ΣΠΣ Induction Ceremony, 13 April 2000

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According to Faraday, induction relates the curl of the electric field to the time rate of change of the magnetic field, as demonstrated in this-here device.... Oh, I'm sorry: wrong induction ceremony.

I wish to congratulate you, the new inductees into ΣΠΣ, on your accomplishment and to encourage you "to advance and diffuse the knowledge of physics," as it says on the physical-society membership card. I've always wondered, if the knowledge of physics diffuses, why do we have to work so hard to learn and to teach it?

It is customary at an academic exercise such as this for a Greek-letter society to recite a passage in a classical tongue. Unfortunately, the only classical language I know how to fake is Latin, but I got some coaching in Greek, so here goes:

$$\delta\acute{o}\varsigma\ \mu o\iota\ \pi o\widehat{\upsilon}\ \sigma\tau\widehat{\omega}\ \kappa\alpha\grave{\iota}\ \kappa\iota\nu\widehat{\omega}\ \tau\grave{\eta}\nu\ \gamma\widehat{\eta}\nu \quad ,$$

attributed to Archimedes: "Give me a place to stand, and I will move the Earth." The lever, the water wheel, and the textbook "Archimedes's principle" of displaced volume have indeed moved, if not the Earth, then the civilizations that reside on it. None of you will have trouble coming up with a long list of physical discoveries and inventions that have changed the world, but let me offer a short one: Hooke's law, Newtonian mechanics, electricity, radio, lasers, nuclear energy, the transistor, and as we learned in a physics colloquium earlier this month, Day-Glow plastic.

Of course, there's another principle of Archimedes that isn't mentioned in the textbooks. Already an old man, Archimedes responded to an emergency call to the defense of his city, Syracuse, against a Roman invasion led by the general Marcus Claudius Marcellus. The ramparts, catapults, and machines he invented were so successful, they held off the Romans for eight months. If he had tried something like that today, the Syracusan national laboratory would probably have revoked his Q clearance and jailed him on suspicion of handing state secrets to the Chinese.

Unable to take the city by force, Marcellus besieged Syracuse; famine, rather than arms, eventually compelled the surrender. According to legend, Marcellus was so impressed by this one man's defense against a Roman legion that he planned to honor Archimedes and sent a soldier to summon him. Unfortunately, Archimedes, deep in thought, was working out mathematical proofs in the sand and failed to obey the soldier, who consequently slew him. I call this Archimedes's second principle: if a funding agency offers you a grant, don't turn it down. I won't mention Archimedes's third principle, but it has something to do with running around naked in the streets shouting "$\epsilon\acute{\upsilon}\rho\eta\kappa\alpha$!"

I've been reading students' teaching evaluations, and apparently people think that they live in the first generation to get professors who are eccentric, ill-dressed, dottering slave-drivers who couldn't explain the lever principle to a Roman soldier without invoking ten blackboards full of fractional-order Bessel functions of the third kind. Actually, though, I've checked the history books, and there have been hundreds of generations of students putting up with professors who are eccentric, ill-dressed, dottering slave-drivers who couldn't explain the lever principle to a Roman soldier without invoking ten blackboards full of fractional-order Bessel functions of the third kind. Let me cite one example from Westfall. A student sees his professor walking down the street on campus and says "there goes the man that has writt a book that neither he nor any body else understands." The campus was Cambridge, and the professor, of course, was Isaac Newton.

In the corpus of Newton's work, nothing can match the simplicity and majestic splendor of the second law:

> Mutationem motus proportionalem esse vi motrici impressæ,
> et fieri secundum lineam rectam qua vis illa imprimitur;

I *told* you I could fake Latin. The crib sheet reads

> The change in motion is proportional to the motive force impressed, and is made in the direction along the line in which this force is impressed.

Some cretin in the textbook department Bowlderized the poetry into

$$F = ma \quad ,$$

but you can appreciate in the original phrasing that this idea was of no merely practical utility, not just a formula to solve some problem at the end of the chapter with levers and inclined planes, but the embodiment of earth-shattering revolution that prompted Pope to write his famous epitaph:

> Nature and nature's laws lay hid in night:
> God said, 'Let Newton be!' and all was light.

You've probably heard the follow-on:

> It did not last: the Devil, shouting "Ho,
> Let Einstein be" restored the *status quo*.

Most of my favorite Newton quotes, however, come from the *Opticks*. I own an $8 paperback edition printed by Dover. The role of this book in intellectual history is perhaps best represented by the fact that my edition has not one but three introductions. I quote from the title page: "with a Forward by ALBERT EINSTEIN, an Introduction by SIR EDMUND WHITTAKER, a Preface by I. BERNARD COHEN, and an Analytical Table of Contents prepared by" some graduate student I've never heard of.

Newton's portrait gazes off to the side and out of the cover in blue-tinged black-and-white, his mouth slightly downturned, almost frowning, as he sits serenely on a throne-like chair. The nearly black background forms an overall impression of eighteenth-century musty reserve. In the middle of the cover, however, like Oz landed from a tornado on top of monochrome Kansas, a bold horizontal band in all the colors of the spectrum spells out the title: "O-P-T-I-C-K-S." OK, so physicists don't know how to spell, but I doubt anyone on the Kansas Board of Education knows how to spell either.

In Book Two, Part Three, Proposition VIII, Newton reports his experiments on light transmission through hammered gold and observations of a variety of

other substances that draw him to the conclusion that most of matter consists of empty space, or "pores." He writes

> How bodies can have a sufficient quantity of Pores for producing these Effects is very difficult to conceive, but perhaps not altogether impossible.... [I]f we conceive these Particles of Bodies to be so disposed amongst themselves, that the Intervals or empty Spaces between them may be equal in magnitude to them all; and that these Particles may be composed of other Particles much smaller, which have as much empty Space between them as equals all the magnitudes of these smaller Particles: and that in like manner these smaller Particles are again composed of others much smaller, all which together are equal to all the Pores or empty Spaces between them; and so on...

and here he goes on detailing several more orders of Russian-doll particles for almost a page, and then finally

> And there are other ways of conceiving how Bodies may be exceedingly porous. But what is really their inward Frame is not yet known to us.

Newton allows himself to speculate further on this theme in the 31st and final query at the end of the *Opticks*. He begins by asking whether undiscovered forces may be responsible at the smallest scale of particles for the bending of light, capillary action, and the very cohesion of matter. After building his argument carefully over many pages, and recalling his quantitative experiments on Newton's rings, he works toward the climax:

> By the Table in the second Part of the second Book, wherein the thicknesses of colour'd Plates of Water between two Glasses are set down, the thickness of the Plate where it appears very black, is three eighths of the ten hundred thousandth part of an Inch. And where the Oil of Oranges between the Glasses is of this thickness, the Attraction col-

> lected by the foregoing Rule, seems to be so strong, as within a Circle of an Inch in diameter, to suffice to hold up a Weight equal to that of a Cylinder of Water of an Inch in diameter, and two or three Furlongs in length. And where it is of a less thickness the Attraction may be proportionally greater, and continue to increase, until the thickness do not exceed that of a single Particle of the Oil. **There are therefore Agents in Nature able to make the Particles of Bodies stick together by very strong Attractions. And it is the Business of experimental Philosophy to find them out.**

In this last sentence, Newton has laid out for the next 300 years the reductionist program of particle physics. I really don't how to analyze or say anything intelligent about it; I read his insights and stand in awe. Any garden-variety genius can understand something new; it took Newton to identify correctly those things that would require three centuries to understand.

So at this convocation, I welcome you to the business of natural philosophy. It is a business that will take you to some very distant places, to the centers of stars and atoms; you will also meet up with certain eccentric characters (to be charitable): superconductivity, second sound, anyons, axions, and so forth. However, it is a business, I hope, in which you will be able to apply your knowledge to very practical questions, from how to accommodate the population of the planet without destroying it to how to get a job when you graduate. I am pleased to report that this last question has a relatively easy answer: statistics show consistently low unemployment and high starting salaries among physics graduates at the bachelor's, master's, and doctoral levels.

In your first course, you learned to move weights with levers. In qualifying for admission to ΣΠΣ, you have found a place to stand. Congratulations.