THE QUANTUM TIMES

NEWSLETTER OF THE APS TOPICAL GROUP ON QUANTUM INFORMATION, CONCEPTS, AND COMPUTATION

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Physlets and Open Source Physics for Quantum Mechanics

In recent years physics education research (PER) has begun to extend its reach outside of introductory physics to consider more advanced topics such as statistical mechanics and thermodynamics [1], special relativity [2], and quantum mechanics [3]. The teaching and learning of quantum mechanics is essential for many fields, yet studies show that students' conceptual understanding of quantum mechanics is lacking [4]. This lack of understanding is a critical issue to address because quantum mechanics remains relevant to fundamental research (including quantum computing and information) and development (including modern diagnostic equipment, e.g. PET scans and MRIs). These advances have kept the field of quantum mechanics at a level of pertinence unmatched by other fields.

Along with this research into student misconceptions of these topics many researchers are focused on the development of PER-informed curricular materials to aid in the teaching of these topics [5]. Over the past 10 years, we have developed materials for introductory [6] and advanced physics [7] courses with the results from both current quantum mechanics research and PER in mind.

An effective approach to teaching quantum mechanics with interactive computer-based simulations is to couple these materials with a proven pedagogical approach. Simulations used in this way, can provide both a visual and conceptual framework on which students can base their conceptual understanding and problem solving. Carefully constructed curricular materials, provided with the interactive computer-based simulations, can provide scaffolding which in combination with visuals assist students in conceptual understanding and problem solving. Computer-based exercises can also be used to confront students' misconceptions (the simulation viewpoint vs. the students' viewpoint) [8].

The communication capabilities of the computer also can be exploited, creating a feedback loop between instructor and student, thereby increasing, and not decreasing, the human interaction important for effective teaching. One such approach is called Just-in-Time Teaching or JiTT [9]. The JiTT pedagogy exploits an interaction between Web-based study and an active-learner classroom. Students are given web-based assignments and they respond electronically with their answers before the next class period. The instructor reads the student submissions "just-in-time" to adjust the lesson to suit the students' needs. This pedagogy is also very effective in combination with interactive computer-based exercises. *(continued on next page)*

In This Issue

This issue is the first issue somewhat dedicated to a particular theme. In this case, several of the articles center around the pedagogical aspects of quantum mechanics and quantum information. It is my firm belief that spending time discussing quantum mechanics pedagogy, in addition to its self-evident benefit, can serve to improve *research* in quantum mechanics since it allows us to better hone our own knowledge of our field. As such our lead article comes from two experts in the pedagogical aspects of quantum mechanics, Mario Belloni and Wolfgang Christian, both of Davidson College in North Carolina, the latter of whom is leading a tutorial at the March meeting. Later I include my own reflections on teaching quantum mechanics this semester with some input by Scott Aronson who would likely support my conjecture that pedagogy and research are connected, though you can be the judge of that based on his comments.

This marks our fullest issue to date and, as such, I simply do not have room in this column to list everything! But, of note, we have included a printable schedule of TGQI sessions at the upcoming March meeting in Denver for your convenience including room numbers.

-Ian T. Durham
Editor
Saint Anselm College

One very successful approach uses HTML pages to deliver interactive content. Java applets, called Physlets [10], are embedded in HTML pages and the physics displayed in the Physlet is controlled (scripted) by JavaScript. LiveConnect (Java to JavaScript communication) enables configuration data contained within the script to be passed to the Java applet thereby controlling its behavior. The exercises in this book use multiple representations of energy, separate plots of the energy diagram and the energy eigenfunction (or wave function), the ability to change the simulation via sliders, and the ability to change state by selecting an energy level.

The Physlet-based materials available in [7] and on our Physlet Web site [10] cover many introductory and intermediate topics. However, this scripting approach has its limitations. Physlets' behavior depends on how Web browsers interpret the Java code, the JavaScript, and LiveConnect. In addition, more sophisticated topics need more sophisticated, one-of-a-kind, programs. Users and developers of these types of programs often have specialized needs that can only be addressed by having access to the source code and by storing simulation parameters in platform-independent documents, such as Extensible Markup Language (XML). This is where the Open Source Physics programs and applications are most useful [11].

The core of the Open Source Physics (OSP) project consists of a collection of well-documented physics simulations [12] and a consistent object-oriented Java library [13] that is distributed under the GNU General Public License (GPL). The library contains numerical methods, user-interface components, visualization tools, and an XML framework. It is not, however, necessary to become expert in programming to use OSP material. Although the source code is available for Java experts, OSP simulations are also available as compiled programs that run on any Java-enabled computer.

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Although it would be possible to distribute every OSP program in its own file, this approach is not well suited for the distribution of curricular packages. A large curriculum development project creates hundreds of programs and each program may be used in multiple contexts with different initial conditions. The Launcher program shown in Figure 1 addresses this distribution requirement. Launcher is a Java application that can launch (execute) other Java programs. We use Launcher to organize and distribute self-contained collections of ready-to-use programs, documentatio The OSP Web site currently has four Launcher packages for quantum mechanics. Within each package there is a brief tutorial on the relevant theory and over 25 interactive exercises. Each are briefly described below.

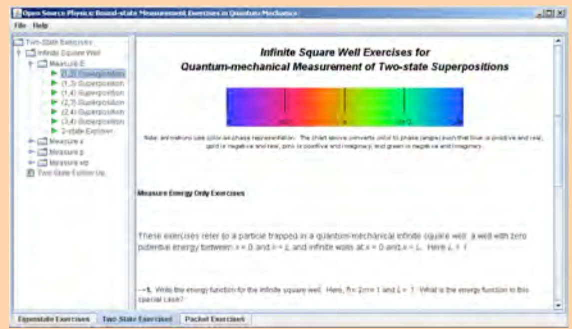

Figure 1: The Launcher package, **osp_qm_measurement.jar**, on the measurement of energy eigenstates, superposition of states, and wave packets. Selecting a tab at the bottom of the screen takes the user to one of the sets of exercises. The pane on the left shows the organization of the "Two-State Exercises" where folders can be opened and nodes (the green arrows) are double-clicked to launch programs. The pane on the right displays the HTML page with the text to the exercises associated with the selected node.

osp_qm_superposition.jar: Contains exercises on energy eigenstates, two-state superpositions, and wave packet dynamics in several standard wells (such as the infinite square well and harmonic oscillator). Time evolution is explicitly shown in the simulation using color to represent the phase of the wave function. In addition to the wave function in position space, users can choose to view probability density, momentum space and expectation values <x> and <p>. The eigenstate exercises focus on the shape of the energy eigenfunction, while the two-state and wave packet exercises focus on the dynamics of these systems via expectation values.

osp_qm_measurement.jar: Contains exercises simulating the measurement of energy eigenstates, superposition of states, and wave packets. One can perform multiple measurements on a single system or perform a single measurement on a set of identically prepared systems (elements of an ensemble). The program allows one to measure the energy, the position, and the momentum. The measurement of the position and momentum are done with a finite precision, which can be set.

osp_spins.jar: Contains exercises on the measurement of spin-1/2 systems. One can perform single or multiple measurements on statistical mixtures, eigenstates, or superpositions. In addition, one can create a spin interferometer to set up a virtual "which-way" experiment.

osp_quilt.jar: Contains tutorial exercises which are part of the Quantum Interactive Learning Tutorials (QuILT) working with Chandralekha Singh at the University of Pittsburgh. These tutorials are grounded in physics education research and are being combined with Open Source Physics quantum mechanics simulations.

All of these materials can be found on the ComPADRE quantum mechanics digital library [14] by searching for "open source physics" and on our own quantum mechanics Web site. Given that there are more than 25 exercises contained in each Launcher package, it can be difficult to find a particular exercise to use in teaching. To address this issue, the OSP project is currently populating the BQ-OSP Database with material (see resources at right). The search feature on this database will allow users to easily "look" into these packages and also specify the course level (introductory, upper-level, or both) in searches. This database can also be used to manage course pages and curricular materials.

-Mario Belloni and Wolfgang Christian
Department of Physics
Davidson College

Bennett & Zeilinger in Gdansk

The Senate of University of Gdansk (Poland) has awarded professors Charles H. Bennett and Anton Zeilinger Doctor Honoris Causa degrees. The formal ceremony was held on October 12th, 2006.

The two outstanding scientists had a very big influence on the development of a new brand of science -- quantum information. They both symbolize the initial inspiration and insight that led to this development. Prof. Bennett worked on the link of physics with computer science having written pioneering *(continued on next page)*

References & Links for Open Source Physics

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[6] W. Christian and M. Belloni, *Physlet® Physics: Interactive Illustrations, Explorations, and Problems for Introductory Physics* (Prentice Hall, Upper Saddle River, NJ, 2004).
[7] M. Belloni, W. Christian and A. J. Cox, *Physlet® Quantum Physics: An Interactive Introduction* (Prentice Hall, Upper Saddle River, NJ, 2006).
[8] M. Belloni and W. Christian, *Comp. Sci. Eng.* 5 January/February, 90-96 (2003); M. Dancy and R. Beichner, *Phys. Rev. ST Phys. Educ. Res.* **2**, 010104 (2005); N. Finkelstein, et al., *Rev. ST Phys. Educ. Res.* **1**, 010103 (2005).
[9] G. Novak, E. Patterson, A. Gavrin, and W. Christian, *Just-in-Time Teaching: Blending Active Learning with Web Technology*, Prentice Hall, Upper Saddle River, NJ, 1999.
[10] See for example, http://webphysics.davidson.edu/physlet_resources
[11] The Open Source Physics code library, documentation, and curricular material can be downloaded from the website: http://www.opensourcephysics.org/default.html.
[12] *An Introduction to Computer Simulation Methods: Applications to Physical Systems 3/e*, H. Gould, J. Tobochnik, W. Christian, Addison Wesley 2007.
[13] *Open Source Physics: A Users Guide with Examples*, W. Christian, Addison Wesley 2007.
[14] ComPADRE: http://www.compadre.org and also on the ComPADRE quantum mechanics digital library (The Quantum Exchange) at http://thequantumexchange.org/.

Download the launcher at:
http://www.opensourcephysics.org/apps/qm
/index.html.

Additional information on the QuILT project:
http://www.opensourcephysics.org/quilt

BQ-OSP database:
http://www.bqlearning.org

pioneering works on the reversibility of classical computation in the 1970's and on quantum cryptography in the 1980's. In the 1990's he co-authored the fundamental works on teleportation, distillation of entanglement, and dense coding, which are considered by now classics in the field. His ideas inspired a considerable amount of research performed at Gdansk.

Prof. Zeilinger is an experimentalist who is interested in the foundations of quantum theory. Thanks to his work with Daniel Greenberger and Michael Horne in 1989, a new realm of strictly quantum, paradoxical phenomena was discovered. These are now known as GHZ correlations. Later Zeilinger, in collaboration with researchers at Gdansk, hammered out the principles followed by optical experiments involving the entanglement of more than two photons. This led to a series of stunning experiments in which his group was able to realize many of the theoretical ideas of quantum information, including the ideas of Bennett and his collaborators. In addition, Prof. Zeilinger is also a pioneer in molecular interferometry.

As it stands, the most famous experiment in quantum information links the names of Bennett and Zeilinger. Bennett co-authored the paper that described the theoretical discovery of the teleportation process that was first demonstrated four years later by the Zeilinger Group. Both scientists can be thought of as icons of the two complementary sides of quantum information research, that is the creation of theoretical ideas, and their corresponding laboratory realizations.

Independently, in its last session, which took place on the 2nd of November 2006 the Serbian Academy of Sciences and Arts elected Anton Zeilinger as a foreign member of the Academy.

-Caslav Brukner
Fakultät für Physik
Universität Wien
(Department of Physics, University of Vienna)

-Marek Zukowski
Instytut Fizyki Teoretycnej i Astrofizyki
Uniwersytetu Gdanskiego
(Institute for Theoretical Physics & Astrophysics, University of Gdansk)

Resources and links for Bennett & Zeilinger

Information about the award including photographs of the ceremony and PDF copies of the laureate lectures can be found at
http://iftia9.univ.gda.pl/~wlask/hc/

Charles Bennett at IBM:
http://www.research.ibm.com/people/b/bennetc/

Anton Zeilinger at Vienna:
http://www.quantum.at

University of Gdansk:
(includes English language pages)
http://www.ug.gda.pl/pl/
http://www.iftia.univ.gda.pl/

Serbian Academy of Sciences and Arts:
(includes English language pages)
http://www.sanu.ac.yu

Charles Bennett (l) and Anton Zeilinger (r) receive honorary doctorates from the University of Gdansk. Photo: Brukner/Zukowski.

Student Paper Awards

Once again this year, the GQI will award two "Best Student Paper" prizes at the APS March meeting---one for theoretical work, and one for experimental. The awards, each consisting of a \$500 cash prize, will be sponsored by the Perimeter Institute of Theoretical Physics in Waterloo, Canada, and the Institute for Quantum Computing at the University of Waterloo. All undergraduate and graduate students who are both first author and presenters of an oral or poster presentation are eligible.

To be registered for the competition, a brief nomination letter from the student's supervisor stating that the results described in the presentation are substantially the student's own work and that the student is currently enrolled at a degree-granting institute, should be sent via email to Chris Fuchs at cafuchs@research.bell-labs.com. The two equally weighted criteria for the award are quality of scientific results and quality of the presentation. Judging will be undertaken by an ad hoc committee consisting of five or more senior members of GQI.

-Christopher Fuchs
Bell Labs

QCMC 2006: Karaoke Dreams

QCMC 2006, the latest incarnation of the biannual conference on Quantum Communication, Measurement, and Computing, was held from 28 November to 3 December in Tsukuba, Japan, easily continuing its 20-year tradition as one of the highest quality meetings for both theoretical and experimental quantum information. Tsukuba, joining an impressive list of QCMC venues (that have most recently included Glasgow, Boston, and Capri), gave conference attendees a true taste of Japan. The banquet's entertainment included traditional performances from both Kyoto players in formal kimonos and a twenty-member percussion troupe who at one point invited physicists from the audience to perform with them on stage; in the giant, resounding Odaiko drum, Jonathan Dowling may have met his acoustic match, but Barry Sanders' drum performance was probably more technically correct (and considerably less emotionally troubling than his performance of Black Eyed Peas' "My Humps" later that evening in a local Karaoke bar).

In addition to a reputation for the excellent hospitality of its host cities, QCMC has earned a scientific reputation for the unsurpassed quality of the research presented there, and this year was no exception. Each of the conference's five days contained impressive results, but talks by this year's recipients of the Quantum Communication Award, Phillipe Grangier and Bill Wooters, deserve special note. Professor Grangier, who as a graduate student worked on Aspect's famous nonlocality experiment, showed how his lab produced "Schrödinger kittens", a type of entangled state with a complex negative Wigner function, by coherently subtracting a single photon from Gaussian quadrature-entangled light pulses. Bill Wootters gave a fascinating theoretical talk on the generation of Wigner functions for discrete systems, providing a new alternative to the traditional density matrix characterization.

Some common themes found throughout the conference included entanglement production, cooling of micro-structures to the quantum regime (Dirk Bouwmeester's group optically cooled a micro-mechanical mirror to 135 mK), further extending quantum information to the realm of atoms and molecules, and theoretical limits on physical implementations of quantum information systems (Jeff Shapiro presented a no-go result for the use of cross-Kerr phase shifts in nonlinear fibers for conditional gates, an important if slightly disappointing result for those of us hoping for an all-optical quantum computer in the next year or two). Although the highest numerically scored performance of the conference may have gone to Paul Kwiat (for his robotically judged 99% Karaoke performance, rather than his talk on photonic quantum information), I was personally most satisfied by Charlie Bennett's speculative yet quantitative talk on "whether God remembers where the raindrops fell," in which he explored limits on the information storage capacity of the earth itself.

On a more serious note, Professor Osamu Hirota, who started the conference series two decades ago, surprised and saddened attendees with the announcement of his retirement from QCMC. His efforts have been greatly appreciated by the community and his leadership will be sorely missed. Professors Shapiro and Kumar announced they would, at least temporarily, be trying to fill his shoes, so the community can expect an announcement in the coming year concerning QCMC 2008, which we can only hope will follow QCMC 2006's excellent example.

-Joseph Altpeter
Department of Physics
University of Illinois at Urbana-Champaign

The Quantum World Traveler

As someone who teaches at a small liberal arts college and who is relatively new to this field, I don't get to attend as many of these terrific conferences as I wish I could (Oh grant money, wherefore art though? What? You say I have to actually *write a proposal* to get the money? But I thought money grew on trees?). Nonetheless, for you lucky folks who can, here are some conferences that may be of particular interest to the quantum foundations, information, and computing community. My hope is that the March meeting in a few weeks is as fun as QCMC seemed to be (if you skipped or skimmed it, it's worth going back and reading Joe Altpeter's amusing article summarizing that conference).

One conference I could easily attend, assuming I could muster up the registration fee, comes from just east of where I grew up (that would be Buffalo – no jokes, please, I'm very sensitive and proud). In any case, my father's alma mater will be hosting ninth **Rochester Conference on Coherence and Quantum Optics (CQO9)**, which has been held once each six years since 1960 (if my father had not been an English major he might have known about this conference in its earliest days). It will be held on campus at the University of Rochester sharing the week of June 10-16, 2007 with a sister conference, the **International Conference on Quantum Information (ICQI)**. The conferences will be held back-to-back with coordinated sessions on the Wednesday. An announcement letter has been included near the end of the newsletter (as a separate page).

Topics of interest in CQO9 will include all aspects of optical coherence and quantum optics, including topics such as cavity QED, singular optics, quantum coherence in condensed matter systems, particle coherence in Bose and Fermi contexts, Schrödinger cats, quantum control, coherence in the ultra-short wavelength regime, and theory and observation of quantum entanglement.

Themes that will be included in ICQI include quantum imaging, creation and measurement of high-order entanglement, transverse effects and Schmidt modes, state discrimination and cryptography, orbital angular momentum and entanglement, quantum lithography, linear optical computing, and optical storage of quantum information.

More complete descriptions and additional information about registration, deadlines, publication requirements, etc., will be available on the Optical Society of America's (OSA) website under the Meetings category (see information box below). As a note, I spent the first twenty-three years of my life in Western New York and I only remember a single June that wasn't utterly lovely.

A little further afield, our own Barry Sanders will be chairing/co-chairing two conferences this coming year with submission deadlines fast approaching. Barry, it seems, will have two whole days to travel between the two. The **Photons, Atoms, and Qubits 2007 (PAQ07)** is being held 2-5 September 2007 at the Royal Society of London's beautiful facilities (I spent time wading through dusty old letters in their library one March a few years ago – absolutely fascinating). Invited speakers include Paul Davies of Macquarie University who is the author of one of my favorite books, *The Mind of God*, and Nobel Laureate Claude Cohen-Tannoudji from École Normale Supérieure who is coauthor of the now classic *Quantum Mechanics, Vols. I & II* with Bernard Diu and Frank Laloë. From there, Barry and perhaps others will fly (presumably though it is theoretically possible to get there via other means) to Kish Island, Iran, for the **International Iran Conference on Quantum Information 2007 (IICQI 2007)**, being held 7-10 September 2007. The program is still being developed and will include both contributed and invited talks. Participants from Calgary (IQIS), Oxford, Imperial, Santa Barbara, UCL, Heidelberg, Innsbrück, and Iran's own Sharif University of Technology have confirmed participation. As a note, Kish Island is a free zone which means no visa is required to visit the island which is most accessible via Dubai in the United Arab Emirates (UAE). Visas are required to visit mainland Iran.

Back in Canada (Barry's going to be a well-traveled man this year), the APS' Division of Atomic, Molecular, and Optical Physics will be holding its **38th Annual Meeting** in Calgary from 5-9 June (see announcement in November issue of *The Quantum Times*). In addition the month of June (and the last few days of May) is devoted to a series of workshops being held in Waterloo, Ontario, under the auspices of **The Quantum World** and co-sponsored by the Perimeter Institute for Theoretical Physics (PI) and the Institute for Quantum Computing (IQC) at the University of Waterloo. Clearly Canada (specifically Waterloo, if you believe Dave Bacon) is the center of the quantum metaverse. Now what does that make Barry?

Finally I would feel remiss if I did not mention the upcoming **15th UK and European Meeting on the Foundations of Physics** at the University of Leeds (UK) from 29-31 March 2007 (yes, it is a bit late if you're coming from outside of Europe). Invited speakers include Lucien Hardy and Anton Zeilinger and the organizing committee includes Steven French who was the external examiner on my PhD thesis and who was at least partly responsible for my move into the world of quantum foundations.

There are numerous other conferences and workshops around the world that are of potential interest and nearly all have been compiled by Dan Lidar at USC and posted to the web (see box below).

-ITD (with contributions from Joe Eberly of the Department of Physics, University of Rochester)

Conference links

Rochester Conference & ICQI
http://www.osa.org/meetings/topicalmeetings/CQO/default.aspx
http://www.osa.org/meetings/topicalmeetings/ICQI/default.aspx

Photons, Atoms, and Qubits
http://paqconf.org/

IICQI/Kish Island, Iran
http://iicqi.sharif.ir/

APS AMO
http://phas.ucalgary.ca/DAMOP07/

The Quantum World
http://www.quantumworld.ca

UK/European Foundations of Physics
http://quantum.leeds.ac.uk/~sonwm/fop07/

Dan Lidar's conference listings
http://qserver.usc.edu/confs/

Editorial: Language and Logic in Quantum Research and Pedagogy

I would venture to say that most physicists these days would agree that teaching often informs our research just as research informs our teaching. Granted, not all of us teach in the formal sense of the term, but in a way we all teach in a more abstract sense when we publish papers, even those targeted at a very specific audience. For those of us who teach undergraduates or who regularly lecture or write for non-science audiences, the challenge involves distilling a seemingly unapproachable subject into terms that at once convey understanding without diluting meaning. For myself there is an added component of rational caution cultivated by the pedagogical styles of Tom Moore (of Pomona College and author of the text *Six Ideas That Shaped Physics*) and Jeff Schnick (my colleague at Saint Anselm and author of *Calculus-Based Physics*). This is further fed by the influence of my father and mother who are retired English and French teachers, and a few other English teachers from my past (I still have my high school copy of *Warriner's Grammar and English Composition* on my office bookshelf). In short, I give a great deal of attention to language and how it is used to convey ideas in physics, particularly quantum physics. As I like to tell people sometimes, I am the type of person who likes to pick lint off people's clothing.

Since the last issue of this newsletter, two particular threads on Dave Bacon's blog The Quantum Pontiff have prompted interesting discussions that led, ultimately, to my decision to focus some attention on pedagogy in this issue of *The Times*. Most recently, Dave included the following quote from Dietrich Marcuse's book (presently out of print) *Principles of Quantum Electronics*, published by Academic Press in 1980 (though written in 1970):

> It is true that the quantum theory of the LC circuit must be regarded as more correct than the classical theory, but the difference between the results of classical and quantum theory are unobservable by experiments with LC circuits.

A few people had some valid points to make about the science behind the statement, but my ultimate problem with it has absolutely nothing to do with the science at all, but rather with the wording (and I should add that they are not to be construed as a commentary on the book as a whole which may or may not be any good depending on who you are or what you are looking for). The statement could very well be about the theory of cheese balls or Dr. Seuss and the problem would remain. The sentence is self-contradictory since it says, in essence, "theory *A* must be regarded as more correct than theory *B* despite the fact that the difference between the results of theories *A* and *B* are unobservable by experiment."

Clearly Marcuse is making a prediction (in 1970) that had a very high probability of being correct. However, it highlights a general problem shared by a number of scientific disciplines in how they represent themselves both to the public and within their own communities: the mistaken substitution of "certitude" for "high probability." Take an example from outside our own discipline (bear with me on this). I would be surprised if there were many physicists (particularly high-energy physicists) who doubt that proton decay is possible; however recent experiments from the Super-Kamiokande detector in Japan suggest the half-life of such a decay is longer than the present age of the universe. As such, no decay has yet been observed. In this case the best we can truly say is that proton decay is highly probable but we should *not* take that to mean it is *certain* since certainty in science involves evidence. A similar example might be magnetic monopoles (predicted by an otherwise highly accurate theory but never found).

But what does all this have to do with us and, in particular, pedagogy in general? Well, let me answer that by first relaying the greatest compliment a student has ever paid to me. Last year at graduation a psychology student who had taken my two-semester algebra-based physics course (which includes a brief introduction to Bell's inequalities), told me, rather excitedly, that physics had taught her to question *everything* (her emphasis). Sometimes I worry that we forget to do just that both in our own research as well as our conveyance of physics to others, whether they be students, fellow scientists, or the general public.

That leads me to the second thread on The Quantum Pontiff that is of relevance. Some months ago a discussion ensued that led to a bit of a debate between myself and Scott Aronson concerning, to some extent, how quantum mechanics is taught. This grew out of my comment concerning normally rational physicists who do not believe entanglement has yet been demonstrated. This same discussion had floated to the surface of weekly research meetings with my colleagues Jeff Schnick, David Guerra, and George Parodi, all three of whom are somewhat new to quantum information (but not to their respective primary fields). The consensus, after studying paper after paper including most of the experiments of Paul Kwiat's group, was that entanglement consists of two distinct parts: correlation and non-locality. What I perceive to be the sticking point for "non-believers" (who do not necessarily include my colleagues) is the non-locality aspect. In this case, I always point to Alain Aspect's papers describing his pioneering experiments that very clearly and unambiguously demonstrate both aspects. In Aspect's papers and, indeed in the experiments themselves, it is quite clear which aspect of the experiment demonstrates correlation and which aspect demonstrates non-locality (or, perhaps more accurately, that the experiment on the whole demonstrates both). But why, then, would someone have trouble seeing the same thing in Kwiat's work? Here is Scott Aronson's answer to that (via a private communication):

> If physicists learned quantum mechanics from a more modern perspective – as a theory of information, qubits, probabilities, and observables, and only incidentally as a theory of atoms, photons, etc. – then they would immediately see the Bell inequality for the triviality that it is.

Scott continues with this argument:

> To wit: suppose we have two players Alice and Bob, who are cooperating (i.e. are "on the same team") and can agree on a strategy in advance (i.e. are classically correlated), but who *can't* communicate with each other. Suppose also that Alice receives a bit A and Bob receives a bit B, both of which are completely random. Their goal is to output bits X and Y respectively such that
>
> X XOR $Y = A$ AND B.
>
> In other words, X and Y should be different if A and B are both 1; otherwise X and Y should be equal.
>
> Now we ask: what is the maximum probability with which Alice and Bob can win this game, if they use the optimal strategy? The Bell inequality is simply the statement that, if Alice and Bob share an EPR pair, then they can win this game with 85% probability, whereas without an EPR pair they can only win it with 75% probability.
>
> To explain this, I didn't have to say anything whatsoever about detectors, Stern-Gerlach apparatuses, etc., or about the interpretation (or even the framework!) of quantum mechanics. Indeed, I could simply treat an "EPR pair" as a magic black box, that enables a certain game to be won with a probability that would be provably impossible in a classical, local picture of reality.

Let me comment on that from the perspective of one who is currently teaching (i.e. this semester) quantum mechanics for the first time (though I teach elements of it in both my algebra-based course and in my course on modern physics). It is true that quantum mechanics is one of the only sub-disciplines within physics that has no consistent introductory pedagogy. When I was in graduate school I was taught from *Quantum Physics* by Gasiorowicz which is a semi-traditional approach (though Dirac notation does appear) and I supplemented that with Liboff's *Introduction to Quantum Mechanics* and Bohm's somewhat dated *Quantum Theory* (just for explanatory purposes really). Compare that with Sakurai's *Modern Quantum Mechanics* or van Fraassen's *Quantum Physics: An empiricist's view* (which is not really a textbook, but interesting to note nonetheless) or Nielsen and Chuang's *Quantum Computation and Quantum Information*. Granted, the latter is not strictly a book on quantum mechanics, but in the preface the authors specifically state their hope that it be used for introductory courses in quantum mechanics. In any case, good luck trying to find two books that not only agree on the pedagogy and the ordering of the topics, but agree simply *on the topics themselves*. For my class this semester I finally decided to use both Nielsen and Chuang as well as Sakurai, but my students, who are bright, have nonetheless had trouble with certain aspects of both (while acknowledging, at the same time, that both are very good).

Let's then take a look at both books' treatment of Bell's inequality. Sakurai's discussion gives Wigner's derivation of Bell's inequalities while Nielsen and Chuang's discussion (specifically the introductory section in chapter two) argues from the CHSH version of Bell's inequalities. In both cases it is quite clear that the quantum and classical predictions are notably different and that experiments to date obey the quantum prediction. What is less clear, to the students, it seems, is precisely how *locality* is assumed within the context of either derivation. Kwiat's experiments tend to test the CHSH inequalities (or Tsirelson's inequality) and the experimental descriptions do nothing to clarify the point for the student (and indeed for some physicists). On the other hand, Aspect's experiments quite clearly demonstrate non-local behavior to the uninitiated. That is to say Kwiat's experiments are terrific and in no way should my comments be taken to be an indictment of them. But from a pedagogical standpoint, they do not clarify the central problem for the student (and I will add that, in addition to having very bright students in this class, I have brutally honest ones).

And so where does that leave us – or me in particular? First, it is necessary to tie the results of both the derivation of Bell's inequalities in any form to what the students know from special relativity for that is immediately where they head in their mind when they are confronted with the term "locality." I would venture to say the same should be true for physicists writing for other physicists, scientists, or laypeople. A cosmologist, for instance, just might have a similar thought process as those students and oftentimes our language presumes too much prior knowledge even for fellow physicists.

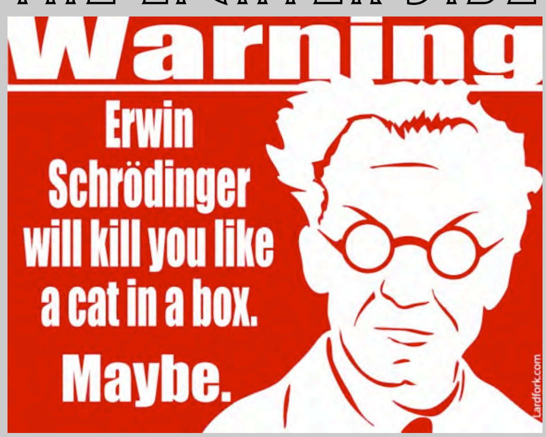
Second, it is necessary to examine the language (which includes notation) in extreme detail to ascertain precisely what it is that is being said. Is theory *A* highly probable or absolutely certain? There is a difference. Scott Aronson's explanation actually is pretty clear about nonlocality since Alice and Bob are expressly prevented from communicating at all (classically or otherwise), but then he was writing to a fellow quantum mechanic.

In short, it is necessary that we not only are thoroughly careful about the language we use but also the internal logic of that language in order that we convey the most accurate picture. Too often we can be ever so slightly cavalier about our language, missing the subtleties inherent in it, thus misrepresenting or confusing a point or perhaps even misreading someone else's point (think about that the next time you review a paper for a journal).

And for those who are interested, I will try to include a short report "from the trenches," as it were, once the semester has ended.

-Ian T. Durham
Department of Physics
Saint Anselm College

THE LIGHTER SIDE



Thanks to H. Jakubowski & D. Wheeler

Comments on Group Name

In our previous issue, we made a call for extended comments regarding the naming of this topical group. The following two letters were received regarding this topic and will hopefully stimulate more discussion leading to a final resolution of the issue. Thank you to the contributors for their comments and for giving their permission to reprint them.

My recommendation for the group name is, in order of preference: **Quantum information and foundations** or **Quantum information and concepts**.

My sense is that the term "Quantum Information" has come to encompass the subjects of quantum communication, cryptography and computation. The time of "quantum information theory" implying quantum Shannon theory seems to have passed. In any case, computation and cryptography certainly count as instances of quantum information-processing, so the present usage seems appropriate.

The term "concepts" or "foundations" should appear in the group name in order to explicitly include researchers who explore more foundational and conceptual issues. This was part of the original mandate of the topical group, and explains the presence of the term "concepts" in the current name. Such research has always played a critical part in the development of the field of quantum information and should be fostered in the topical group.

-Rob Spekkens
Department of Applied Mathematics and Theoretical Physics
University of Cambridge

My suggestion for the name is to keep it simple: **Topical Group on Quantum Information**.

Of the other names in the placeholder title, Computation and Concepts, the first seems to be unnecessary, since "quantum computation" is generally taken to be part of "quantum information". "Concepts" is a bit vague, and runs the risk of being confusing. I also worry that, along with "foundations", "concepts" may give the impression that the group includes things like philosophical aspects of quantum mechanics, and I, personally, would rather stay away from that, keeping the group focused on well defined questions.

In the same way that "quantum information" includes computation, I would say that it includes cryptography and communication, so I don't see the need to have those words in addition. Other words like science and technologies are probably understood to be part of the theme and don't need to be made explicit.

Coherence and coherent are obviously important features of QI, but are a lot broader than quantum information. This raises the issue of what this topical group is about. I am part of the newly formed Joint Quantum Institute (mentioned in the most recent newsletter of TGQI). Our focus is indeed quantum coherence, and it includes QI, but is by no means limited to it. It includes also work on cold quantum gases, and work on spin systems in solids, all things covered by other divisions of the APS. Part of our reason for being is that these are also cross-over areas, merging AMO and CM and other interests, hence our desire to create a joint institute--joint both in the sense of institutions: NIST, UMD, and NSA, and in disciplines. But it was not my impression that TGQI was to be that broad. Maybe I am wrong, but it seems that the focus of the TG is really on quantum information and not that broader role of quantum coherence in physics. Is this the home for someone who, for example, studies how to take atoms out of a BEC in a coherent atom laser beam? That is obviously an interesting and relatively new aspect of quantum coherence in AMO, but I don't get the impression that it is what the TGQI is about. On the other hand, I would be entirely comfortable including the "analog quantum computing" in the TG. That is, the simulation of one quantum system (e.g., a solid) with another (e.g., and optical lattice with gas atoms). I consider this to be an example of a sort of quantum information processing, albeit not the usual image of that processing.

If my assumptions about the nature of the group are correct, then I stick with Topical Group on Quantum Information.

One final question is whether, as part of the APS, one should have "physics" in the title. I think not, since people already know it is part of APS, so "physics" is understood. Also, quantum information physics, abbreviated as QIP, runs the risk of being confused with "quantum information processing", a subject that is too narrow for what I think this topical group is about.

So, not clever or thrilling, but utilitarian and telling: Topical Group on Quantum Information.

-William Phillips
National Institute of Standards and Technology (NIST)

Staying connected & informed

Staying up to date on the field of quantum information while simultaneously staying up to date on modern technology (which are rapidly converging anyway) can seem daunting at times. But for those who are tech-savvy, Imperial College, London, has just launched **Quantum Information – LIVE**, a regular streamed broadcast of the quantum information seminars at the Institute for Mathematical Sciences. The broadcasts, which require RealPlayer, stream both audio and video while also allowing the user to view any slides from the presentation. Information on this broadcast series can be found at http://www3.imperial.ac.uk/quantuminformation/events/live.

And for those of you who are *particularly* tech savvy (and, dare I say, hip), I am proposing the organization of the world's first entirely virtual 3-D conference on quantum foundations and information to be held in (on?) the rapidly growing virtual world of **SecondLife** (for full details see http://www.secondlife.com since I just can't do it justice here). Numerous organizations including dozens of major universities have developed "virtual" campuses and meeting halls "inworld" including the UK's version of NIST, the National Physical Laboratory. Being a "resident" of SecondLife myself, I envision a supplemental meeting location for those who cannot, for whatever reason, make any of the major conferences in a given year. The task, of course, would be the learning curve in regard to the technology itself, but it would make a nice alternative for some, particularly considering today's travel costs. While it will hopefully never substitute for the enriching experience of visiting a host city for a particular conference, it could prove to be an exciting alternative that might even be able to host regular seminars and workshops. If anyone is interested in pursuing this as a possibility, please contact me, Ian Durham, at idurham@anselm.edu (or, if you're *really* savvy, IM Cyrus Bohm "inworld").

Newsletter information

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Quantum resources

Meetings list (courtesy of Daniel Lidar):
http://qserver.usc.edu/confs/
Quantum wikis:
http://www.quantiki.org
http://qwiki.caltech.edu

TQGI Executive Committee

Chair
Carl Caves, University of New Mexico
Chair-elect
Lorenza Viola, Dartmouth College
Vice-chair
David DiVincenzo, IBM Corporation
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Charles Bennett, IBM Corporation
Members-at-large
Christopher Fuchs, Bell Labs
Raymond Laflamme, University of Waterloo

Contact information, including APS-sponsored meetings and conferences, back issues of the newsletter, current by-laws, committees, and other information can be found at our website:

http://units.aps.org/units/gqi/

Position announcement

And from my colleagues over in the Computer Science department here at Saint Anselm (with whom we are discussing the possible creation of a Computational Physical Sciences Program):

Saint Anselm College invites applications for an assistant professorship in computer science. This is a one-year position (renewable up to 3 years) to start in August 2007. Ph.D. required (will consider ABD). Duties include teaching a variety of undergraduate computer science courses and advising students. A commitment to excellence in teaching is paramount. Candidates must be supportive of the mission of this Catholic college. Applications will be accepted until the position is filled. Applicants should send a letter of application, a curriculum vita, and contact information for three references to: Professor Carol Traynor, Chair, Department of Computer Science, Saint Anselm College, Box 1658, 100 Saint Anselm Drive, Manchester, NH 03102-1310. Phone: (603) 656-6021, e-mail: ctraynor@anselm.edu.

APS March Meeting sessions sponsored by the
Topical Group on Quantum Information, Concepts, and Computation

Session A33 GQI/DAMOP
Focus Session: Quantum Limited Measurements
8:00-10:24 AM, Monday, March 5, Convention Center, Room 403

Session B33 GQI
Focus Session: Quantum Foundations I
11:15 AM-2:15 PM, Monday, March 5, Convention Center, Room 403

Session D2 GQI
Ion Traps for Scalable Quantum Computation
2:30-5:30 PM, Monday, March 5, Convention Center, Four Seasons 4

Session D33 GQI
Focus Session: Quantum Foundations II
2:30-5:30 PM, Monday, March 5, Convention Center, Room 403

Session H33 GQI
Focus Session: Superconducting Qubits I
8:00-11:00 AM, Tuesday, March 6, Convention Center, Room 403

Session J32 DAMOP/GQI
Quantum Computing in AMO Systems
11:15 AM-1:51 PM, Tuesday, March 6, Convention Center, Room 402

Session J33 GQI
Focus Session: Superconducting Qubits II
11:15 AM-2:03 PM, Tuesday, March 6, Convention Center, Room 403

Session L4 DCMP/GQI
DCMP/GQI Prize Session
2:30-5:30 PM, Tuesday, March 6, Convention Center, Korbel 2B-3B

Session L33 GQI
Focus Session: Superconducting Qubits III
2:30-5:30 PM, Tuesday, March 6, Convention Center, Room 403

Session M33 GQI
GQI Business Meeting
5:45-6:45 PM, Tuesday, March 6, Convention Center, Room 403

Session N2 GQI/DCMP
Progress in Superconducting Quantum Computing
8:00-11:00 AM, Wednesday, March 7, Convention Center, Four Seasons 4

Session N33 GQI
Quantum Measurement
8:00-10:12 AM, Wednesday, March 7, Convention Center, Room 403

Session P33 GQI

Focus Session: Superconducting Qubits IV
11:15 AM-2:03 PM, Wednesday, March 7, Convention Center, Room 403

Session S33 GQI

Physical Implementations of Qubits
2:30-5:18 PM, Wednesday, March 7, Convention Center, Room 403

Session U2 GQI/DCMP

Quantum Cryptography and Quantum Communication I
8:00-11:00 AM, Thursday, March 8, Convention Center, Four Seasons 4

Session U33 GQI

Quantum Algorithms, Simulation, and Error Correction
8:00-11:00 AM, Thursday, March 8, Convention Center, Room 403

Session V33 GQI

Quantum Cryptography and Quantum Communication II
11:15 AM-1:51 PM, Thursday, March 8, Convention Center, Room 403

Session W33 GQI

Quantum Entanglement
2:30-5:06 PM, Thursday, March 8, Convention Center, Room 403

Session X33 GQI/DAMOP

Focus Session: Quantum Information at the AMO/Condensed-Matter Boundary
8:00-11:00 AM, Friday, March 9, Convention Center, Room 403

Session Y33 GQI

Decoherence and Quantum Control
11:15 AM-2:15 PM, Friday, March 9, Convention Center, Room 403

A full BAPS for GQI sessions, including abstracts, can be viewed and downloaded at http://flux.aps.org/meetings/YR07/MAR07/Unit_MAR07_GQI.pdf.

THE NINTH ROCHESTER CONFERENCE ON COHERENCE AND QUANTUM OPTICS (CQO9)

THE INTERNATIONAL CONFERENCE ON QUANTUM INFORMATION (ICQI)

Collocated Topical Meetings

UNIVERSITY OF ROCHESTER CAMPUS
ROCHESTER, NEW YORK, USA

June

10-15

2007

Dear Colleague,

We encourage you to submit a paper for the International Conference on Quantum Information (ICQI) sponsored by OSA, which will be held June 13-15, 2007, in Rochester, New York, USA. ICQI, collocated with the Rochester Conference on Coherence and Quantum Optics (CQO9), June 10-13, concentrates on optical techniques for quantum information.

The two groups will host joint sessions to provide a perspective on the developments in the field for the past few years and highlight the latest advances in a series of tutorials, historical reviews, invited papers and poster sessions. This is your opportunity to present your work in a setting that encourages one-on-one interaction and the exchange of ideas with your colleagues in the field.

Submissions are encouraged but not limited to the following areas:

- Quantum imaging
- Quantum lithography
- Creation of high-order entanglement
- Transverse effects and Schmidt modes
- Orbital angular momentum and entanglement
- Linear optical computing
- Optical storage of quantum information

The submission deadline is February 12, 2007, 12:00 p.m. noon EST (17.00 GMT). To submit your paper, visit the submission site at
http://www.osa.org/meetings/topicalmeetings/ICQI/submissions/default.aspx

We hope to see you in Rochester.

Sincerely,

Robert W. Boyd, Univ. of Rochester, USA, Co-Chair
Bahaa Saleh, Boston Univ., USA, Co-Chair