NEWSLETTER
ONTARIO ASSOCIATION OF PHYSICS TEACHERS
(An Affiliate of the American Association of Physics Teachers)
April, 2004

Information, Entropy and String Theory

by Geoff Potvin

When physicists consider a system that is a collection of many smaller objects, such as a gas of molecules or a star or an evolving galaxy, the tools of statistical physics usually turn out to be quite useful in determining the system's important properties and behaviour. When the number of constituent objects is very large there will be many microstates of the system corresponding to a given configuration. Entropy corresponds to a measure of the number of these microstates, and so is a rough measure of the information contained in the system.

In the last century, the tools of statistical physics were applied with great success to highly exotic systems; prominently, black holes. It was shown that black holes, contrary to expectations, have non-zero entropy that is proportional to the area of their event horizon (the place where the interiors and exteriors of black holes are separated). Later, compelling arguments were made to suggest that a black hole is the object with the highest entropy for a given size and mass.

However, one would naively expect that the entropy of a black hole would be proportional to its volume. If spacetime is quantized, then there should be a shortest length scale (the quantum length scale of gravity) and so a given volume of space could be divided into a number of fundamental volume-units. But this is in contradiction to the findings of general relativists! Somehow the information that can be trapped in a region should be bounded by the surface area of the region not its volume. This is rather analogous to a hologram (in which the information to make an image "look" three-dimensional is actually contained on a two-dimensional surface), and so is loosely called "holography". A successful theory of quantum gravity, or at least a successful cosmological model of our Universe, would be expected to give a fundamental reason for holography.

About ten years ago string theory, the best theory of quantum gravity so far, underwent the "duality" revolution, the second revolution since it was originally cast. The five theories of "superstrings", previously thought to be distinct, were shown to be dual to each other. When two theories are dual, it means that they are two descriptions of a single physical system and, generally, one theory is a good description of physics just where the other theory is not, and vice-versa. Also, the five superstring theories were shown to be limits of a single, badly understood theory. Called M-theory, it looks like an eleven dimensional theory of gravity at low energies, but the full formulation is not yet understood.

Another wave of duality hit soon after, which showed that certain gravity theories (containing strings) were dual to certain quantum field theories (not gravitational at all, more like the Standard Model of particle physics). In a controlled way, the gravitational theory living in a region breaks down near its boundaries. But the quantum field theory starts to be a good description (mathematically) exactly when the gravity theory breaks down. So it is loosely said that the quantum field theory "lives on the boundary" of the gravity theory. Again, these are two theories that describe a single physical system in different regions, and contain the same information, even though they look very different. Since the quantum field theory lives on the boundary, we can see that the information in the gravity theory is limited by the information living on its boundary. This is like a particular technical example of the principle of holography.

The search for other dualities continues because they could be of primary importance in understanding exotic regions of spacetime (such as the interiors of black holes, or the very tiny, early Universe), or to make predictions about extremely difficult problems in quantum field theory. For example, it is hoped that a gravity theory can be found that is dual to the quantum field theory of the quarks—constituents of protons and neutrons. At energies accessible to experiments, quarks tend to stick together very strongly (which is why we only see quarks in bound states of two or three), so it is extremely hard to measure individual characteristics of quarks. It is equally hard to make mathematical predictions for the interactions of quarks. But if we knew what the dual theory was, we could make very simple predictions of quark behaviour.

***Geoff Potvin** is a Ph.D. Candidate in the Department of Physics at the University of Toronto. His research focuses on the resolution of space - time singularities in string theory.*

Conference Reminders!

1. Please be sure to register for the upcoming conference! Registration details can be found at www.uoit.ca/schoolofscience . Cheque details are as follows:
Payable to: University of Ontario Institute of Technology.
Send to: Carol Slaughter, School of Science, UOIT, 2000 Simcoe St. North, Oshawa ON L1H 7K4

2. Conference accommodation must be phoned in separately.

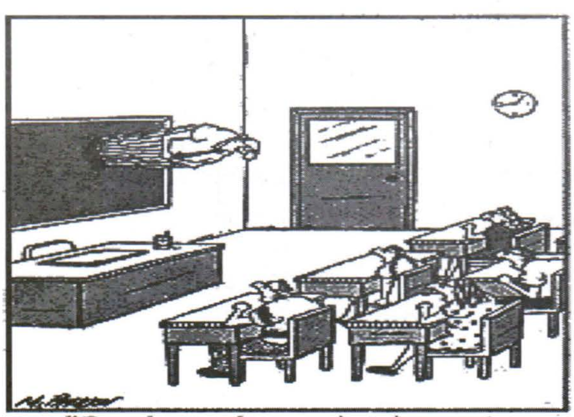
3. Remember that there is a Share & Exchange session as part of the program (see web site for details). Please participate by bringing your best activities, tests, and exams. This is an opportunity to show case what you've done, and bring resources into your department!

Annual Election, 2004

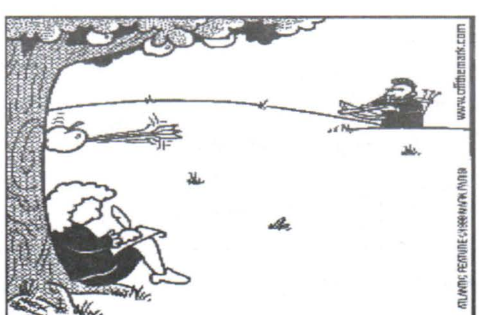
The OAPT membership at large is asked to nominate members for the following three positions of the OAPT Executive Committee for 2004-2005:

- **Vice-President** (chairman of the Section, succeeds the President the following year),
- **Secretary-Treasurer** , and
- **member-At-Large**.

Please submit your nominations to Elzbieta Muir (emuir@sympatico.ca) by e-mail by April 30, 2004.



"Good morning, and welcome to The Wonders of Physics."



SIR ISAAC NEWTON WOULD HAVE DISCOVERED GRAVITY YEARS EARLIER HAD WILLIAM TELL NOT WANDERED BY

Looking for a new source of physics simulations? Be sure to check out this site, which boasts a number of smooth simulations.

http://webphysics.ph.msstate.edu/jc/library/

The Demonstration Corner

Motion of the Centre of Mass 2

Patrick Whippey, Department of Physics & Astronomy,
The University of Western Ontario.

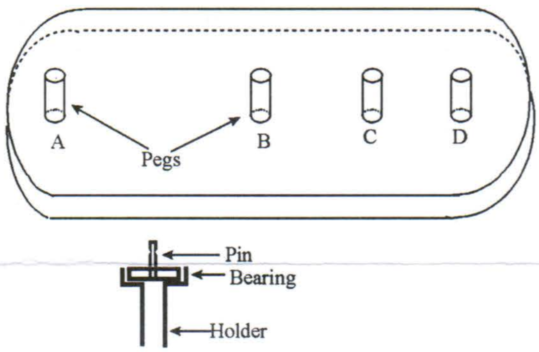


Figure 1: Plastic Base with Four Pins

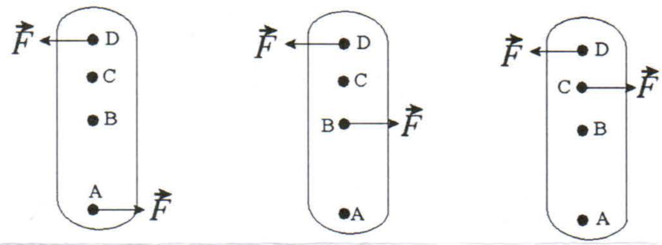


Figure 2: It Rotates about Where?

Do we really believe Newton's Laws? This demonstration was born many years ago when a perceptive student challenged the assertion that a body free to move always rotates about its centre of mass. This demonstration requires an air table.

Figure 1 shows a piece of plastic 15 cm long, 10 cm wide and 0.9 cm thick. It has four pegs attached, each 1.0 cm high and 0.6 cm in diameter. There are also two holders 2.0 cm high and 1.2 cm in diameter. These are a snug fit over the pins, so that the holders can be put over any of the four pins A, B, C and D. The holder has a small bearing in the top, with a pin in the middle, so that the pin can rotate with a minimum of friction. The pin has a small notch in it so that a loop of string can be put over it. You may find it useful to get help from your machine shop to make the holder. The other end of the string hangs over a pulley, not shown, with a 20 gram mass attached. Thus each string exerts a force of magnitude $F = 0.2$ N on the system.

The piece of plastic is placed on the air table, and forces are applied as shown in Figure 2. In each case, about which point does the object rotate?

The system always rotates about the centre of mass, regardless of which pair of pins is used for the strings.

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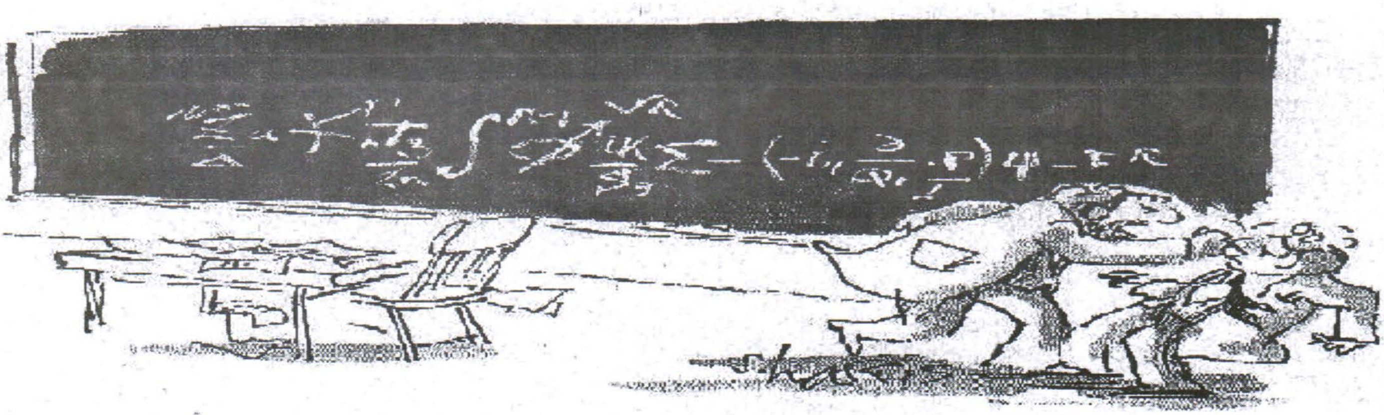
Submissions describing demonstrations will be gladly received by the column editor.



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Let's Play: Quotable Quotes!

Here's the deal. Identify the famous scientist who said the quote below. Be the first person to email your response (c/w mailing address) to the editor, Paul Passafiume, at paulpassafiume@hotmail.com and you'll win a prize! It's that easy. Here we go!

Think you know it, eh?!

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27-29, May, 2004

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Friday	Physics Education Research: Joe Redish, University of Maryland Afternoon Tours. Banquet. Donald Schmitt Architect
Saturday	Canada in Space – Douglas Staley Carleton University Wind as an Energy Source – William Russell Contributed papers by teachers.

Contributed Papers

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http://www.uoit.ca/schoolofscience/OAPT2004/index.html

If you cannot access the web, contact:
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