AN EXPERIMENT IN TEACHING GENERAL SCIENCE

by

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A Thesis submitted for the Degree of
Master of Arts
in the Department
of
Philosophy

The University of British Columbia

October, 1938.
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AN EXPERIMENT IN TEACHING GENERAL SCIENCE

Introduction
Purpose and Scope of the Investigation

The new course in general science now established in the Senior High School Curriculum of British Columbia supplants the more specialized courses of physics, chemistry and biology. The new course attempts to fuse the special sciences into one course - "General Science", "designed to give the pupil a view of the whole field of science, and an understanding of important principles, rather than a somewhat narrow knowledge of one or more of the specialized sciences."¹

The newer trends in science education stress the importance of using science in meeting the everyday needs of the pupils. Accordingly a wider range of curriculum materials can be utilized.

To the writer the following quotations represent in large measure the working hypothesis of the new science course.

"Let us in the high school, however, be free to help the child in his efforts to know and to interpret the world in which he lives; let us have the liberty to make that science which is bound up with his everyday living meaningful and

¹. Programme of Studies for the Senior High Schools of British Columbia, p. 160.
enjoyable, a rich, satisfying, vital experience long to be remembered."

"Science courses at the secondary school level, if we agree with all the leaders of modern science education, should be concerned with the applications of science in the civic, sociological, and social aspect of modern life. The objectives of the Commission for the Reorganization of Science, as given in most courses of study, as gleaned from the writers of modern secondary textbooks, and as given by the members of the group responsible for the Thirty-first Year Book, all make the socio-civic objectives predominate."

"After thirty years of teaching and supervising in secondary schools, the writer has become more and more convinced that the socio-civic values of science must come first if science is to do its best work for the future citizens of the democracy."

With the introduction of these changes the pupils will undergo a new type of experience. Whether the results will be different cannot be decided from "a priori" considerations. A valid method of verifying the conclusion reached is by experimentation of the controlled type.

Such an experiment was carried out by the writer. In

this investigation the new course General Science IV was taught to one group of pupils in such a manner as to bring their everyday experiences to the fore, as well as to emphasize the social significance of science. To another comparable group the course was presented in such a way as to neglect these factors, and to present the material as a body of organized knowledge. The purpose of the investigation was to discover whether the results in the two groups would be sufficiently different to warrant the adoption of one method in preference to the other.

Both groups were taught by the writer, who endeavored at all times to maintain equal interest and enthusiasm. The achievements of one group were never presented as a goal to the other group.
Setting of the Investigation.

This enquiry was made at Magee High School, Vancouver, British Columbia, during the term extending from September 1937, to June 1938.

Acknowledgements.

The writer wishes to express his appreciation to Mr. C. B. Wood and Dr. J. W. Pilcher of the Department of Education of the University of British Columbia, for their generous assistance throughout this investigation.

To friends who in many ways aided the writer in his work, appreciation is also expressed.
Chapter 1.

MATCHING THE TWO GROUPS OF PUPILS

The first step in this investigation was to obtain two similar groups of pupils. This was done during September 1937, by arrangement with the school administration. There were five Grade X classes enrolled in General Science IV. The two groups that had been assigned to the writer were made similar by an interchange of a number of students from the remaining three classes.

In arranging the two groups the following data were used: the means and distribution of intelligence quotients, the chronological ages, and the achievement in grade nine general science as determined from the letter grades based on the curve of normal distribution, as well as the scores from an achievement test based on the grade nine work. This latter test was given shortly after school opened. From a study of this data twelve interchanges were made in order to make the two groups similar. For a number of reasons nine pupils, five from one group and four from the other, were too exceptional.

* These intelligence quotients were obtained from the pupils' Progress Record Cards. These tests had been administered in 1934 and 1935 by the Bureau of Measurements, Vancouver School Board. Fifty-five of these were obtained from the Otis Self-Administering Test of Mental Ability, Intermediate Examination, Form A. The remainder had been measured by the National Intelligence Test and Terman Group Test of Mental Ability.
to be included. Due to individual time-tables they could not be transferred. Although they travelled along with their classes, their test results and other related data are ignored in this report. The above data are included in table I. A study of this information will show that the two groups are nearly alike.

As a further check on the two groups the first unit of the new course, General Science IV, was taught as a trial unit to each of these two groups in an identical manner. Two achievement tests were given to the two groups at the close of the unit. The means, medians, standard deviations and correlation coefficients of the test scores and intelligence quotients were calculated. These results are given in tables II and III. A study of these data showed the two groups to be comparable. Following these tests the investigation was pursued as outlined in the succeeding chapter.

To make sure that the tests indicating the general level of intelligence were fairly accurate, a second test, namely the Terman Group Test of Mental Ability, Form B, was administered to all of the pupils in April 1938. The intelligence quotients were obtained from this test and correlated with those of the previous test. The coefficient of correlation was found to be $0.87 \pm 0.031$, indicating that the general level of intelligence had been fairly accurately measured.
Table 1.
Chronological Ages, Intelligence Quotients, Grade IX General Science Letter Rating, Scores of Grade IX Achievement Test, and Scores of Objective and Subjective Achievement Tests for Unit 1.

<table>
<thead>
<tr>
<th>&quot;Social&quot; Group</th>
<th>&quot;Pure Science&quot; Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>R. A.</td>
<td>15</td>
</tr>
<tr>
<td>D. A.</td>
<td>15</td>
</tr>
<tr>
<td>D. A.</td>
<td>15</td>
</tr>
<tr>
<td>H. B.</td>
<td>14</td>
</tr>
<tr>
<td>R. B.</td>
<td>15</td>
</tr>
<tr>
<td>P. B.</td>
<td>14</td>
</tr>
<tr>
<td>M. C.</td>
<td>15</td>
</tr>
<tr>
<td>R. C.</td>
<td>14</td>
</tr>
<tr>
<td>S. F.</td>
<td>14</td>
</tr>
<tr>
<td>N. F.</td>
<td>14</td>
</tr>
<tr>
<td>P. F.</td>
<td>14</td>
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<tr>
<td>R. H.</td>
<td>14</td>
</tr>
<tr>
<td>D. H.</td>
<td>15</td>
</tr>
<tr>
<td>D. K.</td>
<td>15</td>
</tr>
<tr>
<td>D. L.</td>
<td>14</td>
</tr>
<tr>
<td>D. L.</td>
<td>15</td>
</tr>
<tr>
<td>H. M.</td>
<td>14</td>
</tr>
<tr>
<td>J. M.</td>
<td>15</td>
</tr>
<tr>
<td>G. M.</td>
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<tr>
<td>G. M.</td>
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<tr>
<td>M. M.</td>
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<tr>
<td>P. M.</td>
<td>16</td>
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<tr>
<td>S. N.</td>
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<tr>
<td>H. N.</td>
<td>15</td>
</tr>
<tr>
<td>W. O.</td>
<td>15</td>
</tr>
<tr>
<td>L. P.</td>
<td>14</td>
</tr>
<tr>
<td>F. R.</td>
<td>15</td>
</tr>
<tr>
<td>J. S.</td>
<td>15</td>
</tr>
<tr>
<td>A. S.</td>
<td>15</td>
</tr>
<tr>
<td>R. U.</td>
<td>15</td>
</tr>
</tbody>
</table>

* These two pupils left school in January 1938. Since they were a similar pair their leaving did not affect the results of this investigation.
### Table II.

Means, Medians, and Standard Deviations for Intelligence Quotients, Grade IX Achievement Test, and Objective and Subjective Achievement Tests of Unit 1.

<table>
<thead>
<tr>
<th></th>
<th>&quot;Social&quot; Group</th>
<th>&quot;Pure Science&quot; Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Q.</td>
<td>M. 116, Mdn. 114, σ 7.31</td>
<td>M. 115.7, Mdn. 114, σ 7.5</td>
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<tr>
<td>Gr. IX. Test</td>
<td>33.6, 32, 9.3</td>
<td>33.1, 34, 9.8</td>
</tr>
<tr>
<td>Unit 1 Obj.</td>
<td>51.4, 50, 8.2</td>
<td>53.1, 53, 11</td>
</tr>
<tr>
<td>Unit 1 Subj.</td>
<td>25.9, 24, 7.8</td>
<td>27.6, 27, 8.1</td>
</tr>
</tbody>
</table>

### Table III.

Coefficients of Correlation and Probable Errors for Intelligence Quotients, Grade IX Achievement Test and Objective and Subjective Achievement Tests of Unit 1.

<table>
<thead>
<tr>
<th></th>
<th>&quot;Social&quot; Group</th>
<th>&quot;Pure Science&quot; Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r_{I. Q., Gr. IX Ach.}$</td>
<td>.50 ± .092</td>
<td>.52 ± .088</td>
</tr>
<tr>
<td>$r_{Obj., Subj. Unit 1}$</td>
<td>.80 ± .044</td>
<td>.81 ± .042</td>
</tr>
<tr>
<td>$r_{I. Q., Obj. Unit 1}$</td>
<td>.60 ± .078</td>
<td>.52 ± .089</td>
</tr>
<tr>
<td>$r_{I. Q., Subj. Unit 1}$</td>
<td>.62 ± .076</td>
<td>.55 ± .086</td>
</tr>
</tbody>
</table>
Chapter II.

SUBJECT MATTER ARRANGEMENT AND METHODS OF TEACHING

This chapter aims to present the main differences in subject matter arrangement, and methods of teaching, that were employed with each of the two groups.

Subject Matter Arrangement for the "Social" Group

The class to which the general science was taught with social emphasis, were given an arrangement of material that was as closely allied to their everyday experience as the writer could make it. Practical situations and applications were made the center of discussion, the necessary laws and principles growing out of such a presentation. Further, the arrangement and presentation were ever aiming at the thought of showing the pupils how man has made his discovery of scientific facts and principles subserve his needs. To facilitate this plan the general method of teaching used was that of inductive developmental procedure, i.e. the pupils were aided in developing a generalization by proceeding mentally from specific details to general meanings.

Subject Matter Arrangement for the "Pure Science" Group

With the other group a sincere attempt was made to teach science as an organized body of knowledge. The laws, theories, and principles became the center; the practical illustrations or applications being incidental, merely used
to help impress the principles, and serve as a means of rousing interest by showing that the principles did find application. With this group, quantitative problems were used to a greater extent, their purpose being to aid in driving home the principles. The general method of teaching was both deductive and inductive in its thought movement. This procedure was followed since it seemed to be best suited for the purpose in hand, namely, the presenting of a well organized body of facts and principles.

Both treatments required careful preparation in order to fit into the time available.

Method of Treatment for the "Social" Group

In order to clarify the above explanation two outlines will be given. The first will present the treatment given the former, or "social" group. The second will serve to illustrate the treatment given the latter, or "pure science" group.

In each case the topic deals with light. Many other topics from the prescribed course might have been selected, but the one on light is of reasonable length and importance to illustrate the manner of treatment that was applied to the entire course beyond unit one.

With the "social" group the arrangement of material outlined in the course was followed closely. The reading assignments were taken very largely from the reference textbook "Science for To-day", since the presentation therein
could be more closely adapted to the development of each of the major and subordinate generalizations, and in this way was a closer approximation to the objectives set for this group. As the lessons progressed, important points were presented on the blackboard. Notes were made by the pupils and were checked at the close of each unit by the teacher. Periods usually commenced with a review of previous work or a discussion of assignments. At the conclusion of a unit the pupils prepared essays, the title of which embodied the concept set forth in the caption of the unit.

Statement of the Title of Unit II

The major generalization or title for this unit is stated as follows: "Civilization has progressed as man has learned to use and control energy". To work this abstraction with its sociological implications over into a meaningful experience for the pupils, proved to be a difficult problem. However, it was attempted by writing the above quotation on the blackboard, and informing the pupils briefly of the broad implications implied in it. This statement was to be the keynote for the development of the unit, and all subsequent material was to lead to its amplification.

An outline of the study given to the "social" group on the title of Unit II follows.
Study of the Title of Unit II

Meaning of "civilization"

Man has been reclaimed from a savage state since he is a thinking animal. In the lowest state of savagery, man conquered fire. Later he used fire and heat to make weapons and tools, and used these to improve living conditions. Later he discovered gunpowder, how to use the compass, and how to use steam power. As a result of this advance from the savage state we say man became "civilized".

What is progress?

We commonly understand progress as a moving forward, an improvement of conditions of living as compared with the ancient world. Science gives us a dominant note of progress in our civilization. It has ever sought to make this world a better place in which to live.

Energy

While the scientist has been unable to inform us what energy is in itself, yet he has been able to tell us much about it. For instance, there are many kinds of energy - kinetic, potential, heat, electric, etc. Energy changes its forms. For example, the energy of heat can be transformed into electricity, light, or mechanical energy. While we have no direct knowledge of energy, the above manifestations of it are commonly observed. For many centuries man was limited in his energy resources to those which he could obtain through the use of his own muscles.
and those of beasts of burden. When man learned to use the energy of heat, electricity, oil, and other natural resources, his power to extend civilization progressed rapidly.

The class was asked to consult source books in the library and at home and to write out and bring to class the following day information on the meaning and significance of the words "civilization", "progress", "control", and "energy". A number of pupils were called upon to read the work they had prepared.

This introduction was used largely as a motivating device, as well as to show the relation of the topic (in this case light) to the longer unit of which it is a part.

Having briefly considered the title, the pupils were informed that the main purpose of this unit was to try to understand as fully as possible the contributions science has made to improve methods of living. The unit would deal with each of the different kinds of energy, and we would endeavor to relate these in a clear way to the main topic.

Introduction to the topic "Light" as Presented to the "Social" Group

Life is absolutely dependent upon light. We require light for vision. What would our life activities be like without this sense of vision? Man has been able to exercise his intelligence largely through his sense of sight. Human progress has depended upon discovery and invention and these
are possible largely by seeing. The process of photosynthesis
which we studied in unit one was dependent upon light energy
for manufacturing the lifeless substance of the soil and air
into food.

Artificial light has been a problem of mankind since
earliest times. Can we imagine what fire and light meant to
the home life of primitive man? The first fire he kindled
produced artificial light. The light gave him power over
darkness. In his huts and caves he found lamps to be a
necessity. First he used firelight, then he learned to place
red coals in niches in the walls. Later he used torches.
He probably disliked the quality and smokiness of pinewood
torches and sought to develop better means of lighting. In
this way he exhibited his superiority by adapting materials
at hand to his growing requirements. Through the centuries
methods of lighting improved slowly as civilization advanced.

Resin was extracted from wood and burned in containers.
Some early peoples learned to use vegetable and animal fats.
These were the forerunners of the oil-lamp and the candle,
which, in various forms, served the artificial lighting
requirements until about the eighteenth century, when other
forms came into common use. This period we may note as the
beginning of the science of light-production, since the early
oil-lamp and candle were not scientific developments in the
modern sense.

Many lighting devices evolved as life activities
11.

became more complex. The candle was greatly improved, not only by experience, but by the application of scientific knowledge regarding waxes, fats, wicks, and the chemistry of combustion.

Similar improvements in the lamp took place, particularly with the advent of the glass chimney, which not only protected the flame from drafts, but also improved combustion by increasing the air supply. (Our studies on convection currents and combustion allow us to appreciate the science in this.) More complex mechanical lamps followed. However, it will not be necessary for us to consider these.

Coal gas was discovered and its use for gas-lighting advanced greatly in the nineteenth century. Illuminating gas, and gas mantles followed. We may appreciate the gas mantle by a demonstration of the Welsbach model. (Demonstration follows.)

In 1879 Edison succeeded in overcoming many difficulties to give the world the first incandescent filament lamp or electric bulb. (The pupils report on the story of Edison's work in producing the light bulb.) The electric lamp has undergone many improvements since then, brought about by careful scientific research.

We can well realize that light has been, and is, most valuable to society, and has had powerful civilizing effects. Real achievement in the use of light was not accomplished in a haphazard way, but by a scientific study designed to discover
many properties, laws, and principles concerning the nature of light. Not until this was done did progress become rapid. We can appreciate more fully these achievements by a careful study of the behavior of light and some of the important facts and principles relating to it.

Outline of the topic "Light" as Taught to the "Social" Group

Procedure:

Oral discussion, with pupils contributing to the development of the topic.

Presentation:

What is our most important source of natural light? The sun. How does sunlight travel to the earth? By coming in very small waves through the ether. What do these waves produce when they affect the eye? Vision. The scientists inform us that light is a form of energy. What particular form would you call it? Radiant energy. How rapidly does light travel? One hundred eighty-six thousand miles per second.

We shall pull down the window shades and darken the room. Are there any sources of light in the room? None. A small opening is made in the screen, and a beam of light comes through to strike a mirror. What do you observe about the direction taken by the beam of light? Is it bent or straight? Straight. What happens to the light after it reaches the mirror? It is reflected. Why is the mirror visible now? It reflects light to our eyes. Turn on the
lights. Why are all the objects in the room visible now? The light is reflected to us from them.

How is this lighted lamp filament visible to us? It gives out its own light. It is self-luminous. How does this differ from the other objects in the room? They are visible by reflected light. From our previous work what would you say is the ultimate source of the light energy from the lamp bulb? The sun.

Class assignment.

For next day you are to write an account tracing the energy of the lamp back to its source, pointing out how this energy has been captured and controlled for the benefit of mankind.

Presentation:

On a dull day we are unable to see the sun, yet we have light. Why? The rays of the sun are reflected from the many dust and moisture particles in the air until they affect the nerves of the eyes. You may at sometime have noticed the sunlight reflected from the windows of a distant house making it look as though the source of light were behind them. Is all the sunlight reflected from the window? No. Why not? Some of the rays pass through the glass, or are transmitted. Considering the facts we have just mentioned what would you say happens to a beam of light when it strikes a window? It is reflected and transmitted.

On your table you will find cardboard, oiled paper,
frosted glass, and plain glass. Hold each of these in turn to the light from the window. Compare the passage of light through each. Does light pass through the cardboard? No. What name do we give to such a substance? Opaque. Does light pass through the oiled paper and frosted glass? Yes. Are objects visible through them? No. What name do we give to these? Translucent. Does light pass through the plain glass? Yes. Are objects plainly visible through it? Yes. What name do we give this? Transparent. Do all substances reflect or transmit light equally well? No. Name and classify some light sources that are controlled by the use of such materials.

How does a window pane feel on which the sun has been shining? Warm. Why? The heat from the sun warms it. There is no glass so clear that all the light falling upon it will go through it. We know that some of the light is reflected, and some is transmitted, but the remainder is absorbed and transformed into heat energy.

We have learned that the various objects in the room are visible by reflected light. However, not all the light is reflected. Some is absorbed by the objects. Some objects reflect and absorb more than others. To sum up, what may happen to a beam of light when it strikes an object? It may be reflected, transmitted, or absorbed.
Presentation:

If we wish to see ourselves in a mirror where do we stand? Directly in front of it. If we stand in a room on one side of a mirror what do we see? We see only the opposite side of the room. (Several pupils given mirrors.) The reflection of trees and landscape can be seen on smooth water if one stands in the right position. If this position is changed sufficiently the reflection cannot be seen. These common observations may be explained by considering the following demonstration.

Demonstration:

The room is darkened. A beam of light from a small hole in the window blind is reflected on to a mirror lying flat upon a table. A pointer is held vertically to the mirror at the point where the rays fall upon it. The pupils are asked to compare the angles formed by each ray with the pointer. The mirror on the table is tilted and the pointer placed at right angles to this new position. Again the angles are compared. The mirror is then held perpendicular to the beam. It is observed that the ray which strikes the mirror makes an angle approximately equal to the ray which is reflected. These two angles are called respectively the angle of incidence and the angle of reflection. Careful experimentation has shown that the angle of incidence is equal to the angle of reflection. A diagram is drawn illustrating the law of reflection. Now we can explain each of the problems previously
Demonstration:

Why are the illustrations on the pages of your textbooks clearer than the ones on this newspaper?

We have on the wall a sheet of newspaper and a highly polished piece of metal. How are they visible to us? By reflected light. If they both reflect light can we explain why we can see our reflections in the polished metal only? How do the surfaces of these two bodies compare? The metal is much smoother than the paper. What effect will a smooth surface have upon the reflected rays? It will reflect them regularly. What effect will the comparatively irregular surface of the newspaper have upon the light rays? It will scatter them. This is called irregular reflection or diffusion. A labelled diagram is drawn on the blackboard.

Can we explain the preceding question now that we understand diffusion of light? (Several pupils called upon to do so.)

Frosted lamp bulbs, translucent lamp shades, anti-glare glass for automobiles are used to control light. Explain. The light is diffused by transmission. The greater part of the light which enters our homes and other buildings is diffused light. What diffuses this light? Dust, moisture in the air, and various objects on the surface of the earth. This scattered light is less glaring than direct sunlight, and so is easier on the eyes.
Demonstration:

As we walk along in the bright sunshine we observe what is called our shadow. What causes the shadow to form? The light waves have been stopped by our body which is opaque. Not only have the light waves been cut off from the dark part on the ground, but from all the space included between it and our body.

A book is placed close to a white screen. A lighted candle is set before the book. The book is slowly moved toward the source of light. What do you observe? At first the shadow is distinctly black. Does this illustrate how light travels? Yes, in straight lines. Why is the space on the screen dark? The book cuts off the light. As the book is moved toward the source of light a dark spot is seen bordered by a fringe that shades off from total darkness to complete illumination. The dark central portion is called the umbra, and the shaded portion the penumbra.

Why is the penumbra not as dark as the umbra?

Diagram and explanation.

Presentation:

We have on the table before us a large number of colored objects. The clothes we are wearing are of many different colors. Pictures and paintings owe much of their beauty to color. Nature uses color in many ways, particularly for maintaining life. Can we obtain an explanation for color?

Take the glass prism that is on your table and hold
it toward the sunlight. What do you observe? A patch of light having all the colors of the rainbow. Name the colors you see. What is this band of colors called? Spectrum. The so-called white light of the sun has been broken up into seven colors.

Demonstration:

To obtain an explanation of the cause of this let us take this inclined plank. The top half is smooth, but the lower half is covered with baize which has been cut at an angle and fastened tightly to the plank. A carriage runs down the plank. One wheel strikes the baize before the other and the carriage is slewed around. Explain. One wheel is retarded more than the other, so that the carriage changes its direction. This bending from a direct course is called refraction.

Using this idea we may account for the spectrum we observed. (Diagram of a beam of light passing through the prism is drawn on the blackboard.) The beam strikes the prism at a sharp angle. The light on one side of the beam enters the prism before the light on the other side. The glass retards the light which enters first, and the beam is slewed away from its previous straight line. This is inevitable since the air and glass are not of uniform densities. Further, since this glass is a prism, the waves pass through different thicknesses of glass. The waves whose direction is changed the most pass through the greatest thickness of glass, that is, they are refracted the most. When the light emerges from
the prism, the longest waves which have travelled more rapidly through the glass are refracted the least and come out first. The shortest waves travel more slowly in the glass and are refracted the most. On leaving the glass the rays travel in straight lines but are spread out and arranged in order from longest to shortest wave length. Red light corresponds to the longest, and violet to the shortest waves. We believe that each color of the spectrum is caused by a distinct wave length.

Presentation:

Here are three books. Note their colors,—red, green, and blue. Are they luminous or non-luminous? Non-luminous. The eye sees each book and our brain interprets the sensation as red, green, and blue. What kind of light enters this room, and is reflected from the various objects, including the books? Sunlight. We observed during the demonstration that light is composed of several colors. We must proceed to explain, therefore, why this book is red. What light does the book reflect? Red. What must happen to the other colors of the spectrum? They are absorbed. (Similar questions for green and blue books.) What light waves are reflected from this note paper? All waves comprising white light. What light waves are reflected from this carbon paper? None. All the light waves are absorbed, so the object appears black. Black is the absence of color. Why does this window glass appear white? All light waves pass through. Why does this
glass appear red? Only the red waves are transmitted, the others are absorbed. (Similar for green and blue glass.)

To dye cloth, a substance is put into it that will absorb all the color waves of white light except those that produce the desired color.

Have you ever matched pieces of cloth in the artificial light of a store and then found them to be different in color in daylight? What is the cause of this? In artificial light the waves are reflected equally, but in daylight one reflects the color waves in different amounts, or additional waves are reflected by one piece of material and not by another.

Demonstration:

This piece of wire has been heated from room temperature to bright red heat. Why does the wire appear red? Emission of red rays. We have seen this Bunsen flame change in color from yellow to green and red as we added sodium, barium, and strontium salts. Explain the change in colors in each case. The colors of the lights depend upon the wave length of the light waves they transmit. Can you make a statement that will summarize these facts about color? Colors of objects result from the absorption of some rays and the reflection and transmission of others.

Presentation:

When we drive in an automobile on a dark road, the headlights illuminate the road in front. How does this light
reach us? Reflection. What effect would these same headlights have on a man facing them? Blinding. If you look at the sun on a bright day you realize how uncomfortable and painful direct bright light can be. Exposure to the direct light from a single electric light may produce glare, thus reducing one’s ability to see. Glare results in eye strain and defective vision. We may think of light as having two opposing qualities. One that makes it possible to see, and the other, namely glare, which defeats vision.

In lighting our homes it is not enough just to have light. It is controlled and directed light that we need. The science of illumination has discovered in large measure how to control light by the use of shades and reflectors, that gather in the light rays, and then re-direct them to the place where they are needed. Light control is greatly aided by applying the important scientific principles of reflection, diffusion, absorption, and refraction. Good lighting practice requires that consideration be given the quality and quantity of the light, its intensity, position, direction, and suitability to the particular task. Why is the amount of window space to floor space in a building about one-fourth? To receive adequate daylight. How does a room with a southern exposure get much of its light? Direct rays of the sun and diffusion. A room with a northern exposure? By diffusion only.

The amount of light which enters a room is only one
of the factors that influence good lighting. If the walls and decorations of a room are dark will the room appear light? No. Why? The dark substances absorb the light and reflect but a small amount. If a room is to be made as light as possible what changes would you suggest? White walls and ceiling, light draperies and furniture.

Not only is the color important. The finish of the surface has much to do with the amount of reflection. A smooth, glossy finish produces a glaring effect, while a rough or dull surface tends to diffuse the light and produce a softer effect. Here are a few interesting figures. A good white paper reflects about 80% of the light, cream paper 56%, red paper 12% and dark green 5%.

Heavy curtains and shades may cut off an amount of light to make lighting inadequate. Light-colored translucent shades are better than dark-colored opaque ones.

Presentation:

What are the three systems of electric lighting in common use? Direct lighting, indirect lighting, and semi-indirect lighting.

What is the direct system? Lights are so arranged that their rays fall directly on the surfaces to be lighted. What is its chief disadvantage? It produces glare in some spots and dimness in others. What advantage does it have? It is more economical on electricity. How may the glare be offset somewhat in this system? Frosted lamps or frosted or
etched glass bowls may be used to diffuse the light.

What is the indirect system? An inverted opaque reflector is hung under the lamp. The light is transmitted or reflected to the ceiling and is then sprayed over the room by diffuse reflection. What is its chief advantage? It produces a subdued light without glare or marked shadow. What is its disadvantage? It is expensive to use.

What is the semi-indirect system? It combines the principles of both direct and indirect lighting. A translucent bowl is placed under the lamp. Some light passes through the bowl and shines downward, while a large part is thrown to the ceiling, and diffused over the room. What are its chief advantages? It gives a subdued, restful light and is not expensive.

On what basis should lighting fixtures be chosen. Selected on the basis of light control and appearance.

What type of lighting should be used in the living room? The lamps should provide suitable light for rest and recreation. Common types are ceiling fixtures, wall brackets, and portable lamps. Thought should be given to the shades. They should prevent glare, but not obstruct the light unduly. They should be chosen to blend with the color scheme of the room both day and night. (Discuss dining-room, kitchen, etc., in similar manner.)

Presentation:

If you had to do some prolonged reading of fine print
on poor paper, what kind of light would you choose? A bright light without glare. Would you require the same conditions in order to read larger print on good paper? The light need not be so bright. In general, the intensity of the light depends upon the type of work being done.

Lighting engineers have studied the requirements for good lighting conditions and have developed various instruments for testing adequate illumination in such a way that guesswork is eliminated. One of the most commonly employed devices is the sight meter or foot-candle meter. By exposing this instrument to the light and reading a scale, one can tell at a glance whether or not the lighting is adequate. This device depends upon the use of a photo-electric cell. You will recall the demonstration one of our members gave on this a short time ago.

As we move a printed page away from a source of light, how is the illumination affected? It decreases. This decrease in the brightness of the light as the distance increases is the reason why so small a change in the distance of a lamp makes so great a difference to the ease with which we read the printed page.

Demonstration:

How can the picture from this film slide projector be made larger? By increasing the distance between the screen and the projector. Having done so, what difference do you see between the two pictures? The second is not so bright
as the first. Measure the area of the two pictures we have just considered. One is four times as large as the other. Why is the second picture not so bright? The light from the lamp has spread out to cover a larger area. How could we make this larger projection brighter? By using a more powerful light source. This lamp used is one hundred watts, or one hundred candle power. What does that mean? It emits the equivalent of one hundred standard candles.

On what two factors does the illumination of an object depend? On the intensity of the light source, or candle power, and on the distance from the source of light.

The light emitted by one candle on one square foot of surface at a distance of one foot is a foot-candle of illumination. If the distance is two feet, the same rays of light illuminate a surface of two by two, or four square feet, so that each square foot of surface gets but one-fourth of a foot-candle of light. At a distance of four feet, the same rays illuminate four by four or sixteen square feet of surface, each square foot receiving one-sixteenth of a foot-candle of illumination.

Summary.

How has "civilization progressed as man has learned to use and control the energy of light"? The influence of scientific discovery in the field of lighting has had a great effect upon our lives. The importance of the following was discussed: the use and control of natural and
artificial light in the home, the use of artificial light for street-lighting, traffic control, automobile lights, advertising signs, airport beacons, lighthouses, and light-ships, the achievements of the photo-electric cell, the art of color in clothing, home decorating, painting, and the value of color to living things.

Method of Treatment for the "Pure Science" Group

As indicated earlier the "pure science" group followed a procedure of stressing principles of science. The sociological captions found in the prescribed course were totally ignored, and the everyday aspect was purposely neglected unless it forced its way to the front. Reading assignments for this group were given almost entirely from the physics, chemistry, and biology reference books, since the organization of these books fitted more closely the objectives set for this class. Important points were written on the blackboard as the lessons progressed. A greater number of arithmetical problems was provided to aid in the driving home of principles. Pupils were required to make their own notes which were later examined by the teacher. At the beginning of a period pupils were often asked to give a resumé of former work or to discuss the previous day's assignment. When a unit of work was completed the pupils submitted a review outline of the work covered.

As an introduction to Unit II the pupils were informed that we would study energy. We would discuss its transformation and would consider such topics as machines, heat,
magnetism, electricity, sound, and light. Our main purpose was to gain an understanding of the fundamental principles related to these topics.

Outline of the Topic "Light" as Taught to the "Pure Science" Group

Procedure:
- Lecture with questions and answers.

Presentation:
Light

Light is the form of radiant energy, which, by its effect upon the nerves of the eye, excites the sensation of vision. In our study of heat we learned that heat energy may be transmitted by waves in the ether. Heat and wireless waves are longer than light waves. The eye is sensitive only to waves of certain wavelengths.

What is a luminous body? It is one that emits light, i.e. is self-luminous, or is visible on account of its own light, e.g. sun and stars, heated platinum wire.

What is an illuminated body? It is one that is visible since it reflects light which it has received, e.g. moon and planets.

What is a transparent body? It is one that allows light to pass through it in such a way that objects are distinctly visible through it, e.g. glass, water, mica.

What is a translucent body? It is one that transmits light, but also diffuses (scatters) the light so that objects cannot be distinctly seen through it, e.g. oiled paper,
frosted glass, ground glass, thin paper.

What is an opaque body? It is one that does not allow light to pass through at all, e.g. wood, bricks, stone, iron.

What are some important sources of light?
1. Light from disturbances at high temperature, e.g. sun, stars, bodies heated to incandescence.
2. Light from friction and chemical action, e.g. combustion of oil, gas, and other fuels.
3. Light from phosphorescent substances, e.g. luminous paint.
4. Light from electrical disturbances, e.g. aurora.

For our purpose we may picture the nature of light:
1. composed of waves
2. travels through a vacuum
3. waves are extremely short .000039 cm. to .000081 cm. in length.

Propagation of Light

Demonstration: (teacher and pupils working together). Place a small burning candle on a table. Take two pieces of cardboard about a foot square, with a hole near the center of each. Hold the cardboards between your eye and the flame of the candle in such a way that you can see the source of light through the holes. You will see that the holes and the source of light are in a straight line. Move one of the cardboards sideways, then up and down. You can no longer see the source of light. This proves that light travels in straight lines.
From a luminous point, light moves outward in all directions. If the medium is of uniform density the light travels in straight lines.

Reflected and Diffused Light

Diagrams with explanations. Pupils assisting to formulate definitions:

A ray is a single line of light coming from a luminous point.
A beam of light is several parallel rays.
Reflection is a turning or throwing back of light rays from a surface.

The normal means the perpendicular to the reflecting surface at the point of incidence.

The angle of incidence is the angle between the incident ray and the normal.

The angle of reflection is the angle between the normal and the reflected ray.

Law of Reflection

Demonstration: Use the Hartl optical disk, reflector and lamp to show reflection.

Definition formulated by pupils: The angle of incidence equals the angle of reflection.

Pupil experiment: prove the law of reflection by the common method using pins, mirror, and protractor.

What is regular reflection?

Demonstration: A beam of light from a projector falls upon a mirror. It is reflected, forming a bright spot on the wall, showing that the parallel beam was reflected as a parallel beam. Diagram to illustrate.
Definition formulated by pupils: When light falls upon a highly polished surface, the greater part of the light will be reflected regularly; that is, a parallel beam is reflected as a parallel beam.

What is irregular reflection or diffusion?

Demonstration: Similar to above, except that a piece of white paper is substituted for the mirror. No bright spot is shown, the light being diffused. Diagram to illustrate.

Definition: When light falls upon an unpolished surface, the reflected rays are not parallel, but scattered.

How are shadows formed?

Demonstration using candles, object, and curtain. Diagrams to illustrate.

The formation of a shadow depends on the fact that light travels in straight lines. Since an opaque body absorbs light, the space behind the object is in darkness and is called a shadow.

If the light source is a point the shadow is sharply defined. No part of the shadow receives light and is called the umbra.

The penumbra is that portion of a shadow which is partly illuminated.

Speed of Light

Light travels with a speed of 186,000 miles per second.

Methods for determining speed of light:

1. Romer's method - diagram and explanation.
2. Michelson's method - diagram and explanation.

Refraction

Pupil experiment: Draw a heavy pencil line on a sheet of paper and place a piece of plate glass over it. Look directly in front of the line. Move to the right and then to the left and look at the line. What do you notice in each case?

Explanation with diagram: The phenomenon that you observed is caused when the light coming from the line to the eye has its direction changed.

Definition formulated by pupils: Refraction is the bending of a light ray which takes place whenever light passes obliquely from one medium to another of a different optical density.

What is the spectrum?

Demonstration: Show the spectrum using the optical disk, prism, and screen.

Explanation with diagram: When the light passes through the prism it is refracted at both surfaces and comes out in a different direction from that at which it entered. Not only is the light deviated, but it is spread out or dispersed into its component colors. Violet deviates the most and red the least. The fact that different colors are refracted unequally enables us to see the spectrum. The violet light is refracted more than the other colors because it has the shortest wave length. The red rays are bent the least
because they have the longest wave length.

Color

Color is a property of light that depends on its wave length. Bodies are colored because they are able to reflect or transmit certain wave lengths of light. If a beam of white light falls upon a red body the body reflects only the red wave lengths and absorbs the others. If red light falls upon a blue object the object reflects little or none of the light and it appears black. If green light falls upon a green body, it reflects the light, appearing green. An object appears white if it can reflect all the colors that compose white light. A body appears black if it does not reflect any color, that is, a black body absorbs all colors.

Experiment: To demonstrate this we shall place a white ribbon in the various parts of the spectrum. It appears red in the red, and blue in the blue. Place a red ribbon in the red of the spectrum and it appears red. Place it in the blue and it appears black.

Color of Transparent Bodies

The color of a transparent substance depends upon the color it transmits. A piece of red glass appears red since it absorbs all the colors which compose white light except red, which it allows to pass through. A piece of blue glass is blue for a similar reason. Common window glass is colorless because it transmits all colors of white light equally well.

Experiment: Pupils given pieces of glass of different
colors for observation purposes. Explanations needed.

Photometry

The Intensity of Illumination

This is measured by the quantity of light that falls on a unit area of surface. This depends on:
1. the intensity of the source of the light
2. the distance from the source

The intensity of illumination is measured in foot-candles. A foot-candle is the quantity of light received one foot distant from a light-source of one candle power. The brightness of a light source is measured in candle power. One candle power is the rate at which one standard candle emits light.

Law of Inverse Squares

Photometry is the process of measuring the relative intensities of light. The instruments used for this purpose are called photometers.

Demonstration: Use a Rumford photometer.

The intensity of illumination varies inversely as the square of the distance from the source.

Pupil experiment: Use Bunsen grease spot photometer.

Types of Light

- Direct
- Indirect
- Semi-indirect
Chapter III.

FACILITIES AND EQUIPMENT

The science equipment of the school in which the investigation was conducted consists of three well equipped laboratories, one for each of the three sciences: chemistry, physics, and biology. These are conveniently situated on one floor of the building. All necessary apparatus for teaching high school science is available, in addition to many charts and large printed diagrams of industrial processes. Also included are collections of commercial raw materials and products, rocks and minerals, birds, fossils, insects, and microscopic studies. Four different aquaria are kept. The classes met the first and fourth periods every morning of the school week. The chemistry and physics laboratories could be obtained for four out of these five weekly forty minute periods. The biology laboratory was available by arrangement with the biology teacher as the need arose.

Forty copies of each of the following text books recommended by the Programme of Studies were available after their purchase in November:

These books were available for classroom or laboratory use whenever required. Students were allowed to borrow them for overnight or week-end use. Five copies of the following were obtainable in the library: Walker, J. F., Elementary Geology Applied to Prospecting, King's Printer, Victoria, B. C., 1936. Abundant general reference books such as encyclopedias and text books on science were available. However, there were relatively few science books of a general or popular nature.

In addition to the aids previously mentioned, the school is equipped with a motion picture machine, adapted for silent or sound films as well as a film slide projector. These could be used in the classroom, laboratory or auditorium. A number of films and film slides recommended for the course, as well as several others that were loaned by the Department of Visual Education, Vancouver School Board, were shown. In the case of film slides pupils were asked questions as the slides were shown, while in the case of the moving picture films questions were given at the completion of the picture. Where possible, the questions were selected to suit the problem of this investigation. Both groups were shown the same films.
Chapter IV.

THE TESTING PROGRAMME

Objective and Subjective Achievement Tests Used

In order to compare the work of the two groups objectively, achievement tests were devised by the writer. No standardized tests on general science were suitable for the new course. At the conclusion of Units II, III, IV, and V, two achievement tests were given: one of the objective type and one of the subjective type. The former was used largely to measure the pupils' knowledge of facts, laws, principles, theories, hypotheses, and the meaning of significant words, while the latter was used largely to test their understanding of the meaning, use, and significance of the knowledge. In addition to the above tests, two others were given close to the end of the school session in June. One of these was a test designed to measure the achievement of the groups in respect to their understanding of scientific facts and principles as applied to novel scientific devices, as well as to their appreciation of the social utility of the device. These devices had not been discussed or alluded to in any way, and so far as the writer was aware, were gathered from sources unavailable to the pupils. The second of these tests was a delayed recall one, based on the first two units. Its purpose was to determine how much of the earlier work of the course had been retained. No warning whatever was given the pupils before these two tests, but they were informed that the results would not, in any way, be considered in their term's work.
The tests were of such length that they could be administered by the teacher within the forty minute class period. In the case of the two longest units, one and two, a longer objective test was given, requiring the use of two periods. Mimeographed copies of the tests were used for the examinations.

Scoring the Tests

All tests were scored by the teacher on a point basis. In scoring the objective tests, one point was allowed for each answer, the total number of points representing the pupil's score. In order to increase the reliability of the subjective tests, the following procedure was used for scoring the tests. A schedule of points was assigned to each question in proportion to its relative importance. The same question on every paper was rated before proceeding to the next question. Points were assigned on the basis of the relative quality of the pupil's answer. The quality of the written expression was not rated. The sum of the scores on each question represented the pupil's score.

In the few cases where pupils were absent for a period of time and so were unable to take the test, their score was estimated for comparative purposes by the usual formula.

The scores were tabulated and the appropriate statistical methods were applied for determining whether or not

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* See appendix, p. 87.
significant differences had been established. These results are tabulated on pages 39, 40 and 41.

Samples of all the tests used for comparative purposes are included in the appendix to this report.

Note: The writer has on file all data used in connection with this investigation. Any person interested may have access to the data upon request.
Table IV.

Scores of the Objective and Subjective Tests, "Scientific Devices" Test, and Delayed Recall Test for the "Social" Group.

<table>
<thead>
<tr>
<th>Pupil</th>
<th>Unit II</th>
<th>Unit III</th>
<th>Unit IV</th>
<th>Unit V</th>
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R. A. 64 42 29 33 29 28 50 35 28 33
D. A. 61 32 24 29 30 25 55 32 29 27
D. A. 61 22 32 35 37 28 52 35 29 27
H. B. 89 46 33 50 44 38 60 39 40 48
R. B. 72 47 39 47 38 35 62 41 41 38
P. B. 85 43 41 49 46 34 70 48 36 54
M. C. 57 18 22 17 19 15 36 22 10 19
R. C. 58 16 18 25 21 19 32 22 15 28
S. F. 47 17 12 25 25 19 54 28 17 22
N. F. 47 21 26 23 25 23 43 27 27 26
P. F. 57 25 27 25 30 26 46 36 32 24
R. H. 57 29 30 31 31 28 45 32 28 34
D. K. 78 59 57 56 42 33 69 46 42 58
D. L. 45 18 17 21 26 15 31 22 16 32
D. L. 76 41 40 44 40 32 63 36 41 37
H. M. 43 32 25 24 20 22 46 32 20 29
J. M. 65 34 38 36 43 31 63 33 39 35
G. M. 54 34 24 31 25 21 49 20 24 27
G. M. 56 29 28 35 29 28 40 32 30 35
M. M. 56 28 25 34 24 24 50 33 28 24
P. M. 44 11 14 23 16 20 31 17 13 14
S. N. 67 32 31 37 31 23 51 31 29 27
H. N. 56 28 26 23 26 22 43 28 22 26
W. O. 76 36 37 38 38 29 67 42 31 33
L. P. 48 14 24 25 26 18 47 30 19 30
P. R. 47 21 19 30 12 12 18 26 26 24
J. S. 53 24 31 34 34 27 58 33 15 31
A. S. 49 25 26 23 29 20 50 26 24 19
R. U. 76 39 38 50 37 30 67 44 44 41
J. W. 59 21 27 34 28 25 54 30 29 17

Boys = 20
Girls = 10 Total = 30.
Table V.


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<tr>
<th>Pupil</th>
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<th>Unit IV</th>
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<td>39 31</td>
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<td>21 31</td>
<td>45 28</td>
<td>60 31</td>
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<tr>
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<td>87 27</td>
<td>26 28</td>
<td>31 28</td>
<td>45 31</td>
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<td>40 41</td>
<td>32 33</td>
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<tr>
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<td>35 32</td>
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<td>20 24</td>
<td>19 15</td>
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<td>37 14</td>
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<td>25 14</td>
<td>41 20</td>
<td>13 24</td>
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<td>P. P.</td>
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<td>27 40</td>
<td>33 25</td>
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<tr>
<td>T. R.</td>
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<td>21 26</td>
<td>18 17</td>
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<tr>
<td>B. W.</td>
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<tr>
<td>R. W.</td>
<td>70 36</td>
<td>50 23</td>
<td>28 27</td>
<td>50 36</td>
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Boys = 18
Girls = 12 Total = 30.
Table VI.


<table>
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<tr>
<th>Test</th>
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<th></th>
<th>&quot;Pure Science&quot; Group</th>
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<td>Mdn.</td>
<td>$\sigma$</td>
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<td>9.9</td>
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<td>28.</td>
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<td>Delayed Recall</td>
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<td>9.0</td>
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Table VII.


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<tr>
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<td>.85 ± .03</td>
<td>.75 ± .05</td>
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<td>.86 ± .03</td>
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<tr>
<td>Units II and III obj. tests</td>
<td>.60 ± .08</td>
<td>.69 ± .07</td>
<td>.75 ± .05</td>
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</table>
Chapter V.

PUPIL INTEREST

In order to supplement the objective results obtained from the testing program, an earnest attempt was made to observe and record the interest shown by the pupils of each group. As a means for comparing the interest manifested by each group, several devices were used. In these, as in all other work, rivalry between the two classes was avoided. Care was taken in all of these projects to ensure that the interest shown by the pupils should be genuine.

Outside Reading by Pupils

For one of these the co-operation of the school librarian was enlisted to obtain a check of the reading done by the two groups. For this scheme, which was in operation from December until June, a number of science books of the more popular type, such as "Great Men of Science" by Grove Wilson, "Romance of Electricity" by Wilfred L. Randall, and "The Story of Geology" by Allan L. Benson, as well as a number of current science magazines such as "Science Digest", "Science News Letter", and "Popular Science Monthly", supplied by the writer, were placed on a special shelf near the librarian's desk. This literature was available only to members of the two groups. Each group was informed of the arrangement. The pupils were told that the reading they did was purely voluntary, and that no attempt would be made to
consider this in relation to school grades. The books and magazines were available during the students' weekly library period, during the noon hour, or after school hours. Books could be borrowed for a week, but the periodicals were not to be taken from the library.

In accordance with the library regulations the pupils signed library cards each time they borrowed a book or magazine. From these cards a check was made of the reading done. This check revealed that the members of the "social" group had made a total of two hundred and twenty-two calls for magazines, and eighty-four calls for books, while the "pure science" group had made a total of one hundred and thirty-nine calls for magazines, and fifty-three calls for books. An analysis of the library cards showed that almost all the members of the "social" group made use of some of this extra material, while just a few members of the "pure science" group did all the outside reading.

**Check on Library Books**

After the library closed for the year, a check was made of all the books of a scientific nature on the library shelves that had not been used as reference or source books. This did not include the special group of books previously mentioned. From the library cards in the books an examination was made of the total number of these books that had been taken out for reading by the members of these two groups. The "social" group had a total of twenty-nine, and the "pure
science" a total of twenty-four. This slight difference is in favor of the "social" group, but is not sufficient to be significant.

**Scrapbooks**

To obtain additional evidence of interest two scrapbooks, one for each class, were made voluntarily outside the classrooms by the pupils. They contained a miscellaneous collection of science news items, collected mainly from newspapers, with a few from magazines. Clippings contributed by a pupil bore his name or initials. In the case of more than one pupil bringing in the same clipping, the initials or names of all were included on the one item placed in the book. News items relating to class work were sometimes brought to class for discussion before being entered in the scrapbook. A very limited time was given to this, however, since the course proved to be quite lengthy and time was at a premium. At the close of the term the "social" group had compiled one hundred five separate items, the "pure science" group sixty-six. The former group showed that not only were there a greater number of pupils contributing, but that there was a more equal distribution of material collected than with the latter.

**Posters**

It was suggested to the pupils that they bring photographs and illustrations from newspapers or magazines, that
were related to scientific topics, and post them on the board provided in the classroom. The number of pictures collected was small, there being twenty-two from the "social" group, and twelve from the "pure science" group. In the case of the poster contributions this was a difference in favor of the former group.

Questionnaires

Two questionnaires were given to each group, one at the close of Unit II and the other at the close of the term. In both cases the pupils were asked not to sign their names. This instruction was given in order that the pupils would be under minimum restraint in giving replies. The first of these questionnaires was designed to find out the interest of the students in Unit II as well as their reaction to it. An analysis of the replies to this questionnaire showed a slight difference in responses to the first question. With the "social" group twenty-five found unit II an interesting one, and five did not. In the "pure science" group nineteen replied in the affirmative and eleven in the negative. No significant difference was shown in replies to the other questions.

The second questionnaire contained questions to elicit their preference for certain units, topics, books, and magazines, as well as questions designed to disclose their interest in high school science. With this questionnaire no significant difference was shown between the two groups except in the case
of the sixth question: "If it were possible for you to "drop" science without affecting the requirements would you wish to do so?" The "social" group gave six responses to "yes" and twenty-two to "no". The "pure science" group eleven responses to "yes" and eighteen to "no". 

Diary

A running diary of the significant questions, topics, interest toward experimental work conducted in the school and at home, or other evidences of interest by each group was kept by the writer. No significant difference was apparent from a study of the diary.

* A sample copy of each questionnaire is included in the appendix.
ANALYSIS OF THE STATISTICAL RESULTS OF THE EXPERIMENT

As already noted, the two groups of pupils were closely matched in intelligence level and school achievement and can be considered comparable groups.

Examining, first of all, the scores on the various tests given, the means and medians for the "science" group are, in every test but one, slightly higher than those for the "social" group; but for any single test the difference is not a significant difference.

The spread of the scores, as indicated by the standard deviations, is practically the same for both groups in nearly every test.

Comparing the correlations between the subjective and the objective tests for each of the four units in the curriculum, we find, first, for the "social" group that the correlations vary from .90 to .79 and for the "pure science" group from .87 to .65. There is thus much less variation with the "social" group. Secondly, we find the correlations are consistently higher for the "social" group than for the "pure science" group; and for many of the correlations this is a significant difference. How can these differences be interpreted? It means that, when two different types of tests are used for the same unit, the agreement between the scores on the two types is greater for the "social" group, i.e. the
type of test used has less effect on the scores of the "social" group than of the "pure science" group.

From the statistical analysis of the results, then, we must conclude that insofar as our tests measure achievement, there seems to be little difference between the achievement of the two groups of pupils other than that there is some indication that the achievement of the "social" group is somewhat more consistent, in that a variation in the type of test used has less effect on the scores obtained by the pupils in the "social" group.
Chapter VII.

SUMMARY

The experiment was devised for determining the relative values of two methods of teaching general science, previously described, as applied to the new course General Science IV as prescribed for the high schools of British Columbia.

In formulating the tests measures were sought of the pupils' knowledge of facts, laws, principles, hypotheses, theories, and the understanding and use of this knowledge.

From the results of the tests it would seem to make little difference whether the teaching be from the socialized point of view or from the pure science point of view. Perhaps the tests were inadequate as measures of achievement, or, perhaps, they favored one point of view rather than the other. There may have been results of achievement in science not measured by the tests.

In order to have some check on the latter point an attempt was made to find whether the "socialized" teaching developed a greater interest in science in general. The evidence of interest in science is necessarily fragmentary, but it would seem that though the knowledge of scientific facts is about the same for both groups, the "social" group as a whole seemed more interested in science generally.
BIBLIOGRAPHY


Curtis, F. D., Digest of Investigations in the Teaching of Science, Blakiston, 1931.


Hunter, G. W., Science Teaching at Junior and Senior High School Levels, American Book Co., 1934.


APPENDIX.

GENERAL SCIENCE
(Grade IX)

Encircle the T before all true statements and the F before all false statements. The example has been marked correctly. Do not guess. Right - Wrong = Score.

Example: O F Oxygen is an element.

T F 1. Steam is a gas.
T F 2. Warm air is lighter than cold air.
T F 3. Ice is heavier than water.
T F 4. Water exerts an upward pressure.
T F 5. Winds blow toward a "low" center.
T F 6. A siphon is a device for pumping water.
T F 7. A hurricane is a storm originating at sea.
T F 8. The density of a body is the same as its specific gravity.
T F 9. The earth is the great storehouse of energy.
T F 10. Bacteria are always present in the air.
T F 11. Hydrogen is soluble in water.
T F 12. Oxygen is tested with a burning splint.
T F 14. Hydrogen is more plentiful than helium.
T F 15. A liter is used to measure liquids.
T F 16. The density of water is 13.6 grams per c.c.
T F 17. The density of water changes when the temperature is changed.
T F 18. One degree on the Fahrenheit scale is equal to nine-fifths of a degree on the Centigrade scale.
T F 19. The process of osmosis enables a plant to assimilate its food.
T F 20. All vibrating bodies produce audible sounds.
T F 21. Houses are heated mainly by conduction.
T F 22. A thermometer measures the amount of heat in a body.
T F 23. Burning increases the amount of oxygen in the air.
T F 24. Circulation of air in a room is necessary for good ventilation.
T F 25. Carbon dioxide is more fatal than carbon monoxide.
T F 26. A generator turns because of the current of electricity through its armature.
T F 27. An electric fuse is based upon the magnetic effect of an electric current.
T F 28. Electric power is measured in Watts.
T F 29. When a liquid wets the surface of a tube placed in it the surface of the liquid will be concave, and the liquid will rise in the tube.
TF 30. Machines are used because they do more work than is put into them.
TF 31. Copper is commonly used to insulate electricity.
TF 32. A moving object has had work done on it.
TF 33. Scientists believe that energy is not destroyed.
TF 34. Lubricating oil helps a machine to work by causing friction.
TF 35. Potential energy is the capacity for work which a body has due to its position.
TF 36. A flywheel in motion is an example of Kinetic Energy.
TF 37. A street car uses static electricity for motive power.
TF 38. Heat causes the vibration of molecules.
TF 39. A dry cell changes chemical energy into electrical energy.
TF 40. Temporary magnets are usually found in an electric motor.
TF 41. Matter can be created and destroyed.
TF 42. The divisions of a barometer are in degrees.
TF 43. If water is cooled from 60°F to 40°F it becomes heavier per cubic foot.
TF 44. The mercury stays up in a mercury barometer because the vacuum above holds it there.
TF 45. Rain water is healthy to drink.
TF 46. In the Doldrums the air is constantly rising upwards.
TF 47. Light travels at 186,000 miles per hour.
TF 48. Parallax error can be avoided by using accurate instruments.
TF 49. The world's greatest deserts are found in the region of the Doldrums.
TF 50. The North Magnetic Pole is situated in a North Easterly direction from Vancouver.
In each of the following sentences you are to find the right answer, draw a line under it and then put the number that is front of it in the parenthesis at the end of the line.

1. The usual method of preparing oxygen is to decompose by heat some (1) element; (2) solution; (3) solute; (4) compound; (5) ore ( )

2. The man who discovered oxygen was (1) Lavoisier; (2) Dalton; (3) Priestly; (4) Einstein; (5) Boyle ( )

3. Hydrogen may be set free from water by (1) synthesis; (2) combustion; (3) electrolysis; (4) combination; (5) distillation ( )

4. Water contains a percentage of hydrogen by weight which is as follows: (1) 10%; (2) 22.2%; (3) 88.88%; (4) 11.11%; (5) 5.2% ( )

5. The lifting power of helium is (1) twice; (2) 50 percent; (3) 1.29; (4) 96%; (5) 80% as much as hydrogen( )

6. A liter of oxygen contains (1) 500 c.c.; (2) 1000 c.c.; (3) 100 c.c.; (4) 375 c.c.; (5) 10 c.c. ( )

7. Balloons filled with hydrogen are dangerous because of (1) occlusion; (2) combustion; (3) osmosis; (4) activity; (5) electrolysis ( )

8. Hydrogen is collected by displacement of (1) mercury; (2) alcohol; (3) water; (4) air; (5) oxygen ( )

9. One physical property of hydrogen is that it is (1) heavier than air; (2) easily liquefied; (3) soluble in water; (4) heavier than oxygen; (5) lighter than air ( )

10. One cubic centimeter of water at 4°C weighs (1) 1 gram; (2) 1 kilogram; (3) one ounce; (4) 100 milligrams; (5) 4 grams. ( )

11. Water has its greatest density at (1) 0°C; (2) 4°C; (3) 100°C; (4) 1°C; (5) 10°C ( )

12. One cubic foot of water weighs (1) 1 kg; (2) 20 lbs; (3) 100 lbs; (4) 75.5 lbs; (5) 62.4 lbs. ( )

13. A common solvent is (1) iron; (2) water; (3) mercury; (4) lead; (5) salt ( )

14. Matter in suspension in water is removed by (1) boiling; (2) aeration; (3) filtration; (4) disinfectants; (5) condensation ( )

15. Nitrogen compounds are needed by animals to form (1) fats; (2) carbohydrates; (3) proteins; (4) salts; (5) acids ( )

16. Clear cool weather indicates that the reading of the barometer is (1) about to move higher; (2) about to move lower; (3) is to remain stationary; (4) to change suddenly; (5) to change slowly. ( )

17. A closed compartment in which men can work under water is (1) a compressor (2) a caisson; (3) a safe; (4) cycle; (5) a pump ( )
18. A green leaf is a factory fitted to manufacture starch by (1) osmosis; (2) transpiration; (3) photosynthesis; (4) liquefaction; (5) solution.

19. A hydrometer measures (1) air pressure; (2) specific gravity; (3) temperature; (4) distance; (5) volume.

20. A device for detecting an electric charge is (1) a galvanometer; (2) a condenser; (3) a magnet; (4) a thermometer; (5) an electroscope.

21. Light is necessary for green plant life to (1) produce carbohydrates; (2) give them color; (3) help pollination; (4) keep them warm; (5) absorb moisture.

22. A force pump pumps water more steadily than a lift pump because (1) the handle is longer; (2) of an air chamber; (3) the piston is shorter; (4) the valves open more readily; (5) the cylinder is larger.

23. Changing water into water vapor is (1) condensation; (2) evaporation; (3) transpiration; (4) respiration; (5) filtration.

24. The best method of purifying water is (1) boiling; (2) filtering; (3) treating with oxygen; (4) electrolysis; (5) distillation.

25. Water rises up through the soil by (1) capillary action; (2) osmosis; (3) diffusion; (4) convection; (5) radiation.

26. Sound travels at the rate of (1) 186,000 feet per sec.; (2) 1100 ft. per second; (3) 150 ft. per sec; (4) 5000 ft. per sec.; (5) 5280 ft. per sec.

27. A substance that could be used for insulating electricity is (1) tin; (2) silver; (3) rubber; (4) iron; (5) mercury.

28. Two seconds after the steam is seen from a steamer whistle the sound is heard a distance away of (1) 11,560 ft.; (2) 1760 yds; (3) 1 kilometer; (4) 2200 ft; (5) 6600 ft.

29. When brakes are applied to a moving machine the energy is changed into (1) chemical energy; (2) heat energy; (3) electrical energy; (4) light energy; (5) mechanical energy.

30. The number of vibrations per second of the note C is (1) 256; (2) 512; (3) 584; (4) 100; (5) 1200.
GENERAL SCIENCE IV
Unit I
Objective Test

Complete the following statements by filling in the blank spaces at the right with a word or phrase.

1. Materials are recognized by their

2. The change that takes place when milk sours is classified as

3. The inability to decompose magnesium proves it to be

4. How many atoms are there in $2(NH_4)_2SO_4$?

5. Compounds are represented by

6. Ferrum is the Latin word for

7. The spontaneous intermingling of gases is called

8. Standard temperature for measuring gases is

9. The smallest particle of water possible is

10. The electron theory assumes that atoms are composed of both

11. A change in which the identity of a substance is not lost is known as

12. Elements are represented by

13. When heated, gases

14. Diffusion and Brownian effects are evidences that particles of a gas are

15. The combining power of an atom is called

16. The fraction of the earth's surface covered by water is

17. The hemisphere where most of the earth's water is found is

18. The speed of molecules is affected by

19. Burning started as a result of the accumulation of heat due to slow oxidation is known as
Unit I, Objective, (cont'd.)

20. A substance composed of two or more elements combined according to a fixed ratio by weight is _______________________.

21. Stated in centimeters of mercury, standard pressure is _______________________.

22. What law states the relation between the weight of the materials used in a chemical reaction and the weight of the product formed? _______________________.

23. The decay of wood is an example of the chemical process of _______________________.

24. The gas used to fill the glass tubes which make the red letters in advertising signs is _______________________.

25. If a compound contains only two elements the name of the compound ends in _______________________.

26. The Atomic Theory was formulated by _______________________.

27. The chemical equation representing the combination of carbon and oxygen is _______________________.

28. The atomic weight of oxygen is _______________________.

29-34. The six important elements composing the living matter of a cell are (29) _______________________, (30) _______________________, (31) _______________________, (32) _______________________, (33) _______________________, (34) _______________________.

35-37. Write names for (35) Ag NO₃ _______________________, (36) Mg Cl₂ _______________________, (37) Cu O _______________________.
Unit I, Objective, (cont'd.)

38-40. Write formulae for
(38) sodium hydroxide

(39) ammonium sulphate

(40) iron carbonate

In each of the following sentences you are to find the right answer, draw a line under it, and then put the number of it in parenthesis at the end of the line.

1. The component of the atmosphere essential to life is:
   (1) oxygen; (2) nitrogen; (3) carbon dioxide;
   (4) argon; (5) hydrogen ( )

2. The depth of the atmosphere surrounding the earth is at least (1) 10 miles; (2) 1 mile; (3) 50 miles;
   (4) 200 miles; (5) 1000 miles ( )

3. As one ascends a high mountain (1) atmospheric pressure increases; (2) the oxygen content of the air increases; (3) there is no change in pressure; (4) the atmospheric pressure decreases; (5) the temperature increases ( )

4. The gas in the air that supports combustion is:
   (1) carbon dioxide; (2) nitrogen; (3) oxygen;
   (4) hydrogen; (5) helium ( )

5. A substance used to test for carbon dioxide is
   (1) a burning splint; (2) limewater; (3) silver nitrate; (4) water; (5) litmus paper ( )

6. The atmosphere is: (1) a compound; (2) a mixture;
   (3) an element; (4) without weight; (5) diatomic ( )

7. A naturally occurring compound of a metal is called:
   (1) a silicate; (2) granite; (3) an ore; (5) non-metal; (5) a simple substance ( )

8. The percentage of oxygen in the entire weight of the earth's crust is: (1) 10; (2) 30; (3) 50;
   (4) 40; (5) 75 ( )

9. The percentage of oxygen in the air by volume is
   (1) 5; (2) 10; (3) 20; (4) 50; (5) 80 ( )

10. All living things are spoken of as: (1) plants;
    (2) animals; (3) organisms; (4) inorganic matter;
    (5) organic matter ( )

11. Air pressure to the square inch at sea level is:
    (1) 32 lbs.; (2) 15.6 lbs.; (3) 80 lbs.;
    (4) 15 lbs.; (5) 62.5 lbs. ( )

12. Average air pressure at sea level is sufficient to support a column of mercury to a height of
    (1) 15 in. (2) 32 in. (3) 34 in. (4) 30 in. (5) 100 in.( )

13. Copper, iron, sulphur, and nitrogen are all
    (1) minerals; (2) compounds; (3) gases; (4) metals;
    (5) elements ( )
14. Anything from which energy may be released or that forms material for growth or repair of the body is (1) oxygen; (2) nucleus; (3) food; (4) tissue; (5) a stimulant

15. A collection of cells more or less alike having the same function is known as (1) an organ; (2) a system; (3) an amoeba; (4) a vacuole; (5) cell wall

16. The process of a cell getting rid of waste material is called (1) respiration; (2) assimilation; (3) digestion; (4) excretion; (5) secretion

17. An example of a single celled plant is (1) a clover; (2) a bacterium; (3) a water cress; (4) a poppy; (5) a paramoecium

18. A necessary process in all living things is (1) condensation; (2) reproduction; (3) perspiration; (4) bathing; (5) electrolysis

19. Heat in the body is produced by oxidation of the (1) tissues; (2) cell membrane; (3) organs; (4) food; (5) vacuoles

20. Where green plants are growing (1) the amount of oxygen in the air increases; (2) the amount of nitrogen in the air decreases; (3) the amount of carbon dioxide increases; (4) there is no change; (5) the nitrogen in the air increases

21. The gas given off by germinating bean seeds is (1) oxygen; (2) carbon dioxide; (3) nitrogen; (4) ammonia; (5) hydrogen

22. A mature cell may (1) divide into two cells; (2) become a tissue; (3) become an organ; (4) disappear; (5) divide into six cells

23. The power to respond to stimuli is known as (1) motion; (2) growth; (3) assimilation; (4) irritability; (5) circulation

24. The living part of a cell is the (1) blood; (2) cell membrane; (3) lymph; (4) protoplasm; (5) heart

25. The process by which food is changed into the proper liquid form is (1) absorption; (2) filtration; (3) transpiration; (4) evaporation; (5) digestion

26. When oxygen unites rapidly with other substances the process is called (1) combustion; (2) evaporation; (3) condensation; (4) ventilation; (5) transpiration

27. A thermometer measures (1) air pressure; (2) humidity; (3) density; (4) temperature; (5) specific gravity

28. The denser central portion that governs the actions of a cell is (1) cell membrane; (2) cytoplasm; (3) nucleus; (4) protein; (5) vitamin

29. Bacteria are (1) insects; (2) worms; (3) flies; (4) moths; (5) plants
30. The smallest particle of an element which can take part in a reaction is (1) a molecule; (2) an electron; (3) a proton; (4) an atom; (5) a neutron.

31. The pressure on 400 c.c. of gas was doubled, the volume at the same temperature becoming (1) 800 c.c.; (2) 200 c.c.; (3) 50 c.c.; (4) 100 c.c.; (5) 600 c.c.

32. When a gas is compressed, provided the temperature is constant, the particles (1) become smaller; (2) come closer; (3) lose their energy; (4) gain energy; (5) decrease in temperature.

33. Molecules of gases differ from molecules of liquids in that the former are (1) closer together; (2) farther apart; (3) are restricted in motion; (4) are always colored; (5) are heavier.

34. The process by which inanimate matter is changed until it becomes part of a living cell is (1) assimilation; (2) absorption; (3) digestion; (4) osmosis; (5) filtration.

35. The ratio between the height of a column of mercury and the height of a column of water, where both are being supported by atmospheric pressure will be approximately (1) 1 to 34; (2) 1 to 14.7; (3) 1 to 62.5; (4) 1 to 30; (5) 1 to 13.6.

36. Which of the following processes produces heat in a way fundamentally different from the others? (1) respiration; (2) burning; (3) rusting of iron; (4) decay; (5) friction.

37. An example of a chemical element is (1) sugar; (2) water; (3) brass; (4) bronze; (5) nitrogen.

38. Combustion is the same as (1) burning; (2) melting; (3) freezing; (4) boiling; (5) evaporating.

39. The number of different kinds of substances out of which everything else is made is about (1) one; (2) eighty-three; (3) 500; (4) three; (5) ninety-two.

40. The use of the same food elements over and over by living things is known as (1) the energy cycle; (2) the matter cycle; (3) growth; (4) decay; (5) digestion.
1. How would you decide if a given substance were a living or a non-living thing?

2. Why is a cell called the unit of both structure and function?

3. Why does the carbon dioxide of the air collect near the floor of a room?

4. In the "Brownian Movement", do we actually see the molecules move? If NOT what is it that moves and why?

5. Explain why water and carbon dioxide do not burn.

6. Is the fact that a candle disappears on burning at variance with the law of Conservation of Matter? Explain.

7. If the temperature of a given mass of gas varies what will have to be done to keep the volume constant? Explain.

8. Why are oily rags more likely to start a fire than oil spilled on the floor?

9. Is a theory an expression of truth? If not, what is the distinction?

10. Water is found on the outside of a vessel containing water. How would you find if water soaks through the walls of the vessel or comes from some other source?

11. Devise an experiment to illustrate how you could measure your lung pressure. (Note: time will permit a brief indication of necessary steps).

12. A cup taken from very hot water is inverted and placed on a smooth surface. Why is it now difficult to lift the cup?

13. If air were as light as hydrogen would atmospheric pressure be altered? How?

14. Does the fact that a substance undergoes no change on heating prove it to be an element? Why?

15. If water were used in place of mercury in a barometer, would there be any difference in the relative heights? Why?
In each of the following sentences you are to find the right answer, and put the number of it in parenthesis at the end of the line.

1. An example of a complex machine is (1) pulley; (2) lever; (3) bicycle

2. One horsepower is equal to (1) 3,300 ft.lbs./sec.; (2) 500 ft.lbs./sec.; (3) 550 ft.lbs./sec.

3. If the friction in a machine is increased, its efficiency is (1) increased; (2) decreased; (3) the same.

4. In a machine designed to perform useful work, the work put into it, as compared with the work obtained from it, is (1) more; (2) less; (3) the same.

5. Convection currents do not take place in (1) solids; (2) liquids; (3) gases.

6. Heat is transmitted in a vacuum by (1) conduction; (2) convection; (3) radiation.

7. When the gas in the mechanism of an electric refrigerator is compressed the temperature of the gas (1) increases; (2) decreases; (3) remains the same.

8. The density of water at 40°C is (1) the same as; (2) greater than; (3) less than its density at 4°C.

9. The temperature of the steam in a steam boiler under 5 pounds more than atmospheric pressure is (1) 100°C; (2) greater than 100°C; (3) less than 100°C.

10. When the water boiling in a kettle is changed to steam, heat is (1) liberated; (2) absorbed; (3) neither liberated nor absorbed.

11. If a block of ice is melting, its temperature is (1) constant; (2) decreasing; (3) increasing.

12. A boy in front of a fire will receive heat mainly by (1) conduction; (2) convection; (3) radiation.

13. The volume of ice formed when water freezes is (1) the same as; (2) less than; (3) greater than that of water.

14. If the temperature of a gas in a closed cylinder is increased, its density (1) decreases; (2) increases; (3) remains the same.

15. One thermometer is wrapped with white cloth, another with black cloth. Both are exposed to the sun for a few minutes. The former will show (1) a higher temperature; (2) a lower temperature than; (3) the same temperature as, the latter.

16. When water is cooled from 3°C to 0°C, its volume will (1) remain the same; (2) increase; (3) decrease.

17. When the water in a lake freezes, heat is (1) liberated; (2) absorbed; (3) neither liberated nor absorbed.
Unit II, Objective, (cont'd.)

18. Substances that are good absorbers of heat are (1) good radiators; (2) poor radiators; (3) good reflectors.

19. Water in an open vessel, at a height of 5,000 ft. above sea level (1) cannot be boiled; (2) can be boiled easily; (3) boils at a higher temperature than at sea level.

20. If a charged rubber comb is brought in contact with the knob of an electroscope, the leaves diverge since (1) the leaves are magnetized; (2) protons go into the leaves; (3) electrons go into the leaves.

21. A storage battery needs to be recharged periodically in order to (1) decompose the water; (2) renew the condition of the plates; (3) give off hydrogen.

22. When a permanent magnet is heated, its magnetic force (1) increases; (2) decreases; (3) remains the same.

23. The carbon terminal of a dry cell is (1) positive; (2) negative; (3) positive or negative.

24. Two coils connected in series have resistances of 50 ohms and 100 ohms respectively. The total resistance is (1) 5,000 ohms; (2) 50 ohms; (3) 150 ohms.

25. The maximum current a fuse should carry is (1) greater than; (2) less than; (3) the same, as the current it protects.

26. Light in a medium of uniform density travels (1) through opaque objects; (2) in straight lines; (3) in curved lines.

27. A body that emits light is (1) translucent; (2) transparent; (3) incandescent.

28. A non-luminous body becomes visible when it (1) refracts; (2) absorbs; (3) reflects. light.

29. The wave length of blue light is (1) shorter than; (2) longer than; (3) the same as, red light.

30. A beam of light passing from one medium to another at an oblique angle is (1) totally reflected; (2) refracted; (3) destroyed.

31. Totally indirect lighting gives a better quality of light because of (1) absorption; (2) refraction; (3) reflection.

32. The angle of reflection is (1) greater than; (2) less than; (3) equal to, the angle of incidence.

33. Lamps and shades should be cleaned often to prevent (1) diffusion; (2) absorption; (3) refraction.

34. At a temperature of 20°C sound travels (1) 256 ft./sec.; (2) 1130 ft./sec.; (3) 186,000 ft./sec.

35. As the temperature of the air is decreased, the speed of a sound through it (1) increases; (2) decreases; (3) does not change.
65.

Unit II, Objective, (cont'd.)

36. Sound, in general, travels fastest through (1) gases; (2) liquids; (3) solids

37. If the length of a violin string is altered, other things being equal, the sound produced will be (1) louder; (2) of better quality; (3) of different pitch

38. A beam of light 1 foot from its source covers an area of 1 sq. in. Then 3 ft. from its source it will cover an area of (1) 3 sq. in.; (2) 6 sq. in; (3) 9 sq. in.

39. The purpose of ice in a refrigerator is to (1) prevent radiation of heat; (2) make the water vapor condense; (3) absorb heat

40. The product of E M F and amperage is (1) volts; (2) ohms; (3) watts

Complete the following statements by filling in the blank spaces at the right with a word or phrase.

1. The point about which a lever turns is called the...

2. A machine is generally used to multiply..... (2)

3. The energy of a body due to its position is called its..... (3)

4. The kind of energy possessed by the wound watch spring is..... (4)

5. The work done by a girl holding a ten-pound flatiron for 1 minute is .... (5)

6. A barrel of oil that is too heavy for a man to lift can be rolled up to a desired level (6)

7. A form of energy due to molecular motion is. (7)

8. If the auditory nerve is stimulated, the sensation produced is..... (8)

9. A dynamo transforms mechanical energy into (9)

10. As a pile driver hammer falls its (10) energy increases

11. In batteries electricity results from a change of (11a) to (11b) energy

12. A positively charged body is one that has..(12)

13. Unlike magnetic poles...... each other (13)

14. The work capable of being done by a three horsepower motor per minute is..... (14)

15. The order of lever illustrated by the nutcrackers is.. (15)

16. The unit which measures current strength is(16)

17. The principle which states that the ability to do work can neither be created nor destroyed is... (17)

18. An electric current in a circuit is thought. to be a.... (18)
Unit II, Objective, (cont'd.)

19. The unit of electrical power is the... (19) _________
20. Electric lamps for home lighting are usually connected in .... (20) _________
21. The number of ropes supporting the load in a pulley system is also an expression of its.... (21) _________
22. The screw-driver acts on the same scientific principle as the ..... (22) _________
23. In the third class lever speed is gained to the loss of .... (23) _________
24. The increase in length of a copper bar when heated through 10°0 depends upon .... (24) _________
25. The thermocouple is a device used to measure (25) _________
26. The quantity of heat required to raise the temperature of 10 lb. of water from 60°F to 75°F is .... (26) _________
27. If more heat is applied to some boiling water in an open vessel, the temperature of the water will.... (27) _________
28. The number of degrees between freezing and boiling on a fahrenheit thermometer is.. (28) _________
29. Another name for fusion is .... (29) _________
30. The outstanding property of water made use of in hot-water heating systems is ... (30) _________
31. Sound is a form of ..... energy (31) _________
32. Sound waves may be reflected; such reflected waves are called..... (32) _________
33. A body may be seen because it ....or.... light. (33) _________
34. Light is a form of ..... energy. (34) _________
35. The velocity of light is about .... (35) _________
36. White light is made up of several.... (36) _________
37. For satisfactory illumination the nature of paint or paper on a wall should be... (37) _________
38. The color of a green object depends on the reflection of... (38) _________
39. There is a change of state when ice melts, but no change in ..... (39) _________
40. The principle upon which the ordinary thermometer is based is.... (40) _________
41. The essential part of an electromagnet is (41) _________
42. The principal way by which heat is transmitted from the stove to the water in a kettle on it is .... (42) _________
43. The pitch of a sound depends upon the number of ..... (43) _________
44. Musical tones of high pitch travel with a speed that is .... the speed of low-pitched (44) _________
45. Objects that appear black...most of the light that falls on them

46. When white light passes through a prism the rays that are bent most are the...

47. Color is a property of light which depends upon its...

48. Most people can see the colors that lie between the ..(a). and the ..(b) in the rainbow.

49. A substance that allows light to pass through it, but which cannot be seen through is...

50. Evaporation of a liquid may be increased by the pressure on its surface.

51. The vacuum in a thermos bottle is used to offset the transfer of heat by...(a) and (b)...

52. The solution in a dry cell is...

53. The liquid commonly used in a simple voltaic cell is...

54. Metals when heated expand at... rates

55. Metals can be charged with static electricity only if...

56. Water evaporating from the surface of the body...the temperature.

57. When the air surrounding a radiator is heated, its density.....

58. The region around a magnet where its effect may be felt is its....

59. The first man to measure the velocity of light was....

60. That part of a shadow formed by the exclusion of only part of the light is called....

61. The intensity of light is rated in....
1. Does a machine produce energy? Why?
2. Why is it easier to move a large stone with a lever?
3. Hot water poured into a thick walled glass tumbler will likely break it. Why?
4. What color will a piece of red paper appear to be in yellow light? Why?
5. When the bulb of a thermometer is plunged into hot water the mercury drops slightly before it begins to rise. Why?
6. Why is ice placed at the top of a refrigerator?
7. What will be the cost of operating a 200 watt lamp on a 100 volt circuit for 10 hours at 4 cents per kwh?
8. Why in a steam heating system are smaller radiators required?
9. Why do kettles usually have handles of wood or coiled wire?
10. Does sound travel faster than light? How do you know?
11. Is the telephone a good illustration of the transformation of energy? Why?
12. Why may a fuse "blow out" when the insulation wears on an ironing cord?
13. Placing ice cream between feather pillows will keep it from melting rapidly. Why?
14. Explain clearly the chief characteristics by which musical notes differ from one another.
15. Ice below 0°C is heated to a temperature above 100°C at normal atmospheric pressure. What changes take place in (a) state; (b) temperature; (c) volume?
GENERAL SCIENCE IV
Unit III
Objective Test

Complete the following statements by filling in the blank spaces at the right with a word or phrase.

1. The number of gases in the atmosphere is ...
2. The most plentiful gas in the atmosphere is ...
3. The lowest gaseous shell which surrounds the earth is ...
4. Insects and animals breathe in order to obtain ...
5. During the day a green leaf gives off to the atmosphere the gas ...
6. The rare gas used to fill light bulbs is ...
7. The height of the atmosphere which will balance a mercury column 76 cm. in height is ...
8. The relative weight of a volume of dry air compared with that of a similar volume of moist air is ...
9. The scientist who first measured the pressure of the atmosphere was ...
10. The type of barometer that operates without a liquid is the ...
11. The instrument which keeps a weekly record of the atmospheric pressure is ...
12. The process by which plants manufacture starch is ...
13. Combustion tends to increase the supply of ...... in the air.
14. The important device on a street car which makes use of air under pressure is ...
15. For a rise in altitude of approximately 900 feet the barometer falls ...
16. An ordinary water siphon can operate provided the liquid is not to be raised more than ...
17. Limewater is used to test for the presence of ...
18. At sea level the atmospheric pressure is about ...
19. Another term for cyclone is ...
20. The temperature at which the moisture in the air begins to condense is the ...
21. In the northern hemisphere the direction of circulation of air in an anti-cyclone is ...
22. The differences in readings between the wet and dry bulb thermometers is a measure of ...
Unit III, Objective, (cont'd.)

23. Normally, when lows follow highs, the weather is...
24. Deflection of the planetary winds is caused mainly by...
25. Lines passing through all points having the same temperature are called...
26. Condensation occurs when the air is...
27. The device which measures wind velocity is called an...
28. The unequal expansion and cooling of the air produces...
29. The amount of rainfall is measured by a device called the...
30. Great air pressure differences are likely to be the cause of...
31. The important instrument used to forecast weather is...
32. The quantity of moisture the air is able to sustain depends mainly upon the...
33. Usually, high pressure areas in the northern hemisphere areas move in the direction of (a) to (b)...
34. Weather is indirectly and primarily the result of contrasts in...
35. The two important air-conditions controlled by the air-conditioning device are (a) and (b)...
36. The air in a cyclonic region is cooled by...
37. The principal factor taken into account when weather predictions are made is...
38. The names of four common cloud forms are...
39. The portion of the atmosphere to which the weather is confined is...
40. The portion of the atmosphere in which there is no temperature change is...

This sketch is taken from a weather map.

41. the region shown is termed a...
42. the lines are called...
43. the weather in this region is likely to be...
Unit III, Objective, (con't'd.)

The sketch below represents the planetary wind system.

44. The region of the doldrums is numbered.

45. The region of the trade winds is numbered.

46. The region of the westerlies is numbered.

47. Ocean currents are started chiefly by...

48. Large bodies of water prevent extreme changes of temperature in the surrounding country due to...

49. During the summer solstice the earth is the sun than during the winter solstice.

50. The ocean currents do not directly warm or cool land; however they do so indirectly by...
1. If a small quantity of air is introduced into the space above the mercury in a barometer tube, how is the reading affected? Why?

2. Should a mercury barometer be hung in a vertical position before a reading is taken? Why?

3. Calculate the air pressure on an area of 10 sq. feet.

4. Draw and explain the action of a force pump.

5. How is the relative humidity of the air affected by temperature?

6. In determining the relative humidity of the air, why is one of the thermometer bulbs surrounded by a moist cloth?

7. Write an account of the wind movements in a high and a low and the relative temperature effects in each.

8. Explain using a diagram why the earth has seasonal changes.

9. Why is our climate more equitable than that of Winnipeg?

10. At midday in summer the land surrounding a lake or ocean is usually warmer than the adjoining water. Will the air move toward the land or toward the water? Explain, using a diagram.
Complete the following statements by filling in the blank space at the right with the necessary word or phrase.

1. Hydrogen burns in air to form...
2. The solubility of hydrogen gas in water is 2.
3. Hydrogen gas may be prepared in the laboratory by adding zinc to...
4. A scientific name that may be used for water is...
5. The decomposition of water by an electric current is called...
6. Under ordinary conditions the solubility of oxygen in water is...
7. The effect of large bodies of water on climate is to...
8. Dissolved and suspended solids can be removed from water by...
9. The purest form of natural water is...
10. A solution containing a small quantity of solute is called...
11. The solubility of most solids is increased by...
12. On separating from solution, some solids assume a definite geometrical form; such solids are called...
13. A chemical element that is used to disinfect water is...
14. What effect will the addition of alcohol to water have upon the freezing point?
15. The solubility of gases in water increases with increase of...
16. The process of purifying water by passing through layers of sand and gravel is...
17. Impure salt may be purified by the process of...
18. A solution which contains a large amount of solute is...
19. Solutions that conduct electricity are called...
20. A solution of glycerine will not conduct electricity because it contains no...
21. Temporary hardness in water may be removed by...
22. Water which is permanently hard may be softened by...
23. A test for a supersaturated solution is to...
24. The taste of boiled water may be restored by...
26. Soap may be made by heating .26 with 26.
27. .27.
28. Water which causes soap to "curdle" before forming a lather is.. 28.
29. The process by which water is changed to steam by heat and the steam cooled to produce water is called.. 29.
30. A pressure applied to an enclosed liquid is .30. in all ..31.
31. 31.
32. The density of a substance is usually compared with that of .32.
33. The pressure on an object immersed in a 33.
34. liquid depends on .33. and .34.
35. A liquid rather than a gas is used in an hydraulic press because.. 35.
36. Water is heaviest at a temperature of.. 36.
37. A body weighing 1000 lbs. floats on water, the weight of the displaced water is.. 37.
38. If a body having a volume of one liter sinks in water, it will appear to have a weight of.. 38.
39. The rising or lowering of the level of liquids in fine tubes is called.. 39.
40. A block of copper has a volume of 7 c.c. and a weight of 62.3 g. The density in grams per c.c. is .... 40.
41. A column of water ten feet high exerts a pressure of.. 41.
42. The specific gravity of gasoline compared with that of water is.. 42.
43. In a balanced aquarium the plants give off..43.. which is used up by .44.
44. 44.
45. For the benefit of the fish the water in the ocean, lake or stream should not be.. 45.
46. The plant which forms the scum on stagnant water is.. 46.
47. The tiny microscopic animals and plants found in water are called..47.; these are found in the upper levels of the water where .48... and ..49. are more abundant.
48. 48.
49. 49.
50. Fish obtain oxygen from the water by means of.. 50.
1. Why is water called the universal solvent?

2. Why is surface water usually impure?

3. In general, how does a rise in temperature affect the solubility of solids? of gases?

4. When a body is submerged in water, why is it not pushed sideways?

5. Why does water exert pressure on submerged surfaces? What controls the amount of pressure?

6. If you saturated water at $80^\circ C$ with some solid and then cooled the solution to $10^\circ C$, throwing in a crystal of the solid, what kind of a solution would you have? Why?

7. "Light bodies float on water". This statement is not true. Explain the scientific truth that the above statement attempts to make.

8. Can plants and animals live in distilled water? Why?

9. How would you determine the quantity of dissolved solid matter in a sample of sea water?

10. Why must the mineral concentration in water be very low in order that plants and animals may survive?
Complete the following statements by filling in the necessary word or phrase.

1. The type of heavenly body which shines by emitting its own light is a ..
2. The centre of our solar system is..
3. The number of planets now known to be in the solar system is..
4. Besides the planets the solar system consists of
   (i) ........................................
   (ii) ........................................
   (iii) ........................................
5. Two hypotheses that have been advanced by scientists to account for the formation of the earth are
   (i) ........................................
   (ii) ........................................
6. The hypotheses which is generally accepted now is the..
7. The fact that some sixty elements found on the earth have also been found to exist on the sun tends to support the hypothesis
8. Three methods which have been used for estimating the age of the earth are.
   (i) ........................................
   (ii) ........................................
   (iii) ........................................
9. Of the above three methods, the one giving the best approximation is...
   Studies of such methods indicate an approximate age of ..
10. In order to account for the changes which are ever occurring in the level of the earth's surface the earth's interior is believed to be..
11. The two causes of mountains forming are
    (i) ........................................
    (ii) ........................................
12. The regions in which volcanoes are most likely to be found are...
13. The pressure forcing geyser and hot spring water upwards is caused by..
14. Most earthquakes are due mainly to..
15. That molten rock is present in the earth is indicated by..
16. The process which tends to level down the surface of the earth is known as..
17. Hills of mixed up soil and stones formed by a retreating glacier are called..
18. Soil may be transported by..(i), (ii), (iii)
Unit V, Objective, (cont'd.)

19. The decay of organic matter in the soil produces valuable plant food known as...

20. Waterfalls are formed by differences in...

21. Decaying organic matter aids in the weathering of rocks by producing..i. which aid in ..ii. the rock...

22. Changes in temperature may aid in the breaking up of the rocks by causing them to...

23. Rocks may be ground away by the action of wind because it carries...

24. Two components of the air which aid in the breaking up of rocks are..i. and..ii. The component which produces changes mainly by chemical action is ..iii. and the one by physical action is ..iv.

25. The land which is formed by deposits of soil at the mouth of a river is called a...

26. One of the most powerful eroding agents other than water is...

27. Weathering differs from erosion in that the latter...

28. Soil remaining in the place where it weathered is called...

29. The three essential materials supplied by soils for plant growth are ..i. ..ii. ..i. ..ii. ..iii.

30. Soil that contains much humus is called...

31. Fossils are found only in.... rock...

32. A "young" valley is characterized by...

33. A rock which has been formed under water from shells of sea animals is...

34. Rocks which have been derived from molten magma are called...

35. Rocks which have been altered by heat and folding are called...

36. The rock from which all other rocks are formed is...

37. Granite contains the minerals..i. ..ii. ..iii.

38. The type of rock formed by the cementing of mud and silt is known as...

39. That high land was once ocean bottom is evidenced by...

40. The chemical composition of marble is similar to that of...
Unit V, Objective, (cont'd.)

41. The process which produced sandstone was

42. Marble is an example of a ..... rock.

43. A common substance which contains aluminum is.

44. The property of aluminum that makes it useful for constructing airships is ....

45. An alloy of aluminium is...

46. Aluminium is obtained from its oxide by the process of...

47. Iron is obtained from its ores by the process of...

48. The metal obtained from haematite is...

49. Iron obtained from the blast furnace is known as..

50. Steel is used in the construction of buildings and bridges because of its great

51. A coating of zinc is sometimes put over iron to prevent..

52. The most abundant metal in the earth's crust is..

53. One difference between steel and wrought iron is that the former usually contains more.

54. Stainless steel contains the metals .i, i and .ii.

55. Brass is an alloy of .i and .ii.

56. An important mineral containing copper is

57. Galena is an important ore of..

58. An important difference between sedimentary and igneous rocks is that the latter usually contains..

59. Much of the mineral wealth of Canada is located in areas which are...

60. Some rocks on exposure to the air turn a reddish color due to the .i of the .i of the .ii of the .iii in the rockii.

iii
1. What do you understand by (a) the Solar System; (b) The Universe?

2. What is the difference between "top soil" and "sub soil"? Which is the better for plant growth? Why?

3. Why do some rocks appear in layers?

4. In what ways have earthquakes revealed information about the earth's interior.

5. Account for the formation of unsorted, sorted, and residual soils.

6. Why do we believe that some mountains were previously under water?

7. How could you tell whether a mountain is young or old?

8. How have hills and valleys been formed by water?

9. What method is believed to give the best estimate of the earth's age? Why?

10. Distinguish between an ore and a mineral.

11. Why was iron obtained long before aluminium?

12. In what way does erosion affect the distribution of weight of the earth's surface?
I. Classify the following as physical or chemical changes; give a reason for each classification.
(a) Evaporation of a sugar solution
(b) Burning of wood
(c) Zinc dissolves in sulphuric acid
(d) Explosion of dynamite
(e) Melting of snow
(f) Magnetizing an iron bar.

II. From the formula \( H_2 \) answer the following questions:
(a) How many atoms are represented?
(b) How many molecules?
(c) What weight of the element is represented?

III. Balance the following equations:
(a) \( HgO \rightarrow Hg + O_2 \)
(b) \( Zn + HCl \rightarrow ZnCl_2 + H_2 \)
(c) \( H_2 + O_2 \rightarrow H_2O \)
(d) \( Mg + O_2 \rightarrow MgO \)

IV. Classify the following as elements, compounds, mixtures:
soil
aluminium
concrete
sand found at the beaches
nitrogen
lead
salt
sugar

V. Write formula for the following:
(a) zinc sulphate
(b) sodium nitrate
(c) hydrogen chloride
(d) carbon dioxide

VI. A number of samples of chemically pure water obtained from several sources were tested and each was found to contain 88.8% oxygen and 11.2% hydrogen by weight. Name and write out the scientific law which the above statement illustrates.

VII. (a) The stopper is removed from a bottle of perfume. Explain why the odor is distributed over the room.
(b) What change in pressure would you expect to take place in a bicycle tire if:
(i) an equal weight of air is added?
(ii) the temperature increases several degrees?
(iii) " decreases several degrees?
(iv) an equal volume of hydrogen is substituted under the same conditions?
Delayed Recall Test (cont'd.)

VIII. A man lifts the handles of a wheelbarrow exerting a force of 100 lbs. at a distance of 5 feet from the axle of the wheel. If the forces of the load acts downwards at a point 2 feet from the axle find:

(a) the weight of the load lifted
(b) state the principle that is implied in the above question.

IX. In which of the statements below has the specific heat of copper been applied? Why?

(a) 9 grams of copper heated from 20°C to 30°C requires 90 calories of heat.
(b) 9 grams of copper heated from 20°C to 30°C requires 180 calories of heat.
(c) 9 grams of copper heated from 20°C to 30°C requires 8 calories of heat.

X. Of two containers, one has two liters of water at the freezing point and the other one liter of water at boiling point. Compare these two bodies of water with respect to their differences in

(a) temperature measured in °C and °F
(b) quantity of heat.

XI. How would you show that the color of an object is due to the absorption of some colors of white light falling upon it?

XII. Four standard candles are placed two feet away from a screen. What is the intensity of the light on the screen?
"Scientific Devices" Test

Read the following paragraphs and write answers to the questions which follow each one:

I. In order to remove tiny specks of dust from rolls of miniature camera film a hard rubber comb which has been rubbed briskly with a silk handkerchief is passed along the surface of the film. The comb picks up the dust specks.

1. Why does the dust adhere to the comb?

II. An airplane engineer has lately patented a device for sealing the doors of planes. A tube of rubber containing air at ground level pressure is fitted around the door jamb. When the plane reaches a fairly high altitude the door becomes very difficult to open.

1. Why is the door difficult to open?
2. What scientific fact is taken advantage of in this device?
3. How will this device affect the comfort of people in the plane when it is flying at high altitudes?

III. Glass manufacturers have made a new type of window glass. The pane is made of two sheets of glass separated by a uniform dry air space. The pane is sealed at the edges. Visibility is in no way impaired by its use.

1. What advantage is obtained by having an air space between the glass panes?
2. Why is the air dried?
3. In what way will the extra cost of purchasing such window glass be offset?

IV. In a far northern lake an unusual method is used to help break the ice. A wide strip of oil and lampblack is laid across the ice. This, in combination with the sun's rays, cuts a channel along the strip to such a depth that the remaining ice in the strip is easily broken.

1. Would a colorless oil serve in place of the lampblack and oil equally well? Why?
2. Of what value is the application of the above scientific principle to the residents in the region of this lake?

V. A new method of preventing the formation of ice on airplane wings, propellers, wireless aerials and other parts involves painting the parts with a special metal paint through which an electric current will pass.
"Scientific Devices" Test (cont'd.)

V. (cont'd.)

1. Why is a metal used in the paint?
2. In what way will the ice be prevented from forming?
3. Of what value is this application to the transportation business?

VI. A recent development in the coal industry uses a special liquid to separate coal from slate. The mixture of coal and slate as obtained from the mine is run through this liquid which separates the coal from the slate, the latter sinking to the bottom of a tank, the former rising to the surface.

1. Why would water not serve equally as well as this liquid?
2. What physical property must a liquid have to be useful in this sink and float process?
3. Name the scientific law or principle which is made use of in the above process.
4. What benefits to the coal industry are possible by the successful application of this process?
Questionnaire on Unit II

Do not sign your name. Give well considered answers. If your answer is yes, encircle yes; if no, encircle no. Be honest in your replies.

1. Did you find Unit II an interesting one? Yes, No. Comments:

2. Did you find Unit II a difficult one? Yes, No. Comments:

3. Do you think a more intensive study of the Unit should have been undertaken? Yes, No. Comments:

4. Do you think that the consideration of "energy" as studied in this Unit worth while? Yes, No. Comments:

5. As a result of your studies in this Unit have you gained any further appreciation of the ways in which the results of scientific investigation affect your daily life? Yes, No. Comments:
Questionnaire Given at the Close of the Years' Work

DO NOT SIGN YOUR NAME
GIVE WELL CONSIDERED ANSWERS
BE HONEST IN YOUR REPLIES

1. Rewrite in rank order the units of this year's work that interested you most.
   1. Matter (Chemistry)
   2. Energy (Physics)
   3. Air, Weather and Climate
   4. Water
   5. Earth (Geology)
   6. Living Things (Biology)

2. Mark with a circle five of the topics below which interested you the most. Mark with an X five that you found the least interesting.
   The Composition of Compounds
   Atoms, molecules, electrons
   Thermometers
   Weather
   Barometers
   The Earth's Origin
   Refrigerators
   Sun and stars
   Reading of the electric meter
   Glaciers
   Heating systems
   Washing machine
   Metals, ores, rocks
   Study of water
   Fuses
   Hydraulic press
   Light
   Sound
   Law of definite proportions
   Machines
   Air conditioning
   Winds
   Volcanoes
   Telephone
   Use of hygrometer
   The transformation of energy
   Climate, people and progress
   Thermos bottle
   Iron and Steel
   Combustion
   Violin

3. Which of the four reference text books did you find (a) most interesting? (b) most useful?
   Science for Today
   New Elementary Physics (a)
   New Practical Chemistry
   Dynamic Biology (b)
4. Did you find reading material in the library adequate to your needs for this course (General Science IV)?
   YES  NO

5. Do you intend to continue your studies in science next year?  YES  NO

6. If it were possible for you to "drop" science without affecting the requirements, would you wish to do so?
   YES  NO

7. Mark your first, second and third choices in the following list of magazines of which you have read a few articles.

   National Geographic
   Popular Mechanics
   Popular Science Monthly
   Scientific American
   Science Digest
   Science News Letter

8. Name two books of a scientific nature (not the reference texts) which you have read during the past year that have interested you very much.
The Formula Used for Estimating an Absent Pupil's Score on a Test, Knowing His Score on Another Test.

In order to do this it is necessary to know the mean scores and the standard deviations of both tests and the correlation between the tests.

The formula is:

\[
\frac{\bar{X}}{\sigma_X} = r \times \frac{Y}{\sigma_Y}
\]

where \( \bar{X} \) = estimated deviation of the score from the median

\( \sigma_x \) = standard deviation for the test

\( y \) = deviation from the mean

\( \sigma_y \) = standard deviation