PENNSTATE 1855

Subject Matters
from the Center for Science and the Schools

For Science Teachers
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An Elevator into Space?

Carbon Nanotubes May Bring Science Fiction to Life

If You Can Dream It, You Can Do It is the title of a book by Christopher Lowell. Although you may question that philosophy, many scientists seem to use it as their mantra. Perhaps this is the reason that *science fiction* so often becomes *science fact*.

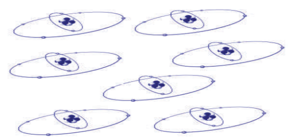
Consider an idea at the center of the novel, The Fountains of Paradise by Arthur C. Clarke. Clarke envisioned a **Space Elevator**, an incredible piece of engineering that would stretch from the surface of the Earth into outer space. The Earth end would be anchored on the equator, and the space end would be a satellite in geosynchronous orbit. People and supplies would be lifted up and down with an elevator, escaping the planet's gravitational pull without a rocket.

Clarke's novel was written in the 1970's and for a long time had been considered the stuff of *imagineering* – engineering possible only in the mind. But here at the beginning of the 21st Century, many people – including a group at NASA – are starting to imagine Clarke's vision becoming a reality. That's because it is now possible to conceive of materials strong enough to reach into orbit.

What makes this story even more interesting is that the material that is causing people to reconsider Clarke's fantasy is mundane old **carbon**. To understand the role that carbon might play in the realization of this dream, you have to recognize that a major problem is finding a material strong enough to act as a track for the elevator. Steel is strong, but one calculation suggested that if the steel cable were 1 mm across at one end, it would have to be 40 billion km at the other end!

Enter mundane carbon. We are all familiar with one of the forms – or allotropes – of carbon known as *graphite*, because it is the stuff of our pencil "leads." We are also familiar (some more than others!) with a second form of carbon: diamond. Until 1985, those were the only two important players on Team Carbon. But then scientists Harry Kroto, Richard Smalley, and Robert Curl unveiled a third form of carbon that they made from graphite, which they dubbed **Buckyballs**, because of its molecular resemblance to the geodesic dome created by Buckminster Fuller and to the pattern on a soccer ball.

Before the dust had settled on that discovery, Sumio Iijima of the NEC Laboratory in Japan



described a fourth form of carbon (also prepared from graphite), the **carbon nanotube**. The prefix ***nano-*** refers to the fact that the dimensions of these structures are on the order of billionths of a meter. The suffix ***-tubes*** describes their shape: hollow cylinders. Plain old graphite is composed of sheets of carbon atoms; carbon nanotubes form when these sheets roll up into cylinders.

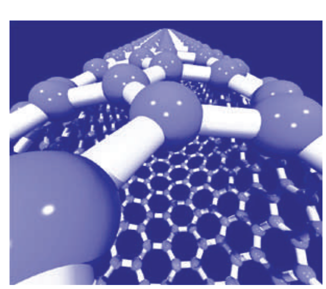
One fact that made the discovery of nanotubes so exciting was that studies showed that they were at least 100 times stronger than steel. Suddenly, the concept of an elevator to space doesn't seem quite so impossible. And nanotubes have lots of other fascinating properties that are being studied today. Perhaps we should say, "If you can dream it, carbon nanotubes can do it."

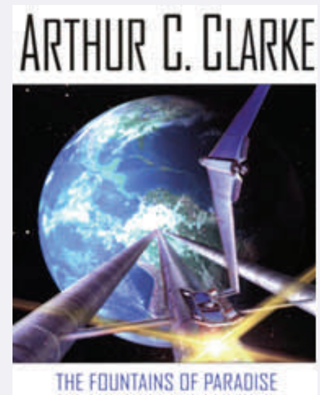
Research on nanotubes is going on all across the Penn State campus, for more terrestrial applications than a Space Elevator. Check out the links in the sidebar to learn more.

Curricular Connections

A foray into the topic of Buckyballs and nanotubes gives teachers of physical science classes a rich opportunity to approach chemical bonding from a very modern perspective. Additionally, it may help students build a genuine understanding of one of the most fundamental concepts in science: The structure-property relationship of diamond is a network structure in which all carbons have four single bonds to other carbons; that is why diamonds are so hard, as well as poor conductors of electricity. Graphite has double bonds within its structure and the electrons in these bonds have mobility, making it a good electrical conductor. Because Nanotubes are rolled graphite sheets, they are highly conductive, and this is one of the characteristics that research scientists and engineers are trying to exploit.

A "Nanotechnology in the Secondary Science Classroom" curriculum is being developed at Penn State. It includes an entire module on this topic that teaches these concepts in a structured-inquiry format. The module will soon be available through CNEU (see pg. 2).





Space Elevator Articles:

1. http://science.nasa.gov/headlines/y2000/ast07sep_1.htm
2. http://www.space.com/businesstechnology/technology/elevator_update_020819.html
3. http://www.sciencenews.org/articles/20021005/bob9.asp

PENN STATE Research Sites:

1. Dr. Steve Fonash, Penn State Innovation Park – http://www.cneu.Penn State.edu/research.html
2. Dr. Craig Grimes, Penn State UP - http://www.ee.psu. edu/grimes/
3. Dr. Vince Crespi at Penn State UP - http://www.phys.psu.edu/people/display/?person_id =202 mode= research
4. Dr. Richard Bell at Penn State Altoona - http://www.personal.psu.edu/faculty/r/c/rcb155/Research/Research.htm

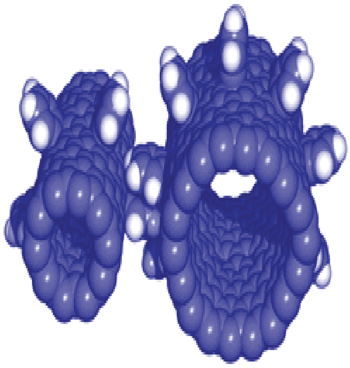
Pennsylvania Sci &Tech Standards

3.4.10.A (Bullets #5 & #9)

3.4.12.A (Bullet #4)

3.6.12.A (Bullet #2)

3.7.12.B (Bullet #2)



www.pbs.org/wgbh/nova/teachers/programs/2216/buckybal.html *-- PBS site to support the NOVA program, "Race to Catch a Buckyball"*

http://www.seed.slb.com/en/scictr/lab/buckyball/index.htm -- build a Buckyball model

http://www.chem.wisc.edu/~newtrad/CurrRef/BDGTopic/BDGtext/BDGIntro.html -- Univ of Wisconsin online "text-book" on the topic

http://www.pa.msu.edu/cmp/csc/nanotube.html -- The Nanotube Site

http://www.ipt.arc.nasa.gov/index.html -- NASA's nano-technology site, which includes a nanotube section

http://www.research.ibm.com/nanoscience/nanotubes.html -- IBM research on nanotubes

http://physicsweb.org/articles/world/11/1/9 -- nice background on nanotube properties and structure

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Research on Teaching & Learning

Much research has been conducted into what students know about the particulate nature of matter and what misconceptions they hold. Jean Piaget found that young children are able to spontaneously produce a notion of "small bits," "particles," or "atoms." However, the characteristics they apply to them often do not match the characteristics that scientists attribute to atoms.

Secondary students tend to have a more sophisticated view of atoms and can, for example, represent a solid as an orderly arrangement of atoms. However, they often cannot explain what holds the structure together. In one study, science education researcher Rosalind Driver noted that, "Researchers concluded that the pupils understood most attributes of the particle model 'one at a time' but were 'not able to pull all these attributes together as a single conception of molecular behavior within a solid.'"

The relationship between structure and property is one of the most fundamental concepts in science. The topics of Buckyballs and nanotubes allows the teacher to explore this important concept within the context of subject matter that represents the cutting edge of science.

Both the *National Science Education Standards* and *Benchmarks for Science Literacy* emphasize the *nature of science*– the processes and practices through which scientific advances are made. These two topics lend themselves well to an examination of the realm of science, because the stories behind the discoveries of Buckyballs and Nanotubes are rich with insights into how science works.

The web sites listed in the sidebar to the left contain excellent information related to these discoveries, which you may wish to share with students.

Opportunities @psu

There are two large research groups at Penn State University that offer educational outreach on nanotechnology. One is the Materials Research Science and Engineering Center (MRSEC) and the other is the Center for Nanotechnology Education and Utilization (CNEU). Some of the outreach opportunities provided by these groups:

MRSEC

www.mrsec.psu.edu/outreach

1. **Summer Teacher Workshop** "Nanoscience and Technology;" June 26 – July 1; http://app. outreach.psu.edu/Science4Educators/

2. **Student Opportunities** – Summer camps, junior mentoring, etc.; http://www. science-camps.psu.edu/

3. **In-Class Demonstrations** – contact Dr. Ron Redwing rdr10@psu.edu

CNEU

www.cneu.psu.edu

1. **Educator Workshop on Nanotechnology**—May 9-11, contact Lisa Daub ldaub@engr.psu.edu or 814-865-9635

2. Nanochip Camps for Students – Mrs. Phi Oanh Pharm, Outreach Associate, ppham@engr.psu.edu or 814-865-6962

3. ***Nanotechnology in Secondary Science* Curriculum Modules**. Information about these will be available soon: http://www.cneu.psu.edu/edOutreachSecEd.html

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Other opportunities

Through Penn State's GREATT project, grad students in science and engineering work with K-12 students and teachers on hands-on science with a transportation technology twist. GREATT is sponsoring a free two-day summer workshop for teachers Aug. 11-12. For more info, visit http://csats.psu/ GREATT/stw

Teacher Research Sabbatical Fellowships

Eligible for a sabbatical leave in 2005-06? Do you teach in or near Philadelphia? With generous support from Boeing, Penn State has begun a unique sabbatical program for middle and secondary science teachers, which will provide fellowships to support work in cutting edge research fields at University Park.

For 2005-06, up to three teachers will receive $20,000 each to supplement their school district sabbatical support for a half-year period. Teacher Fellows will have the opportunity to contribute to new science, meet Penn State scientists and engineers from around the university, and help us build a regional network that connects Penn State science and Philadelphia-area schools.

For more information, please visit the Center for Science and the Schools website:

http://csats.psu.edu