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ABSTRACT

Presented is one of a series of publications, Resources in Education, related to the Science Program of the Fairfax County Public Schools, 1974. A program description for K through 12 is presented to include the major goals of science education. A program description of each level is presented and Primary, Middle Elementary and Upper Elementary science units are included. The program of studies for grades K-6 is presented in a separate section, Section B, and that for grades 7-12 is under separate cover. A seventh grade Environmental Science course is outlined. The program includes Introductory Physical Science (IPS), Earth Science (ESCP), Biology (BSCS), Special Materials Biology, CHEM Study and both PSSC and Project Physics. Biology II and Advanced Chemistry are also included. (EB)

SCIENCE

PROGRAM OF STUDIES

FAIRFAX COUNTY PUBLIC SCHOOLS
Department of Instructional Services
Division of Curriculum Services
September 3, 1974

PROGRAM OF STUDIES
SCIENCE

CONTENTS

PROGRAM OF STUDIES

SCIENCE

SECTION A

PROGRAM DESCRIPTION

Science Program (K-12)

Science education seeks as a primary objective to develop in students skills that will result in productive and efficient thought processes. The purposes of science education are to encourage exploration and discovery; to identify relationships through experimentation; to describe and measure with precision; to stimulate purposeful imagination and inference; and to become acquainted with the conceptual schemes that undergird the world of science.

The science program of the Fairfax County schools in sequential to the extent that elementary science units develop basic observational and critical thinking skills, vocabulary, and attitudes toward inquiry which enable the student to succeed in the more abstract and technical courses of intermediate and high school.

The major goals of science education are:

- To enable future citizens both to criticize and to appreciate the effects of the sciences on their society; to understand the history of science and its present alternative prospects.
- To give a practical grasp of scientific methods of grappling with problems, at least sufficient for problems which students will face in their individual and social life.
- To help students to understand the world better factually, and especially the world as it affects them concretely, and not be spectators of the mysterious doings of scientists or of their products.
- To kindle enthusiasm for the intrinsic delights of scientific knowledge, in part because it will make life more enjoyable, in part because society has need of scientists in every field of human difficulty.
- To understand the place of science among the other intellectual and esthetic pursuits: briefly, to see the sciences as being themselves a humanistic enterprise, as much as literature, the arts, history, and religion, connected closely with them even while differing from them.
- To increase the range and depth of understanding of natural processes and to relate the problem of exploiting science to possible deleterious consequences for society.
- To provide students with rich and various experiences of individual thinking and foster critical attitudes on the one hand, and develop capabilities for cooperative enterprise and mutual aid on the other.

- To help students to understand the position of their future job or activity in the productive web of society as a whole, technically and scientifically as well as socially, so as to establish a sane and healthy self-knowledge.

- To educate our students so that they may distinguish ends from means, probabilities from certainties, evidence from propaganda, rational belief from superstition, and science from quackery.

Elementary Science Program (K-6)

Fairfax County's elementary science program is based upon a number of curriculum projects sponsored by the National Science Foundation. The kindergarten program is Science A Process Approach, Part A, which was developed by the American Association for the Advancement of Science. Grades one through six use the Elementary Science Study (ESS), which was developed at the Educational Development Center. These activity-centered programs consist of a series of individual units covering a wide range of topics in natural and physical science. Each science unit places materials into children's hands so that each child can investigate, through them, the nature of the world around him. Through this process children acquire much useful information, not by rote but through their own active involvement in problem-solving activities. This kind of learning experience brings home even to very young students the essence of science - open inquiry combined with experimentation.

The main emphasis of the Fairfax County elementary science program is to develop critical thinking and to foster such positive attitudes as curiosity, initiative, self-reliance, and persistence. In addition, many of the elementary science units can be used to extend and develop skills in mathematics and language arts.

In order to provide program flexibility and to insure maximum utilization of materials, the elementary science units for grades 1-6 are supplied on a two-year cycle. Each unit is designed for use at one of three levels--lower primary (grades 1 and 2), middle elementary (grades 3 and 4), and upper elementary (grades 5 and 6). Although the sequencing of units within the two-year cycle varies from school to school, by the end of each two-year cycle all children will have worked on all units in the cycle. A brief description and list of objectives for each elementary science unit is included in the next section.

Program Topics (K-6)

Kindergarten

Science--A Process Approach - Part A

Grades 1-2 (ESS Units)

Attribute Games & Problems
Brine Shrimp
Growing Seeds
Match & Measure I
Primary Balancing
Primary Learning Activities
Tangrams

Grades 3-4 (ESS Units)

Attributes & Shapes
Batteries & Bulbs I
Butterflies
Colored Solutions
Ice Cubes
Mystery Powders
Rocks & Charts
Sink or Float

Grades 5-6 (ESS Units)

Batteries & Bulbs II
Behavior of Mealworms
Click & Print
Gases and "Airs"
Kitchen Physics
Mapping
Peas and Particles
Pendulums
Small Things & Pond Water

Intermediate and Secondary Science Program (7-12)

As life has become increasingly complex, a well planned and implemented science program in intermediate and secondary schools has become essential to fulfill two distinct but equally important needs of society: (1) an educated populace able to cope with and function effectively in an extremely complex modern world and (2) a professional community of scientists to probe the unknown and to apply intelligently the knowledge thus gained to the solution of human and environmental problems.

The majority of students today receive very little formal education in science beyond high school. Therefore, intermediate and secondary science programs must assure that all citizens of tomorrow obtain at least a basic understanding of science if they are to cope with their individual and public responsibilities. Beyond this minimum, school science programs should be the catalyst to stimulate interested and talented students to pursue advanced studies in the various scientific disciplines in order that they may either become scientists or fill roles of leadership in society, government, and industry where knowledge of science is basic to rational planning and decision making.

The sequence of courses outlined below aims to accomplish both of these goals.

Intermediate School Courses:

7th grade - Environmental Science
8th grade - Introductory Physical Science (IPS)

Secondary School Courses:

9th grade - Earth Science
10th grade - Biology
11th grade - Chemistry
12th grade - Physics

Although the list above indicates the grade level at which most students take these science courses, there are frequent variations in this sequence either due to scheduling problems or individual preferences. For example, it is often advisable for a ninth grade student to avoid overloading during his first year of high school. He may therefore wish to postpone earth science to tenth grade and biology to eleventh grade.

Most students do not take all the above subjects. However, earth science and biology are especially recommended for all students because of today's environmental and natural resource problems. Students with some mathematical facility, particularly those who plan to study science in college, should also be encouraged to take chemistry and physics. In addition to the regular program, some schools offer a variety of additional elective science courses appropriate to the special needs and interests of students and faculty members.

Descriptions and objectives for each of the basic courses in the above outline and for the most commonly taught alternative science electives are presented in the following section.

PROGRAM OF STUDIES

SCIENCE

GRADES K-6

SECTION B

OBJECTIVES

Elementary Science (K-6)

The elementary science program is designed to develop critical thinking skills and to foster positive attitudes such as curiosity, initiative, self-reliance, and persistence--traits which are essential if children are to succeed in the crucial task of learning how to learn. In developing the elementary program a great deal of attention has been placed on the blending of cognitive, affective and psychomotor skills. There are five basic developmental goals which are common to all of the units:

Curiosity and Interest
Initiative and Inventiveness
Observation and Record-Keeping
Independent Critical Thinking
Persistence

In addition, there are a series of specific objectives for each unit of study. Teachers should feel free to create additional unit objectives as the classroom situation warrants.

Developmental Goals

Curiosity and Interest - Science in the school provides the child with an opportunity to explore the real world, the world of technology as well as the world of nature. At school the child should constantly be encouraged to explore and ponder the nature and significance of changes in living and non-living things.

Initiative and Inventiveness - Throughout their years in elementary school, children will have opportunities to practice the methods of science and to use tools and apparatus needed to investigate a variety of scientific problems. Children, like scientists, must be allowed to inquire and make discoveries in their own way. The teacher should encourage each child to find out what he or she can. In doing this the teacher should not set any limit on what the individual child may achieve. The child should be encouraged to progress as far as time, resources, and interest allow.

Observation and Record-Keeping - When a pupil has discovered something, he or she will usually want to communicate the findings. Pupils should be encouraged to choose a medium that will express his or her discovery in a satisfying way. Sometimes children will prefer to use the written word, sometimes the spoken word. Some choose to paint pictures; others build models. On occasion they can be assisted to make graphs and express their findings with numbers. This creative activity is the tangible product of direct inquiry and independent study.

Since these creations are a representation of the world as the child sees it, the teacher should look for a child's honest expression of his or her own activities, and encourage the development of new modes of communication by each child.

Independent Critical Thinking - Inquiry science offers children the opportunity to discover that there may be several ways of testing an idea or making an observation. Students should be encouraged to develop methods to test their ideas before accepting or rejecting them; as increased intellectual development occurs, they become willing to accept factual evidence despite preconceived ideas that are contradictory.

Facts are gathered during the course of a unit and are integrated into patterns. Year by year these patterns become generalized and as they are applied to new situations, the child's concept of the world becomes more sophisticated. Eventually it resembles in some degree a scientist's conceptual scheme.

Persistence - Children must be encouraged to continue to investigate the materials provided in each science unit even after their novelty has worn off or after other classmates have finished. To this end, teachers may wish to respond positively to pupils' requests for permission to work at home on activities begun in school, for extra time to finish uncompleted experiments, or for permission to look for information about science topics which the class is investigating.

Children gradually learn to deal with distractions so that they are not at the mercy of their environment; thus they are better able to tie together related observations into a coherent explanation. As they perceive changes which take place as time passes, students begin to understand the necessity of waiting and keeping records in order to observe these changes in things. As children mature, they learn to suspend judgment until they have made sufficient observations and become more willing to risk making mistakes without feelings of inadequacy.

KINDERGARTEN

The Kindergarten science program is Science - A Process Approach--Part A. This program emphasizes five basic processes: observing, measuring, using space/time relationships, using numbers, and classifying. The primary emphasis in Part A is on Observing and the secondary emphasis is on Using Space/Time Relationships.

During the school year, children have an opportunity to investigate color, shape, texture, size, temperature, and take an active part in classifying experiences. Besides observing objects and comparing them according to their likenesses and differences, young children become aware of the phenomena of change. They classify sets of objects according to common characteristics and common purposes. They receive practice in counting numbers, and identifying and naming time intervals.

During the year children will:

1. identify the primary and secondary colors.
2. identify common two-dimensional shapes: triangle, circle, square, and ellipse.
3. describe two or more characteristics of an object such as color, size, shape, and texture.
4. classify a series of objects according to one common attribute.
5. distinguish between temperature in two places or at two times, using a color-coded thermometer.
6. identify, by means of a one-to-one correspondence, sets that contain the same number of members.
7. identify the directions up, down, forward, back, left and right with respect to objects and one's own body.
8. identify objects as moving or not moving.
9. distinguish between two sounds in terms of volume, duration, and pitch.
10. identify color changes.
11. recognize changes in such characteristics as temperature, size, shape, and color observed in solid-liquid changes.
12. distinguish between solid objects that melt and those that do not melt under specified conditions.
13. distinguish the relative length of two objects.
14. order lengths from the shortest to the longest.

15. order collections of objects from greatest to least according to the number of objects in each.

16. construct arrangements of objects from pictures and diagrams.

17. identify common 3-dimensional shapes: cone, cylinder, sphere, cube, and pyramid.

18. identify common 2-dimensional shapes that are components of common 3-dimensional shapes.

19. identify the ordinal position of an object or event in a collection of five objects or events.

20. identify the ordinal relationship between any two or more of the counting numbers one to five.

21. identify objects in terms of similar and different odors.

22. identify the taste of objects as sweet, sour, or salty.

23. construct a classification of a set of objects into two or more groups.

24. identify the number of members in a set from zero to twelve.

25. tell the time, on the hour, from a clock face.

26. distinguish the time required to perform familiar activities in terms of clock intervals.

27. name the days of the week.

28. classify animals on the basis of gross physical or behavioral characteristics.

ATTRIBUTE GAMES AND PROBLEMS (Grades 1-2)

Attribute Games develops thinking skills by providing an opportunity for children to deal with problems involving classification and the relationships between classes. The understandings and skills developed are useful in many areas of the curriculum - science, social studies, mathematics, language arts, or wherever classification is used. The kit contains four kinds of problem-solving materials - attribute blocks, people pieces, color cubes, and creature cards. The variety of materials supplied in the kit allows children to develop the power to generalize by applying a strategy learned in one context to a similar problem in a different context.

In this unit, children will:

1. deal with problems involving classification and relationships among classes.
2. develop power to generalize by applying a strategy learned in one context to a new situation.
3. recognize regularity in patterns.
4. identify or create transformation of patterns.
5. construct and identify sets and subsets.
6. isolate bits of information and deal with them one at a time.
7. use reasoning rather than memory to solve problems.
8. manipulate attribute pieces with dexterity.
9. reproduce (or map) a model constructed in one color or size attribute by using another color or size attribute.
10. construct abstract classes similar to Creature Cards.
11. develop visual discrimination skills.
12. continue to investigate materials after their novelty has worn off.
13. make comparisons in terms of one property or variable.

BRINE SHRIMP (Grades 1-2)

Brine Shrimp introduces young children to the study of living things. These small salt-lake crustacea hatch from very tiny eggs and provide children with the opportunity to become acquainted with organisms of minute size. In raising brine shrimp, children increase their powers of observation and ability to focus on detail. Simple experiments to test the effect of temperature or quantity of salt can be designed and carried out. Children are often stimulated by their experience with the brine shrimp to write and draw extensively, providing an impetus for integrating science with language arts.

In this unit, children will:

1. describe the properties of brine shrimp eggs.
2. become acquainted with some of the problems confronting living organisms.
3. record pictorally (by painting, drawing, or making models) their observations of the external structure and digestive system of brine shrimp.
4. identify and sequence the development of brine shrimp from eggs to adults.
5. focus on details.
6. prepare a solution to hatch the brine shrimp eggs.
7. ask questions based on their observations of the brine shrimp.
8. attempt to find out about the brine shrimp by themselves.
9. appreciate the need for giving the proper care to living things.
10. become acquainted with organisms of minute size.
11. use books for supplementing ideas or information.
12. discuss and record impressions of living and non-living things in the environment.
13. express their own ideas and listen to the ideas of others.
14. gather answers to simple problems by investigation.
15. perceive changes in the brine shrimp which take place as time passes.
16. begin to understand the necessity of waiting and keeping records in order to observe changes in the brine shrimp.
17. continue to work at home on activities begun in school.

GROWING SEEDS (Grades 1-2)

Growing Seeds offers children the opportunity to study the germination of seeds and plant growth. Children determine the characteristics of seeds, examine their internal structure, and learn to make graphs to chart plant growth. Life of Beans and Peas is an extension of this unit and involves a study of plant reproduction through successive generations.

In this unit, children will:

1. determine the characteristics of seeds through observation of the growth cycle.
2. examine the internal structure of seeds.
3. observe the structure of a growing plant and attempt to determine the purpose of the parts.
4. make simple graphs to chart plant growth.
5. appreciate the need for giving proper care for their own plants.
6. explore and ponder the variety of plants in the environment.
7. collect and describe seeds and seed pods.
8. use books for supplementary ideas or information.
9. discuss, compare, and classify both living and non-living things by their attributes.
10. demonstrate awareness of seasonal changes in plants.
11. recognize the need for measurements in determining plant growth and change.
12. record observations by painting or drawing.
13. perceive changes which take place as time passes.
14. understand the necessity of waiting and keeping records in order to observe changes in things.
15. collect samples of seeds for observation and investigation.
16. experiment with some of the factors that affect plant growth, such as, light and temperature.

MATCH AND MEASURE I (Grades 1-2)

The ultimate aim of Match and Measure I is to help children to develop an understanding of the measurement process. The activities included in this unit have been designed to help children gain an intuitive knowledge of length, capacity, volume, and time, and develop a basis for more formal work with measurement.

In this unit, children will:

1. begin measuring through a simple matching process.
2. work with measurement as a practical tool in the context of other classroom projects.
3. measure length, area, and volume using a variety of tools and techniques.
4. recognize a need for standardized measurement.
5. begin using standard units of measure such as feet, yards, meter, and centimeter.
6. discuss relationships between results when different tools and/or units of measure are used.
7. demonstrate skill and purpose in manipulating tools and materials.
8. appreciate the importance of comparing estimates with measurements.
9. recognize the need for accurate record-keeping.
10. appreciate that there may be several ways of measuring a particular object.
11. continue to investigate materials after their novelty has worn off.
12. attempt several lines of investigation when they are presented with new material.
13. understand the meaning of words which describe various types of quantity.
14. recognize the need to learn the meaning of new words associated with measurement and use them correctly.
15. request extra time to finish uncompleted measuring projects.

PRIMARY BALANCING (Grades 1-2)

Children use a variety of materials ranging from weights and washers to four-foot balance beams to gain experience with balance and weight. By using arbitrary units of weight, children develop measurement skills and acquire an understanding of the need for developing standard systems of weight and measures.

In this unit, children will:

1. determine when something is balanced.
2. order objects serially by weight.
3. recognize that the weight of a given substance remains constant when the shape is changed.
4. determine that smaller objects may weigh more than larger ones.
5. develop measurement skills through the use of arbitrary units of weight.
6. make predictions and experiment to check predictions.
7. demonstrate skill and purpose in manipulating tools and materials.
8. perfect motor skills used in balancing objects.
9. recognize and use approximation as a necessary tool in the balancing process.
10. demonstrate understanding of the need for standard units of weight and measurement.
11. transfer balancing concepts to aesthetic expression, for example, the mobile.
12. persist in activities using the trial and error method.
13. record and tabulate information gained during the work with the balance.
14. use representational symbols for recording information on charts or blank graphs.
15. demonstrate awareness of cause-effect relationship.
16. express their own ideas about balancing objects and listen to the ideas of others.

PRIMARY LEARNING ACTIVITIES (Grades 1-2)

This unit consists of five sub-units: Geo-Blocks, Pattern Blocks, Mirror Cards, Attribute Games, and Tangrams. By working with this variety of materials, children gain experience with geometric shapes, symmetry, classifications, matching and analyzing patterns. In addition, the activities in each of the sub-units provide practice in motor coordination and sensory perception.

By working with Geo-Blocks, children will:

1. solve classification problems and establish relationships among a variety of geometric shapes.
2. develop manual dexterity in manipulating the blocks.
3. develop a perception of spatial relationships by comparing one block to another.
4. demonstrate skill in understanding basic geometric relationships of area, shape, and proportion.
5. assess the relationship between the position of an object and a person's perception of the object.
6. locate geometric shapes found in the three dimensional world in which we live.
7. view drawings and photograph cards and compare them with block constructions to develop accurate observation.
8. develop or improve skills related to: part and whole comparisons, number/quantity relationships, ordering and sequencing.

By working with Pattern Blocks, children will:

1. construct patterns of open and closed designs.
2. acquire a feeling for the size and shape relationships among the blocks.
3. demonstrate improved sensory perception and motor coordination.
4. recognize regularity in patterns.

By working with Mirror Cards, children will:

1. improve their skill at visual discrimination.
2. demonstrate familiarity with a mirror's properties.
3. develop a feeling for symmetry while analyzing patterns in order to match the picture on one card to the picture on the other.
4. demonstrate their ability to make predictions and control patterns.

(See the section on Attribute Games and Problems and Tangrams for a description of the units and the objectives.)

TANGRAMS (Grades 1-2)

The Tangram materials provide children with opportunities to work with the basic geometric relationships of area, shape, and proportion. The tangram is a geometric puzzle consisting of seven pieces dissected from a square. The unit includes a set of problem cards that begin with problems involving smaller groups of the seven-piece set, in order to help children to develop skill in dealing with basic geometric relationships before they confront more complex problems.

In this unit, children will:

1. match a tangram shape to its outline.
2. demonstrate skill in understanding basic geometric relationships of area, shape, and proportion.
3. manipulate shapes with dexterity improving fine motor skills.
4. apply familiarity with shape relationships to new problems.
5. select from among a variety of problems those which they can solve.
6. understand that there may be several ways of solving many of the tangram problems.
7. deal with distractions so that they are not at the mercy of their e ironment.
8. construct tangram problems for other children to solve.

ATTRIBUTES AND SHAPES (Grades 3-4)

Attributes and Shapes provides children the opportunity to extend many of the classification and perceptual experiences offered on the primary level. Included in the kit are Attribute Games and Problems, Tangrams, and second part of Mirror Cards, and some books and games on attributes and symmetry. The materials allow children to improve and refine their skills at dealing with symmetry, classification, and informal geometry.

(See the sections on Attribute Games and Problems, Tangrams, and Primary Learning Activities (Mirror Cards) for a description of those units and their objectives.)

In this unit, children will:

1. make symmetrical patterns following a model or create their own symmetrical patterns.
2. develop visual discrimination by noticing differences.
3. discuss their experiences in determining the geometric relationships of area, shape, and proportion.
4. improve spatial insights by working with mirrors.
5. identify similar and congruent shapes.
6. demonstrate awareness of symmetry in shapes and structures.
7. develop methods for solving problems.
8. improve visual memory.
9. develop their own games based on classification skills learned in the unit.

BATTERIES AND BULBS I (Grades 3-4)

Batteries and Bulbs I is an introduction to the study of electricity. Investigations with simple circuits using flashlight batteries, small bulbs and wire are followed by more complex circuit analysis involving several bulbs and several dry cells. Students learn to read and draw schematic circuit diagrams, and to solve hidden circuit problems.

In this unit, children will:

1. light a bulb using a bulb, wire, and battery.
2. investigate how a light bulb works.
3. make careful and precise observations.
4. use the trial and error method to explore and design simple circuits.
5. read and draw schematic circuit diagrams incorporating previously agreed upon symbols.
6. verify predictions through experiments and generate simple rules to account for the behavior observed.
7. test a variety of substances obtained from school or home for conductivity.
8. demonstrate interest in investigating new equipment.
9. demonstrate interest in the way that discoveries of electricity were made in the past.
10. cooperate with others in science activities.
11. show purpose and manual facility in using equipment.
12. demonstrate skill in devising and constructing simple apparatus.
13. make meaningful written and pictorial records of their observations.
14. test ideas as to whether or not the bulb will light before accepting or rejecting them.
15. formulate theories to explain observed phenomena.

BUTTERFLIES (Grades 3-4)

In this unit, children witness the complex life cycle of an insect by raising butterflies in their classroom. While they watch and care for their butterflies, students ask many questions about them. In time, they find answers to some of their questions, develop an appreciation for the way in which this insect lives, grows, and reproduces, and are introduced to the concept of metamorphosis. The excitement the butterflies generate extends naturally into activities in other subject areas, particularly art and language arts.

In this unit, children will:*

1. identify the four developmental stages of the butterfly and describe the sequence of change.
2. transfer the concept of life cycle to other animals through observations in the environment, discussions, and illustrations.
3. formulate questions about their insect and then vary conditions to seek the answers.
4. demonstrate their understanding of the relationship between the butterfly and its environment by creating the appropriate habitat for the butterfly.
5. assume responsibility for the proper care and protection of the insect.
6. demonstrate their aesthetic appreciation for the butterfly through a variety of creative activities.
7. make meaningful written records of their observations.
8. look for information to learn more about butterflies.
9. measure the caterpillar to determine the approximate growth rate.
10. perceive changes which take place in the insect as time passes.
11. express their own ideas about caterpillars and butterflies and listen to the ideas of others.

COLORED SOLUTIONS (Grades 3-4)

This unit utilizes food coloring, water, salt, and transparent containers to introduce children to the concept of density and the layering of liquids. Students observe the patterns created by food coloring as it spreads in plain water, and test for the effect of such things as temperature and color concentration on the appearance and behavior of the liquids. They investigate what happens when salt water and fresh water are combined and experiment with salt water in various concentrations. The liquids can be layered in transparent tubes according to their density. Experience with the liquids enables children to develop a scheme for classifying liquids according to density, and to pursue some research problems using the information they have mastered while working with the unit. The use of color not only makes it possible to differentiate easily among the liquids; it also adds an aesthetic dimension to the activities.

In this unit, children will:

1. test for the effect of such things as temperature, color concentration, and density on the appearance and behavior of liquids.
2. make predictions and draw conclusions about the behavior of liquids.
3. develop a scheme of using symbols instead of words for classifying the layers of liquids according to density.
4. pursue research problems using information mastered while working with the unit.
5. devise their own experiments to verify hypotheses.
6. demonstrate an understanding for the need to keep variables constant.
7. formulate questions to pursue through their own investigations.
8. demonstrate the proper technique for using simple scientific apparatus.
9. compare their observations of the behavior of the solutions with those of others.
10. make meaningful written records of their observations.
11. attempt to tie together related observations of the behavior of the liquids into a coherent explanation.

ICE CUBES (Grades 3-4)

The unit, Ice Cubes, introduces children to the study of the properties of ice and to the effects of heat, surface area, specific heat, and conductivity on melting rates. The unit can also help children begin to understand something about freezing point, freezing point depression, density and the use of thermometers. In the course of their work, students collect data from their observations and experiments and gain considerable experience in constructing tables and graphs, and in measuring temperature, volume, weight, density, and duration of time.

In this unit, children will:

1. identify factors which influence heat transfer.
2. investigate the effect that surface area, air temperature, and insulation have on the melting rate of ice.
3. determine why ice floats in some liquids and sinks in others.
4. develop an understanding of freezing point, freezing point depression, and density.
5. make careful and precise observations and compare their own observations with those of others.
6. measure time intervals accurately.
7. measure temperature using Celcius thermometers.
8. test various materials for their insulating qualities.
9. identify the effects that soluble substances such as salt have upon the freezing point of water.
10. use data obtained from their experimentation to construct tables and graphs.
11. discover that touch is not a reliable way of determining the temperature of a particular object.
12. attempt to resolve inconsistent observations.
13. attempt to identify and control variables.

MYSTERY POWDERS (Grades 3-4)

Mystery Powders involves children in investigative science as they determine the properties of ordinary white powders (starch, baking soda, plaster of Paris, granulated sugar, and salt). Initially students will attempt to identify the powders on the basis of very little evidence or observation. However, the unit Mystery Powders demonstrates to children the unreliability of such quick inferences, especially those assumptions that conclude that materials are alike because they are similar in appearance. In learning to identify the powders and devising ways of distinguishing them from one another, students obtain answers to their questions directly from the materials. This experience provides an introduction to some methods of investigatory science. From the preliminary activities in which they use their senses to become familiar with the powders, children progress to more sophisticated analysis utilizing indicators such as heat, iodine, and vinegar. Towards the end of the unit, they use the techniques they have developed to try to determine the presence of individual powders when two or more are mixed together.

In this unit, children will:

1. identify some physical and chemical properties of the powders.
2. demonstrate the use of simple chemical tests for identifying the powders.
3. describe the reactions of simple chemical tests performed on the mystery powders.
4. strive to make objective observations.
5. compare his or her own observations with those of others.
6. attempt to resolve inconsistent observations.
7. attempt to tie together related observations into a coherent explanation.
8. choose a suitable means of expressing observations such as making meaningful written records or clear graphic records.
9. establish the composition of each powder mixture.
10. participate in classroom activities and discussion.
11. look for materials to extend activities at school or at home.
12. appreciate the reasons for safety regulations.
13. increase their vocabulary of descriptive terms.
14. change their ideas in response to new evidence.
15. develop methods for solving problems or testing ideas.
16. examine critically the results of his or her own work and the work of others.

ROCKS AND CHARTS (Grades 3-4)

Rocks and Charts involves children in the close examination of twenty-one rocks and minerals. Students begin by examining a small number of rock samples to determine some obvious characteristics such as texture and color. As children record their observations and become familiar with additional samples, they discover other characteristic properties. By the time children finish the unit, they will have devised a classification system utilizing such features as density, crystalline structure, hardness, magnetic attraction, luster, electrical conductivity, and reaction to a weak acid. The general understanding and skills developed are useful in many areas of the curriculum--science, social studies, mathematics, language arts, or wherever classification is used.

In this unit, children will:

1. develop visual discrimination by isolating the common characteristics of the rock samples.

2. recognize the need for a standard system of classification.

3. design a classification system by isolating common characteristics.

4. conduct experiments to provide a more detailed classification system.

5. develop skills in recording information by making charts to categorize the specimens according to information gathered.

6. locate and select relevant information in reference materials to extend investigations on rocks and minerals.

7. make careful and precise observations and compare their observations with those of other students in the class.

8. use precise vocabulary in describing the characteristic properties of the rocks.

SINK OR FLOAT (Grades 3-4)

Preliminary activities in the Clay Boats section of this unit give children an opportunity to gain an intuitive understanding of the concepts of buoyancy and density. During the Sink or Float activities, children carry out investigations which lead them to a more formal understanding of the relationship between the volume of a floating object and the amount of the weight it can support. By working with objects and liquids of different densities, children learn that an object's ability to float in a given liquid involves properties of both the object and the liquid.

In this unit, children will:

1. carry out investigations to discover the relationship between the volume of floating objects and the weight they can support.
2. graph the results of their experiments and interpret this data.
3. classify materials as to buoyancy and density.
4. make and use a hydrometer to measure the density of liquids.
5. demonstrate skill in devising and constructing simple apparatus.
6. show purpose and facility in using equipment.
7. investigate the relationship between the density and the buoyant force of a liquid.
8. make clear graphic records of observations when this method is appropriate.
9. make careful and precise observations and compare their own observations with others.
10. classify a variety of objects and attempt to establish relationships among them.
11. recognize the need for accurate record-keeping.

BATTERIES AND BULBS II (Grades 5-6)

Batteries and Bulbs II extends and applies concepts of electricity introduced in Batteries and Bulbs I. In the course of this study, students carry out experiments with flashlight batteries, small bulbs, wire, magnets and a compass and draw conclusions based on their observations. They explore and design complex circuits, discover the relationship between magnetism and electricity, and construct a number of electrical devices.

In this unit, children will:

1. light a bulb using a bulb, wire, and battery.
2. use the trial and error method to explore and design complex circuits.
3. find out what is inside a battery.
4. verify predictions through experiments and generate simple rules to account for behavior observed.
5. perform experiments to discover the relationship between electricity and magnetism.
6. construct and use a galvanometer.
7. make at least 2 suggested or self-initiated projects based on their study of batteries and bulbs.
8. cooperate with others in completing science activities.
9. show purpose and manual facility in using equipment.
10. demonstrate skill in devising and constructing simple apparatus.
11. make meaningful written and pictorial records of their observations.
12. test ideas as to whether or not the bulb will light before accepting or rejecting them.
13. formulate theories to explain observed phenomena.
14. demonstrate interest in investigating new equipment.
15. demonstrate interest in the way that discoveries of electricity were made in the past.
16. attempt to integrate prior knowledge of electricity with current observations.

BEHAVIOR OF MEALWORMS (Grades 5-6)

Behavior of Mealworms stimulates children to ask questions about the observable behavior of an unfamiliar animal and then directs them to ways of finding the answers for themselves. As children observe and experiment, they learn about the process of scientific inquiry while they gather information about the sensory perception of the mealworm. The primary objective of the unit is to help children learn how to carry out an investigation.

In this unit, children will:

1. ask questions about the observable behavior of the mealworm.
2. design experiments which test their theories of animal behavior.
3. recognize difficulties resulting from an inability to control all pertinent variables.
4. investigate conditions that affect the growth of a colony of mealworms.
5. make charts to record the results of their experiments.
6. examine and carefully describe the characteristics of the organism.
7. distinguish the various stages in the life cycle of the mealworm.
8. relate the life cycle of the mealworm to life cycles of other living things.
9. appreciate the need for giving the proper care to living things.
10. suggest variations on previous experiments.
11. participate in classroom activities and discussions.
12. increase their vocabulary of descriptive terms.

CLICK AND PRINT (Grades 5-6)

In this unit, children learn the fundamental processes involved in photography: loading a simple camera with film, taking pictures, developing the film without a darkroom, and printing pictures. After children have learned to take pictures and develop their own film, they are encouraged to use photography as a tool of communication just as they would write a story or paint a picture. The skills developed in the unit can be used to facilitate creative writing activities or to document a science experiment.

In this unit, children will:

1. load a camera with film and take pictures.
2. develop their film and print pictures.
3. show purpose and manual facility in using science equipment.
4. demonstrate a willingness to work cooperatively with other students.
5. extend activities used in science to other fields of experience.
6. complete a suggested project in language arts, social studies or science using photographs taken in connection with this unit.

GASES AND "AIRS" (Grades 5-6)

Gases and "Airs" is an introduction to the study of air. Through a series of experiments children investigate the nature of air and describe its observable properties. As students watch the changes air undergoes when it interacts with common objects found in the environment (rocks, plants, iron), they gain some insight into the composition of air.

At first children study the physical properties of air. They establish that air is "real" and that it occupies space. Then they investigate why water rises when a glass is placed over a burning candle standing in water. A discussion of this experiment leads children to design and carry out their own experiments in an attempt to discover some basic physical and chemical properties of air. As children conduct their experiments they gain skill in manipulating a variety of laboratory materials, isolating and controlling variables, observing, measuring, recording, and predicting.

In this unit, children will:

1. make careful and precise observations and compare their observations with those of others.
2. attempt to establish relationships by comparing observations with previously recorded information.
3. predict, design experiments which test their predictions, and draw conclusions as to the nature of air.
4. decide on methods of collecting and recording experimental data.
4. utilize measurement as a tool in determining the analysis of air.
6. demonstrate dexterity and facility in manipulating a variety of laboratory materials.
7. attempt to identify and control variables that affect the outcome of an investigation.
8. describe air in terms of its observable characteristics.
9. develop techniques of collecting and separating gases.
10. investigate the effect of heat, and air pressure on the volume of a gas.
11. determine through experimentation that a burning candle in a closed container goes out before consuming all of the oxygen.
12. establish what fraction of air will combine with steel wool to produce rust.
13. accept responsibility for their own and others' safety during experiments.
14. risk making mistakes in hypotheses about the nature of air without feelings of inadequacy.

Science K-6
Section B
September 3, 1974

KITCHEN PHYSICS (Grades 5-6)

Kitchen Physics is a study of the characteristic properties of a number of common liquids. Children investigate such properties as surface tension, adhesion, and viscosity. A series of experiments are performed to test the effect of surface tension and cohesive forces on the absorption and evaporation of different liquids. Children construct and calibrate a balance capable of weighing objects to one-tenth of a gram in order to investigate problems involving the concept of density. Then the balance is converted into a tensiometer which permits a quantitative analysis of the surface tension of a variety of liquids.

In this unit, children will:

1. describe the characteristic properties (such as surface tension, adhesion, and viscosity) of common liquids.
2. determine the principles governing the operation of a balance.
3. examine the effects of changing the position of the fulcrum when attempting to balance an object.
4. construct and calibrate a balance.
5. use a balance to differentiate and order by weight a set of very small objects.
6. investigate problems involving the concept of density.
7. convert a balance to a tensiometer in order to make quantitative measurements of the surface tension of various liquids.
8. demonstrate the effects of surface tension and cohesive forces on the absorption and evaporation of different liquids.
9. analyze data obtained from a study of the liquids to explain experimental results.
10. make and interpret graphs to describe empirical relationships.
11. strive to learn and use descriptive terms correctly.
12. demonstrate dexterity and facility in manipulating a variety of laboratory materials.

MAPPING (Grades 5-6)

Mapping provides children with an opportunity to learn to describe verbally and pictorially the location of objects found in their environment. During the unit students devise ways to represent three dimensional objects in two, develop a more descriptive and precise vocabulary, make scale drawings, and learn to use a magnetic compass, transit and clinometer. The primary focus of Mapping is on the making of maps; however, a number of map reading activities have been included. In addition, the unit offers teachers many opportunities to develop skills in mathematics, language arts, and social studies.

In this unit, children will:

1. map the position of a variety of objects found in the environment.
2. use precise vocabulary in describing the relative position of an object.
3. select and use reference objects in describing the relative position of an object.
4. invent a series of symbols to represent objects found in the environment.
5. select and use a scale in units of measurement appropriate for the area or object represented.
6. develop perception of spatial relationships by constructing two dimensional drawings of three dimensional objects.
7. use a compass to determine the relative position of a variety of objects found in the environment.
8. develop the approximate angular direction between two or more objects using a transit.
9. demonstrate proficiency in determining the approximate height of several objects using a clinometer.
10. prepare a simple map to scale of the classroom or an area of the school yard.
11. develop an awareness of the usefulness and variety of information that maps contain.
12. demonstrate a willingness to work with others in Mapping activities.
13. make accurate calculations and record them in an organized format.

PEAS AND PARTICLES (Grades 5-6)

Peas and Particles is a unit on large numbers and estimation. Children have the opportunity to develop a number of strategies for dealing with large numbers, sizes, distances, and the making of accurate measurements. At the beginning of the unit, youngsters estimate large numbers of peas, beans, and other objects in jars. In the process, they develop a variety of counting methods which can be compared and refined. The numbers generated by their estimations can also be the basis for discussions of the usefulness of approximate numbers and rounding off numbers. Later children apply similar strategies to problems of their own choosing. The activities give children experience with numbers and counts as we often meet them in newspapers, budgets, surveys, and other areas of everyday life, rather than as exact figures in textook problems.

In this unit, children will:

1. develop strategies for dealing with large numbers, sizes, and distances.
2. have confidence in their ability to work with large numbers through practical applications.
3. invent, suggest, and explore measuring and counting techniques.
4. refine their skills in estimation, approximation, and exponential numeration.
5. select a degree of precision in measurements that is appropriate to the problem being pursued.
6. work cooperatively with other students during the estimating activities.
7. demonstrate facility in manipulating science materials.
8. decide on the most appropriate means of record keeping to express results.

PENDULUMS (Grades 5-6)

The study of pendulums offers children the opportunity to observe, investigate, and reflect upon the many physical phenomena associated with swinging objects. With pendulums secured to a frame, children compare the effects on the pendulum's motion of the length of the string, the weight and shape of the bob, and the amplitude of the swing. A number of questions concerning energy transfer are investigated when the children couple two pendulums together to observe the effect one swinging object has on another.

In this unit, children will:

1. discover the physical phenomenon associated with swinging objects.
2. experiment with a pendulum to determine the effects of varying the length of string.
3. investigate the effects of the bob's weight and shape.
4. conduct a variety of pendulum experiments in order to accumulate sufficient evidence to make predictions.
5. use science equipment in constructive ways.
6. select the graphical form most appropriate to the information being recorded.
7. demonstrate dexterity and facility in manipulating science materials.
8. make and interpret graphs.
9. examine evidence critically.
10. accept factual evidence from observations of the pendulum despite preconceived ideas that are contradictory.
11. participate in classroom activities and discussions.

SMALL THINGS AND POND WATER (Grades 5-6)

Small Things introduces children to the microscopic world. Children learn to operate the instruments needed to make it accessible, and become familiar with the appearance and structure of minute living and non-living things. Children first explore magnification with water drops and hand lenses. They then become acquainted with a microscope, and gradually improve their slide-preparation techniques while investigating crystal growth, plant cell structure, micro-animals, and cell division and growth.

Pond Water introduces children to the diverse forms of life in a pond. It has three main components: a field trip to a pond, classroom observation of the water and mud brought back, and experimentation. Using hand lenses and microscopes, children learn, through their own observations, about the tremendous variety of living things where they thought none had existed. They begin to understand the complicated interactions of pond life and to identify some of the many animals and plants found in the pond.

In this unit, children will:

1. demonstrate interest in using scientific equipment and instruments for extending the range of human senses.
2. become familiar with terms related to the microscope.
3. prepare their own slides.
4. transfer an image seen through a microscope to paper.
5. become informed about scientists associated with early discoveries related to the microscope.
6. examine many materials to determine the existence of a cellular structure.
7. discuss the relationship of a cell to its function.
8. begin to distinguish between different kinds of protozoa.
9. discover a variety of living things in pond water.
10. devise experiments to find out more about one-celled living creatures.
11. begin to understand the interdependence of living things.
12. collect specimens, label them, and provide proper care and suitable environment for them.
13. participate in classroom activities and discussions.
14. observe accurately.
15. produce meaningful written records of their observations.

PROGRAM OF STUDIES

SCIENCE

GRADES 7-12

SECTION B

ENVIRONMENTAL SCIENCE (Grade 7)

The central theme of the seventh grade science course, "Investigations in Environmental Science", is the concept of an ecosystem. The students are involved in numerous hands-on activities, working directly with plants and animals both inside and outside of the classroom. In the first module, Organisms and Populations, the students, working in teams of four, build their own aquarium and terrarium systems. They observe the interactions of plants and animals within these systems. They observe and record information about the changes that take place over time. The aquaria and terraria represent "mini-ecosystems" through which the students can explore basic ecological principles.

In the second module, Communities and Ecosystems, the students explore the concept of food-energy transfer. Students gain direct experience with a food chain, and the concept of food chains is then expanded to include the food relationships among all the organisms in the aquaria and terraria.

The third module, People and Their Environment, relies upon the knowledge of ecosystems the students have acquired in the previous two modules. The students become aware of the dependence of organisms on each other and on their environment. They learn that any change in either the living or physical environment can upset the balance of the ecosystem. They experiment with this concept by manipulating variables in the mini-ecosystems.

The students complete numerous investigations involving water pollution, air pollution, noise pollution, and solid waste disposal. They examine land use policy in the context of a simulation game, The Redwood Controversy, which encourages them to make environmental decisions. The over-all theme of this module is to encourage students to ask questions, seek answers to environmental problems, and to become aware of their role in their own ecosystem, including their responsibilities as custodians of its future.

In the fourth module, Environmental Factors, the students explore the concept of an organism's response (growth and behavioral) to changes in selected environmental factors. Factors which are investigated include light, temperature, water, chemicals, and gravity. Through observations of plants and animals, students develop an understanding of what is meant by optimum range and variation in response. In class discussion, these concepts are then related to the concepts of adaptability, survival of the fittest, and natural selection in an ecosystem.

"Investigations in Environmental Science" has been designed to be taught as either a one-semester or two-semester course. In the past, seventh grade science has usually been offered as a one-semester course. However, a number of schools have now begun to offer a full year of science for seventh-graders and the course has been designed with that option in mind.

A. Module A: Organisms and Populations

The student should be able to:

1. make good observations, both qualitative and quantitative.

2. select appropriate ways of measuring the properties of living and non-living materials.

3. formulate hypotheses about organism behavior.

4. seek answers to problems through experimentation.

5. observe and record data about organisms.

6. graph and analyze physical and biological data.

7. maintain records which show evidence of change over time in an ecosystem.

8. record and plot data on population changes.

9. demonstrate an understanding of the main principles involved in the care of living things.

10. design experiments to solve problems.

B. Module B: Communities and Ecosystems

The student should be able to:

1. identify organisms as producers, primary consumers, and secondary consumers.

2. construct food chains.

3. analyze data obtained from an experimental food pyramid.

4. define and give examples of an "endangered animal".

5. construct a food web.

6. explain the process of decomposition in a food web.

7. identify specific examples of how man has upset food webs.

8. diagram ecosystems which illustrate the relationships between the living and non-living factors.

C. Module C: People and Their Environment

The student should be able to:

1. define the term pollutant and give specific examples.

2. record and graph data which shows the effects of a pollutant on a living organism.

3. examine attitudes about pollution.

4. test for the presence of a pollutant in a given system.

5. design an experiment to test the effects of a pollutant on a living organism.

6. role-play situations in which environmental problems must be resolved through a decision-making process.

7. describe and give examples of environmental trade-offs.

8. define and give examples of limiting factors.

9. give specific examples of conflicts between technology and the environment.

10. demonstrate positive attitudes towards solving environmental problems.

D. Module D: Environmental Factors

The student should be able to:

1. identify environmental factors.

2. design experiments to determine an organism's response to an environmental factor.

3. graph and interpret an organism's response to changes in an environmental factor.

4. demonstrate an understanding of the concepts of range and optimum range.

5. compare plant and animal responses to environmental factors.

6. demonstrate an understanding of the concept of variation.

7. demonstrate an understanding of adaptability as it relates to survival of the organism.

8. design experiments to determine an organism's response to interacting environmental factors.

9. graph and interpret data from experiments on interacting environmental factors.

Physical Science (4120)
Section B
September 3, 1974

INTRODUCTORY PHYSICAL SCIENCE (Grade 8)

The Introductory Physical Science course is introduced at the eighth grade level to provide an opportunity for students interested in minimum science participation to complete one unit of a laboratory science for high school graduation. It will present students with the background and skills needed for high school science programs. Situations which would help develop a skill for organization of procedure and thinking are incorporated in the program.

The theme of IPS is the sequential development of evidence for an atomic model of matter. The course places its emphasis on the understanding of this model through use of quality laboratory experiences for students. The main goals of this program are to:

- provide experiences that would enable the student to perfect basic laboratory skills.
- provide opportunities for the student to make observations based on direct experiences.
- present situations for the student to apply mathematics to experimental results.
- develop the ability of the student to correlate abstract ideas with concrete situations.

The course material includes the following topics: Quantity of Matter - Mass; Characteristic Properties: Solubility and Solvents; The Separation of Substances; Compounds and Elements; Radioactivity; and the Atomic Model of Matter.

It would be expected that all students would complete the above areas during the school year. It would be possible for accelerated groups to cover the following topics as well: Sizes and Masses of Atoms and Molecules; Molecular Motion.

A. Part One: (Introduction and Chapter II)

The student should be able to:

1. apply the appropriate safety procedures in the laboratory. Special emphasis should be placed on county regulations governing the use of alcohol and alcohol burners.
2. prepare a written organized lab report.
3. make and record detailed observations of an activity.
4. collect gas by displacement of water.
5. measure volume accurately in a graduated cylinder.

6. calculate volume from linear measurement (applying formula).

7. measure the volume of an irregularly-shaped object.

8. estimate accurately one unit beyond the visible unit of measure.

9. assemble the balance.

10. recognize the parts of the balance and function of each.

11. calibrate the balance arm.

12. measure mass accurately.

13. recognize that a 0.1 bead change is due to the limitation of the balance.

14. construct a line graph.

15. read and interpret a graph.

16. construct a histogram.

17. use class data assembled in a histogram to compare results.

18. perform the functions of addition, subtraction, multiplication, and division of whole numbers and decimals.

19. express ordinary numbers in powers of ten (scientific notation) and convert powers of ten to ordinary notation.

B. Part Two: (Chapter III)

The student should be able to:

1. accurately measure the dimensions and mass of:

   a. a regularly-shaped solid.
   b. an irregularly-shaped solid.
   c. a liquid.
   d. a gas.

2. apply mathematical functions necessary to find the mass of one unit of volume.

3. transfer knowledge of scientific notation to problems dealing with the density of gases.

4. read a centigrade thermometer.

5. observe very minute changes in expansion of matter by the use of an amplifier.

6. recognize that elasticity involves not only expansion but contraction of matter.

7. coordinate the measurements of time and temperature in laboratory procedure.

8. identify a plateau as an indication of the freezing-melting point; recognize that a substance solidifies or melts during the plateau period.

9. relate temperature to the action of freezing or melting.

10. demonstrate the processes of graphing and include two sets of values on the same graph.

11. transfer knowledge of histograms to a new situation.

12. construct capillary tubes from ordinary glass tubing.

13. develop the concept that the amount of mass involved does not affect melting or freezing point.

14. determine that a plateau is also an indication of boiling point when a liquid changes to a gas.

15. explain the difference between a constant plateau and one which changes during continued heating.

16. differentiate between theoretical and practical problems as posed in the text.

C. Part Three: (Chapters IV and V)

The student should be able to:

1. note the differences in the ability of substances to dissolve in a liquid.

2. determine the solubility of a substance quantitatively.

3. relate the solubility of different substances quantitatively.

4. recognize that a rise in temperature and stirring increase solubility.

5. discuss the differences between wood and grain alcohol.

6. compare the solubility of substances in different solvents.

7. identify a true solution by its clearness: any cloudiness indicates some material is undissolved.

8. recall and demonstrate safety procedures used in the handling of acids.

9. interpret the density of gases in relation to the density of air qualitatively.

10. test the flammability of a gas.

11. utilize the effect of a gas on limewater.

12. explain the effect of temperature on the solubility of a gas in a liquid.

13. discuss the characteristics of hydrogen and carbon dioxide.

14. demonstrate the extreme solubility of ammonia gas in water.

15. recall observations made in the first experiment performed in this course and relate them to a more sophisticated procedure.

16. remember the procedures used in measuring density, recording boiling point temperatures, determining flammability and graphing.

17. recognize that each substance retains its own characteristic properties even when mixed in a solution.

18. apply the procedures used previously to separate and identify liquids.

19. use the proper procedure for determining odor of a substance.

20. summarize the data collected during several days of experimentation and compare the results.

21. predict the uses of various petroleum products according to their characteristic properties.

22. make a direct separation of solids from liquids.

23. separate two substances by the processes of filtration and evaporation.

24. perform fractional crystallization to separate two substances both of which are soluble in the same solvent.

25. recall the procedures of filtration and distillation to separate black ink.

26. observe the separation of black ink by paper chromatography.

27. describe methods for separating mixtures of gases.

28. explain the effect of low temperatures on gas and identify instruments used to measure such temperatures.

29. differentiate between mixtures and pure substances.

D. Part Four: (Chapters VI, VII, and VIII)

The student should be able to:

1. determine and apply appropriate safety measures when necessary.
2. recall and use the procedures for collecting gas by displacement of water, determining solubility, and testing for flammability.
3. calculate ratio.
4. explain the function of direct current as related to electrolysis.
5. perform mass measurement with care and accuracy.
6. explain the law of constant proportion and relate it to the laws of nature.
7. investigate the reaction of finely-divided copper when heated in air.
8. interpret the meaning of multiple mass measurements to determine the completion of a reaction.
9. identify a reverse process such as a reduction experiment.
10. recognize the difference between elements and compounds.
11. compare the characteristic colors that some elements impart to a flame.
12. differentiate between shades of the same color.
13. observe and compare line spectra.
14. identify elements according to their spectra.
15. interpret the action of certain substances which would demonstrate that all elements do not have permanence.
16. discuss the historical background of present knowledge of radioactivity.
17. draw inferences from the spray-can analogy that these particles emanate in all directions.
18. organize the results of an experiment into a model.
19. predict the results of new experiments.
20. test a model to verify predictions.

21. recall and explain the properties of matter already encountered.

22. construct a compound to illustrate constant composition.

23. compare the masses of the same elements which combine to form more than one compound.

24. demonstrate an understanding of the mathematical functions necessary to solve proportion.

25. investigate more than one compound formed by the same elements to verify the law of multiple proportions.

26. relate the law of constant proportions to the law of multiple proportions.

27. summarize and account for the atomic model of matter.

Earth Science (4194)
Section B
September 3, 1974

EARTH SCIENCE (Grade 9)

Earth science interrelates the disciplines of astronomy, geography, geology, meteorology, and oceanography to present a comprehensive picture of the physical world on which human beings, as well as every other form of life, depend for existence. The importance of understanding the composition of this physical world, and the natural processes which alter and mold it, is increasingly apparent as polution alerts, energy crises, resource depletion, and water shortages jolt us into an awareness of the effects of modern technology.

In what ways and to what extent can we expect to alter the phsical environment without deleterious consequences? To what extent do earth processes and finite resources place ultimate limits on our activities? Answers to these questions will affect each individual's lifestyle; they demand of everyone certain value judgments. Today few people have the basic knowledge essential to enable them to comprehend fully the significance of those questions in terms of society and the future of mankind.

Earth science can initiate this quest for knowledge. It provides the opportunity for students to understand better the interrelationships of the various parts of the physical environment and to see where humans fit into the picture. It also enables them to think in terms of both very short and very long time intervals and to project ideas into a future which goes beyond five years, or a life time, or a century. Adequate solutions to current problems of mankind demand such long term awareness.

Only during high school years, particularly at 9th and 10th grade levels, is it possible to reach a majority of students at a time when they are both curious and open to new ideas, as well as sufficiently mature to comprehend environmental complexities as these relate to society.

Earth science builds on and reinforces basic scientific concepts and attitudes learned in elementary and intermediate school science courses. It introduces, in simple terms, explanations of abstract concepts which are studied in depth in later science courses.

The earth science approach most commonly used in Fairfax County is the ESCP (Earth Science Curriculum Project). This was developed under the sponsorship of the American Geological Institute and was funded by the National Science Foundation. The text, laboratory exercises and resource materials were originally produced by the combined efforts of scientists, teachers, writers, and science educators, but have now been revised and updated. ESCP is laboratory-oriented and stresses the idea that students learn by doing. The investigations sometimes employ data collected by scientists in the field for laboratory compilation and analysis. Models simulating field conditions are also used to clarify physical processes and concepts of time and space.

The objectives listed on the next page are based on the newly revised (1973) edition of Investigating the Earth; however, the old ESCP edition is still thought to be a valuable source for materials to supplement these objectives.

A. Part One (Chapters 1-4)

The student should be able to:

1. identify the assumptions and inferences made in determining the circumference and volume of the earth and explain how the size of the earth can be measured.

2. demonstrate some comprehension of scale and of relationships between a model such as a globe and the earth.

3. cite proofs that the earth and moon each rotate on an axis and revolve around the sun.

4. explain the seasons in terms of earth motion and describe seasonal variations in the apparent path of the sun in the sky.

5. explain why tides occur.

6. demonstrate how phases of the moon and eclipses occur.

7. list similarities and differences between the moon and the earth.

8. describe the significant similarities and differences between the lithosphere, hydrosphere, and atmosphere.

9. explain the classification of rocks as igneous, sedimentary, and metamorphic based on mode of origin.

10. demonstrate skill in using laboratory instruments such as the balance, the metric ruler, and the graduated cylinder.

11. calculate densities, using accurate measurements of volume and mass.

12. differentiate among the following: atom, electron, proton, neutron, isotope, ion, molecule, element, compound, mineral, and rock.

13. describe the water molecule and list properties caused by its structure.

14. explain mineral characteristics in terms of atomic structure.

15. discuss the relative importance of certain chemical elements, particularly oxygen, on the earth and the moon.

16. recognize the presence of change in the world and infer the presence of change in materials and processes that, to our senses, seem not to be changing.

17. explain why accurate, precise measurements are important in detecting earth changes and be able to make such measurements.

18. explain simply the principles governing the flow of energy, particularly with respect to the three ways heat can be transferred from one place to another.

19. relate radioactive decay to the generation of new energy in the crust of the earth.

20. describe how heat is generated in the sun and transferred to the earth.

21. use Newton's laws of motion to account for common experiences involving inertia, momentum, velocity, speed, and acceleration.

22. explain how differences in mass or distance between two objects cause variations in gravitational attraction.

23. describe the earth's magnetic field, including field intensity, inclination, and declination.

24. explain how measurements of gravity and magnetism can aid in the discovery of mineral resources.

25. compare the physical and chemical properties of fresh water and seawater.

26. identify the most abundant ions in seawater.

27. describe the processes that change the salinity, temperature, and density of seawater.

28. trace the path of energy from the sun to ocean waves and currents, both surface and deep.

29. use a model to demonstrate the movement of water particles in surface waves.

B. Part Two (Chapters 5-9)

The student should be able to:

1. show how the processes of evaporation, condensation, and precipitation are involved in the water cycle.

2. identify factors that control evaporation and condensation, and describe energy changes during these processes.

3. determine the relative humidity and dew point, given the temperature and vapor pressure.

4. compute the height to which moist air must be lifted for condensation to occur when given the temperature and dew point.

5. explain how air masses are formed.

6. identify stable and unstable air masses by the types of clouds in the sky.

7. relate the earth's distance from the sun to the natural occurrence of water in the gaseous, liquid, and solid states.

8. demonstrate how the earth's shape and orientation in space determine the distribution of incoming radiation.

9. explain how the earth's atmosphere affects insolation.

10. demonstrate how land and water absorb energy at different rates and explain how this unequal heating, aided by gravity, produces convective circulation.

11. make a model that demonstrates how the earth's rotation modifies basic convective circulation to produce easterly and westerly winds.

12. describe the life cycle of a frontal cyclone and the typical weather that it produces.

13. explain why large cyclones and anticyclones commonly occur together and relate local weather changes to the moving patterns of weather.

14. distinguish between cyclones, tornadoes and hurricanes.

15. identify and explain the locations of at least three major climactic regions on a model continent, relating these to factors which determine energy and moisture budgets for various parts of the earth.

16. list three factors that may have caused the ice ages.

17. list ways in which the climate of cities differs from that of the surrounding country and explain how urbanization causes these differences.

18. describe how fresh water is stored on the earth.

19. discuss properties of porosity, permeability and capillarity as they are related to underground water movement and storage (consider capillary and gravity water).

20. show how runoff is dependent upon the form and intensity of precipitation, the character of the surface materials, and the storage conditions beneath the surface.

21. explain why evaporation and transpiration depend on both the water and the energy available.

22. describe in general terms how flood forecasts are made.

23. show ways in which human activities have affected movement, storage, and quality of water.

24. list chemical and physical weathering agents and describe the effects they have on earth materials.

25. recognize weathering products and discuss how they differ from the parent rock.

26. describe how resistant minerals are separated from less resistant minerals.

27. trace the development of soil profiles and discuss how mature soils reflect the climatic and topographic conditions under which they formed.

28. distinguish between weathering and erosion.

29. discuss the role gravity plays in the process of erosion.

30. compare the erosional effects of water, ice, and wind on the earth's surface.

C. Part Three (Chapters 10-14)

The student should be able to:

1. state the relationship between the settling rate and the particle size of various sediments.

2. describe the depositional pattern that forms near shore, on the continental shelf, and on the continental slope.

3. construct or describe a model of a typical continental margin from the shore to the abyssal plain.

4. contrast the types and thicknesses of sediments along the continental margins with those of the deep-ocean floor, and the way in which they were deposited.

5. give examples of events that could change sea level.

6. describe the features of a geosyncline and discuss the development of geosynclinal mountains through the three stages of deposition, deformation, and uplift.

7. compare modern areas of shallow-water deposition with ancient geosynclinal basins.

8. contrast features formed from compressional and tensional forces.

9. explain the development of coral atolls and flat-topped seamounts.

10. cite evidence supporting the idea of continental drift, and show how sea-floor spreading and plate tectonics explain this movement.

11. identify rock specimens as metamorphic, igneous (volcanic or plutonic), or sedimentary based on texture and composition.

12. explain the reasons for the textural differences between volcanic and plutonic igneous rocks.

13. discuss how temperature, pressure, mineral solutions, and time affect rocks at the surface.

14. discuss various theories for the origin of granitic rocks.

15. explain the relation of plutonic rocks to the occurrence of regional metamorphism.

16. trace the changes in quartz and feldspar grains in a granitic rock as the rock undergoes these processes: weathering, erosion, deposition, folding, metamorphism, and then melting and recrystallization as a granitic rock.

17. differentiate between a compressional and a shear wave.

18. show how seismic data is used to determine the earth's overall internal structure.

19. determine earthquake epicenter locations when given only the differences between P- and S- wave arrival times for three stations.

20. explain the differences between the bases for the Mercalli intensity scale and the Richter magnitude scale which are used to measure earthquakes.

21. discuss the importance of heat flow and magnetic reversals to the theory of plate tectonics.

22. explain how the kinds and arrangement of rocks in an area, along with erosion and deposition, contribute to the development of land-forms observed in the field, in photographs, or on topographic maps.

23. construct a topographic map from a three-dimensional model.

24. use a topographic map to identify variations in landscapes.

25. identify the dominant leveling process in any landscape.

26. rank the relative importance of streams, glaciers, wind, and waves in producing landforms.

27. recognize general regional patterns of the landscape of the United States.

D. Part Four (Chapters 15-22)

The student should be able to:

1. differentiate between relative and absolute time.

2. demonstrate familiarity with two different scales of time: (a)long time intervals (geologic time) and (b)calendar and clock time.

3. explain the use of U^{238} and C^{14} in geologic dating.

4. demonstrate familiarity with the Geologic Time Scale and some of the major events in geologic history.

5. determine the origin of rocks from observing actual rocks or illustrations of outcrops.

6. correlate rock layers using fossils, rock types, position in a sequence, or other means.

7. reconstruct the sequence of a series of geologic events from cross sections of an area.

8. infer what the climate might have been in the past from fossils and other clues in the rocks.

9. trace the circulation of materials such as water, carbon, and calcium from the nonliving world to the biosphere and back again.

10. examine different types of fossils to determine the way in which they were preserved.

11. interpret paleontologic evidence to support the theory that organisms have evolved from simple to more complex forms.

12. describe the dominant life forms in each of the three eras of geologic time.

13. demonstrate the geometrical increase of numbers associated with population growth, and realize the limitations placed on population growth by the finite nature of earth resources.

14. use cross sections, geologic maps, and other geologic illustrations to reach conclusions about the geology and history of an area.

15. describe typical features of a landscape shaped by glaciers.

16. describe surface features of the moon and describe the evolution of the lunar landscape.

17. cite some differences in composition of rocks gathered so far on the moon from those gathered on the earth.

18. give examples of how study of the moon will provide greater understanding of the development of the earth and the solar system.

19. identify some of the early astronomers and their individual contributions to our knowledge of astronomy.

20. describe the general mechanics of the solar system, major and minor members, and relate the law of gravitation to planetary motion.

21. contrast the characteristics of the two main planet groups by listing some known physical characteristics of the various planets in each group.

22. contrast the theories of the origin of the solar system.

23. describe how scientists determine a star's temperature, chemical composition, luminosity, motion, and distance from the earth.

24. describe the evolutionary pattern of the sun and other stars from the initial gas cloud to the final white dwarf stage, indicating how the physical characteristics and speed of evolution depend on the mass of the initial cloud.

25. explain how H-R diagrams support the theory of stellar evolution.

26. describe the Milky Way galaxy--its size, shape, rotation, and the sun's location in it--and indicate how scientists obtained this information.

27. describe the different types of galaxies and the distribution of nearby galaxies, and compare our Milky Way galaxy to other galaxies in terms of size and shape.

28. explain what changes occur as speed increases according to Einstein's theory of relativity.

29. contrast the theories of the origin of the universe and show how the Doppler effect indicates that it is expanding at present.

BIOLOGY (Grade 10)

A Biology course should familiarize young people with the great ideas and concepts of biology which have so profoundly changed our view of our place in nature, and which have enabled us to use nature (wisely or unwisely) in our own self-interest. Such familiarization cannot be gained by reading; it cannot be gained by listening--even listening to the most accomplished scientists; it can be gained only by doing the kind of things scientists do in their laboratories.

The BSCS Biology programs emphasize discovery through laboratory experiences with living things. The process of inquiry is of central importance. Science is not learned from books but by asking questions of nature, and the laboratory is the place where the student becomes aware of the questions which can be most fruitfully asked.

Lab experiences, reading and discussions lead to an understanding of the following biological themes:

- science as inquiry.
- change of living things through time: evolution.
- preservation of life in the face of change: regulations and homeostasis.
- diversity of type and unity of pattern of living things.
- complementarity of organisms and environment.
- complementarity of structure and function.
- genetic continuity of life.
- biological roots of behavior
- history of biological concepts

Three versions of the BSCS program are available, the Green, Yellow, and Blue. Each is a one-year course intended for use primarily at the tenth grade level. Each version places emphasis on different biological concepts.

Green Version - Biological Science: An Ecological Approach

The Green Version is ecological in approach. From a consideration of the web of life, populations, and communities, it presents a survey of the patterns of life in various types of environments, and in the past as well as the present. It looks briefly at the form and structure, reproduction, and heredity of the individual; it emphasizes adaptation in evolution and in behavior in order to place humans in their proper relationship to the biosphere.

A. Part One: The World of Life: The Biosphere (Chapters 1-3)

The student should be able to:

1. identify in the environment some questions a biological scientist could profitably investigate.
2. explain the interdependence of living things using the concepts of matter and energy, food webs, energy pyramids, cycles, and balance in nature.
3. demonstrate an understanding of interdependencies of populations by studying a natural community.
4. relate the factors of mortality, natality, immigration, and emigration and their effects on population density.
5. utilize graphs of population studies, identify each as an open or closed population.
6. analyze data of population studies and predict results of studies using different organisms.
7. relate the following concepts to each other: individual, population, community, abiotic factors and ecosystem.
8. recognize examples of predation, parasitism, commensalism, mutualism, and competition as they relate to the energy concept.

B. Part Two: Diversity Among Living Things (Chapters 4-6)

The student should be able to:

1. demonstrate the ability to use a taxonomic key to identify organisms.
2. describe the basis upon which plants are classified and the rules for assigning a scientific name.
3. classify a group of plants from primitive to advanced by studying their structures.
4. describe the contributions to the history of microbiology of the following: (a) Leeuwenhoek, (b) Pasteur, (c) Spallanzani, (d) Robert Koch.
5. investigate the effects of micro-organisms on food.

6. group given organisms into kingdoms, protist, plant, or animal and explain methods of grouping.

7. examine the growth, structure, and nutrition of bacterial populations by culturing and observing them in the laboratory.

8. recognize the difficulty in classifying the viruses as living things.

C. Part Three: Patterns in the Biosphere (Chapters 7-10)

The student should be able to:

1. describe factors that make a micro-organism infectious or noninfectious to a particular host.

2. demonstrate knowledge and understanding of Koch's postulates.

3. determine the pH of selected soil samples and relate this information to the environment from which the sample was taken.

4. demonstrate knowledge and understanding of the nitrogen cycle.

5. investigate the question: What role do microbes play in the formation of soil?

6. describe how factors in the environment effect the individual and investigate the effect of some of these factors in the laboratory.

7. compare the various biomes as to biotic and abiotic features.

8. design a schematic representation that demonstrates succession.

9. define and list factors that determine the geographic range of a selected species.

10. describe ways man has changed terrestrial ecosystems.

11. compare different kinds of ecosystems of the hydrosphere.

12. investigate the amount of dissolved oxygen in a variety of water sources and state the effect this will likely have on aquatic life.

13. demonstrate the effects of salinity on a variety of aquatic organisms.

14. describe the most acceptable methods for determining the geological age of materials.

15. state Oparin's hypotheses and describe Miller's experiments as to the possible origin of life.

16. discuss the time span required for evolution by studying the major plant and animal forms as they appeared from the Precambrian times to the present.

17. describe the paleontological evidences of the evolution of the horse.

18. discuss the basis for the principle, "The present is the key to the past." State exceptions.

19. state and describe paleontological concepts that are important to the natural scientist.

D. Part Four: Within the Individual Organism (Chapters 11-15)

The student should be able to:

1. describe the historical development of the knowledge of the cell from Hooke's early scientific approach through Schleiden and Schwann's statement of the "cell theory."

2. relate the cell theory to a laboratory study of a variety of tissues.

3. list, describe, and give the functions of the basic structures common to plant and animal cells.

4. measure the rate at which certain materials move through a membrane. Relate this information to a living cell.

5. examine mitosis in living plant cells, describe the various stages, and state the significance of the process.

6. state how differentiation and aging are related to cell biology.

7. state the generalized chemical equations for cellular respiration and photosynthesis. Identify and compare:

   a. raw materials for the reaction
   b. products of the reaction
   c. structures involved
   d. environmental conditions necessary for the reaction to occur

8. state some conditions under which enzymes will function as catalysts in living things.

9. demonstrate the process of fermentation and how this relates to the more common form of respiration.

10. discuss how the chemical and physical characteristics of carbohydrates, fats, proteins, and nucleic acids make them well-suited as sources of energy, enzymes, and hereditary material.

11. illustrate the various pigments present in green leaves using paper chromatography.

12. investigate the rate of photosynthesis under various intensities of light.

13. trace the movements of nutrients and waste products in a plant.

14. investigate transpiration and make some conclusions about what this has to do with transporation of materials in stems.

15. demonstrate the relationship between water and turgor pressure in a living plant.

16. describe the growth process in plants as related to the functions of meristematic tissues.

17. describe mechanisms that regulate the plant's response to light.

18. contrast and compare nonvascular plants with the vascular plants.

19. identify structural adaptations and their functions which enable man to complete the process of digestion, absorption, and elimination of wastes.

20. relate the role of enzymes to their specific functions in the digestive process.

21. contrast and compare the process of transporting materials in unicellular and multicellular organisms.

22. identify structural adaptations and their functions which enable man to transport materials.

23. identify structural adaptations and their functions which enable man to carry on respiration.

24. identify structural adaptations and their functions which enable man to excrete wastes.

25. identify nervous-endocrine structural adaptations and their functions which enable man to receive and react to stimuli.

26. identify muscular and skeletal adaptations which enable man to move.

27. construct a definition of behavior.

28. describe behavior in organisms that lack nervous systems.

29. define and relate homeostasis to the physiology of man.

30. identify examples of innate behavior (reflexes and instincts), learned behavior (conditioning, trial and error) and reasoning in animals.

31. state and describe a minimum of two behavioral patterns that are recognizable among animals.

32. describe how human behavior can be controlled or altered by the use of chemicals.

E. Part Five: Continuity of the Biosphere (Chapters 16-18)

The student should be able to:

1. compare sexual and asexual methods of reproduction and describe examples of each.

2. define meiosis, describe the various stages, and state the significance of the process.

3. compare reproduction of algae, moss, and angiosperms.

4. compare the embryonic development of a chicken with a mammal as to:

   a. internal or external development
   b. means of nourishment of the individual
   c. protection of the embryo
   d. source of oxygen supply

5. illustrate Mendel's laws of dominance and segregation by explaining a monohybrid cross.

6. relate the "laws" of probability to the "laws" of inheritance.

7. apply the principles of segregation and independent assortment by describing a dihybrid cross.

8. describe how some traits are inherited by means of multiple alleles using human blood types as an example.

9. demonstrate understanding of the genetic mechanisms of linkage, crossing over, recombination, nondisjunction, and mutation.

10. illustrate an understanding of the structure and function of DNA.

11. differentiate between the genetic makeups of males and females.

12. illustrate sex-linked characteristics.

13. demonstrate the inheritance of the sickle-cell trait.

14. state Darwin's theory of natural selection and evidences which he used to substantiate his theory.

15. discuss the factors in the evolution of new species emphasizing variability among members of the species, overpopulation, limited resources to support life, the struggle for survival, and isolation.

F. Part Six: Man and the Biosphere (Chapters 19-20)

The student should be able to:

1. indicate the basic problems encountered when studying the evolution of man.

2. illustrate how human groups are genetically related by using gene frequencies of blood types.

3. describe the cultural evolution of man from the hunting and gathering man to the industrial man and its relation to the ecological crises of today.

4. identify the dangers inherent in an unchecked world population growth.

Yellow Version - Biological Science: An Inquiry Into Life

The Yellow Version uses an approach commonly used in some of the better college courses, treating first the unity of life in its chemical and cellular aspects. then discussing the diversity of the earth's living beings, from microorganisms to plants and animals, and finally emphasizing the continuity of life through heredity and evolution.

A. Part One: Unity (Chapters 1-8)

The student should be able to:

1. explain the role of statement of problem, formulation of a hypothesis, deduction, experimentation, observation, and collection of data in the solution of biological problems.
2. demonstrate the ability to use the metric system units of weight, length, and volume.
3. hypothesize as to the origin of organisms.
4. identify by name and give the function of the essential parts of a compound microscope.
5. demonstrate the ability to use the compound microscope by locating and identifying organisms in a sample from a hay infusion.
6. describe the historical development of the knowledge of the cell. Include the contributions of Hooke, Schleiden, Schwann and Virchow.
7. state the cell theory.
8. distinguish between vitalism and mechanism.
9. identify and give examples of each of the following: element, compound, and mixture.
10. differentiate and identify the various organic and inorganic molecules which comprise the living cell.
11. measure the rate at which certain materials move through a membrane. Relate this information to a living cell.
12. measure the energy content in kilocalories of certain assigned foods.
13. compare and contrast the basic structures and functions common to plant and animal cells.
14. investigate the function of an enzyme as a catalyst.
15. distinguish between the processes of mitosis and meiosis.
16. define fertilization and mutation.

17. explain the concept of species.

18. identify the variety of places where organisms live.

B. Part Two: Diversity (Chapters 9-23)

The student should be able to:

1. explain the relationship of structures and functions common to all animals.

2. contrast one-celled organisms with multicellular organisms regarding the problems they have in transporting materials.

3. identify structural adaptations and their functions which enable man to complete the processes of digestion, absorption, and elimination of wastes.

4. explain the dependence of specialized animal cells on the activities of other cells.

5. identify the structural adaptations and their functions which enable man to transport materials.

6. identify the structural adaptations and their functions which enable man to carry on respiration.

7. identify the structural adaptations and their functions which enable man to excrete wastes.

8. define homeostasis and relate the process to excretion.

9. explain the importance of the constancy of blood composition.

10. identify nervous-endocrine structural adaptations and their functions which enable man to receive and react to stimuli.

11. distinguish between sexual and asexual reproduction.

12. demonstrate and utilize the information and concepts of reproduction to answer some personal questions about human reproduction.

13. demonstrate knowledge of the Linnean classification system.

14. trace the movement of nutrients and waste products in plants. Identify all structures involved.

15. state the generalized chemical reaction for photosynthesis. Identify:

    a. raw materials for the reaction
    b. products of the reaction
    c. structures involved
    d. environmental conditions necessary for the reaction

16. describe the mechanisms for the movement of material in a living plant.

17. relate the structures of the flower to the production of fruits, seeds, and the continuation of the species.

18. describe mechanisms that regulate the plant's response to its environment.

19. demonstrate the ability to use a taxonomic key.

20. compare the major plant groups: algae, mosses and liverworts, club mosses, horsetails, cone-bearing trees, and flowering plants, according to their structures.

21. discuss the importance of fungi as related to decomposition, disease, and food.

22. state the similarities and differences among a bacterium, a virus, and a typical cell of a more complex organism.

23. discover the growth, distribution, structure, and nutrition of bacterial populations by culturing and investigating them in the laboratory.

24. recognize the relationship of Koch's postulates to progress in the science of medicine.

25. list ways micro-organisms are beneficial or harmful to man's well-being.

C. Part Three: Interaction (Chapters 24-26)

The student should be able to:

1. identify examples of innate behavior (reflexes and instincts), learned behavior (conditioning, trial and error), and reasoning in animals.

2. compare behavior patterns of a simple animal to that of a more complex animal.

3. describe how human behavior is controlled and altered by the use of drugs.

4. explain the interdependence of living things using the concepts of energy, natural cycles, food chains, food webs, energy pyramids, abiotic factors, and succession.

5. demonstrate an understanding of interrelationships among plants, animals, and environment by studying a particular biotic community.

6. compare the ecosystem studied in the field to other ecosystems.

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D. Part Four: Continuity (Chapters 27-36)

The student should be able to:

1. illustrate Mendel's law of dominance and segregation by explaining a monohybrid cross.

2. verify Mendel's laws in the laboratory.

3. relate the "laws" of probability to the "laws" of inheritance.

4. apply the principles of segregation and independent assortment by describing a dihybrid cross.

5. demonstrate understanding of the inheritance of a trait which has multiple alleles by using as an example the inheritance of human blood types.

6. identify traits in man that are inherited in a Mendelian fashion.

7. explain the chromosome theory of inheritance.

8. differentiate between the genetic makeups of males and females.

9. identify two characteristics of sex-linked abnormalities by analyzing the traits of color blindness and hemophilia.

10. list several known abnormalities that occur in the genes and chromosomes of humans.

11. illustrate an understanding of the structure and function of DNA.

12. describe the relationship of increase in cell number, growth, differentiation, and organization to the development of individuals.

13. compare the embryonic development of a chicken with that of a salamander as to:

    a. internal or external development
    b. means of nourishment of the individual
    c. protection of the embryo
    d. source of oxygen supply

14. contrast the theories of epigenesis and preformation.

15. examine how aging and cancer are related to the study of embryology.

16. describe three hypotheses as to the origin of life and indicate why such theories are difficult to substantiate.

17. discuss the time span required for evolution by studying the major plant and animal forms as they appeared from the Precambrian Era to the present time.

18. describe the most acceptable methods for determining the geological age of materials.

19. state Darwin's theory of natural selection, and evidences which he used to substantiate his theory.

20. discuss the factors in the evolution of new species emphasizing variability among members of the species, overpopulation, limited resources to support life, the struggle for survival, and isolation.

21. indicate the basic problems encountered when studying the evolution of man.

22. describe the cultural evolution of man to the ecological crisis of today.

23. recognize the inherent dangers in an unchecked world population growth.

24. discuss the implications of "Tragedy of the Commons" as it applies to air pollution, water pollution, population growth, and land abuse.

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Blue Version - Biological Science: Molecules to Man

The Blue Version is a daring attempt to introduce the high school student to molecular biology by way of the successive stages in the evolutionary development of life on earth. The evolution of the cell, the evolution of the multicellular organism, and the evolution of higher levels of organization--populations, societies, and communities--supply a frank evolutionary theme throughout.

A. Part One: Interaction (Chapters 1-5)

The student should be able to:

1. recognize that ideas (hypotheses and theories) are as important to science as are facts.

2. discuss critically that science is a creative activity, that creativity is most often expressed in the recognition and posing of problems, the formulation of hypotheses as solutions to problems, and in devising experiments to test hypotheses.

3. illustrate that theories are usually called hypotheses when first formulated.

4. recognize that the great variety of living things is one of the strangest facts in biology.

5. recognize that there is no one best way to classify organisms; organisms are classified by many different means depending on the reason for classification.

6. illustrate that an ecosystem is an interacting combination of autotrophs (producers) and heterotrophs (consumers).

7. construct a very fundamental classification system which separates all organisms into autotrophs and heterotrophs.

8. describe the classification system developed by Linnaeus which is similar to the major system in use today in which each "type" of organism is given a genus and species name.

9. analyze all forms of social behavior in relation to survival value for society.

10. explain how social adaptations of individual members of groups which were advantageous for group survival tended to persist as compared to those social adaptations that were disadvantageous to group survival.

11. illustrate, that in societies, the welfare of the group takes precedence over the welfare of the individual.

12. recognize that communication is the key to effective social organization, regardless of whether the society is of men or of honeybees.

13. demonstrate that communities and ecosystems of nature are the product of a long evolutionary process, are generally quite resistant to most natural or non-human intervention, but change rapidly and unpredictably as a result of human intervention.

14. recognize the interrelationships that exist between living and non-living factors of an ecosystem are extremely complex, are not at all well understood by man, and, as a result, may sustain irreversible and unpredictable effects because of man's intervention.

15. illustrate that man must learn to live in harmony with the communities and ecosystems of nature.

16. recognize that some basic ethic with respect to nature must be evolved by western man.

17. state the major assumption of the theory of evolution is that things living today are modified descendants of things which have lived in the past.

18. describe Darwin's theory of natural selection as a theory which attempts to explain the process of evolution.

B. Part Two: Evolution of Life Processes (Chapters 6-10)

The student should be able to:

1. recognize that the first living organism was a heterotroph of the procaryotic (bacterial) type of organization.

2. illustrate that the major advantage of the Heterotroph Hypothesis is its assumption that a simple organism evolved in a complex chemical environment.

3. describe that the cell runs on energy and has its own special form of energy.

4. demonstrate that life today could not exist without photosynthesis.

5. describe how energy is released in respiration by a series of reactions in which electrons gradually approach and finally combine with oxygen to make water.

C. Part Three: New Life (Chapters 11-15)

The student should be able to:

1. describe the chemical nature of nucleic acids and their function in reproduction and transmission of characters.

2. identify the two major categories of cells: procaryotic (bacteria and blue-green algae) and eucaryotic (all other organisms except viruses, which are not cellular).

3. recognize that multicellular organisms always contain only the eucaryotic cell type, which is its basic unit of structure and function.

4. illustrate that procaryotic cells and eucaryotic cells have a certain few structures in common: cell wall, cell membrane, and ribosomes.

5. illustrate that eucaryotic cells contain many organelles (chloroplasts, mitochondria, lysosomes) which give a cell a composite nature.

6. describe mitosis as the process whereby visible chromosomes are replicated and distributed.

7. describe that mitosis of all eucaryotic cells is essentially the same and involves some system in which the duplicated chromosomes are organized near the center of the cell before distribution.

8. relate why multicellularity evolved only from the eucaryotics and not from the procaryotics.

9. define reproduction and emphasize its essential function, continuation of the species.

10. interpret the function of natural selection in the evolution of a variety of asexual and sexual methods of reproduction and the adaptive advantages of some of these methods.

11. identify the reproductive processes of some sexually reproducing animals--to state:

    a. advantages of sexual reproduction in animals
    b. advantages of internal development
    c. location and functions of embryonic membranes
    d. roles of hormones in reproduction of mammals

12. identify the process of reproduction in plants.

13. illustrate the process of meiosis as fitting into the process of development.

D. Part Four: Genetic Continuity (Chapters 16-19)

The student should be able to:

1. identify processes by which a one-parent cell or fertilized egg becomes a fully formed individual of the species being studied.

2. describe the significance of Mendel's experimental procedures and his interpretation of results.

3. demonstrate knowledge and understanding of heredity patterns, for example, selective breeding for better types or against undesirable types.

4. illustrate advantages of genetic prediction (probability).

5. describe the principles of Mendel as they apply in patterns unknown to him (partial dominance, multiple alleles, etc.).

6. distinguish between sex chromosomes and autosomes.

7. identify the connection between mutation and evolution.

8. recognize known cause of mutation as well as steps that can be taken to prevent possible harmful results.

9. recognize that the genetic nature of man is becoming altered by the worldwide application of biological and medical knowledge.

E. Part Five: Life Processes I: Energy Utilization (Chapters 20-23)

The student should be able to:

1. state the general function of transport systems in conducting nutrients to the cells and removing waste materials.

2. demonstrate an understanding of the concept of homeostasis by giving an example of some regulatory activity in the body which maintains balance of internal environment.

3. describe various mechanisms of circulation of fluids in a variety of animals.

4. contrast the open and closed type of circulatory systems with respect to efficiency and size of animal.

5. describe the cohesion-tension theory and compare with capillary action and root pressure as mechanisms of fluid movement.

6. describe how the forces of osmotic pressure and blood pressure causes an exchange of fluids through the walls of the capillaries.

7. state the transport function of xylem and phloem.

8. describe the movement of carbon dioxide, oxygen, and water molecules into and out of the leaf at different times of the day and night.

9. trace the flow of blood through the heart, to the lungs and body, and back to the heart.

10. describe the function of various cellular, fluid, and dissolved components of the blood.

11. cite the function of valves in the veins and heart as a mechanism of insuring one way flow of blood.

12. diagram the arrangement of structures and cells that make up a leaf and explain how the structure relates to function.

13. recognize the contribution of heart valves and elastic and muscular arteries in maintaining blood pressure.

14. describe the function of roots in transport of materials in a plant.

15. identify the function and importance of the close association between the respiratory and circulatory systems.

16. distinguish between the terms cell respiration, general respiration, and breathing.

17. identify the necessary gas requirement for respiration, oxygen, and its by-product, carbon dioxide.

18. compare and contrast various respiratory systems in aquatic, land, invertebrate, and vertebrate animals.

19. recognize that digestion involves a chemical breakdown of large food molecules into smaller molecules.

20. compare and contrast the functions of various specialized regions of the digestive tract in simple and complex organisms.

21. contrast extracellular and intracellular digestion and list various methods by which materials are taken into cells.

22. describe various digestive processes exhibited by some plants.

23. describe the role of the hormone gastrin in the digestive activity in the stomach.

24. describe the regulation of pancreatic secretions as food passes into the intestine.

25. identify the parts of the digestive tract where carbohydrate, protein, and fat digestion occurs.

26. describe the conditions necessary for digestion in each part.

27. describe the action of enzymes and other components of the digestive juices on carbohydrates, proteins, and fats.

28. trace the path of food through the sequence of structures in the human digestive tract and indicate the mechanical treatment of food in each structure.

29. describe the absorption of food molecules into the capillaries and lymph vessels of the villi in the small intestine.

30. state that excretion of waste products is necessary to help maintain a balance (homeostasis) between the cell and the external environment.

31. suggest the major functions of excretory systems as excretion of waste products, regulation of water, salt, and ion balance in the cells.

32. describe the processes of filtration and reabsorption in the production of urine in the human kidney.

33. relate the parts of a nephron in the human kidney, including the blood vessels, to its structural arrangement and its function.

34. list a few of the substances regulated by the kidney such as urea, glucose, acids and bases, bicarbonate ions.

F. Part Six: Life Processes II: Regulation and Coordination (Chapters 24-27)

The student should be able to:

1. recall the process of homeostasis as being the maintenance of a constant and balanced internal environment.

2. describe the major distinguishing characteristics of animal hormones and endocrine glands.

3. discuss the interaction of the secretions of the pituitary gland and other endocrine glands as examples of homeostatic feedback control, using either the pituitary-thyroid or the pituitary-ovary interactions as examples.

4. explain the actions of the hormones gastrin and secretin in control of the digestive process and the interaction of ovarian and pituitary hormones in control of the female reproductive cycle.

5. describe the interaction between nervous regulation and hormonal regulation of many body activities.

6. define a stimulus as any environmental change that causes an organism to respond.

7. describe the mechanisms by which the nerve impulse travels along a nerve fiber.

8. describe the transmission of nerve impulses across the synapse between two nerve cells.

9. describe the action of the reflex arc in control of certain involuntary activities of the body.

10. discuss the role of the brain in control of involuntary activities.

11. demonstrate that behavior does not just "happen", it is cause. Whether innate or learned, it comes about in response to various stimuli.

S. M. Biology (4398)
Section B
September 3, 1974

Special Materials Biology (Grade 10)

BSCS Special Materials is designed for the student whose previous scholastic record exhibits deficiencies in reading ability, attention span, and motivation. The main emphasis is to actively involve students having such deficiencies in inquiry-oriented and laboratory-centered experiences central to the study of biological science. There is a minimum of textual material.

Major concepts encountered in the course include ecological relationships, cell energy processes, reproduction and development, and the continuum of genetic patterns of inheritance. For those students who did not take Introductory Physical Science (IPS) the course provides a general introduction to the study of science. On the other hand, students intending to take no further science will discover SM Biology to be diversified in approach and fascinating in its survey of change and interaction among living organisms in the total environment.

Special Materials Biology introduces the student both to biological concepts and to the ways these concepts develop. The framework of the curriculum includes topics which stress: (1) ecological relationships, (2) cell energy processes, (3) reproduction and development, and (4) patterns of inheritance.

Students enrolled in SM Biology should develop:

- an increased understanding of the biological ideas within each of the four major topics of the program.
- an increased ability to recognize biological problems and formulate reasonable hypotheses, to design experiments and utilize experimental controls.
- an ability to interpret data and modify interpretations as new information is obtained.
- an increased knowledge of measurement and experimental error.
- an ability in essential laboratory skills and an interest in devising methods to solve unexplained problems.
- a critical attitude toward information that lacks supportive data.
- an increased knowledge of the contribution of biological investigation and science, in general, to problems facing the human species.

Specific curriculum objectives corresponding to the four major topics are outlined below. They represent the minimum levels of achievement expected of students who enroll in the course.

A. Part One - Ecological Relationships

The student should be able to:

1. classify things into meaningful groups useful for organizing and handling information.

2. recognize grouping systems as useful means of communication which change as new knowledge is acquired.

3. identify structure as the key to classification.

4. apply techniques to the study of groups of similar individuals living in a definite place at a definite time.

5. recognize increase and decrease in population number due to favorable or unfavorable conditions.

6. recognize how individuals in a population interact with their environment and individuals in a population interact with each other.

7. identify how populations interact with other populations forming systems we call communities.

8. suggest how studies of communities provide useful information about the roles organisms play in relation to each other.

9. suggest how the biological community is influenced by physical factors of the ecosystem.

10. identify that, with time, biological systems tend to become more complex and better able to withstand changing conditions in the ecosystem.

B. Part Two - Energy Relationships

The student should be able to:

1. recognize energy in its many forms as the ability to do work.

2. identify how living things use energy that is measurable and transformable from one form to another.

3. illustrate how photosynthesis makes energy available to living organisms.

4. illustrate the similarity of living things to machines with combustion engines via the processes of respiration and of burning.

5. measure the release of carbon dioxide in various activities as an indicator of energy requirements.

6. measure energy stored in foods as evidence for the regulation of energy use in living systems.

7. describe catalytic activity in chemical reactions as evidence for enzymatic controls present in living things.

8. apply the need for energy in the synthesis of compounds and other cell activities to enzymatic reactions involved in glycolysis.

9. describe cells as structural units of living things.

10. apply the transformation of food into energy for the cells' activities to the process of diffusion.

11. relate the demand for energy to activities within the cell.

C. Part Three - Reproduction and Development

The student should be able to:

1. illustrate the origin of life from life.

2. perform experiments testing the hypothesis of spontaneous generation.

3. apply the reproductive process sexually and asexually to an assurance of the continuity of life.

4. compare sexual reproduction with asexual reproduction.

5. describe the similarity of sexual reproduction in plants and animals.

6. compare anatomical structures of reproduction between plants and animals.

7. apply the hormonal control of the reproductive process to a pattern of development specifically as it relates to the ovarian cycle.

8. compare the patterns of development between organisms as it relates to the process of fertilization.

9. describe the development of an embryo as a continuous process.

10. relate concepts of mitosis and cell differentiation to the development of the new individual.

D. Part Four - Patterns of Inheritance

The student should be able to:

1. recognize the scheme for the transmission of characteristics from one generation to the next.

2. relate inheritance of traits to transmission via chromosomes.

3. apply the inheritance of traits, normal or defective, from parental to filial generations.

4. relate a model of genetics to how genes operate.

5. apply the model of inheritance to the presence of traits in people.

6. explain the presence of pigment in the hair and skin.

7. explain where melanin originates biochemically and its influence

8. relate the study of skin color to people.

9. describe the incidence of albinism among people.

10. explain the different skin color among people he has seen.

11. describe how sunlight affects skin color.

12. describe hemophilia and its relation to Queen Victoria.

13. explain the incidence of hemophilia and the fact that usually only men have hemophilia.

14. determine his own blood type and observe its frequency of occurrence in the population.

15. apply the knowledge typing of blood offers to the solution of other problems of disease.

16. explain how genes control the Rh factor.

17. suggest how genetics might be beneficial in solving problems in future years.

18. recognize the role and priority genes play in the cause and occurrence of disease.

19. contrast male and female chromosomes.

20. recognize how abnormalities arise with too many or too few chromosomes.

21. relate patterns of x and y chromosomes to the causes of monosomy-x and other abnormalities.

22. compare the inheritance of defective genes on sex chromosomes with the inheritance of defective genes on other chromosomes.

23. relate code method of organization to gene function.

24. illustrate how DNA makes copies of itself.

25. explain how DNA code operates.

Biology II (4392)
Section B
September 3, 1974

BIOLOGY II (Grades 11 and 12)

Biology II is a course which assumes that the student is ready to explore, in depth, questions about life that invite investigation by the intellectually curious. Emphasis is placed on experiences which simulate biological research. The student will be expected to work individually or in small groups pursuing experimental investigations with a minimum of dependence upon the teacher. Individual responsibility for learning is emphasized.

Biology II is not a continuation of tenth grade biology nor is it an advanced placement biology course. It should not be taken in place of physics, chemistry, or biology. It is designed for science-oriented students who, having had most of the other science courses and an extensive math background, are now ready to use their experience, insight, imagination, and creativity in problem-solving laboratory activities of their own design.

The primary goal is an understanding of the processes of science through careful planning of research, record keeping, analysis and interpretation of results with other teams, and the search of related biological literature. The processes of science are most extensively dealt with than extensive additional content or "facts of science."

In most schools the Biology II course is based on the BSCS text Biological Science: Interaction of Experiments and Ideas with extensive use of supplementary materials including Selected Materials For Second Year Biology, Fairfax County Department of Curriculum and Instruction, 1969.

This course should help students to:

- become interested in science as a career.
- develop skills associated with the way a scientist works.
- learn to utilize a variety of resources in order to solve scientific problems.
- relate chemistry, physics, biology, earth science, and math as essential in solving scientific problems.
- learn to work without the constant direction of the teacher, individually or in small groups.

CHEM - Study Chemistry (Grades 11 and 12)

CHEM Study is an investigative approach to the learning of chemistry. The classroom discussion of a concept generally follows the laboratory investigation. The knowledge of chemistry historically developed from laboratory investigations and this discovery process is an integral part of the scientific process.

CHEM Study employs a quantitative rather than a qualitative approach. Mathematical skills are frequently used in making measurements and in problem solving.

Chemists do experiments, make observations, record data, propose model systems and seek regularities. CHEM Study chemistry students learn by doing these same things. The importance of the investigative approach in CHEM Study mandates the development of competence in the laboratory. The following are general objectives for laboratory skill development:

The student should be able to:

1. read and follow directions carefully.
2. identify and use common laboratory equipment safely and efficiently.
3. be knowledgeable about the use and location of safety equipment.
4. make a record of observations which is accurate, detailed, complete, and relevant.
5. prepare a comprehensive laboratory report including all calculations, following the rules of significant figures and uncertainty in measurement. The laboratory report should include all units used in measurement and the data should be organized into tabular and/or graphic form, if appropriate.
6. be responsible for the laboratory, leaving all equipment clean and in place.

The student-centered problem-solving discussions following laboratory investigations are another important aspect of the CHEM Study course. The following critical-thinking objectives apply to the entire course:

The student should be able to:

1. originate model systems to fit what the student has observed in the laboratory.
2. recognize that a model system is a useful tool in learning, but not attribute to the situation under study all of the characteristics of the model system.
3. develop questions to test their model systems.
4. seek regularities in the results of their laboratory investigations.
5. relate regularities, as they are discovered, to previously-discovered regularities.
6. apply the knowledge of regularities to given chemical substances in order to predict probable behavior.

Chemistry (4491)
Section B
September 3, 1974

There are three revisions of the CHEM Study program in addition to the original version. The original version was developed under a grant from the National Science Foundation. The similarities of the versions are greater than the differences. Regardless of the version used, most teachers will make some modification through addition or deletion of material, or rearrangement of the sequence of topics. All of the CHEM Study versions contain more material than it is possible to cover in a year of high school chemistry. The supplementary material may be used to provide enrichment or project work for selected students.

The following conceptual objectives for the CHEM Study course are based upon the sequence utilized by Parry, et al. in Chemistry, Experimental Foundations:

A. The Observational Basis of Chemistry

The student should be able to:

1. use the scientific approach - observe, organize, wonder why, and seek regularities
2. use significant figues and uncertainty in measurement
3. observe the three phases of matter, recognize phase changes, and explain the energy transfers involved.
4. recognize a chemical change and a phase change and measure the energies evolved in the two kinds of change.
5. discuss the Atomic Theory as a scientific model system.
6. compare the weights of equal volumes of gases at the same temperature and pressure.
7. correlate pressure-volume data for several gases, seeking the relationship, PV = constant.

B. The Atomic Theory

The student should be able to:

1. discuss the formation of new substances on a particulate basis with the concept of simple and more complex substances.
2. develop an explanation of why different weights of gases are required for most gases to get PV = constant.
3. discuss Avagadro's Hypothesis as a model system which provides the simplest explanation of the combining volume ratio of gases.
4. relate the following concepts:
   a. relative weights of atoms
   b. relative weights of molecules.
   c. the mole as a number.
   d. relative weights of moles.
5. use models of molecules to discuss monatomic, diatomic, and multiatomic structures. Discuss limits of model systems, i.e., real molecules are not made of styrofoam, do not have discrete boundaries, etc.
6. use the charges on ions to practice writing formulas.

7. use symbols and formulas to show rearrangements of particles in a chemical change.

C. The Conservation Laws

The student should be able to:

1. use conservation of atoms and conservation of mass to balance simple equations.
2. use molecular ratio to establish mole ratio and volume ratio for gases
3. perform several chemical reactions and give the balanced equation for each. Relate what has been observed to the various parts of information given by the equations.
4. solve simple problems involving the mole concept.
5. use units for dimensional analysis in problem solving.
6. explain the properties of gases in terms of the Kinetic Molecular Theory.

D. The Kinetic Molecular Theory

The student should be able to:

1. solve problems involving gas behavior as related to changes in temperature, pressure, and volume.
2. solve problems involving mixtures of gases for partial pressures, number of molecules, and number of moles.
3. state and work with the relationships between the various temperature scales.
4. explain the significance of absolute zero, standard temperature and standard pressure.
5. explain phase changes on a particulate basis in terms of the Kinetic Molecular Theory and the accompanying energy changes.

E. Atomic Structure, The Periodic Table, and Changes in Matter and Energy

The student should be able to:

1. solve solution and dilution problem expressing concentration in moles per liter.
2. relate electrical charge to ions, subatomic particles and to the neutrality of atoms, molecules, and solutions.
3. discuss the various models of the nuclear atom.
4. relate ion formation and chemical change to the transfer of electrons and bond formation.
5. relate the fluctuations in ionization energies to metallic and non-metallic properties and to the periodic table.
6. discuss typical chemical families, giving their distinctive characteristics and relating these to the position of the family on the periodic table.
7. use the periodic table to predict chemical characteristics.

8. describe the primary subatomic particles; their charge, mass, and location in the atom.
9. explain the meaning of mass number, atomic weight, and isotopes. Use the A, Z system of notation.
10. identify the kinds of radiation and the role radioactive particles and energy play in nuclear changes.
11. balance simple nuclear equations for fission and fusion reactions.
12. measure energy changes in chemical reactions and relate these changes to ΔH for the heat of reaction.
13. solve problems relating to the law of Additivity of Heats of Reaction.
14. explain the concept of threshold energy or activation energy as related to an activated complex.
15. relate the energy effects in chemical changes to kinetic and potential energies.
16. relate the probability of reactions and the reaction rate to the theory of molecular collisions.
17. relate reaction rate and collision theory to temperature, activation energy, catalysts, and reaction mechanisms.
18. illustrate graphically and interpret a set of data for a typical kinetic energy distribution.
19. describe the progress of a reaction in terms of potential and kinetic energy changes and the role of the activated complex.

F. Equilibria - Chemical, Solubility, and Acid-Base

The student should be able to:

1. recognize the qualitative characteristics of an equilibrium system.
2. relate the effects of changes in temperature, changes in concentration, and presence of a catalyst to changes in amounts of substances that occur as equilibrium is approached or disturbed.
3. relate Le Chatelier's Principle to the factors affecting equilibrium systems.
4. solve equilibrium problems, using the mass action expression, and the equilibrium constant to calculate concentrations of substances present at equilibrium, and vice versa.
5. predict relative quantities of reactants and products in an equilibrium system, using the value of the equilibrium constant as a basis for the prediction.
6. apply equilibrium principles to the special cases of solubility equilibria, acid-base equilibria, and the equilibrium of any aqueous system.
7. compare the various models of acid-base theory - traditional, Bronsted - Loury, and Lewis. Explain weak and strong acids and bases in terms of these various theories.
8. use concept of pH in problem solving.
9. solve pH problems involving the presence of a buffer in a solution.

G. Oxidation-Reduction

The student should be able to:

1. describe reduction and oxidation in terms of gain and loss of electrons.
2. relate the gain and loss of electrons to the relative electron affinities of different kinds of atoms.
3. apply the rules for oxidation numbers to determine the oxidation state of elements in compounds.
4. balance oxidation-reduction equations.
5. make quantitative studies of the transfer of electrons from one half cell to another.
6. predict the spontaneity of a given redox reaction.

H. Electromagnetic Radiation, Atomic Structure and Molecular Architecture

The student should be able to:

1. relate the various parts of the spectrum to the energies of various colors of light.
2. describe the ground state of an atom in terms of energy and explain how an excited state may be attained.
3. relate the absorption or emission of energy by an electron in an atom to the quantum theory.
4. develop the energy level concept for the hydrogen atom.
5. correlate ionization energies with the electron configurations of multi-electron atoms.
6. relate ionization energy to the distribution of electrons in the upper energy level orbitals of an atom.
7. use orbitals and the pairing of electrons as a model for predicting chemical behavior.
8. explain bond polarity as related to the electron affinities of the bonding atoms.
9. explain molecular polarity in terms of bond polarities and molecular geometry.
10. predict the shape of a molecule when given the bonding orbitals of the central atom in the molecule.

Advanced Chemistry (Grade 12)

A second year of chemistry is offered in some of the Fairfax County Public Schools. The content of the course varies from school to school, but has one goal in common: to make a more comprehensive investigation of some aspects of chemistry than it is normally possible to cover in the first year course. The course frequently emphasizes inorganic chemistry, biochemistry, descriptive chemistry, introductory physical chemistry, and/or quantitative analysis.

Since the course content varies, only general objectives are cited here.

The student should be able to:

1. work independently, assuming a considerable degree of responsibility for the learning process.
2. devote more time to laboratory work and research in the literature than in the first year course.
3. make detailed and comprehensive laboratory investigations.
4. apply advanced mathematics to the solution of chemistry problems.

PHYSICS (Grades 11 and 12)

The high school physics course increases the student's level of awareness and understanding of the seemingly complex laws that govern the physical world. The student is exposed to the mathematical formulation of these laws and becomes acquainted with the evidence leading to the development of these laws through laboratory experimentation. In addition, physics provides experience in the type of independent and analytical thinking characteristic of all science.

Two physics courses developed with National Science Foundation support are offered in Fairfax County high schools. The first, P.S.S.C. Physics, was developed by the Physical Science Study Committee at Education Development Center and the Massachusetts Institute of Technology. The second course, Project Physics, was developed at Harvard University.

Physics (4510)
Section B
September 3, 1974

P.S.S.C. PHYSICS

The PSSC Physics course provides the student with a general introduction that emphasizes the most central concepts of physics. Included among these are the dual wave-particle nature of light, the conservation laws (mass, energy and momentum) and atomic theory. It is directed particularly at the student who will pursue further study of science in college. This student will have gained the necessary background in the content of physics, as well as a rigorous exposure to the methods of scientific inquiry.

As the development is mathematically sophisticated, it is suggested that PSSC students have above average mathematical skills. Algebra II is strongly recommended as a prerequisite. Thus, the course is best suited for students at the 11th and 12th grade level. A previous course in Chemistry is useful, but not absolutely necessary.

The course has a strong laboratory emphasis. Students gain experience in laboratory technique. They learn to analyze and determine the proper significance of their data. Whenever possible, this process is utilized to deduce physical laws before having been exposed to them in class. They also learn to express their findings in laboratory reports.

The course material is organized into four major areas: Light and Wave Motion; Electricity and Magnetism; and Modern Physics - i.e., atoms and photons. The first three comprise the most important concepts from pre 20th century (classical) physics. The fourth rests on the framework provided by the first three.

Below are specific objectives of the PSSC course based on the third edition of the text:

A. Light and Wave Motion (Chapters 1-8)

The student should be able to:

1. describe typical sources of light.
2. describe what happens when light strikes an object (transparent, colored, opaque).
3. explain how the direction of light may be changed (reflection, scattering, refraction, diffraction).
4. describe experiments that measure the speed of light.
5. perform experiments demonstrating how objects are located using light.
6. use ray diagrams to predict regions of shadow.
7. use ray diagrams to predict the location of images in simple optical systems: plane and spherical mirrors, lenses.
8. distinguish between real and virtual images.
9. measure experimentally some of the optical properties of lenses and spherical mirrors (notably focal length).

10. predict the behavior of simple optical systems by algebraic analysis.

11. make experimental measurements of refraction, and determine the index of refraction of selected materials.

12. explain what is meant by critical angle, and measure the critical angle of selected materials.

13. describe what is meant by a wave.

14. demonstrate selected wave properties in one dimension (coil spring) and two dimensions (ripple tank).

15. define frequency, period, velocity, and wavelength of periodic waves. Show the relationships among these and use the relationship to analyze the behavior of wave systems.

16. perform experiments to demonstrate pulses, and periodic waves; demonstrate phase, superposition, interference, nodes reflection, refraction, diffraction, shadow, focusing.

17. use a stroboscope to "stop" the action being observed in the ripple tank.

18. explain refraction as caused by difference in speed in different media.

19. demonstrate interference with light. Explain the interference in terms of the light waves. Algebraically relate the waves to the geometry of the system.

20. demonstrate and explain simple color experiments including dispersion and interference.

21. demonstrate and explain limits to resolution in optical systems.

B. Mechanics (Chapters 9-17)

The student should be able to:

1. describe kinematic relationships both graphically and algebraically.

2. make quantitative analyses from graphical data.

3. prepare graphs showing displacement vs. time; velocity vs. time; acceleration vs. time from appropriate data.

4. describe velocity and acceleration as slopes on graphs.

5. find slopes of graphs that are not straight lines. Explain the significance of these slopes.

6. find values of velocity from displacement-time graphs. Find values of acceleration from velocity-time graphs.

7. describe distance covered and velocity as areas under curves.

8. measure selected velocities and accelerations experimentally.

9. describe displacement, velocity, acceleration, force, in terms of vectors and vector components.

10. derive Newton's Law of Motion from his own experimental data.

11. explain the meaning of net force.

12. predict the behavior of selected objects under the influence of known forces.

13. distinguish between inertial and gravitational mass.

14. demonstrate the operation of centripetal force to give centripetal acceleration (curved motion, uniform circular motion.)

15. describe and give examples of simple harmonic motion. Predict the behavior of simple mechanical systems obeying $F = -Kx$.

16. describe planetary motion in terms of Kepler's laws. Describe planetary motion approximately as uniform circular motion.

17. give examples illustrating the laws of conservation: momentum and energy.

18. predict the behavior of selected systems using the relation between impulse and momentum.

19. give examples of systems that contain energy.

20. apply the concept of energy in the analysis of selected systems: particularly kinetic and potential. Explain and use the concept of the total energy of a system.

21. apply the total energy concept to a planetary system: kinetic plus gravitational potential.

22. distinguish between elastic and inelastic collisions. Perform detailed analyses of head-on (straight line) elastic collisions. (Advanced students may be able to do this vectorially for oblique collisions.)

23. explain the energy content of a gas as related to temperature.

C. Electricity and Magnetism (Chapters 18-23)

The student should be able to:

1. demonstrate and explain the existence and source of the two different kinds of electrical charge, and that like charges repel, unlike attract. State the law of electrical force.

2. apply the vector nature of electric force in the analysis of static systems.

3. state important differences between gravitational force and electrical force.

4. demonstrate the difference between insulator and conductor.

5. explain electrostatic induction.

6. describe an experiment that demonstrates that electrical charge is made up of elementary charges, all of the same size.

7. apply the concept of "electric field." Describe the conditions that produce a uniform electric field. Predict the behavior of a charged particle in a uniform electric field.

8. explain the concept of electrical potential energy.

9. define coulomb, ampere, volt, circuit, resistance (ohm), watt. State the relations among these, and apply them in the analysis of elementary electrical systems.

10. explain a magnetic field as a result of the motion of charges (current).

11. measure magnetic fields with respect to earth's magnetic field by means of a compass and component vectors.

12. determine experimentally the magnetic effect of changes in current, and changes in turns of wire.

13. measure the magnetic field of a particular coil, using a current balance. Explain the functioning of the current balance, in terms of the vector nature of magnetism, current, and force.

14. measure the mass of the electron, using the circular motion produced by the electrical force on the moving elementary charge.

15. describe the effect of a changing magnetic field through a coil of wire. Explain the functioning of a transformer.

16. describe electromagnetic waves as a consequence of the acceleration of electric charge.

17. define the terms: electric field (vector), magnetic field (vector), direction of propagation, transverse, polarize, frequency, wavelength, spectrum, speed of light. Relate these to electromagnetic waves.

18. describe the electromagnetic wave as a transmission of energy.

D. Modern Physics (Chapters 24-27)

The student should be able to:

1. describe the structure of atoms in general terms.

2. describe and explain the experiments that led to the present understanding of the structure of the atom.

3. apply the elastic collision concept to analyze collisions on an atomic scale.

4. explain the meaning of "photon."

5. describe both particle and wave properties of photons, and make judgments as to which is applicable in given situations.

6. describe the photoelectric effect.

7. explain the energy relationship $E = hu - B$, and explain the sources of the constant h. (u is substituted for the Greek letter nu.)

8. use the "electron-volt" as a unit of energy.

9. explain the production of photons in apparatus such as an x-ray tube. Explain and use the relation between accelerating potential and wavelength.

10. recall that particles may show wave properties, and predict the wavelength to be expected of certain particles at selected speeds.

11. explain the use of a stream of particles to get an interference pattern, and describe uses of such interference patterns.

12. describe electron orbitals in terms of integral numbers of wave lengths.

13. write a mathematical statement of the total energy of a simple atom (hydrogen): kinetic plus electrical potential.

14. show the effect on total energy of changing the number of wavelengths in an orbital.

15. prepare an energy-level diagram for the hydrogen atom.

16. predict the photo-emission spectrum of hydrogen from the energy-level diagram. Test the prediction experimentally.

17. explain the spectra of other elements in terms of their atomic structure and energy levels.

18. explain absorption spectra in terms of atomic structure.

PROJECT PHYSICS

The Project Physics course is intended to increase the student's knowledge of the physical world by concentrating on the ideas that characterize physics as a science at its best, rather than concentrating on isolated bits of information. It is also intended to show that the ideas of physics have a tradition as well as methods of adaptation and change. It is structured in such a way as to increase the opportunity for each student to have immediately rewarding experiences in science while gaining knowledge and skills that will be useful throughout life. It is possible for the teacher to adapt the course to a wide range of student interests and abilities.

Efforts have been made to present much of the course material in a verbal rather than mathematical context. However, because of the crucial role mathematics plays in physics, some is retained. Consequently, mathematics through Algebra II is recommended as a prerequisite, although not entirely essential. Although chemistry would be of some benefit, it is not a necessary prerequisite. Although the course is normally taken by 12th graders, there is no reason why it could not also be taken in the 11th grade.

The course has a strong laboratory emphasis. By conducting specially designed experiments, the student gains insight into the role of the laboratory in the development of physical understanding. Experience is gained in the proper collection and analysis of data as well as the effective presentation of results in written reports.

Physics is presented in a humanistic context. The relevance of physics to history, philosophy, religion, art, and music is stressed. An attempt is made to aid in the development of good citizenship by providing insight into technological, economic, social, and political ramifications of physics. The relationship of physics to the other sciences is also emphasized. Considerable content from astronomy and chemistry is included.

The course is developed around six basic units. First, the student is introduced to the concepts of motion. With this grounding in the elements of kinematics and dynamics, motion in the heavens is introduced in Unit II. This material forms the basis for a development of the scientific consequences of the triumph of mechanics, the conservation laws of momentum and mechanical energy, and the first and second laws of thermodynamics in the third unit. The fourth unit presents electricity and magnetism in the context of fields at rest and in motion, and traces the subsequent failure of the mechanistic view.

The origins of modern physics and the atomic and nuclear models of matter are introduced in the last two units. The chemical laws for the atomic model are examined, and electrons and quanta are discussed. The Rutherford model of the atom provides a bridge to a treatment of the nucleus, from radioactivity to nuclear energy and elementary particles.

The following are specific objectives of the Project Physics course:

A. Unit I - Concepts of Motion (Chapters 1-4)

The student should be able to:

1. classify several motions as to being regular or irregular.

2. explain why we today classify uniform straight-line motion as the simplest motion, whereas the Greeks chose uniform circular motion.

3. explain how a stroboscope "freezes" motion.

4. determine the amount of error involved in various measuring devices.

5. use the proper symbols to calculate speed, distance, time, and acceleration from stroboscopic photographs.

6. prepare qualitative and quantitative analyses of speed from distance graphs and acceleration from speed graphs.

7. construct and label a graph properly from experimental data.

8. describe Aristotle's medieval philosophy of motion and why it was so successful.

9. explain Galileo's method of presentation and use of mathematics in his hypothesis on free fall.

10. demonstrate how Galileo proved his hypothesis.

11. apply the steps involved in the scientific method to laboratory procedures.

12. classify several quantities as to being vectors or scalars.

13. demonstrate two methods of adding vectors used in solving dynamic problems.

14. differentiate between mass and weight.

15. state Newton's three laws of motion and use them to explain several everyday phenomena.

16. calculate with consistent units the resulting acceleration of objects due to various applied forces.

17. demonstrate a constant force which is applied for a specified length of time.

18. explain why Newton's laws are invariant and inertial frames of reference.

19. list several of nature's basic forces.

20. predict where a projectile will land if given an initial horizontal speed.

21. describe several types of projectile motion using the Galilean relativity principle.

22. calculate the speed of an object and force on it while in circular motion using the relationships among the terms period, frequency and radius.

23. distinguish between revolution and rotation, and centripetal and centrifugal force.

B. Unit II - Motion in the Heavens (Chapters 5-8)

The student should be able to:

1. locate the solstices, equinoxes, ecliptic, hour circles, celestial equator, and celestial poles on the celestial sphere.

2. explain how to locate heavenly bodies using the Equatorial and Horizon system.

3. draw, label, and explain the causes of the phases of the moon.

4. diagram the relative positions of the earth, moon and sun during each of the moon's phases and during solar and lunar eclipses.

5. describe the apparent motions of the sun.

6. discuss Plato's explanation of celestial motion.

7. identify the devices Ptolemy used in his geocentric system.

8. explain the heliocentric and geocentric solution to the problems of retrograde motion, parallax, and circular motion of celestial objects.

9. describe the contributions of the Greek philosophers which are still basic to our understanding of the nature of physical theories.

10. discuss the importance of the Copernican septem including arguments for and against it and the assumptions he made.

11. describe how the Copernican system led to calculation of the period of a planet's revolution and the sizes of planetary orbits.

12. recognize why there was no way to determine whether the heliocentric or geocentric system was correct.

13. explain why Tycho's observations were significant.

14. plot the shape of the earth's orbit from photographs taken of the sun, and use the astronomical unit to make various calculations.

15. state Kepler's three laws of planetary motion and explain why they set a precedent in science.

16. define the properties of an ellipse.

17. predict where in its orbit a planet moves fastest.

18. plot the orbit of Mars by triangulation from a plot of the orbit of the earth.

19. list the telescopic observations of Galileo which supported the Copernican system and explain why they were rejected by Aristotelian scholars and why Galileo was forced to deny the Copernican system.

20. explain how Newton used his three laws and Kepler's three laws to formulate the law of universal gravitation.

21. state the law of gravitation verbally and mathematically and use it to calculate the gravitational force between two objects.

22. describe the experiment Cavendish performed to determine the value of the gravitational constant G.

23. explain the significance of the law of gravitation.

24. discuss how several men other than scientists and how political institutions were influenced by Newton.

C. Unit III - The Triumph of Mechanics (Chapters 9-I2)

1. explain why physicists are interested in conservation laws and list several they have discovered.

2. calculate the total momentum of a one-dimensional septem before and after a collision to test the law of conservation of momentum.

3. make calculations of a body's mass or speed using the conservation of momentum equation and use to make predictions.

4. interpret qualitatively a graph of a system's momentum versus time in order to describe an interaction.

5. classify several interactions as elastic or inelastic and determine which quantities are conserved.

6. explain how Newton's laws laid the groundwork for the conservation of momentum equation.

7. define the term work and its unit of measure.

8. describe the transfers of energy that occur in a given problem and calculate the work done with consistent units.

9. predict the amount of kinetic energy gained in an interaction if given the loss in potential energy, or vice versa.

10. analyze qualitatively a kinetic energy graph of a collision.

11. discuss how Joule showed that thermal interactions were directly related to mechanical interactions and mathematically show this relationship and use it to make calculations.

12. explain what is meant by the "loss" of energy in the food chain.

13. discuss the essence of the kinetic theory and why it was successful in leading to useful explanations of known properties of gases and prediction of molecular sizes and speeds.

14. predict the momentum of molecules in a gas using Newton's laws and the kinetic theory.

15. demonstrate Boyle's, Charles', and Gay Lussac's laws, and then construct graphs enabling one to make qualitative analyses of pressure, volume and temperature.

16. state the Second Law of Thermodynamics and its significance.

17. calculate pressure when given force and area with consistent units.

18. describe why a wave is a form of energy.

19. define such terms as wavelength, phase, frequency, period, nodal, antinodal, transverse, longitudinal, and standing waves.

20. match the terms period, frequency, speed, and wavelength with their correct unit of measure and symbol and use them in calculations of any of them.

21. demonstrate transverse, longitudinal, polarized, standing, periodic waves, reflection, refraction, and diffraction of waves, and the Superposition Principle.

22. predict the effects and explain the causes of reflection, refraction, and diffraction of waves.

23. locate constructive and destructive interference in a 2-point source interference pattern and predict the number of nodal lines formed as the separation of the sources changes.

24. calculate the wavelength of a wave from a 2-point source pattern and from a standing wave pattern.

25. cite everyday phenomena which can be explained by various properties of waves.

26. recognize the wave behaviors that can be demonstrated with sound.

D. Unit IV - Light and Electromagnetism (Chapters 13-16)

The student should be able to:

1. list the properties of light which can be explained by the particle and wave model of light.
2. describe several methods used to measure the speed of light.
3. identify the circumstances when light does not travel in straight lines.
4. predict the direction in which a particle and a wave will be refracted in a specified medium.
5. describe how Young's experiment supports the wave model for light and use it to calculate the wavelength of light.
6. identify Newton's contribution to theories of light and color.
7. list several useful applications of the properties of light.
8. discuss why the "ether" was invented and list its properties.
9. demonstrate the existence of the two basic electric charges.
10. demonstrate electrostatic induction with an electroscope and electrophones.
11. calculate with consistent units the electric force between two charged objects.
12. list the similarities in Coulomb's and Cavendish's experiment.
13. calculate the strength of a gravitational field given sufficient data.
14. discuss the significance of the Millikan oil drop experiment.
15. state the law of conservation of electric charge.
16. demonstrate how a current is produced.
17. state Ohm's law with proper symbols and use it to make calculations of current, voltage, and resistance.
18. explain how the power of a current depends upon the amount of current and how this dependence is applicable today.
19. demonstrate the relationship among electric fields, magnetic fields and currents with various apparatus.
20. State Faraday's general principle of electromagnetic induction and how he constructed the first electric motor.

21. describe the basic model for generators today and how they can be used as motors.

22. discuss how Edison developed the light bulb.

23. formulate advantages and disadvantages of electrical technology.

24. explain why the concept of the "ether" could be eliminated.

25. identify the four principles of electromagnetism.

26. explain how Maxwell joined the sciences of electricity, magnetism, and optics.

27. describe how Hertz was able to detect electromagnetic waves and list the similarities in these waves in the electromagnetic spectrum.

28. demonstrate how radio waves can convey information.

29. demonstrate elementary properties of microwaves.

E. Unit V - Models of the Atom (Chapters 17-20)

The student should be able to:

1. discuss Dalton's theory and the theories lending up to it.

2. identify the terms valence, atomic mass, and atomic regularity.

3. explain the modern periodic table and how it differs from that of Mendeleev.

4. discuss the electrolysis effect.

5. calculate the mass and volume of an atom.

6. relate how cathode rays were discovered and what they are.

7. calculate the charge-to-mass ratio for an electron.

8. cite Thomson's method of measuring the ratio of charge to mass for cathode ray particles.

9. describe Millikan's experiment and explain its significance.

10. discuss the photoelectric effect and the experimental results associated with it.

11. explain how Einstein proposed the quantum theory.

12. describe Thomson's first model of the atom.

13. relate the significance of Planck's constant.

14. interpret qualitatively a graph of Einstein's photoelectric equation.

15. identify several elements by observing their spectra.

16. explain and demonstrate how Rutherford explored the inner structure of atoms.

17. discuss the differences between and importance of the Rutherford and Thomson models of the atom.

18. diagram possible transitions of an electron in the Bohr model of the hydrogen atom.

19. recognize the shortcomings of the Bohr theory.

20. list the two postulates upon which the Special Theory of Relativity is based.

21. distinguish between the Special and General Theory of Relativity.

22. discuss the particle-like behavior of radiation.

23. specify how the laws of conservation of momentum and kinetic energy can be applied to photons.

24. relate the equivalence of mass and energy.

25. describe the DeBroglie wave-particle dualism.

26. identify the importance of Schrödinger's form of the quantum theory.

F. Unit VI - The Nucleus (Chapters 21-24)

The student should be able to:

1. state the charges and relative masses of alpha, beta, and gamma rays and explain how each is affected by a magnetic field.

2. explain what is meant by a radioactive decay series.

3. use the concept of half-life to predict the rate of decay of a radioactive sample.

4. explain what is meant by an isotope of an element.

5. explain how the transformation rules of radioactivity follow from the Rutherford-Bohr model of the atom.

6. discuss how a mass spectrograph can be used to determine the isotopes of an element.

7. make proper use of mass number and atomic number in writing an equation representing a nuclear reaction.

8. state the atomic mass standard presently used by physicists.

9. explain the process of artificial transmutation.

10. state the major properties of the neutron and neutrino and explain the role of the conservation laws in their discovery.

11. describe the principles governing the operation of several types of particle accelerators.

12. explain how radioactivity may be artificially induced.

13. explain what is meant by the term "binding energy".

14. distinguish between nuclear fission and nuclear fusion.

15. explain the role of the equivalence of mass and energy in the release of energy in a nuclear reaction.

16. define the term "chain reaction" and explain how such a reaction can be controlled in a nuclear reactor.

17. explain the principles involved in the atomic and hydrogen bombs.

18. indicate the role of fusion as the source of energy in stars.

19. distinguish between the liquid-drop and the shell model of the nucleus.

20. discuss several of the peaceful applications of nuclear physics.