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AUTHOR Flint, William
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ABSTRACT

This report was produced by the Sedro-Woolley Project which has the goal of infusing environmental education into the whole curriculum of a school district. Included are assumptions which the author believes are appropriate to environmental education; a relating of these assumptions to some topics of chemistry and physics; an outline of specific accomplishments to date, as well as projected future activities; definitions and rationalizations of Project Physics and modularization; a rationalization of environment objectives within the modules; and finally, a complete set of specific module objectives. Seventeen "mods" are described with specific contents described. Among the mods are Motion, Energy, E-M Field, Quanta, and Radioactivity. Several of the mods are developed in sequential order with prerequisites while others require only "Tool," the beginning mod which develops the mathematics necessary for all subsequent mods. (Author/TS)

HUXLEY COLLEGE
CENTER FOR ENVIRONMENTAL EDUCATION

THE PROJECT PHYSICS COURSE (MODULARIZED)

for grades 10—12

William Flint

Sedro-Woolley Project Report No. 5
October 1971
U.S.O.E. Project No. 0-0848
Grant No. OEG-0-70-5039

Huxley College of Environmental Studies
A Division of Western Washington State College
Bellingham, Washington 98225

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HUXLEY COLLEGE
Environmental Education Project

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TO THE TEACHER:

Presented here are ideas for multidisciplinary environmental education. The objectives of the ideas and methods suggested are clearly stated. The overall objective is to provide you, the teacher, with an aid in the development of your approach to teaching for and about the environment. These are not learning packages designed to be applied verbatim, but suggestions for ideas and methods that will enable you to develop learning packages. The contents of this report represent only the first treatment of the idea. It is published in this form in order that teachers may have an opportunity to experiment with it.

You will have to design your personal approach to environmental education. You are an environmental educator now, whether you realize it or not, because the environment is all around you and you are teaching about the environment that surrounds both you and your students. The state of the environment indicates that there is something wrong with the way in which you have learned to perceive and behave relative to the environment, and with the way you are teaching others to learn and behave in their environment today.

The ideas presented here are examples of ways in which you can incorporate environmentally beneficial learnings into your curriculum. The intent is not that you "add on" something specifically environmental to your curriculum, but that you incorporate environmental learnings into your treatments of the subject matter with which you have already been dealing. The specific manner in which you treat your responsibility to educate for environmental stewardship is up to you. It is hoped that these and many other ideas will help you in your effort to understand the meaning of "environmental education" and its implications for you as a teacher and as a human organism.

The environmental education development project of which this report is a part is an ongoing one, and it is hoped that all who attempt to use the report will participate in the project by reporting the results of their efforts to the project staff. The staff will compile the ideas and methods collected. This will enable all working on the development of environmental education to share each other's work and will promote the spirit of cooperation essential to the success of any project as broad as this one.

Please report the methods and results derived from your use of this report to:

John Miles, Director
Environmental Education Project
Huxley College of Environmental Studies
Bellingham, Washington 98225

Thank you.

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THE PROJECT PHYSICS COURSE (MODULARIZED)

INTRODUCTION

During the school year 1970-71, the author and 22 other Sedro-Woolley teachers, as well as five teachers from other schools in the Puget Sound region, were involved in an environmental education seminar in collaboration with Huxley College, a division of Western Washington State College at Bellingham, and the Northwest Environmental Education Center.*

The goal of the Sedro-Woolley Project (of which the seminar was a part) is to infuse environmental education into the whole curriculum of a school district. This contribution to the project is an attempt to wed some environmental concepts with the Project Physics curriculum in a modularized form. The following paper consists of some assumptions which I believe are appropriate to environmental education; a relating of those assumptions to some topics of chemistry and physics; an outline of specific accomplishments to date, as well as projected future activities; definitions and rationalizations of Project Physics and modularization; a rationalization of environmental objectives within the modules; and finally, a complete set of specific module objectives.

ASSUMPTIONS APPROPRIATE TO ENVIRONMENTAL EDUCATION

1. Components of the current, generally accepted value system, which is the basis for many of our actions, appear to be in conflict with values which seem to contribute to the maintenance of a quality natural environment; for example, the Judaeo-Christian directive to

*The Northwest Environmental Education Center has since become a part of the Huxley Center for Environmental Education.

"subdue the earth and be fruitful and multiply," our faith in the expanding economy, our respect for the "virtues" of competition, and our belief in the value of basic research simply for the sake of "furthering Science." Environmental education is, more than anything else, a study in values. Do we value our society's concept of "progress" more than we value the environment which has nurtured that society? To what degree should we cultivate each of these contrasting sets of values?

2. Environmental education must be "holistic," interdisciplinary, and/or universal, for two reasons: first, large-scale value changes do not seem as likely to occur when specific environmental problems, or aspects of them, are considered independently of each other; second, a good many of our environmental problems seem to have come about because of our failure to take a "holistic" view of things. One envisions, for example, the governmental agency which permits the construction of a chemical processing plant in a given waterfront area on the basis of short-term economic considerations only, but after all aspects (esthetic, long-term economic, environmental, etc.) of the decision are examined, that same agency may well reconsider its original decision.

3. All components of the biosphere are more or less interdependent; that is, energy flow, inorganic material cycles, plants, animals, their physical environment, etc., all relate to each other. Alteration of any part of the biosphere almost invariably will affect other parts of it. If the alterations are undertaken naively, some of the consequences may not be at all what was anticipated.

4. <u>The biosphere is finite</u>. It is receiving and radiating specific limited amounts of energy, it can support a specific and limited amount of biomass (population), it can tolerate a limited and specific amount of abuse.

5. <u>Humans alter the biosphere</u> by the very fact of their existence, <u>and they are capable of altering it in a reasonable manner</u>.

<u>ENVIRONMENTAL TOPICS RELEVANT TO CHEMISTRY AND PHYSICS</u>

1. Should we humans consider the moral (environmental) significance of our scientific and technological endeavors? That is, should research and development in such fields as nuclear physics, the SST, and genetic engineering be related to the possible consequences of this research and development--or should they proceed "because they are there"? A related question might be, should science happen for the sake of science? Since environmental education is a study in values, it seems reasonable that "science for the sake of science" be scrutinized as a value.

2. Since the very beginnings of scientific thought in ancient Greece, or perhaps earlier, there has been a protracted conflict between the philosophers and the empiricists; or, if you prefer, theoreticians and experimenters. As with many other conflicts, specific lines of battle are often indistinct, but evidence of them is nevertheless abundant. One part of the battle (which began in the 1700s) was that of the quantitative "mechanists," with Newton as their leading advocate, versus the romantic (holistic) philosophers, exemplified by Goethe and Rousseau. Today the participants in what may well be

a related skirmish seem to be the environmentalists and the military-industrial complex. Extremes of the spectrum are tinged with psychosis, and a good many scientists seem to be caught in the middle. The environmentalists are concerned with the interrelations between all the components of the biosphere, and yet many of them are apparently unwilling and/or unable to do any quantitative studies of these interrelations--perhaps because of their aversion to technology. And so, some of the most extreme environmentalists may well find that a good many of their actions have been as unwise and ill-founded as the actions of their opponents. Although the military-industrial complex, with its accompanying scientific research facilities, does seem to be modifying its views toward a holistic environmental concern, there is still a tendency to focus on isolated problems and work intensively on them until they "yield" without giving serious regard to the related consequences of the solutions. Today's science students should be made aware of this contrast in views of science, and they should come to recognize both the value of the holistic view of things and the necessity for disciplined, quantitative research, observation, and measurement.

3. Some specific aspects of man's interactions with the biosphere lend themselves rather well to chemistry and physics. Pollution, heat, radiation, and man's place in the universe are a few.

   a. The natural constituents of water and the atmosphere can be quantitatively compared in high school chemistry with man's introduction of new or additional quantities.

   b. The study of energy in high school physics and chemistry will give students the tools to measure natural and human manipulations of energy in its various forms (such as thermal pollution, rates of energy consumption, entropy, etc.).

c. A knowledge of radioactivity may help high school students discuss environmental radiation effects with more sophistication than before.

d. A familiarization with the history of man's changing concepts of the universe, particularly with regard to celestial motion, may help students to perceive the truly finite nature of Earth and its resources.

WHAT IS PROJECT PHYSICS?

Project Physics is a high school physics course devised by the Harvard Project Physics Curriculum Study (1962-1969), which involved the collaboration of hundreds of physicists, educators, and high school physics teachers, and which was supported by grants from the Carnegie Corporation, U.S. Office of Education, the National Science Foundation, the Ford Foundation, and the Alfred P. Sloan Foundation, as well as Harvard University.

Over half of the traditional physics context has been retained in this course, yet most of it is presented in fresh, new ways. Emphasis of some subject areas has been drastically shifted, and there is considerable new material. (For example: in considering the acceleration of gravity, the life and times of Galileo and the significance of his discoveries in this area are also considered.) Project Physics is a reflection of current physics, and the areas studied fall into three categories roughly equal in size--atomic/nuclear physics, energy, and motion. (A substantial portion of the motion section is devoted to astronomy.)

Project Physics is a serious attempt to humanize physics. The historical background and social effects of significant advances in physics are given extensive coverage. Throughout the course, the relation of physics to the humanities and to the other sciences is repeatedly emphasized.

Project Physics was planned for multimedia. Different students learn in different ways, and the theory is that most students will, at least part of the time, be able to learn in the way that works best for them. Some of the different media are film loops, programmed learning booklets, selected short articles--many of them by famous scientists--bound in "reader" form, movies, slides, a textbook, models, and lab equipment.

Specific teaching methods, tactics, and strategies are left to the teacher. Project Physics makes no attempt to dictate these things.

WHAT ARE MODULES?

Modules (mods) are learning packages, designed to be used by individuals, or small groups of students, working independently. The average mod is designed to take the typical physics student about two weeks to complete. It consists of a set of clearly worded objectives, containing the essence of the actions the student must take to complete that mod; the apparatus and materials necessary for the completion of those objectives; and the student's text. Many mods are independent of each other and can be worked in almost any sequence; however, some mods are prerequisite to the completion of others. A student is encouraged to work through the mods he feels are relevant at the rate he feels optimizes learning for <u>him</u>. Since the student determines the mods and rates (within the limits of some rather minor specifications) a conventional grading system becomes impossible, and more "honest" motivational devices must be developed. (I don't feel we've been very successful in this regard as yet. About forty per cent of the class tends to be "goofing off" at any given moment during classtime, which would be acceptable if this time were made up outside of class; but unfortunately, only about twenty per cent of the class appears to be doing any appreciable outside work.)

If one believes that "the medium is the message"--that an individual learns as much (or more) about an educational medium as he learns about what that medium is meant to convey--then one cannot help but shudder when he contemplates our traditional medium of education: the conventional classroom environment. If one is truly concerned with environmental education, then it seems reasonable that he also be concerned with educational environment. The modules are an attempt to improve educational environment through individualization.

SPECIFIC ACTIONS TAKEN IN THE 1970-71 SCHOOL YEAR

In general, we planned and wrote. We concentrated heavily on developing modules for use with the Project Physics course. (Some outlining of potential modules, and some module development was done in chemistry, but most of the developmental work in chemistry will be done next year.) The first semester of physics was taught in the traditional lecture/lab manner, using Project Physics materials. We used an earlier version of the modules during the second semester (including the modules Waves through Nuclear Energy). As mentioned above, our success with the modules was somewhat limited; however, we intend to use them on a larger scale next year, making some changes in their use, and capitalizing on our experiences this year.

THE PROJECT PHYSICS MODS

A module is regarded as complete when (1) each objective on a student's objective sheet has been initialed by a teacher or a student who has completed that objective (the party initialing the sheet is responsible for that objective); (2) labs requiring the recording of data, graphing, and calculations have been clearly written up, so they can be quickly and easily interpreted; and (3) the student has taken a definition/formula memory test on the underlined items in the mod.

A list of the mods follows.

Mod Title	Prerequisites	Description
Tool	None	Math necessary to do physics and chemistry. A student need not do this mod if he passes the test for it.
Motion	Tool	Uniform motion and acceleration
Newton	Motion	Newton's laws
Celestial	Tool	Celestial observations and history
Orbit	Newton	Gravitation and circular motion
Momentum	Newton	Conservation of momentum
Energy	Momentum	Kinetic and heat energy
K-M Theory	Newton	Statistics, gas laws, and kinetic-molecular theory
Wave	Tool	Wave phenomena and definitions
Light	Wave	Properties of light
E-M Field	Newton	Electric and magnetic phenomena and relations
E-M Waves	Fields and Light	Propagation and properties
Minichem	Tool	Combining ratios, periodicity, electolysis
Quanta	E-M Field	Charge of electron, e/m, photoelectric effect
Mod Physics	Tool	Electron energy levels, quantum mechanics, relativity
Radioactivity	Tool	Measurement, decay, properties
Nuclear Energy	Radioactivity	Nuclear reactions, social implications

Tool Mod

Chem lab manual, p. 137	1. a.	Be able to express any real number in proper scientific notation 95% of the time, or better.
Scientific notation program	b.	Be able to add, subtract, multiply, or divide any two real numbers, using proper scientific notation, with an accuracy of ±1% better than 90% of the time.
Slide rule program	c.	OR, be able to multiply or divide any two real numbers on a slide rule with an accuracy of ±1% over 90% of the time.
Chem lab manual, pp. 139-140; Unit 1 Physics text, pp. 167-168	2. a.	Be able to multiply, divide, add, and subtract quantities containing an expression of uncertainty; the uncertainty figure in the answer is to be accurate within ±10% better than 75% of the time.
Chem lab manual, p. 138	b.	Be able to round off sums, products, etc., to the proper number of significant figures better than 75% of the time.
Any basic algebra text	3. a.	Given any linear equation, be able to express any one of the variable quantities in terms of the other quantities; and given those quantities, be able to solve for that variable within ±1% over 90% of the time.
	b.	Given any monomial equation, be able to express any one of the variable quantities in terms of the other quantities; and given those quantities, be able to solve for that variable within ±1% over 90% of the time.
Chem lab manual, pp. 146-148	4.	Be able to graph one variable against another, and properly label the graph, given a table of data in two variables.
Chem lab manual, p. 134; Tool chart	5.	In order to have a working familiarily with the metric system which is used exclusively in chemistry and physics, be able to state the following quantities from memory within ±20%, 90% of the time: -- Length of a football field in meters and kilometers -- Distance to Mt. Vernon in meters and kilometers -- Distance to the moon in meters and kilometers -- Width of your handspan in meters and centimeters

-- Width of your little finger in meters and millimeters

-- Top speed of the family car (truck) in meters and millimeters

-- Volume of the gas tank of the family car in liters, milliliters, and cc's

-- Volume of a can of pop in liters, milliliters, and cc's

-- Your body mass in kilograms and grams

-- The mass of a penny in kilograms and grams

-- Boiling and freezing (water) in degrees Celsius (centigrade)

-- Your body temperature in degrees Celsius (centigrade)

Unit 1, Physics text, pp. 129-131

6. Be able to write up an experiment in a manner such that someone else with a high school background in chemistry and physics (or better) can quickly and correctly determine what you did and what the results were, using only your write-up and the lab manual. Minimum contents of a write-up are:

   -- Title and name

   -- Objective and procedure (may refer to page in manual)

   -- Applicable sketches

   -- Data with applicable tables and/or sketches, clearly labeled, with proper units

   -- Interpretations, with applicable graphs and/or equations clearly identified and labeled

   -- Always a conclusion capturing the essence of the experiment, supported by data (which in some instances may have to be borrowed)

Motion Mod

1. Read Chapters 1 and 2 (Unit 1, Project Physics) and be able to define and discuss within the framework of the text: average speed, pp. 12, 15-17, 23; uniform speed, p. 15; slope, pp. 18-21, 29; interpolation, p. 21; extrapolation, pp. 21-22; instantaneous speed, pp. 24, 29; velocity, p. 25; acceleration (average, instantaneous, constant), pp. 28, 29, 48-49; Aristotle, pp. 37-41; four-element theory of motion, pp. 37-40; "violent" motion, p. 40; Galileo, pp. 42-60; free fall, pp. 45-47; OC, p. 50.

Exp 4, pp. 145-150

2. a. Using a polaroid camera, take a "stop-action" (stroboscopic) photo of an object moving with uniform motion in one of the following ways:

   -- Stop the motion of a glider on an air track with either a strobe disc or a strobe light.

   -- Stop the motion of a toy jeep, using a blinky.

   -- Stop the motion of a puck on dyalite beads, using either a strobe light or strobe disc.

   b. Make a table of the distance traveled over the time intervals in your picture, similar to the table on p. 148. Graph time against total distance.

   c. Answer questions Q1-Q7.

3. (Do either a or b; then do c and d.)

Exp 5, pp. 153-156

   a. Using the Galileo apparatus similar to that pictured on the bottom of p. 153, measure the descent time of a ball rolling down the incline (at least four times for each of four different distances).

Exp 6, p. 157

   b. Using an inclined airtrack and a stopwatch, measure the descent time of a glider moving down the track (at least four times for each of four different distances).

   c. Graph the square of the average descent time against the distance for that time.

   d. Given that $v_{av} = \Delta d/\Delta t$, and $a = \Delta v/\Delta t$, be able to prove that $d = \frac{1}{2} at^2$; relate this to d/t^2 = constant. (Pp. 50-52.)

4. Measure the acceleration of gravity in <u>one</u> of the following ways, or in another experiment devised by you:

PSSC lab guide	-- by direct fall, using a buzzer, carbon paper, and paper tape.
Offprint, TG	-- by direct fall, using a battery light, strobe disc, and polaroid camera.
Exp 7, pp. 159-160	-- from a pendulum.
Thornton film loop	-- using the counter/timer, and photoelectric cells

5. View the motion slide/tape sequence, and perform activities as directed (p. 58; SG 2.27-2.29; slides; etc.)

6. Be able to work problems similar to 1.3-1.5; 2.17; 2.19; 2.21-2.24.

7. Read any one (or more) of the reader articles listed on p. 31.

Newton Mod

1. Complete Motion Mod.

2. Read Chapter 3 (Unit I, Project Physics), and be able to define and discuss within the framework of the text: Newton's first law, pp. 68, 75-78; Newton's third law, pp. 68, 86-87; force, pp. 70-71; equilibrium, pp. 71-73; resultant force, p. 72; vector and scalar quantities, p. 75; inertia, p. 77; frame of reference, pp. 77-78; mass, weight, pp. 80, 83-85; F = ma, p. 81; kilogram, p. 82; newton (force unit), p. 82.

3. Do one of the following:

   a. Work through the Project Physics program sequence on vectors.

   b. Work through "Introduction to Vectors" in the reader.

   c. Work through the slide-tape-film loop sequence on vectors and perform activities as directed.

   After doing one of the above, you should be able to add and subtract vectors, as well as solve problems containing vector quantities.

4. a. Measure the mass of a cart, blinky, and spring balance.

   b. Apply a uniform force to this cart assembly by pulling it with a weight tied to a string running through a pulley over the edge of the lab bench. Read the force applied from the spring balance.

   c. Predict the acceleration a, using the formula F = ma.

   d. Check your prediction by photographing the cart assembly in operation and determining the blink rate with the counter/timer, or in some similar manner.

   e. Qualitatively determine how:
      -- different forces will affect the same mass;
      -- variations in mass affect the acceleration (force constant).

5. Work through the tape sequence on Newton's laws, and perform activities as directed.

6. Read one of the reader articles listed on p. 93.

Celestial Mod

1. Perform at least one of the following sequences of celestial observations (since these occur over an extended period, it is expected that you will be working on other modules while you are working on this particular objective):

Exp 1 (Unit I), pp. 134-141

a. Observe and record the azimuth and time of sunrise once a week for at least two months.

b. Observe and record the azimuth and time of sunset once a week for at least two months.

c. Observe and record the azimuth and altitude of the moon and draw its shape on successive evenings at the same hour for at least 28 consecutive days.

d. Identify a planet and plot its position on a sky map relative to the stars at one- to two-week intervals for at least two months.

Exp 15 (Unit II), pp. 133-134

e. Determine the size of the earth by observing the altitude of the sun at noon simultaneously with someone else at least 200 miles south of you

2. Read Chapters 5, 6, and 7 (Unit II, Project Physics) and be able to define and discuss within the framework of the text: altitude, azimuth, p. 134 (Unit I); north celestial pole, Polaris, p. 9; celestial equator, ecliptic, equinox, p. 10; retrograde, pp. 12, 25; opposition, p. 12; Plato's problem, pp. 15-19; parallax, p. 20; Ptolemaic system, pp. 21-26; eccentric, epicycle, equant, deferent, p. 23; Copernicus, pp. 29-32; AU, p. 35; Tycho Brahe, pp. 45-51; Uraniborg, pp. 45-46; Kepler, pp. 49; 55-69; law of areas, pp. 57-59; law of elliptical orbits, pp. 59-63; eccentricity, p. 60; empirical, conic sections, p. 63; law of periods, T/R = k, pp. 66-67; Inquisition, Index of Forbidden Books, pp. 75, 76; Pantheism, p. 76; Monkey Trial, p. 77; geocentric, p. 17; celestial sphere, p. 17, 41; Aristotle, p. 18; Aristarchus, heliocentric, p. 19.

Exp 14, pp. 128-132

3. Work through parts A, B, and C of Experiment 14.

Exp 17, pp. 148-150

4. a. Use the U.S. Naval Observatory photographs of the sun to plot (in pencil, on a large sheet of graph paper) the orbit of the sun around the earth.

   b. Convert your graph to the heliocentric system, as is suggested on p. 150.

Exp 19, pp. 158-161

   c. Use the Mars photos and overlays to plot the orbit of Mars on the same sheet of graph paper (in pencil); then answer Q6 on p. 161.

5. Work through the tape sequence on retrograde motion (geocentric assumption, film strip 146, loop 157, machine 140, Part E of Exp 14).

6. View the navigation slide-tape sequence and perform activities as directed (geocentric assumption, Air Almanac, sextant, slides, etc.).

7. Do at least one:

   a. Participate in a debate of the Ptolemaic versus the Copernican concept of the universe with at least three other debaters before an audience of at least five non-science students who will act as "impartial" judges.

   b. Shoot at least one 3-star celestial "fix" correctly, within 30 nautical miles.

   c. "Prove" to the satisfaction of the instructor that the earth goes around the sun, using only observable data (typewritten report, double-spaced).

8. Select, read, and discuss with another person any three of the articles from the Unit II Reader.

Orbit Mod

1. Complete Newton Mod (Celestial Mod also recommended).

2. a. Read Chapter 4 (Unit I, Project Physics) and be able to define and discuss within the framework of the text: $y = \frac{1}{2}at^2$, $x = vt$, pp. 101-104; $y = kx^2$, parabola, p. 104; Galilean relativity, p. 106; period T, frequency f, p. 107; centripetal acceleration and force, pp. 109-113.

   b. Read Chapter 8 (Unit II, Project Physics) and be able to define and discuss within the framework of the text: Newton, pp. 83-87; universal gravitation, pp. 89, 91, 94-96; inverse square law, pp. 90-91; hypothesis, pp. 97-98; mass points, p. 99; $F = G\, mm/R^2$, p. 100; Cavendish, pp. 104-105.

3. Do at least one of the following:

   a. Use a trajectory apparatus to plot on a piece of graph paper the path of a steel ball launched from a trajectory ramp. Then answer Q1-Q5, p. 178, Unit I. (Exp 10 (Unit I), pp. 176-178)

   b. Predict the landing point of a ball launched horizontally from a tabletop. (Use a stopwatch and a meterstick to determine v of the ball; record all your data and calculations in a readable manner.) (Exp 11 (Unit I), pp. 179-180)

   c. Work through film loop 6 (p. 189, Unit I).

4. View film loop 7 and answer the questions for scenes 1, 2, 3, 4 (p. 190, Unit I, problems 4.6-4.10).

5. Work through the tape sequence on centripetal force (Exp 12, slides, aquarium, Exp 13, problems 4.14, 4.16, 4.17, 4.20-4.23).

6. a. View slide-tape sequence on inverse square and "blows" (p. 92).

   b. Use an "inverse square" graphical computer, a ruler, and a compass to plot a stepwise (Exp 21 (Unit II), pp. 170-174) approximation to an orbit on a large sheet of graph paper. (Hopefully, the opposite side to the one you used in the celestial mod.)

c. View film loops 13, 14, 15 (pp. 186-188, Unit II).

7. Be able to prove at least two of the following without references:

a. That the trajectory of a projectile is a parabola (Unit I, p. 103);

b. that $v = 2\pi Rf$, given that perimeter $= 2\pi R$, $v = 2\pi R/T$, $a_c = v^2/R$ (Unit II, pp. 90-91);

c. that $a_c = v^2/R$ (Unit I, p. 111);

d. that $F \propto 1/R^2$, given that $F \propto a$, $T^2 = kR^3$, $v = 2\pi R/T$, $a_c = v^2/R$ (pp. 90-91, Unit III).

8. Be able to work problems similar to Q12-Q14, p. 101; 8.8-8.17 (Unit II).

9. Read the Unit I "Epilogue," pp. 118-119, and the Unit II "Epilogue," pp. 114-120. Reread section 8.10, pp. 111-113 (Unit II).

From the above, it would appear that the conflict between anti-technology forces ("greenies") and the military-industrial complex is really nothing new. The difference may be that in the 1700s and 1800s the opponents were known as Romantics and Newtonian Cosmologists. The Romantics, or "nature philosophers," tried to understand a phenomenon as a whole; and they exalted emotion and feeling at the expense of the reason and calculation used by the Newtonian scientists. The Newtonians believed in the processes of our Unit I: that is, that analysis of the simple aspects of a system leads to an understanding of its more complex features.

With regard to the biosphere (the living part of planet earth), it would appear that our analysis of the simple aspects of the system has led us into dire straits, at the expense of an understanding of the whole world ecosystem.* Obviously "reductionism" (reducing a complex system into its simple components) has merit; and obviously it can get us into trouble. Hypothesize a solution to this problem, or devise a method for accomplishing one of the following:

a. Making people aware of the problem.

b. Selling solutions to the problem to taxpayers.

*Analysis of simple aspects of the system has led to (1) less disease (lower death rate--overpopulation); (2) more live births (overpopulation); (3) better farm production (fertilizers, pesticides, overpopulation); and (4) improved transportation and other "conveniences" (consumption of natural resources, water and air pollution, etc.)

Momentum Mod

1. Complete Newton Mod.

2. (Do this objective before doing objectives 3-6)

   a. Examine one of the following interactions, and gather data as suggested in the instructions:

      -- "Exploding" dynamics carts: take a strobe disc or strobe flash photo with a polaroid camera.

      -- Colliding air track gliders: take a strobe disc or strobe flash photo with a polaroid camera.

      -- Film loop, pp. 169-170.

      -- Stroboscopic photos, pp. 154-160. Do any two events.

   b. Assemble your data in a table similar to Fig. 9-3 on p. 150.

   c. Determine which quantities or combinations of quantities other than mass are unchanged before and after the interaction. Try speed (Q1), velocity (Q2), and combinations of speed or velocity and mass.

3. Read Chapter 9 (Unit III, Project Physics), and be able to define and discuss within the framework of the text: law of conservation of mass, pp. 5-8; momentum, pp. 9-11; law of conservation of momentum, pp. 11-15; isolated or "closed" systems, pp. 6, 8, 19; kinetic energy, pp. 20-21; law of conservation of kinetic energy, p. 21; Leibniz, pp. 22-23.

4. a. Examine one of the following interactions, then do b and c.

      -- Colliding pucks or disc magnets of dyalite spheres: take a strobe disc or strobe flash photo with a polaroid camera.

      -- Film loop, pp. 170-171.

      -- Stroboscopic photos, pp. 161-166. Do any two events.

b. Multiply the mass of each object by its before-the-collision speed, and add the products; then do the same thing for the objects after the collision. Answer Q1 on p. 152.

c. Now compare the <u>vector</u> sums of $m\overline{v}$ for each object before and after the collision.

5. Be able to work problems similar to 9.8, 9.9, 9.11, 9.15-9.20, 9.25, 9.26.

6. Be able to prove <u>one</u>:

a. $m_a\overline{v}_a + m_b\overline{v}_b = m_a\overline{v}_a + m_b\overline{v}_b$, given that $\overline{F} = m\overline{a}$ and $\overline{a} = \Delta\overline{v}/\Delta t$

b. SG (9.34)

c. $Fd = \frac{1}{2} mv^2$ (9.34)

Energy Mod

1. Complete Momentum Mod.

2. Read Chapter 10 (Unit III, Project Physics) and be able to define and discuss within the framework of the text: work, $W = Fd$, pp. 31-32; $Fd = \frac{1}{2}mv^2$, pp. 32-33; joule (energy unit), p. 33; potential (gravitational, elastic, electric, magnetic) energy, pp. 33-35; total mechanical energy, pp. 36-37; $\Delta KE + \Delta PE = 0$, p. 37; Savery engine, p. 43; Newcomen engine, p. 44; feedback, p 45; Watt engine, p. 47; watt (power unit), p. 48; mechanical equivalent of heat, pp. 53-54; first law of thermodynamics, pp. 62-64.

Exp 24, pp. 174-176

3. a. Examine one of the following interactions:
   - -- Colliding dynamics carts, using battery light sources at two different heights, a strobe disc, and polaroid camera.
   - -- Magnet pucks on dyalite beads, with a strobe light and polaroid camera.
   - -- Film loop 26 (p. 194).

   b. Compare total $\frac{1}{2}mv^2$ before, with total $\frac{1}{2}mv^2$ after.

Exp 24, pp. 174-176

4. Do a or b.

   a. Using an inclined air track as suggested under the third method (pp. 176-177), give a glider enough of a push to almost make it to the high end. Mark the high point of the trip with chalk, time the glider's total trip with a stopwatch, measure the distance traveled and the change in height of the glider, and weigh the glider. Compare the glider's potential energy at the high end with its kinetic energy at the low end, using $PE = mah$, and $KE = \frac{1}{2}mv^2$.

   b. Film loop 34, p. 200. Answer the related questions.

5. Work through the temperature and heat cassette sequence (Thornton loop, thermocouples, collisions, etc.).

Exp 27, pp. 182-185

6. a. Using the formula $\Delta H = cm \Delta T$, successfully predict the final temperature (within 3°C) when two different masses of water of known temperatures (differing by at least 15°C) are poured together.

   b. Determine by experiment the specific heat of an unknown metal sample.

   c. Determine the latent heat of melting for ice.

7. Do any two of the following:

   a. Given that in 1950 the population of the world was 2.4×10^9 people, and the world food production was 5.76×10^{12} KCals; assume that the world population doubling time is 30 years, and assume the world food production rate increases at the rate of 2% a year. Graph the number of KCals per person against the change in time from 1950 through 2040 (p. 56).

   b. Assume that the minimum amount of heat given off by each human per day is 2×10^3 KCal; also assume that the minimum amount of heat given off by the food chain necessary to support this human per day is 18×10^3. Finally assume that the maximum amount of heat our planet can radiate away into space is 2×10^{22} KCal/day. (This is assuming the use of an earth-wide air conditioning system, using molten Fe heat exchangers.) What is the "heat limit" on earth's population? Assume a doubling time of 30 years and a present population of 4 billion; calculate how long it will take to reach our heat limit. The area of the surface of the earth is about $5 \times 10^{14} m^2$; calculate how many people this will be per m^2 (pp. 18-19, Population Bomb).

   c. Write a short, one-page paper describing the life and forms of a "packet of energy." This saga should begin with the energy in the form of a photon (light wave) headed from the sun to the earth, and will end with the energy being radiated away from Earth in the form of low-grade heat energy. At some point during the energy packet's life, it will assume these forms: electrical, chemical or biochemical, and physical (potential or kinetic). It must at some time be stored in a plant, and in an animal. The story should be believable (pp. 55, 57, 61).

d. Suppose that because of a different variety of influences (religious, political, economic, and scientific) the steam engine, James Watt, and the industrial revolution had just not come about; and further suppose that many of the major advances in medicine occurred much as they actually have (including such things as sterile surgery and antibiotics). Write a short (one-page) paper discussing the environmental problems we would be having, and contrast them with the problems we actually do have (pp. 47-57, 187).

K-M Theory Mod

1. Complete Newton Mod (Energy Mod also recommended).

2. Read Chapter 11 (Unit III, Project Physics); be able to define and discuss within the framework of the text: kinetic molecular theory of heat, pp. 71, 83-86; pressure, p. 71, 81; density (look up in an outside source); "billiard ball" model, pp. 72-73; Maxwell velocity distribution, pp. 77-79; normal distribution, p. 77; Boyle's law, P = kD, p. 82; Brownian motion, p. 86; P = kD(t + 273), p. 82; Kelvin scale, absolute zero, p. 83; ideal gas law, second law of thermodynamics, pp. 88-90; Carnot, pp. 88-89; Clausius, pp. 78, 80, 89; entropy, p. 89; "heat death", p. 90; Maxwell's demon, pp. 91-92; reversibility paradox, p. 94; recurrence paradox, pp. 95, 98.

Exp 28, pp. 201-207

3. Do a, to get an idea of the reason for this experiment, then do b or c.

   a. Carefully reread section 11.4 (pp. 78-81), and answer Q8. Clausius related a molecule's size and the distance it could travel between collisions, and he actually calculated the size of the molecule. To see how this might be possible, press on!

   b. Use the Monte Carlo randomizing apparatus (a nail-studded board!) and the formula d = RD/2N to indirectly determine the diameter of the marbles placed in the "target" area. (Use the second digits in each random number pair to locate the marbles. For example, 03 47 would be x = 3, y = 7.

   c. Use a large sheet of graph paper, 50 squares on a side, with 40-60 "molecules" located randomly on it, to determine the "mean free path" of a particle bouncing among the "molecules." Use the two-dimensional Clausius equation L = A/Nd to indirectly obtain d, the width of one square.

Exp 29, pp. 208-209

4. a. Use the Boyle's law apparatus (pictured at the bottom of p. 108) and a set of weights to qualitatively determine that pressure is indeed inversely proportional to volume.

b. View the slide/tape sequence on PVT, and perform activities as directed. Write a statement relating volume and temperature, and also temperature and pressure.

c. Write a statement relating volume, temperature, and pressure.

5. Given that $F = ma$, $P = F/A$, $v^2 = v_x^2 + v_y^2 + v_z^2$, and $kT = 1/3\ v^2$, be able to prove that $P = kDT$.

6. a. Many people seem to be concerned about our deteriorating environment; in particular, our natural surroundings. Of course this concern about deterioration implies that some sets of natural surroundings are better than others. Yet, when faced with the problem of specifying the quality of an ecosystem (important when writing laws, proposals, etc.) it becomes difficult to describe a "good" natural environment in precise measurable terms.

Since, within a biological food chain, complex, well-ordered molecules containing stored energy are passed from one organism to another over a period of time, and since the longer and more complex the food chain is, the longer this energy and order will be contained within the ecosystem, is it possible that a natural environment and ecosystem might be qualitatively evaluated in terms of its rate of entropy? (The following references may be helpful in answering this question: (1) pp. 90-93 of the text; (2) excerpts from the Rick Chace film; and (3) Storer's *Web of Life* and Leopold's *Sand County Almanac*. These latter two are general references to provide you with a feeling for what a "quality" ecosystem might be.)

b. If the answer is yes, devise a method which at least seems somewhat reasonable for measuring the entropy of an ecosystem (no matter how simple), and state your method in writing, with necessary diagrams, and give a description of an ecosystem which your method might be used to measure.

c. If the answer is no, state why not in terms of your understanding of entropy and living systems; and propose, if possible, another better single indicator of an ecosystem's quality.

Wave Mod

1. Read Chapter 12 (Unit III, Project Physics). Be able to define and discuss within the framework of the text: medium, p. 106; polarized, p. 108; waves, pp. 105-109; propagation, pp. 109-110; periodic wave, amplitude, period, p. 111; superposition, pp. 113-114; nodal line, p. 117; in phase, out of phase, p. 119; Huygens' principle, p. 125; image, pp. 127-128; rays, angle of incidence, p. 123.

Exp 30, pp. 217-218

2. Demonstrate the following on a giant, suspended "slinky": (1) longitudinal pulse, pp. 106-107; (2) transverse wave, p. 107; (3) low and high frequency (f), p. 111; (4) short and long wavelength (λ), diffraction, p. 124.

Exp 30, pp. 218-219

3. a. Demonstrate the following on a ripple tank: reflection, focus, refraction, pp. 130-132; interference, pp. 114-117; high f long λ, diffraction, p. 124.

Exp 30, p. 219

b. Measure wavelength on a ripple tank, using a strobe disc or standing waves, p. 119, 121.

Exp 31, pp. 224-225

c. Measure wavelength on a ripple tank, using an interference pattern with the formula $\lambda = \frac{xd}{L}$, p. 120.

Exp 31, pp. 220, 224

4. a. Use either sound or ultrasound to demonstrate reflection, diffraction, standing waves.

b. Measure the length of a sound wave by using an interference pattern and the formula $\lambda = \frac{xd}{L}$.

Exp 31, p. 222 or 229

c. Determine the speed of sound through an experiment of your own choosing, utilizing the formula $V = \lambda/T$ or $V = \lambda f$, pp. 111, 112.

5. View wave sequence (if available) and perform activities as directed.

Light Mod

1. Complete wave mod.

2. Read Chapter 13 (Unit IV, Project Physics). Define point source, p. 8; ray, Young, p. 13; poisson spot, pp. 14-15; longitudinal, p. 22; transverse, p. 22; Newton's color theory, pp. 15-20.

3. Be able to compare wave (p. 6) theory of light with particle theory (pp. 5-24). Comparison will include reference to, but need not be limited to, camera obscura, p. 8; reflection, p. 11; refraction, p. 11; interference, p. 13; and polarization, pp. 21-23.

4. Be able to briefly recount significant developments in the history of measuring the speed of light in m/sec, recounting to include Galileo, Roemar, Huygens, Maxwell, Fizeau, ether, and Michelson/Morley. Pp. 9-10, problems 13.4, 108, 110, 123.

5. a. Using the Hartl optical apparatus, and a "D"-shaped piece of glass, obtain the size of the angle of refraction in glass for each angle of incidence (p. 11) from 0° to 85° in 5° steps.

Exp 32, pp. 134-135

   b. Plot the above angles of incidence against the sines of the angles of refraction on graph paper, and relate them mathematically in a formula.

   c. Assuming the speed of light in air is 3×10^8 m/sec, calculate the speed of light in glass.

6. a. Demonstrate diffraction (p. 9, 16) of light, using two fingers and an illuminated showcase bulb.

Exp 33, pp. 136-137; or Exp PSSC, lab 34-34

   b. Use a double slit interference pattern to determine the wavelength (λ), p. 5, of green light in meters and in angstroms (defined as fraction of a meter), p. 20.

   c. Determine the frequency (f), p. 5, of green light, using the formula $c = f\lambda$.

7. Do at least two cf the following:

    a. Make a diffraction pattern and a poisson spot with a laser.

    b. Demonstrate scattered light, using milky water and a flashlight, p. 139.

    c. Demonstrate "refraction" of particles, PSSC lab 21.

NOTE: Two-thirds of the way down on p. 123 of the text, change other to ether.

E-M Field Mod

1. Read Chapters 14 and 15 (Unit IV, Project Physics). Define the following within the framework of the text: charged, positive, negative, p. 56; electrostatic induction, p. 41; smallest charge, Millikan, quark, pp. 50-51; Leyden jar, p. 52; insulator, p. 53; Voltaic cell, p. 54; potential difference, volt, p. 55; $E = v/d$, electron accelerator, p. 56; electron volt, p. 57; Ohm's law, p. 58; watt, p. 59; ampere, p. 63.

Exp 35, pp. 144-145

2. a. Devise an operating electric charge balance, p. 31-35.

   b. Measure the force between a pair of charged spheres with the balance, for at least four different distances, without recharging the spheres, and

   c. Plot force against distance on a piece of graph paper.

   d. Relate your results to Coulomb's law, $F = \frac{kQq}{R^2}$, pp. 37-39. Solve SG 14.2, 14.3.

3. Be able to qualitatively describe verbally and in writing (with the help of sketches):

   a. The electric field (pp. 42-49):

      -- in the area of a charged sphere,

      -- between spheres of like charge,

      -- between spheres of opposite charge,

      -- between oppositely charged plates.

   b. The magnetic field (pp. 31-35):

      -- between like poles,
      -- between opposite poles,
      -- around a conductor (p. 53) carrying a constant current (p. 54) of known direction (p.60),
      -- in the area of a simple coil carrying a constant current (p. 64).
      -- Be able to predict the direction a compass will point if placed either over or under a conductor carrying a current in a known direction (p.60).

c. $F = qE$, SG 14.7-14.9.

4. Use the correct hand rule to qualitatively predict the path of moving charges, either + or -, when their velocity originates at right angles to magnetic or electric force fields with parallel lines of force (p. 67). Define $F = qvB$.

5. View E-M sequence and perform activities directed on tape.

Exp 36, pp. 147-151

6. a. Set up, adjust, and properly connect a current balance, two power supplies, and two ammeters (measure amps, p. 63).

   b. Measure the forces between two current-carrying wires, a and b, one cm apart: (1) when the current in a is const; (2) for at least four different amounts of current in b.

   c. Plot change in force against change in current on a piece of graph paper.

   d. Qualitatively determine how the force between two current-carrying wires varies with the length of one of the wires, if the currents are held constant.

   e. Qualitatively determine how the force between two current-carrying wires varies with the distance between the wires, if the currents are held constant.

   f. Relate F, I (current), d, and l in a single proportionality statement (equation).

Exp 37, pp 152-154.

7. a. Measure the change in F on a wire segment in a constant B field when the current in the wire is varied, for at least four different values of I.

   b. Plot change in F against change in I on graph paper.

   c. Qualitatively determine how the force between a magnet and a current depends on the length of the region of interaction.

d. Detect the B field of planet Earth with the current balance.

e. Qualitatively relate F on a segment of wire to B surrounding the segment and I (size and direction) in the wire.

f. Determine B for one of the magnet yokes in Newtons per amp-meter. (Carefully read Q7 on p. 154.)

8. Generate a measurable electric current, given some wire and a magnet; be able to predict the direction of that current (p. 80). Define Faraday (pp. 76, 78); electromagnetic induction (pp. 77, 78).

9. Be able to graph an alternating current (p. 82) and relate any point on the curve to the armature (loop) position on a simple AC generator (p. 82).

10. Be able to state at least three realistic reasons in support of either AC or DC which you might have given to the Cataract Construction Company to help them make their decision concerning the Niagara Falls Power Plant (pp. 91-94). Define Edison (p. 88); $B = I^2R$; transformer; primary, secondary (p. 91); series, parallel (p. 89).

E-M Wave Mod

1. Complete the following mods: Wave, Light, Fields.

2. Read Chapter 16 (Unit IV, Project Physics).

3. a. View Maxwell, 104-110, 122 slide sequence.

   b. Be able to qualitatively describe, verbally and in writing, with the help of sketches, the propagation of an electromagnetic wave (pp. 104-110, 126). The description is to include specific reference to electric and magnetic lines of force, their direction, varying intensity, and induction.

Exp 39, p. 171

4. Demonstrate the varying resonance of a parallel wired coil and capacitor with an oscilloscope.

Exp 39, pp. 171-174

5. a. Use a microwave generator to demonstrate reflection, diffraction, standing waves (p. 115), interference.

   b. Calculate the wavelength of a microwave generator using a double slit, standing waves, or interference with a reflected wave. Assuming $C = 3x10^8$ m/sec, calculate f.

   c. Demonstrate destructive interference of radio waves due to ionspheric shift with microwave apparatus and reflector.

6. Be able to state arguments relating light waves and Hertz's experiments to each other and to Maxwell's predicted E-M waves. Arguments will include specific reference to speed, reflection, refraction, diffraction, interference (pp. 111-112). Define induction coil and frequency of oscillation (p. 111).

7. a. Be able to compare (with reference to both similarities and differences) the following portions of the electromagnetic spectrum (p. 114): radio, TV, light, X-ray (pp. 117, 120), with respect to propagation, velocity, frequency, wavelength, applications, medium, descriptive models.

   b. View ECM/Spectrum slide sequence.

8. Be able to outline and explain the factors contributing to the fall of the ether concept (p. 121), including specific reference to Maxwell, ether "wind" (p. 123), relativity (p. 123-124).

NOTE: On p. 113 of the text, there is a Q11 mistake in speed of light.

Mini-Chemistry Mod

1. Read prologue and Chapter 17 (Unit V, Project Physics). Define in terms of the text: Democritus (p. 4); theory of the (Greek) atomists (p. 5); Aristotle's four element/quality theory (p. 11); element (p. 11); atomic mass (p. 14).

2. Select and memorize a portion of De Rerum Natura (at least six consecutive lines) by Lucretius (100-55 BC), pp. 3, 5.

3. a. Given a chemical formula (p. 16) of the form A_mB_n, be able to find possible combining capacities (p. 17) of the elements involved (pp. 16, 17, 18). Examples: Q6-18, S.G. 17.9-30.

   b. Given A_mB_n, where a grams of A have combined with b grams of B, be able to calculate the relative atomic masses. Examples: S.G. 17.2, 17.3, 17.4.

4. Given a periodic table with the properties of one element missing, be able to determine approximately the properties of that element (pp. 21, 22, 23). Define, in terms of the text, Mendeleev p. 19); alkali metals (p. 18); halogens (p. 19); eka-silicon (p. 22); nobel gases (p. 24).

Exp 40, pp. 126-128

5. Use an electric current to deposit copper on a cathode (p. 126) which is hanging from the arm of a balance. Measure the size of the current with an ammeter, the length of time the current flows, the change in the apparent weight of the cathode. Compute:

   a. True change in cathode mass, using $1 - D_s/D_c$.

   b. Electric charge used, by using $\Delta Q = I \times \Delta t$.

   c. Number of electrons used, using $Q/1.6 \times 10^{-19}$.

   d. The mass of a copper atom.

6. Be able to use Faraday's first and second laws of electrolysis (p. 28) to solve problems like SG 17.13 to 17.16.

Quanta Mod

1. Complete the E-M Field Mod.

2. Read Chapter 18 (Unit V, Project Physics). Define in terms of the text: electron, p. 33); cathode rays (p. 34), J. J. Thomson (p. 35) Q_e (p. 38); Millikan experiment (pp. 37-39); quark (p. 38); photoelectric effect (pp. 40-43); quanta (pp. 40-47); photon (p. 43); Röntgen (p. 48); x-ray diffraction (p. 51); Thomson's model of the atom (p. 55).

3. Determine the ratio of the charge of an electron to its mass, Q_e/m (p. 36) by doing a or b.

Exp 41, pp. 133-135

a.

-- determine the magnetic field strength B, of a pair of coils, using a current balance and the formula $F = BI\ell$.

-- use this known magnetic field to deflect an electron beam, and measure the radius, R, of the arc which the beam is bent into, using the relation $R = \frac{d^2 + x^2}{2x}$.

-- measure the accelerating voltage, V, and determine q_e/m by using the formula $Q_e/m = 2v/B^2R^2$.

b. Use the Q_e/m slide sequence and data sheets to determine q_e/m.

Exp 42, pp. 136-138

4. a. Using a Millikan apparatus, balance charged latex spheres in an electric field against earth's gravitational field by varying the electric field. Use varying values for V, from 75 to 350 volts; balance at least ten different spheres, and record the voltage each time.

b. Tabulate your values of V and 1/V, and arrange them as suggested in the handbook (see cumulative student data booklet).

c. Using the formula $Q_e = \frac{magd}{V}$, your values for 1/V, and the calculated mass, m, of a latex sphere, determine Q_e.

Exp 43, pp. 139-142

5. a. Use the PVB-100 photoelectric effect module and related equipment to measure the stopping voltage, V, for four different frequencies, f, of light.

b. Compute the maximum kinetic energy of the "stopped" electrons, KE_{max} (pp. 41-42), using the formula $KE = Vq_e$.

c. Plot Vq_e against f on a graph.

d. Determine the slope of your graph and compare it to Planck's constant, h (p. 43).

e. Answer Q5 and Q6 on p. 141.

f. Define: threshold frequency (p. 41); work function, W (p. 142); $KE_{max} = hf - W = Vq_e$ (for example: S.G. 18.6, 18.7, 18.8, 18.9, 18.10).

NOTE: Formula on p. 138 of the text should read $\frac{4}{3}\pi r^3 \times D$

Mod Physics Mod

1. Read Chapters 19 and 20 (Unit V, Project Physics). Define in terms of the text: spectrum analysis (p. 61); Fraunhofer lines (p. 61); Balmer lines (p. 63); Rydberg constant (p. 64); Paschen series (p. 65); Rutherford model of the atom (pp. 66-70); X-rays (p. 66); Geiger, Marsden (p. 67); scintillation (pp. 68-69); Bohr theory of the atom (pp. 71, 72); Franck-Hertz experiment (p. 79); electron shells (p. 83); subshells (p. 85); Einstein (p. 45); relativity (pp. 95-99); relativistic mass, $m = m_e/\sqrt{v^2/c^2}$ (p. 96); $E = mc^2$ (p. 99); Compton effect (p. 100); de Broglie (p. 101); $\lambda = \frac{n}{mv}$ (p. 101); quantum mechanics (p. 104); Schrödinger equation (p. 105); Heisenberg uncertainty principle (p. 110); probability distribution (p. 112).

Exp 44, pp. 146-148

2. a. Observe each of the following light sources through a hand spectroscope: fluorescent lamp, incandescent bulb, neon and helium spectrum tubes. Make a table describing each of these emission spectra (p. 59).

   b. Take a photograph of a hydrogen spectrum tube through a diffraction grating (p. 146), which shows both the spectral lines of hydrogen and the scale on the meter stick.

   c. Find the angle through which each of the spectral lines is bent by using the formula $\tan \Theta = x/1$. Then calculate λ for each of the spectral lines in hydrogen, using the formula $\lambda = d \sin \Theta$.

   d. Calculate the energy of the photons in each spectral line and tabulate this information in an energy level diagram (pp. 78-79).

3. Read and report on a book, or at least three different magazine and/or Reader articles pertaining to either relativity or quantum mechanics, or some relation between the two topics.

4. View slide tape sequences on Einstein and Atomic Structure.

Radioacti'ity Mod

1. Read prologue and Chapter 21 (Unit VI, Project Physics). Define in terms of the text: Becquered rays (pp. 5-7); Marie Curie (pp. 8-12); thorium, polonium, radium (pp. 8-9); α, β, γ rays (pp. 12-16); Ruthford's "mousetrap" (pp. 16-17); radioactive transformation (p. 18); uranium-radium series (pp. 19, 20, 27); activity (p. 21); half-life (pp. 22, 24); decay (pp. 19, 23).

Exp 45, pp. 126-130

2. Do part a or b; then do c and d.

   a. Using the tray of 120 20-sided dice marked in red on one side, shake the dice and roll them onto a large, flat surface. Count the number of dice with the red side up, and record on your data table (see c). Repeat this process at least 100 times.

   b. Use the Geiger counter to count the number of background radiation pulses in a 10-second interval, and record on your data table (see c). Repeat this process at least 100 times.

   c. Organize your data on a distribution table similar to figure 21-2; use your data to make a histogram similar to figure 21-3.

   d. Work through questions Q2 to Q9 and study the material entitled "Predicting random Events" on pp. 128-130.

Exp 46

3. a. Be able to state which instrument is best used to study α particles, and which is best to study β particles, and why.

   b. (Notify the instructor at least three days before you plan to do "b," so he can get the dry ice.)

   -- Use a cloud chamber to determine the number and average range, r, of α particles emitted from your α source per minute through a measured barrier slot opening, a.

   -- Use figure 21-7 to obtain the energy of one of your average α particles in Mev.

-- Determine the rate, C, at which particles must be penetrating a sphere of radius $\underline{r}$ around the $\underset{\sim}{a}$ particle source, using $C/c = 4\pi r^2/a$.

-- Determine the total energy lost per minute in Mev and convert to calories.

Exp 46, pp. 131-133

c. -- Use a Geiger counter to determine average background radiation in counts per minute (if you haven't already done so in Exp 45 c).

-- Insert pieces of absorbing material of uniform thickness one at a time between a β source and the Geiger tube, determining the count rate each time (and recording it!) until the count rate is close to background.

-- Plot a graph of absorber thickness against count rate, which also shows the uncertainty.

Exp 47, pp. 134-135

4. Do part a or part b, then answer Q9 and Q10 on p. 137.

a. -- Roll the 120 20-sided dice marked in red on one side and blue on another, and remove all the dice with a colored surface up. Record the number removed and repeat the process at least 20 times, permanently removing the dice which land colored side up each time.

-- Plot a graph in which each roll is represented by one unit on the horizontal axis, and the number of dice removed after each roll is plotted on the vertical axis.

-- Plot a second graph on the same grid, with the vertical scale representing the number of dice remaining in the tray after each roll.

-- Answer Q1 through Q3, p. 134.

b. -- Using a capacitor, battery, meter, and resistor, wired like figure 21-10, close the switch and record the reading on the meter. Open the switch and take a series of readings at regular intervals. Plot a graph, using time intervals for the horizontal axis and meter readings for the vertical axis.

-- Answer Q4-Q5 on p. 135.

5. Do part a <u>or</u> part b <u>or</u> part c.

Exp 47C, pp. 135-136

a.

-- Isolate a sample of short-lived radioisotope from a thorium nitrate solution, and record the count for 30 seconds, each minute for ten minutes.

-- Graph the <u>net</u> count rate as a function of time.

-- Answer Q6-Q8, p. 136-137.

Exp 48, pp. 138-139

b.

-- Using the setup illustrated in figure 21-14, collect radioactive material for at least two days.

-- Count for ten minutes every eight hours for three days, and plot the net count rate against time.

-- Answer Q1-Q-2, p. 139, and estimate N, the number of atoms in the initial deposit.

Eduquip Manual

c.

-- Use the high volume sampler and Geiger counter to measure the background radiation at one of the specified locations in Skagit County (see map).

-- If possible, determine the half-life or half-lives of the radioactive materials present, and identify them.

-- Record your data on the map for use by future Sedro-Woolley physics classes.

Nuclear Energy Mod

1. Complete Radioactivity Mod.

2. Read Chapters 22, 23, and 24 (Unit VI, Project Physics), and define the following within the framework of the text: isotopes (p. 32); transformation rules (p. 33); mass spectrograph (p. 36); gas diffusion (p. 39); Z, A, nuclide (p. 40); nuclear reaction (p. 41, 68-69); unstable nuclides, deuterium (p. 44); proton-electron hypothesis (p. 50); proton-neutron theory (p. 58); transmutation (p. 53); proof of neutrons (pp. 54-57); neutrino (p. 59); high energy physics (pp. 61-67); bubble chamber (p. 65); positron (p. 70); amu (p. 76); average binding energy per nucleon (p. 78); fission, fusion (p. 81); critical size, moderators (p. 85); plasma (p. 96); nuclear forces (pp. 99-100); activation energy (p. 101); isotopic tracers(p. 103).

3. If available, view the slide-tape sequence on isotopes and nuclear reactions.

4. Select, read, and discuss with another person, any four of the articles from the Unit VI Reader.

Text, p. 85-98; Scientific American offprint; packet, Reader; etc.

5. Take a position in writing (for or against) one of the following, or a similar (nuclear energy related) issue, and back up your position with facts from responsible, authoritative publications:

   a. Since we can't produce electricity without damaging the environment (dams block rivers, coal-fired plants heat and air pollute, nuclear plants heat and radiation pollute, etc.), we must cut back our consumption of electricity.

   b. Fusion reactors are our only escape from a world-wide energy crisis, and our government should launch a crash program to facilitate their development.

   c. The United States should dismantle all nuclear weapons immediately, regardless of what other countries do.

   d. If Seattle needs electricity, Seattle should locate the necessary power facilities within Seattle.

6. Some people say that scientists, industries, and governments should give careful moral consideration to the ultimate consequences of their research and conduct it accordingly. Other people feel that when an idea's "time has come" the idea will be developed anyway, scientists and research organizations may as well follow wherever the dictates of their research take them. Present this dilemma to at least five non-science students or other individuals in <u>one</u> of the following ways:

    a. A play. (Look over the scripts for <u>Galileo</u>, <u>In the Matter of J. Robert Oppenheimer</u>, and <u>The Physicists</u>, which deal with this theme; select one script, or portions of a script, which you feel best presents the theme. Then, in collaboration with several other students in the nuclear energy mod, dramatize your selection as a play, skit, or reading.)

    b. A slide-tape sequence; a motion picture, or related "happening."

    c. A science-fiction or fiction story, or a factual paper or essay at least ten pages in length (typewritten, double-spaced).

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SOURCES INFLUENCING THE CONSTRUCTION OF THIS CURRICULUM

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