CHAPTER 6

Physics for Future Presidents

Richard A. Muller

PHYSICS IS THE LIBERAL ARTS OF HIGH TECH

Physics for future presidents? Yes, that is a serious title. Energy, global warming, terrorism and counterterrorism, health, Internet, satellites, remote sensing, ICBMs and ABMs, DVDs and HDTVs: economic and political issues increasingly have a strong high-tech content. Misjudge the science, make a wrong decision. Yet many of our leaders never studied physics and do not understand science and technology. Even my school, the University of California, Berkeley, does not require physics. Physics for Future Presidents (PffP) is a course designed to address that problem. Physics is the liberal arts of high technology. Understand physics, and never again be intimidated by technological advances. PffP is designed to attract students and teach them the physics they need to know to be effective world leaders.

Is science too hard for world leaders to learn? No, it is just badly taught. Think of an analogous example: Charlemagne was only half literate. He could read but not write. Writing was a skill considered too tough even for world leaders, just as physics is today. And yet now most of the world is literate. Many children learn to read before kindergarten. Literacy in China is 84 percent according to the Organisation for Economic Co-operation and Development. We can—we must—achieve the same level with scientific literacy, especially for our leaders.

PffP is based on my several decades of experience presenting tough scientific issues to top leaders in government and business. My conclusion is that these people are smarter than most physics professors. They readily understand complex issues even though they don't relax by doing integrals. (I know a physics professor who does.) PffP is not Physics for Poets, Physics for Jocks, or Physics for Dummies; it is the physics one needs to know to be an effective world leader.

Can physics be taught without math? Of course! Math is a tool for computation, but it is not the essence of physics. We often cajole our advanced students, "Think physics, not math!" You can understand and even compose music without studying music theory, and you can understand light without knowing Maxwell's equations. The goal of this course is not to create mini-physicists. The goal is to give future world leaders the knowledge and understanding they need to make decisions. If they need a computation, they can always hire a physics professor. But knowledge of physics will help them judge, on their own, if the physicist is right.

AN IDEAL STUDENT

Liz, a former student of my class, came to me during office hours, eager to share a wonderful experience she had had a few days earlier. Her family had invited a physicist over for dinner, someone who worked at the Lawrence Livermore National Laboratory. Over the course of dinner he regaled them with his stories of controlled thermonuclear fusion and its great future for the power needs of our country. According to Liz, the family sat in awe of this great man describing his great work. Liz knew more about fusion than did her parents because we had covered it in class.

There was a period of quiet admiration that followed the physicist's stories. Finally Liz spoke up. "Solar power has a future, too," she said.

"Ha!" the physicist laughed. (He did not mean to be patronizing, but this is a typical tone physicists affect.) "If you want enough power just for California," he continued, "you'd have to plaster the whole state with solar cells!"

Liz answered right back. "No, you're wrong," she said. "There is a gigawatt in a square kilometer of sunlight, and that's about the same as a nuclear power plant."

Stunned silence from the physicist. Liz said he frowned. Finally he said, "Hmm. Your numbers don't sound wrong. Of course, present solar cells are only 15 percent efficient . . . but that's not a huge factor. Hmm. I'll have to check my numbers."

Yes! That is what I want my students to be able to do. Not integrals, not roller-coaster calculations, not pontifications on the scientific method or the deep meaning of conservation of angular momentum. Liz was able to shut up an arrogant physicist who had not done his homework! She had not just memorized facts; she knew enough about the subject of energy that she could confidently present her case under duress when confronted by a supposed expert. Her performance is even more impressive given that solar power is only a tiny part of this course. She remembered the important numbers because she had found them fascinating and important. She had not just memorized them, but had thought about them and discussed them with her classmates. They had become part of her, a part she could bring out and use when needed, even a year later.

PffP is not watered-down physics; it is advanced physics and covers the most interesting and important topics. Students recognize the value of what they are learning and are naturally motivated to do well. In every chapter they find material they want to share with their friends, roommates, and parents. Rather than keep the students beneath the math glass ceiling, I take them far above it. “You don’t have the time or the inclination to learn the math,” I tell them. “So we’ll skip over that part, and get to the important stuff right away.” I then teach them things that ordinary physics students do not learn until *after* they earn their Ph.D.

The typical physics major, even the typical Ph.D., does *not* know the material in this course. He (and increasingly she) knows little to nothing about nukes, optics, fluids, batteries, lasers, infrared and ultraviolet light, X-rays and gamma rays, MRI, CAT, and PET scans. Ask a physics major how a nuclear bomb works, and you’ll hear what the student learned in high school. For that reason, at Berkeley we have now opened this course to physics majors. It is not baby physics; it is advanced physics.

I did make one major concession to my students. They are eager to learn about relativity and cosmology, subjects superfluous to world leadership but fascinating to thinking people. So I added two chapters to the end of the course. They cover subjects that every educated person should know, but that will not help the president make key decisions.

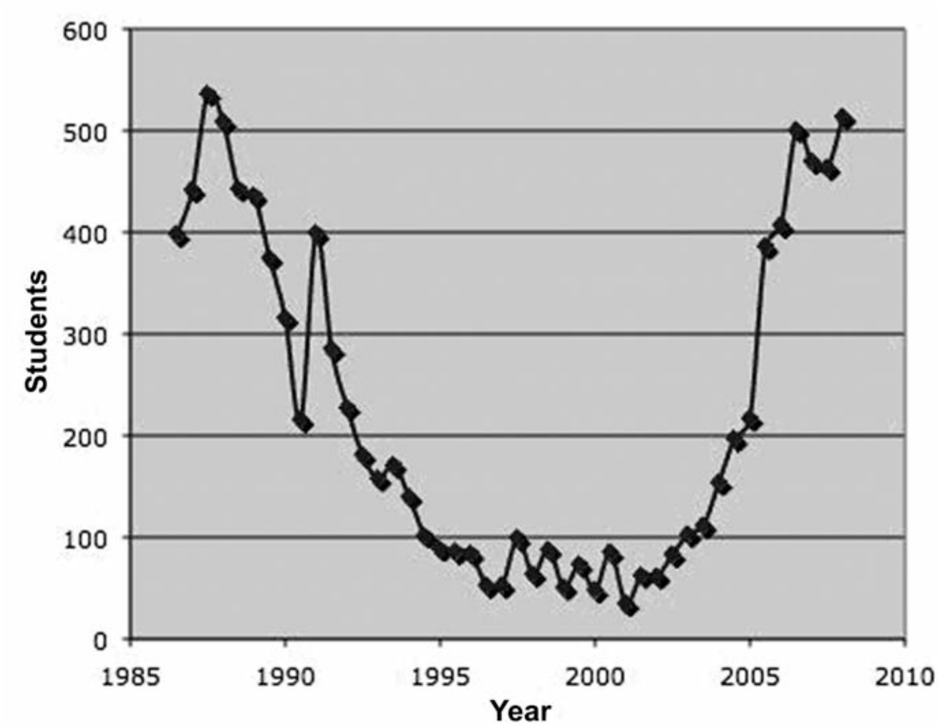
The response to the course has been fantastic. Enrollment grew mostly by word-of-mouth, from thirty-four students in Spring 2001 to more than five hundred by Fall 2006. The class now fills up the largest physics-ready lecture hall at Berkeley. About half of these students previously hated or dreaded physics; many had sworn (after their high school class) never to take it again. But they are drawn, like moths to a flame, to a subject they find fascinating and important. My job is to make sure their craving is fulfilled and that they do not get burned again. These students come to college to learn, and they are happiest when they sense their knowledge and abilities growing.

My greatest award for creating this course came in 2008 when the student newspaper, *The Daily Californian*, surveyed all students on campus. PffP was voted the “best class” at Berkeley. The course received the honor again in 2009. This is an astonishing achievement for a physics class.

Students do not take the course because it is easy; it is not. PffP covers an enormous amount of material. But every chapter is full of information that is evidently important. That is why students sign up. They do not want to be entertained. They want a good course, well taught, that fills them with important information and the ability to use it well. They are proud to take this course, but more important, they are very proud that they enjoy it.

Figure 1 shows the history of enrollment in the “qualitative physics” course at Berkeley. In the 1980s, when physics or chemistry was required for

Figure 1: Enrollment in Physics 10 at the University of California, Berkeley



In 2001, the course was reinvented as Physics for Future Presidents.

all students, enrollment was as high as 500 students per semester. But as alternatives became available, enrollment dropped, reaching a low of thirty-four students in Spring 2001. Although Berkeley still had a "physical science requirement," it could be filled by a wide diversity of less intimidating classes, including courses in physical anthropology, geology, oceanography, and ecology.

When the approach of the course was changed, in Fall 2001, the enrollment began to grow. In 2008, it peaked at the maximum capacity of the lecture hall: 512 students each semester. (Berkeley has larger rooms available, but this is the largest one that can support the demonstrations.)

PEDAGOGY

PffP is fun to teach and fun to take, but it is unlike other courses in qualitative physics. I use several ideas that are unusual. Instructors for a course such as PffP may find it helpful to understand these ideas.

Immersion

I teach by total immersion. Physics majors take one to four years to get a sense of what energy means. They do not learn it from the definition. So in PffP I start using the term, with many, many examples. Students feel as if they are walking into a foreign language class in which the teacher starts speaking Spanish immediately. After a semester of using the word *energy* every class, students begin to understand what physicists mean by the term.

Motivate and Intrigue

Many students in PffP are afraid of physics, sometimes because of a bad experience in high school. The first step is to stimulate their interest so that they forget their fear. Chapters usually begin with a story, anecdote, or puzzling facts. The purpose is to make the student wonder, "How can that be?" Important and intriguing applications are mentioned at the beginning rather than appended to the end.

The order of topics and the structure of chapters in PffP are not traditional. There is no need to put "modern physics" last, following historical order. Students are eager to learn new, exciting things, and in total immersion they do not need to wait. I introduce atomic and nuclear physics early. My goal is to motivate students by putting the most fascinating topics first. Energy is in Chapter 1, explosions in 2, spy satellites in 3, radioactivity in 4, nukes in 5. (See page 122 for the table of contents for the PffP textbook.) The students get hooked early. By the time we get to waves, light, and integrated circuits, students are warmed up and ready to find those exciting, too.

Reading

When I began teaching this course, I decided that it had to be made more attractive to non-science majors. I surveyed my students, focusing on two key questions: What kinds of homework do you enjoy in your other classes? What work would fit in naturally with your study style? Many students said that for other courses they learned by spending a lot of time reading. Based on this feedback, I wrote notes that started out as Web page summaries but evolved into a textbook[1] *to be read*. That may sound silly, but the core idea was to have something that is fun to read and reread. The resulting textbook does not use the standard physics pedagogy of following an intense abstract section with a short "test your understanding" quiz. I did not want to break the flow, so I decided to write about each physics subject in the way a novelist might. I tried to make a textbook that is a page-turner. I encourage students to read quickly and then read again (and again), rather than work through the text slowly.

Images and Figures

I cannot overemphasize the importance of motivation. The images and figures in the PffP textbook are chosen to be intriguing. When the students thumb through the book, the images should stir their curiosity. "What is that?" "That's

1. Richard A. Muller, *Physics and Technology for Future Presidents* (Princeton, N.J.: Princeton University Press, 2010).

amazing!" "I'd love to understand that." Not all the images and figures meet this standard, but I tried to include as many as possible that would stir student interest.

Physics as a Second Language

When I first taught this course, I had students find examples of the misuse of key terms such as *energy*, *power*, *speed*, and *velocity*. I do not use that exercise anymore because it leads to a nonproductive arrogance. Most physics terms existed before physics gave them precise definitions. I ask my students to learn physics as a second language and to be able to use physics terms in their specialized physics sense when talking to other physics-literate people. This approach avoids passing on the arrogance that physicists often affect. When you know how to use specialized language, you can communicate more effectively with other experts.

Math: Multiple Levels

PffP classes can be large and include students with a wide variety of interests and abilities. Majors in English, music, math, and physics all take the course. Some want more math, which I provide, but not before letting students know that the math portion of the lecture is not required. Those who are not interested can sleep for five minutes while I explain, for example, how the relativistic energy equation reduces to Newtonian kinetic energy, satisfying the correspondence principle. Remarkably, the students who "hate" math continue paying attention. They find the math fun as long as they are not required to reproduce it. The PffP textbook takes the same approach, explicitly stating when something is optional.

Don't Cover Everything in Lecture

In liberal arts classes, the lectures make no attempt to cover all the material. Students who enroll in PffP are accustomed to learning things on their own. I spend the lectures on the most subtle material or the most interesting (and therefore most motivational), but I tell students that they are required to learn on their own everything in the textbook that is not marked as optional.

Homework

To make this course attractive, I surveyed my students to find out what kinds of homework they were assigned in the non-physics courses they liked. The answer was simple: reading and writing. To address the former, I tried to write a textbook that is fun to read. I wanted the students to read through the chapter without being distracted by standard physics pedagogy (for example, the chapter-ending "check your understanding" quizzes). Then, to study, they should read it again.

Many of my students are freshmen, and to make sure they do the reading on time, I give frequent short multiple-choice quizzes. These are meant to be easy for anyone who has read (but not yet studied) the chapter but hard to guess for those students who have not. Similar questions appear at the ends of the chapters.

I was surprised to discover that most of my students did not normally read newspaper articles about science and technology. To break this bad habit, many of the homework assignments consist of the following: find a newspaper article that has physics or technology content, and write two paragraphs summarizing the content. Students can earn a high score even if they do not understand the article, as long as they state what it was that they did not understand. (Once students clearly identify what they do not understand, they are 90 percent of the way toward understanding it.) A common semester-end comment from students was: "I didn't know articles like that were for me!"

I tell students that most homework will get a grade of 2—meaning nice job and we did not have time to grade in more detail. Homework that has spelling or grammar errors earns a grade of 1. If a paragraph is so well written that the teaching assistant notices and enjoys reading it, it might earn a rare 3.

For the first homework, a large fraction of the papers are sloppily written and earn a 1. Within a few weeks, the writing improves dramatically. Some seniors have told me that they wrote more in PffP than in any other course, and even though the grading was not detailed, the regular practice improved their writing.

Exams

My exams are 50 percent essay and 50 percent multiple-choice questions. My goal is to make students knowledgeable and articulate about the physics and technological aspects of important issues. I give examples of suggested essay questions at the end of every chapter in the textbook. If you don't have the resources to grade essays, you can give exams consisting solely of multiple-choice questions. The average student at Berkeley gets 75 percent of these correct, earning a B in the course. A sample exam is shown on page 126.

Numbers

It is important for the student to be able to understand the use of large and small numbers, but I do not require that they be able to manipulate such numbers themselves. We review scientific notation in the first discussion sections, but I ask only that they be able to follow the numbers while I perform the manipulation. The highest priority is not to teach computation. I want them to know what is important, what is negligible, and how physics illuminates complex phenomena. I want them to be able to tell when something they are hearing is probably wrong.

Policy and Politics

I emphasize physics and try hard to eliminate policy and politics. I try to cover the technical aspects that one must understand in order to make wise decisions, and I try to avoid most of the nontechnical aspects of the issues. One of my proudest teaching moments occurred in 2006 when a student asked permission for a personal question. He wanted to know my "politics." I was proud that in a class that discusses energy, nukes, the technology of war, global warming, and high tech, he could not figure out for whom I had voted. (And I did not tell him.) It is important to show that physics questions do not have a political spin. We can all agree on the physics. When tricky issues are raised (such as the plutonium economy), I try to give the strongest arguments on all sides. Then the students can think about the subject and decide their own positions.

The students try but can't put me in a category of, for example, pro-nuke or anti-nuke. I don't care what their opinion is. I teach them the plusses and minuses of nuclear power, and let them choose themselves.

Lectures Online

My lectures are available for free online at University of California Television (http://www.uctv.tv), Google Videos (http://video.google.com), YouTube (http://www.youtube.com), and as podcasts on iTunes. Links can also be found on my Web page, http://www.muller.lbl.gov. In one lecture, I asked anyone who was watching or listening outside of Berkeley to email me. The response astounded me. As of this writing (2010), I have received email from ninety-three countries, including Malaysia, Mali, Tibet, Turkey, Kenya, Saudi Arabia, and Iraq.

Respect

Respect for the student is essential. I treat each student in my class with the expectation that he or she will someday be president—if not of the United States, then at least of a major company. Educating future leaders is not just fun; it is a duty. I avoid cartoons and other images that suggest students are "just kids." Pictures and writing should approximate those that adults like and might expect to see in a magazine such as *The Economist.* This really is physics for future presidents.

What I Do Not Teach

I do not teach problem-solving; it is not possible to do so in one semester. If the students in PffP ever need to calculate the velocity of a roller coaster, they will hire a physicist.

I don't explicitly teach the scientific method, for two reasons. The first is that students find it patronizing and boring. The second (if a second one is needed) is that I don't consider the usual scientific method, as taught, to be correct. Few advances are made by testing hypotheses. Most discoveries are made by people who have learned the right level of self-skepticism and are careful enough that when something unusual happens, something that they cannot explain by other means, they pay attention.

I believe in the dictum of the novelist: show, don't tell. After a semester of seeing real science, covering the most important and urgent topics, students get a real sense of what science knows and does not know.

Question Periods

I always take the first ten minutes of class to answer questions on any topic, whether something advanced ("What do you think of string theory?"), technical ("Am I anonymous on the Internet?"), or urban legend ("Do cell phones ignite gasoline at filling stations?"). My willingness to admit when I do not know the answer and to make educated guesses based on physics demonstrates the honesty that is at the core of the scientific method. The material is always interesting and topical, and they can listen without the stress of thinking that they will be tested on it.

Commencement

PffP is not meant to be a complete survey of physics, and the PffP textbook does not try to cover every important aspect of the issues it discusses (an impossible and unreasonable task); nor is it meant to be used as a comprehensive reference text. Rather, PffP approaches the teaching of physics as a commencement, a way of leading students into a life full of the understanding and appreciation of science. Ultimately, what students learn in the course matters less than that they learn a lot. If the course introduces students to physics and demonstrates that advanced material is not beyond their reach, then they will learn far more in the years that follow than they could possibly learn in one semester.

Memorizing

Unlike physics students, liberal arts students do not mind learning numbers and facts. They are empowered when they know things, such as what really happened at Chernobyl, how many people died of cancer at Hiroshima, what spy satellites can really do (and not do), what Moore's Law is (most students have never heard of it), and what the differences are between MRI, CAT, and PET scans. I tell them that whatever their point of view, knowledge will help them. They will be able to win arguments with their friends and parents. They seem to be particularly happy about the latter. Of course, it is also conceivable that as they learn the facts, some students will change their minds on some technological issues.

Fun

Learning is one of the greatest joys in life. Give a child a choice—say, the chance to learn how to ride a bike or unlimited ice cream for an hour—and most children will pick the former. To learn is to feel great. Perhaps the only greater joy is using that learning to contribute something to others.

Yet most students have had the joy of learning beaten out of them, perhaps by bad teachers. Yes, learning is hard, just like playing baseball or playing a video game is hard. The trick is not to mind that it is hard. As students rediscover the joy of learning, they will learn with much less effort. They will be able to devote half as much time to studying, while learning twice as much.

The material in PffP is fascinating. Students *should* find it riveting. If that does not happen, it's because they've lost sight of the joy of learning. Tell them that the trick to learning the huge amount of material presented in the course is to find it interesting. That should be easy, because it is. When students recognize that fact, the automatic learning mechanism turns on. How can they forget things that are interesting, fascinating, intriguing, and important? Encourage students to discuss the material with their friends. Have them present interesting facts to physics majors (choose facts the physics majors probably do not know). Tell the students to discuss nuclear power, radioactivity, energy, lasers, computers, UFOs, earthquakes—everything in the course—with their parents and friends. Any material they discuss with others in this manner (that is, not for the purpose of studying, but to inform others) will be material that they will never forget.

The Table of Contents from the Physics for Future Presidents Textbook

Chapter 1. Energy and Power, and the Physics of Explosions.

Calorie, joule, and kilowatt-hour. Energy in various substances. Surprises: TNT and cookies, gasoline and batteries, electric car hype, hybrid non-hype. Fuel cells. Hydrogen as a means of transporting energy. Uranium, gasoline, and TNT. Cheap coal. Forms of energy. Power. Conservation of energy. Horsepower. Human power. Solar power. Exercise and diet. Wind power. Cost of energy. Kinetic energy. Anti-ballistic-missile systems: smart rocks and brilliant pebbles. The demise of the dinosaurs.

Chapter 2. Atoms and Heat.

Quandaries. Atoms and molecules and the meaning of heat. Periodic table. Speed of sound and light. Energy in heat. Hiss and noise. Temperature. Laws of thermodynamics. Hydrogen escape from atmosphere. Cold death. Temperature scales: F, C, K. Thermal expansion. Global warming and sea level rise. Thermometers. Space shuttle tragedy. Solid, liquid, gas, and plasma. Explosions. Ideal gas law. Airbags, sautéing, fire walking. Heat engines. Wasted energy. Refrigerators and heat pumps. Heat flow. Entropy and disorder.

Chapter 3. Gravity, Force, and Space.

Gravity surprises. The force of gravity. Newton's third law. "Weightless" astronaut. Key orbits: LEO, MEO, and HEO. Rock and sling. Geosynchronous. Spy satellites. GPS location. Oil exploration. Manufacturing in space. Escape velocity. Gravity in science fiction. Falling to Earth. The X Prize. Automobile air resistance and efficiency. Force and acceleration. The g-rule. Rail gun. Circular acceleration. Escape to space. Black holes. Momentum. Rockets. Balloons. Skyhook. Ion rockets. Flying: airplanes, helicopters, balloons. Floating on water. Air pressure. Hurricanes and storm surges. Convection, thunderstorms, and heaters. Angular momentum and torque.

Chapter 4. Nuclei and Radioactivity.

Paradoxes and puzzles. The nucleus and its explosion. Protons, electrons, neutrons, quarks, and gluons. Isotopes. Radiation. Cloud chamber. Radiation and death: the rem. LD50. Poisoning and cancer. Linear hypothesis. Chernobyl. Hiroshima cancer. Denver exposure. Tooth and chest X-ray doses. Ultrasound. Radiation to cure cancer. Dirty bomb. Alpha, beta, gamma rays, and more. Natural radioactivity. Half-life rule. Power for satellites from RTGs. Radioisotope dating: potassium-argon and radiocarbon. Environmental radioactivity. Why aren't all atoms radioactive? Optional: tunneling and the weak force of radioactivity. Forensics: neutron activation. Watch dials. Plutonium. Fission. Fusion. Power from the Sun.

Chapter 5. Chain Reactions, Nuclear Reactors, and Atomic Bombs.

Chain reactions and the doubling rule (exponential growth): examples from chess, nuclear bombs, fetal growth, cancer, population (and Malthus), mass extinction recovery, PCR, germs, computer viruses, urban legends, avalanches, sparks and lightning, compound interest, Moore's Law, folding paper, and tree branches. Nuclear weapons basics. Critical mass. Uranium gun bomb. Uranium enrichment: calutrons and centrifuges. Plutonium implosion bomb. Thermo-nuclear "hydrogen bomb." Boosted bombs. Atomic bombs. Fallout. Nuclear reactors. Plutonium production. Breeder reactors. Dangers: cancer and the plutonium economy. Depleted uranium. Gabon natural reactor. Fuel requirements. Nuclear waste. Yucca Mountain. China syndrome. Three Mile Island. Chernobyl. Paradoxes. Present stockpile.

Chapter 6. Electricity and Magnetism.

Compared to gravity. Charge. Current: amps. Wires and electron pipes. Resistance. Conductors, semiconductors, and superconductors. Fuses and circuit breakers. High-temperature superconductors. Volts. Static electricity. Electric power. Frog legs and Frankenstein. House power. High-tension lines. Electricity creates magnetism: magnets, N & S, permanent, rare-earth, electromagnets. Monopoles? Short range. Electric and magnetic fields. Iron. Magnetic recording, hard drives. Curie temperature. Submarine location. Electric motors. Magnetism creates electricity: electric generators. Dynamos. The Earth and its magnetic flips. Geology applications. Transformers. The Edison/Tesla competition: AC vs. DC. Magnetic levitation. Rail guns again. Automobile battery. Flashlight batteries.

Chapter 7. Waves.

Mysterious uses of waves: UFOs near Roswell, New Mexico, and SOFAR rescuing of pilots in World War II. What are waves? Wave packets and quantum physics. Sound. Sound speed. Transverse and longitudinal. Water surface waves. Tsunamis. Period, frequency, and wavelength. Bending. Sound channel in the ocean and atmosphere. SOFAR and Roswell explained. Whale songs. GPS again. Ozone layer. Earthquakes. Magnitude and epicenter. P, S, L waves. Estimating distance rule. Liquid core of the Earth. Bullwhips. Waves cancel, reinforce. Beats. Musical notes. The ear. Noise-canceling earphones. Doppler shift. Huygens's principle.

Chapter 8. Light.

High-tech light. Electromagnetic waves. Light communication and information theory: the bit and the baud rate. Color and color perception. Rods and cones. White and pseudo-white. Color blindness. Multispectra. Printed color. Oil slick. Images. Pinhole camera. Eyes. Mirrors. Magic with mirrors. Retro-reflectors. Corner reflector. Stealth. Slow light. Index of refraction. Mirages. Diamonds, dispersion, and fire. Prism. Counterfeit diamonds. Other illusions: swimming pools and milk glasses. Rainbows. Lenses. Eyes again. Variable lens. Nearsighted and farsighted. Red eye and stop signs. Microscopes and telescopes. Spreading light. Diffraction. Blurring and spy satellite limits. Holograms. Polarization. Polarized sunglasses. Crossed polarizers. Liquid crystals and LCD screens. 3-D movies.

Chapter 9. Invisible Light.

Anecdote: illegal immigrants seen in the dark. Infrared. Thermal radiation and temperature. Red, white, and blue-white hot. Brown paint for cool roofs. Power radiated by warm object: 4th power. Tungsten inefficiency. Heat lamps. Dew on sleeping bags. Remote sensing of temperature. Weather satellites. Military special ops: "we own the night." Stinger missiles, pit vipers, and mosquitoes. UV and "black lights." Whiter than white. Sunburn. Germicidal lamps. Wind-burn. Ozone layer. Freon, CFCs, and the ozone hole. Greenhouse effect and carbon dioxide. Seeing through dust and smoke, firefighting. Electromagnetic spectrum. Radio, radar, microwaves, X-rays and gamma rays. Radar images. Medical imaging: X-rays, MRI (NMR), CAT, PET (antimatter), thermography, ultrasound. Bats. X-ray backscatter. Picking locks.

Chapter 10. Climate Change.

The temperature record. IPCC. Carbon dioxide and the acidification of the oceans. A brief history of climate. Warming from 1850 to present. Paleoclimate: the end of the last ice age. Cycles of ice and their astronomical causes. Carbon dioxide increase since 1800 and the greenhouse effect. Role of water vapor as an amplifier. Hurricanes and warming. Analysis, compensating for systematic biases. Tornadoes. The melting of Alaska. Dangers of exaggeration, distortion, and cherry-picking of data. Possible solutions to global warming. Alternatives to fossil fuels. Cost of energy. Fisher-Tropsch process: coal to liquid. Capture and storage: sequestering. Energy conservation and energy efficiency.

Chapter 11. Quantum Physics.

High tech is largely based on quantum physics. Electron waves. Spectra and remote sensing. Einstein discovers photons. Laser: a quantum chain reaction. Laser applications: supermarkets, cleaning, weapons. Controlled thermonuclear fusion using lasers. Lasers and eyes. LASIK surgery. Solar cells and digital cameras. Image intensifiers and night vision. Xerox machines and laser printers. Compact discs and DVDs. More on gamma rays and X-rays. Fiber optics limits from quantum physics. Are photons real? Semiconductor electronics. Light-emitting diodes (LEDs); traffic lights and stadium TV screens. Diode lasers.

Diodes to turn AC into DC. Transistor amplifiers and transistor radios. Computer circuits. Superconductors again. Electron microscope. Quantization of waves. Uncertainty principle. Tunneling and alpha radiation. Tunnel diodes. Scanning tunneling microscopes (STMs). Quantum computers.

Chapter 12. Relativity.

The nature of time. Fourth dimension. Time dilation. Twin paradox. The Einstein gamma factor. Time depends on velocity. Not all motion is relative. Length (Lorentz) contraction. Relative velocities. Invariance of the speed of light. Energy and mass. $E = mc^2$. Converting energy to mass. Antimatter engines. Zero rest mass of a photon. Massless particles have no time. Mass of neutrinos. Why you cannot get to light speed. Atomic bomb and relativity. Tachyons. Simultaneity. Pondering time.

Chapter 13. The Universe.

Puzzles. How can the universe expand? What came before the beginning? The solar system. Companion star? Planets around other stars. The Milky Way. Galaxies. Dark matter. WIMPs and MACHOs. Extraterrestrial life and Drake's equation. SETI. Looking back in time. Expansion of the universe. Hubble's Law. The beginning. Dark energy. The Big Bang. The 3K cosmic microwave radiation—created in the Big Bang. Gravity and relativity. Twins in gravity. Black holes again. Finite universe? Before the Big Bang. A Theory of Everything. "The Creation" (a poem).

An Example of a Physics for Future Presidents Midterm Exam

PffP First Midterm Exam

26 Feb 2009

Row________ Seat________

Last name______________________ First________________ SID___________ GSI_________

Essay questions (20 pts): pick **one** and only one to answer; **circle** the one you choose. Write a page **on the back of this sheet**. This side is for your personal notes only. Cover the important points in a clear and concise manner—as if you have only a few minutes to tell the President, your roommate, or your parent what that person needs to know. *Clear, effective writing is important.* If English is a new language for you, state so at the top of your essay. If you need to re-write the essay, ask for a new copy of this page.

1. Critics of solar power argue that the power in sunlight is so weak that it will never be a competitive source of power. Are they right? What are the possible future uses of solar power? Could it be used on the roof of a car, to power the auto? What about a solar-powered airplane? Could a large solar power collector provide power of a gigawatt? Give examples and numbers whenever possible.

2. "Even a high school student can build an atomic bomb." That statement has appeared in books and magazines, but is it true? What is involved in building an atomic bomb? What are the most difficult steps? What steps are the "easiest"? What countries have recently built atomic bombs, or are in the process of doing so, and what approaches are they taking?

Short questions (1 point each, 20 points total). Read the questions carefully so that you don't misinterpret them (e.g., by missing a word such as "not"). Each question has only one correct answer.

Compare the energy in a pound of gasoline to the energy in a pound of a modern computer battery:

( ) The gasoline has about the same energy as the battery
( ) The battery has 10x more energy
( ) The gasoline has 10x more energy
( ) The gasoline has 100x more energy

Sea level rise in the last 50 years is primarily due to

( ) warming sea water
( ) melting ice
( ) increased rainfall
( ) decreased evaporation

Three gases are at the same temperature. The molecules that are moving the fastest are:

( ) hydrogen
( ) oxygen
( ) nitrogen
( ) they all have the same velocity

A "heat pump" is

( ) similar to a refrigerator working backwards
( ) a kind of automobile engine
( ) a device used in a hot air balloon
( ) used in auto air bags

A change in temperature of 1° C is about equal to a change of

( ) 1° F
( ) 0.5° F
( ) 2° F
( ) 300° F

The most common altitude for a spy satellite is:

( ) LEO
( ) MEO
( ) HEO
( ) between MEO and HEO

If the sun turned into a black hole, its gravity near the Earth would

( ) be unchanged
( ) become infinite
( ) go to zero
( ) increase by about 10%

Small differences in gravity have been used to

( ) search for oil
( ) detect nuclear materials
( ) detect nuclear explosions
( ) create antimatter

Alexander Litvenko was assassinated using

( ) plutonium
( ) botox
( ) anthrax
( ) polonium

If you are exposed to 1 rem, the probability that you will get radiation sickness (note: the question is NOT about cancer) is:

( ) zero
( ) 1/100
( ) 1/300
( ) 1/2500

A Tokamak (such as ITER) is used to

( ) store nuclear waste (if it is certified)
( ) create more fuel than it uses
( ) destroy nuclear waste
( ) make fusion

Which was named after the University of California?

( ) a device for reprocessing
( ) a device for enrichment
( ) a method for measuring DNA
( ) a location for nuclear waste storage

Fallout kills primarily due to the radioactivity of

( ) plutonium
( ) uranium
( ) tritium
( ) fission fragments

According to the text, the world population

( ) will double in the next 50 years
( ) growth has recently stopped
( ) is still growing, but will peak in the next 40 years or so at 9 billion people
( ) doubles every 18 months

When a liquid boils, the increase in volume is typically a factor of

( ) 2
( ) 10
( ) 100
( ) 1000

Which fuel is cheapest, for the same energy delivered?

( ) oil
( ) natural gas
( ) coal
( ) AAA battery

A large nuclear power plant typically produces how much electric power?

( ) 1 megawatt
( ) 1 gigawatt
( ) 100 gigawatts
( ) 1000 gigawatts

Smart rocks are

( ) a new design of nuclear fuel
( ) meant to destroy nuclear missiles
( ) the highest quality of coal
( ) a method for purifying uranium

A typical fuel for fusion is

( ) uranium or plutonium
( ) radium
( ) deuterium and tritium
( ) C-14

The Chernobyl accident happened when

( ) the chain reaction grew out of control (a "reactivity" accident)
( ) the fuel lost its coolant (the "China Syndrome")
( ) A fire from outside the reactor spread to the reactor, setting it on fire
( ) A helicopter crashed into the reactor