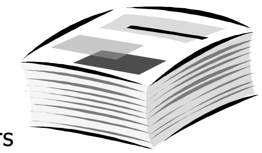
LATIN AND SOUTH AMERICA
Argentina
- **Astrophysics for the Blind** - Publication of two books on Astronomy and Physics for blind and visually handicapped people.

Brazil
- **Day of Physics** (26 May) - local activities will be organized in all the institutes and departments of physics around the country. Outreached events will be promoted as well as classroom-based projects. There will be also a campaign in the mass media for discussing the importance of physics in our society.

Mexico
- **Universidad Nacional Autonoma de Mexico** (UNAM) - the largest university in Mexico which has strong Physics programs both in terms of teaching and research. As part of the celebrations, a series of conferences will be conducted, including several by Nobel laureates, a large Physics exhibit and several contests.

Source: *http://www.wyp2005.org* and links to country activities

Contributions to ICPE Newsletter



Physicists, physics professors, lecturers and teachers, and physics education researchers are invited to contribute to the ICPE Newsletter.

Contributions may be: news of physics education activities, seminars, conferences; research articles; write-up of unique student experiments/investigatory projects; description of teacher demonstrations, improvised equipment and accompanying student experiment; book reviews; and novel physics problems and test items.

Text (including pictures) of contributions is limited to 1-3 pages, single-spaced. Your contributions should reach the editor by mail or e-mail, at the latest by **end of February for the April issue or end of August for the October issue.**

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