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ABSTRACT

Work is reported towards the completion of a prototype duplex-design assessment instrument for grade-12 science. The student course-background questionnaire and the pretest section of the two-stage instrument that was developed were administered to all 134 12th-grade students at St. Clairsville High School (Ohio). Based on the information obtained from the first-stage form, a second-stage form was prepared and adapted to the course level and background of each student in each of four science areas: (1) earth sciences; (2) biology; (3) chemistry; and (4) physics. Second-stage testing plans were made for statewide testing in 40 Ohio schools in March and April of 1991. Additional open-ended items were sought to complete the six forms of the instrument. Two papers on the present stage of the project are provided: "Individualized Educational Assessment: Twelfth-Grade Science" (R. Darrell Bock and Michele Zimowski); and "The Graded Mark-Point Method of Scoring Performance Exercises and Open-Ended Items" (R. Darrell Bock). The questionnaire and pretest from the pilot administration, and individualized test booklets representing four levels of difficulty in the second-stage forms are included. (SLD)

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Final Deliverable - November 1990

Duplex Design Project

SCIENCE PILOT TEST

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Report to OERI/CRESST on the Development of an Instrument for the Assessment of Secondary School Science Education

Dr. R. Darrell Bock
November 29, 1990

Work towards the completion of a prototype duplex-design assessment instrument for 12th-grade science has proceeded on schedule in the fourth quarter. Arrangements were made to pilot test one of the six forms of the instrument in a school in St. Clairsville, Ohio. The student course-background questionnaire and pretest section of the two-stage instrument was administered to all 134 twelfth-grade students of the St. Clairsville high school in October. Based on the information obtained from the first-stage form, we prepared, by computer-controlled laser printer, the second-stage forms adapted to the course background and performance level of each student in each of four science areas---Earth sciences, biology, chemistry, and physics. The second-stage forms, which require 40 minutes of testing time, will be administered on December 4. Our experience in this pilot testing will aid us in making further improvements to the first- and second-stage forms in preparation for state-wide testing in 40 Ohio schools during March and April, 1991.

The second-stage forms contain both multiple-choice and open-ended, essay-type items. Although we experienced no real difficulty in finding suitable multiple-choice items from our pool of 11,500 items, we have not yet found enough good, open-ended items among the assessment materials collected for this project. We are therefore continuing to search for such items, and are making arrangements with a number of science teachers in the Chicago area to supply others in order to complete all six forms of the instrument. In addition, we are now preparing the scoring rubrics for the open-ended items.

Accompanying this report are the following documents showing the present state of the project.

1. Individualized Educational Assessment: Twelfth-grade Science

A conference report to the Massachusetts and California Assessment programs describing the project. This report also describes briefly the laboratory performance component of the project, supported by the National Science Foundation.

2. The Graded Mark-point Method of Scoring Performance Exercises and Open-ended items.

A description of the method to be used in scoring open-ended and laboratory performance responses.

3. The questionnaire and pretest from the St. Clairsville pilot.

4. Test booklets representing the four levels of difficulty in the adaptive second-stage forms.

INDIVIDUALIZED EDUCATIONAL ASSESSMENT: TWELFTH-GRADE SCIENCE

R. Darrell Bock and Michele Zimowski
30 November, 1990

As originally conceived in the National Assessment of Educational Progress (NAEP), educational assessment was intended to report educational outcomes at a high level of aggregation—average attainment for states, regions or the nation. Using efficient techniques of multiple matrix sampling in which each student responds to only a limited number of items randomly selected from a much larger set, NAEP attained high levels of generalizability for numerous educational objectives with relatively small demand on student time. When this technique was adapted to state-level assessments, as in the California Assessment Program, the reporting was extended to the level of separate schools, but there was no attempt to evaluate the attainment of individual students.

Although the state programs based on this conception served well the needs of policy makers, planners, and curriculum specialists, they did not satisfy the requirements of school principles, teachers, and parents, for information that would guide and certify the progress of individual students. Neither did they motivate students by giving them a personal stake in the outcome of their efforts on the assessment tests. To satisfy these additional demands on the testing program, many states adopted, at the expense of duplication of effort and further encroachment on classroom time, a two-tiered program including both matrix-sampled assessment testing and traditional student-level achievement testing. In an effort to serve the purposes of these overlapping testing program in a single, comprehensive assessment, the National Opinion Research Center (NORC) in 1986 began studies of a new approach to educational evaluation that combined features and

benefits of school-level matrix sampling assessment and individual-level achievement testing.

1 The NORC Assessment Design Project

With support from the U. S. Office of Educational Research and Improvement, NORC developed and field-tested in the states of Illinois and California a new type of multi-purpose assessment instrument based on the "Duplex Design" of Bock & Mislevy (1988). The first trial of the design applied to eighth-grade mathematics and provided student-level scores in the content areas of Number, Algebra, Geometry, Measurement, and Statistics, and in the process skill areas of Factual Knowledge, Conceptual Understanding, and Problem Solving; at the same time it provided school-level scores in 45 curricular objectives in eighth-grade mathematics. The results of the field trials clearly demonstrated that the duplex instrument could provide both detailed program evaluation as well as accurate scores for students, and for schools, districts and the state, all based on a testing session intermediate in length between matrix-sampled assessment and traditional achievement testing (Bock & Zimowski, 1989).

Since August 1989, at the invitation of the National Science Foundation and with continuing support from OERI, NORC has been implementing another duplex design in the areas of Earth Science, Biology, Chemistry, and Physics at the twelfth-grade level. Exploiting new technology for computer-controlled laser printing and optical character reading, this project has achieved a breakthrough in large-scale assessment technique by producing test forms individualized to the course background and performance levels of each student taking the science test. These forms include both multiple-choice and open-ended essay questions. In addition, the assessment design incorporates a similarly individualized component of "hands-on" laboratory performance assessment in General Science, Biology, Chemistry, and Physics. The project has also led to the development of materials and procedures for a "Graded Mark Point" method of reliably scoring extended responses the open-ended and laboratory performance

exercises.

The present report describes the goals, principles, and methods of the individualized educational assessment as implemented in a twelfth-grade science assessment instrument now undergoing field trials in the state of Ohio. A pilot school in Ohio will be tested in the first week of December, 1990, and all twelfth-grade students in a stratified probability sample of 40 Ohio schools will be tested in March and April of 1991. A final report of the study is due on November 30, 1991.

2 Two-stage Testing

In addition to the duplex principle, the other major innovation of the NORC assessment design project is the practical implementation of two-stage testing. Since early in the development of item response theory (IRT), it has been known that substantial reductions in testing time, without sacrifice of test reliability, can be obtained by a form of adaptive testing in which students are tested in two stages, where the second-stage test is selected to be maximally informative, given the student's score on the first-stage test. Studies by Lord (1980) showed that with second-stage forms representing at least four levels of difficulty, comparable reliability could be obtained in about one-third the testing time required for a conventional achievement test.

For a long time the logistics of two-stage testing were thought to be too complex to allow applications in large-scale assessment programs. Recently, however, two technological developments have radically changed this picture. One of these is the availability of high-capacity, programmable optical character readers used commercially in processing responses from direct-mail advertising promotions. The readers are capable of scoring test booklets duplicated by any printing method, rather that the high-precision printing previously required for scannable test booklets. The other development is that high-capacity laser printers driven by computers are now able to assemble the material to appear in a test booklet as the pages are printed. The NORC assessment design project, has made use of this technology to imple-

ment large-scale two-stage testing in a practical way.

2.1 First-stage test

The first-stage test booklet is designed to be administered in February. It consists of a student questionnaire, asking for high-school course history in Science and Mathematics, and a twenty-item pretest with five items each in the areas of Earth Science, Biology, Chemistry and Physics. The items of the pretest are widely spaced in difficulty and give a rough estimate of the student's level of proficiency in these subjects. On the basis of a student's response to course background questionnaire and the score on the pretest, he or she is assigned a second-stage form adapted to an appropriate level of science preparation in each of the four areas. The questionnaire and test are designed to be administered to twelfth-grade students by teachers in the participating schools. The completed test booklets are returned to NORC for scanning and analysis, and the results are used to control the generation of the second-stage forms appropriate for each student. Each such booklet is labeled clearly with the student's name on the cover, and each page of each booklet also carries optically readable numbers that identify the student and the items of that particular form.

2.2 Second-stage test

The second-stage test is designed to be administered in late March or early April of the student's twelfth-grade program. The forms of the test are of two types, which can be administered separately or in combination: Type I consists of only multiple-choice items; Type II consists of multiple-choice items *and* open-ended items.

The Type I forms are further divided into a part A and part B, each consisting of 32 items. If the test is to be used to assign scores to students for purposes of certification, it is recommended that each student be administered both part A and part B in 80 minutes of testing time. If the scores are to be used only to evaluate schools or programs, or to inform interested parties, each student may be randomly assigned a part A or part B, to be administered in 40 minutes

of testing time.

The Type II forms each contain 32 multiple-choice items and four open-ended items. Forty minutes of testing time is allocated to the multiple-choice items in the first half of the form, and forty minutes for open-ended items in the second half of the form. These forms are also divided into a part A and part B consisting of sixteen multiple-choice items and two open-ended items. These parts may also be administered separately if highly-accurate student-level scores are not required.

3 Forms and Booklets

Each second-stage test form, including part A and part B, is replicated in parallel six times. In addition, each form consists of four booklets constructed at each of four levels of difficulty: the lowest level is aimed at students who have only one course in secondary-school science; the next two levels are aimed at students with at least two courses in science, with the lower level being assigned to those students who score below the median on the pretest and the higher level being assigned to students who score above the median; the highest level of difficulty is aimed at students with Advanced Placement courses of science.

Because the second-stage forms are produced by computer contingent on information from the student questionnaires and pretest, the relative difficulty can be adapted to the type of course background of each student. For example, if a student has one course in Earth sciences, two in biology, and one in chemistry, the biology content might be pitched at level three, the chemistry at level one, and the physics and Earth sciences at level two. If a student has only one course in general science or Earth sciences, and biology, but has a reasonably good pretest score, the second-stage test will be pitched at level two in biology and Earth sciences, but at level one in chemistry and physics. All possible profiles of student preparation can be accommodated by these computer-generated second-stage forms.

4 Item Structure of the Second-stage Forms

The content-by-process classification of items in the second-stage form is shown in Table 1. The table represents the items of the 64-item form. The open and cross-hatched entries represent one of the possible divisions of the form into part A and part B. Other forms select item- and process-content for part A and part B in all possible combinations. Each test form is a random assignment of items classified according to the categories of Table 1. From a pool of 11,500 items, 24 test booklets have been constructed (six forms at each of four levels of difficulty). Thus, the second-stage instrument consists of stratified randomly parallel forms containing a possible 1,536 different items.

5 IRT Scaling

The instrument is based on a Duplex Design intended for scoring on IRT scales in three directions. At the student level, scale scores can be computed for 1) each of the four content areas and 2) each of the four process categories, for a total of eight scales, plus an overall index of science achievement. At the school level, each of the 64 cells within the content-by-process classification can be assigned scale scores by 3) accumulating information over the 24 test booklets.

For purposes of IRT scaling, the test booklets are connected by common items that link them in all three of these dimensions. There are link items with respect to content and process over the four levels of difficulty within forms for computing student scores, and with respect to the content-by-process elements from one form to another for scaling at the school or program level. These common linking items reduce the total number of distinct item to 1,344. Computer procedures are employed to calculate scores on the linked scales and to generate student-level and school-level reports.

For the forms containing multiple-choice and open-ended items, a student-level report for all four content and all four process dimensions can be generated only if the student takes the complete 80-minute version. If the student takes only the 40-minute part A or part B, only two content areas can be scored and reported.

TABLE 1.
Content-by-Process Item Classification

Content	Part A ☐ Part B ☒			
1. Physics	*****	*****	*****	*****
Mechanics	X			X
Electricity and Magnetism	X		X	
Heat and Kinetic Theory		X		X
Waves, Optics, and Sound		X	X	
2. Chemistry	*****	*****	*****	*****
The Atomic Model	X			X
Chemical Reactions	X		X	
Quantitative Chemistry		X		X
States of Matter		X	X	
3. Biology	*****	*****	*****	*****
of the Cell	X			X
of the Organism	X		X	
Reproduction and Genetics		X		X
Biological Diversity		X	X	
4. Earth Sciences	*****	*****	*****	*****
Space	X			X
Air	X		X	
Water		X		X
Land		X	X	
Process	Knowledge of Scientific Terminology and Facts	Knowledge of Scientific Methods and Procedures	Understanding of Scientific Concepts and Principles	Problem Solving

6 The Laboratory Performance Tests

Performance tests for twelfth-grade science have been developed and tested by Professor Rodney Doran, State University of New York at Buffalo. The exercises are based on principles formulated by Professor Pinchas Tamir, University of Tel Aviv, for the the Israeli Matriculation Examination. At present there are six exercises in each of four areas: General Science, Biology, Chemistry, and Physics. Each exercise requires 80 minutes of laboratory work.

The exercises are designed to be administered by science teachers who set up the experiments using materials supplied by NORC. The instructions to the students are in written form consisting of a Part I, in which students are ask to design the experiment with these materials to answer certain specified questions, and Part II in which explicit instructions for the experiment are given and interpretative questions asked. Students keep a record of their work and write their conclusions on forms supplied with the instructions.

For the Biology and Chemistry exercises students work in pairs assigned by NORC on the basis of course background and pretest scores; for Physics and General Science, students work individually. Any pair of students or individual student is assigned, by NORC, to one of the six exercises in each science area. Students are not assigned to exercises in Biology, Chemistry, or Physics unless they have had at least one full course in that subject.

The student records are returned to NORC for scoring by reading teams recruited from high-school science teachers especially trained for this work. These teams also score the open-ended items of the paper-and-pencil assessment. The ratings made by the readers are scaled by IRT methods developed for the California Direct Writing Assessment.

7 References

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Bock, R. D., & Zimowski, M. F. (1989). *The Duplex Design: Giving students a stake in educational assessment* (Research Report). Chicago: National Opinion Research Center, Methodology Research Center.

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THE GRADED MARK-POINT METHOD OF SCORING PERFORMANCE EXERCISES AND OPEN-ENDED ITEMS

R. Darrell Bock
The University of Chicago and NORC

October 1990

The increasing use of performance exercises and open-ended items in large-scale educational assessment has created a need for dependable and economical methods of scoring the student's responses. In assessment, the three main desiderata of any measurement procedure are 1) acceptable accuracy at the most detailed level of measurement, whether that of individual students, schools, programs, or larger entities, 2) consistency in stability over a period of years in the presence of changes in the compositions of the exercises and items, and of the reading teams who score their responses, 3) sufficiently low unit costs to permit state-wide or nation-wide testing.

The present report describes the method of scoring that will be applied in the current NSF/OERI-supported 12th-grade science assessment project (Bock & Doran, 1989). This method, which we refer to as "graded mark-point" scoring is modeled after procedures developed by Dr. Pinchas Tamir for use in the performance exercises of the Israeli Matriculation Examination. We have attempted to codify his method and make it suitable for the IRT scaling procedures that will be used in the analysis and reporting of assessment results. Development of the method has also been influenced by the scoring and scaling procedures of the California Direct-Writing Assessment, which are now employed on a mass basis. The following sections of this report describe the mark-point method, explain and justify the various steps in the procedure, and present an example of its application to an open-ended item from the Earth Sciences Section of the NSF/OERI 12th-grade science assessment prototype.

1 The Scoring Method

Mark-point scoring makes use of rating forms, typically one $8\frac{1}{2} \times 11$ page in length, that specify certain main "points" that the student should make in responding to the exercise or item. The points should be identified by a person with expert knowledge of the topic in question (preferably the writer of the exercise); the expert must also supply documentation and commentary on the item for use in training the raters. The documentation should include one-sentence descriptions of the points for inclusion on the rating form. The readers who will rate the student responses must first study the documentation to familiarize themselves with the points the students are expected to make in each exercise; then, guided by the brief statements of each point on the corresponding rating form, they will look for each point in the student's paper and mark it for quality on the following six-point graded scale:

0 Point is not mentioned in paper

1 Point is mentioned, but is incorrectly stated

2 Point is mentioned, but is only partly correctly stated

3 Point is mentioned, and is fully correctly stated

4 Point is correctly stated and is partly elaborated

5 Point is correctly stated and is fully elaborated

The number of points to be rated depends upon the type of exercise. For an elaborate laboratory exercise requiring perhaps 90 minutes of student time, the student's written record of hypotheses, observations, and conclusions might be rated on 16-20 distinct points. For a 10-minute response to an open-ended item of a paper-and-pencil test, rating of six to eight distinct points probably would be sufficient. A reader might be expected to spend three to five minutes in rating an open-ended item, but may require 10 to 15 minutes to rate the report of a 90-minute laboratory performance exercise.

2 Rationale of the Method

The mark-point method is designed to operate within the assumptions and limitations of large-scale assessment.

1. The performance exercises and open-ended items of the assessment are assumed to be problem-solving tasks. The main points to be looked for in the student's responses are their applications of scientific principles to the solution of the problem solved. They are not required, however, to use exact scientific terminology in their answers; it is assumed that knowledge of terminology is part of the multiple-choice section of the assessment instrument. The reader must attempt to infer the level of the student's understanding, in whatever language it is expressed.

2. This method of scoring is normative rather than descriptive. It does not attempt to classify the typical types of errors and misconceptions that students will inevitably make in responding to the novel situations presented in the exercises. Although such information may be of interest for some purposes, it is material for background research studies and not directly relevant to the evaluation goals of assessment.

3. The mark-point method is designed to make the rating procedure as objective as possible in order to achieve high levels of agreement between raters. It is the specific points that are to be rated and not an overall impression of the fluency or style of the paper. Some degree of subjectivity necessarily enters into the meaning of the graded categories of the rating scale, but it is assumed that by comparing their ratings of sample papers, the judges can attain reasonable levels of agreement. In an operational assessment that reports only at the school or higher levels, each student paper is read only once. Because papers from the same school are randomly assigned to reading team members, stability of the school mean score is attained by averaging the ratings of numerous readers. If the ratings are to be used in placement, advancement, or certification of individual students, however, more than one reading per paper would be desirable.

4. Because open-ended items require much more student time that multiple-choice items, it is important that a sufficient amount of information be extracted in the scoring process. This is the reason for using the graded scoring categories. When scaled by item response theoretic methods, a graded response typically has greater total information capacity than a multiple-choice item. Six to eight such items can be equivalent to 15 or 20 multiple-choice items.

5. It is assumed that performance exercises and open-ended items evaluate different cognitive processes than multiple-choice items. For this reason it is important that they be scaled separately from multiple choice items in the IRT analysis. If school-level scoring is assumed, separate scales for these items can be constructed even when each student responds to only one such item. For student-level scores, however, six to eight distinct items would be desirable. A relatively long testing time would be required for student-level measurement with open-ended items.

6. The weight that a particular point will receive in calculating a school-level or student-level scale score is determined by the IRT scaling procedure. It depends on the difficulty and discriminating power of the point, and not on the arbitrary numbers zero through five that are used to label the rating categories.

3 Example of an Open-ended Item and its Mark Points

An example of an open-ended item in Earth Sciences appears in Figure 1. The topic is lake effects on climate and weather. The mark points and possible elaborations for this item are as follows:

Principles

1. Winds in middle latitudes are prevailing westerly
2. Large bodies of water warm and cool more slowly under radiant heating than land

Seasonal Effects

1. City B will have cooler springs and warmer autumns than city A
2. City B will have a longer frost-free period than city A
3. City B will be subject to lake-effect snow in winter
4. On clear, calm summer days following cloudless nights, both cities will experience land-to-lake breezes in early morning

5. Under the same conditions, they will experience lake-to-land breezes in the afternoon

Elaborations

1. Students may point out that the typical extremes of summer and winter temperatures in mid-continent, mid-latitude locations will be reduced by the presence of the lake, especially on its eastern shore.

2. Some students may know of the high specific heat of water, relative to earth, and of the effect of wind in mixing the waters of the lake in increasing its heat capacity.

3. Some may observe that we must assume the lake to be at low enough altitude as not to freeze over during the winter if lake effect snows are to be expected on the eastern shore

4. Observant students will also note that the lake is assumed to be deep, so that there is a sufficient volume of water to produce appreciable seasonal effects

4 Mark-point Rating Form

The rating form for this item is shown in Figure 2. It is designed for reading by high-volume optical character recognition equipment.

Earth Science (Water)

The map below represent two cities on the shore of a large lake at 40° north latitude in the middle of a continent. How will the presence of the lake affect the climate of each of the cities at different times of the year and different times of the day? Give reasons for your answers.

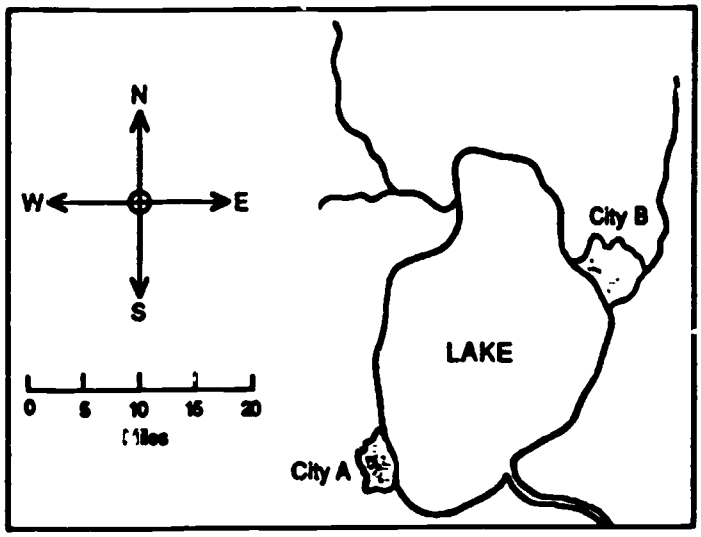


Figure 1

Open-ended item 22003002 Earth Science

School and Student ID No. ☐☐☐☐☐☐☐☐☐☐

Reader ID No. ☐☐☐☐☐☐☐☐☐☐

Date and Time ☐☐☐ ☐☐:☐☐

Topic: Lake Effect

Mark points

1. 0 1 2 3 4 5 ☐☐☐☐☐☐ "Winds prevailing westerly"
2. 0 1 2 3 4 5 ☐☐☐☐☐☐ "Large bodies of water warm and cool more slowly than land"
3. 0 1 2 3 4 5 ☐☐☐☐☐☐ "City B will have cooler springs and warmer autumns than City A"
4. 0 1 2 3 4 5 ☐☐☐☐☐☐ "City B will have a longer frost-free period than City A"
5. 0 1 2 3 4 5 ☐☐☐☐☐☐ "City B will be subject to lake-effect snow"
6. 0 1 2 3 4 5 ☐☐☐☐☐☐ "Both cities may experience land-to-lake breezes in mornings"
7. 0 1 2 3 4 5 ☐☐☐☐☐☐ "Both cities may experience lake-to-land breezes in afternoons"

Reader comments (optional):

Note: Use No. 2 pencil or erasable ball point pen.
Print number in block style: 0 1 2 3 4 5 6 7 8 9.
Mark rating boxes with an "X".
Erase all errors completely

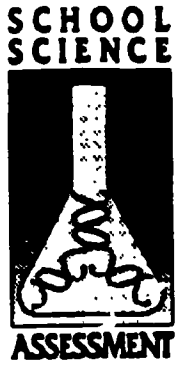
Figure 2

School

Science

Assessment

12th Grade



Questionnaire

Supported by the National Science Foundation and the U.S. Office of Education.

A. Identification

Please print your name in the spaces provided below, last name first. Use block letters only. (Examples: A B C D E F G H I J K L M N O P Q R S T U V W X Y Z.) Please erase mistakes completely.

Last Name:

First Name:

What is your date of birth? (Use numbers only.)

Day Month Year 19

What is your sex? Enter "M" for male or "F" for female.

What is the name of your home room teacher?

Please answer the following questions by marking an "X" in the boxes provided. Mark your boxes like this: ☒. If you wish to change an answer, erase the original mark completely.

B. Course Background

1. Mark the boxes that correspond to the science courses you have taken and the year in which you have taken them. Please include courses you are taking this year.

If you have studied a subject for a Full year then mark the box under "F". If you have studied a subject for Part of a year then mark the box under the "P".

	Grade 9		Grade 10		Grade 11		Grade 12	
Course:	F	P	F	P	F	P	F	P
General Science	☐	☐	☐	☐	☐	☐	☐	☐
Earth Science	☐	☐	☐	☐	☐	☐	☐	☐
Environmental Science	☐	☐	☐	☐	☐	☐	☐	☐
Health	☐	☐	☐	☐	☐	☐	☐	☐
Life Science	☐	☐	☐	☐	☐	☐	☐	☐
1st Year Biology	☐	☐	☐	☐	☐	☐	☐	☐
2nd Year or AP Biology	☐	☐	☐	☐	☐	☐	☐	☐
Physical Science	☐	☐	☐	☐	☐	☐	☐	☐
1st Year Chemistry	☐	☐	☐	☐	☐	☐	☐	☐
2nd Year or AP Chemistry	☐	☐	☐	☐	☐	☐	☐	☐
1st Year Physics	☐	☐	☐	☐	☐	☐	☐	☐
2nd Year or AP Physics	☐	☐	☐	☐	☐	☐	☐	☐
Computer Science	☐	☐	☐	☐	☐	☐	☐	☐
Other science courses:								
(Write the name of the course in the space provided.)								
_____	☐	☐	☐	☐	☐	☐	☐	☐
_____	☐	☐	☐	☐	☐	☐	☐	☐
_____	☐	☐	☐	☐	☐	☐	☐	☐

2. After the eighth grade, how many years of mathematics have you studied?

☐ None ☐ One ☐ Two ☐ Three ☐ Four or more

3. How many courses in computer science or computer programming have you studied?

☐ None ☐ One ☐ Two ☐ Three ☐ Four or more

Please continue on next page

C. Career Plans

1. What do you now plan to do the year after you leave high school? (Mark as many as apply.)

- ☐ Work
- ☐ Go into regular military service (or service academy)
- ☐ Enter an apprenticeship or on-the-job training program
- ☐ Be a homemaker
- ☐ Take academic courses at a junior (two-year) or community college
- ☐ Take courses at a business training school
- ☐ Take courses at a trade school
- ☐ Attend a four-year college or university
- ☐ Other (please specify) _____

2. If you plan to attend a four-year college or university, please complete this question. If not, please go to section D.

In what college programs do you plan to study? (You may mark more than one if appropriate.)

- ☐ Humanities (including English, foriegn languages, history, philosophy, and pre-law)
- ☐ Education (including teacher training)
- ☐ Arts (including studio and performing arts, and art history)
- ☐ Communication (including journalism, television and radio)
- ☐ Business or Commerce
- ☐ Physical Sciences, Biological Sciences, Social Sciences, or Engineering
- ☐ Other (please specify) _____

3. If you plan to study in the physical sciences, biological sciences, social sciences, or in engineering, please complete this question. If not, please go to section D.

In which areas of science or engineering do you expect to study? (You may mark more than one box if appropriate.)

PHYSICAL SCIENCES

- ☐ Chemistry
- ☐ Physics
- ☐ Mathematics
- ☐ Statistics
- ☐ Computer Science
- ☐ Geology
- ☐ Astronomy
- ☐ Other (please specify) _____

BIOLOGICAL SCIENCES

- ☐ Agriculture
- ☐ General Biology
- ☐ Zoology
- ☐ Botany
- ☐ Ecology
- ☐ Pre-medical Studies
- ☐ Other (please specify) _____

SOCIAL SCIENCES

- ☐ Psychology
- ☐ Sociology
- ☐ Anthropology
- ☐ Political Science
- ☐ Economics
- ☐ Other (please specify) _____

ENGINEERING

- ☐ Mechanical
- ☐ Chemical
- ☐ Electrical
- ☐ Aeronautical
- ☐ Civil
- ☐ Other (please specify) _____

D. Aptitude Tests

Mark any of the following tests that you have taken this year or last year.

- ☐ College Board PSAT
- ☐ College Board SAT
- ☐ ACT tests
- ☐ Armed Services Vocational Aptitude Battery (ASVAB)
- ☐ Differential Aptitude Test (DAT)

E. Science Interests

1. After eighth grade have you visited any of the following places? (Mark as many as apply.)

- ☐ A science or technology museum or center
- ☐ A natural history museum
- ☐ A zoo, aquarium or oceanarium
- ☐ A botanical garden, arboreum or nature park
- ☐ A planetarium or observatory

2. Have you ever prepared or helped prepare an exhibit for a science fair?

☐ Yes ☐ No

3. Have you ever attended a meeting of a science club in your school or community?

☐ Yes ☐ No

4. Do you like: (Mark as many as apply.)

- ☐ to watch science programs on television (such as on PBS or the Discovery Channel)?
- ☐ to read science magazines (such as *Discover*, *Scientific American*, or *Popular Science*)?
- ☐ to read books about scientists or scientific discoveries?
- ☐ to hear someone give a talk on science?
- ☐ None of the above.

5. Do you have a science-related hobby (such as radio or electronics, flying model airplanes, collecting plants or insects, keeping an aquarium or terrarium)?

☐ Yes (please specify) _____.
☐ No

Please continue on next page

6. Do you have a pocket calculator for you own use at school (either your own calculator or one supplied by the school)?

☐ Yes ☐ No

7. Is there a personal computer in your home that you can use?

☐ Yes ☐ No

8. Does your school have a computer you can use?

☐ Yes ☐ No

9. How much time do you spend each week using a computer?

☐ None ☐ Up to two hours
☐ Two to five hours ☐ More than five hours

STOP

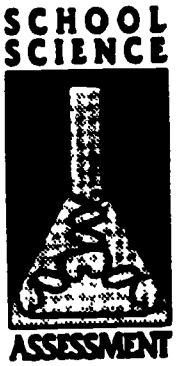
Do not turn this page until instructed to do so.

School

Science

Assessment

12th Grade



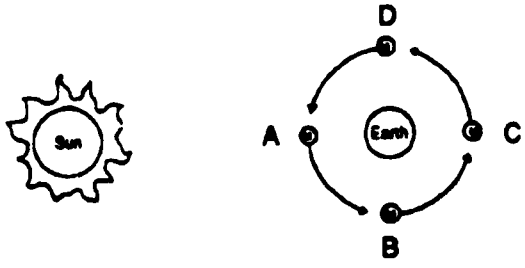
Survey Test

Supported by the National Science Foundation and the U.S. Office of Education.

1. The three basic particles of atoms are

- ☐ electron, nucleus, element.
- ☐ proton, neutron, element.
- ☐ molecule, electron, proton.
- ☐ molecule, electron, proton.
- ☐ electron, proton, neutron.

2. In which position is the Moon during a solar eclipse?



- ☐ location A
- ☐ location B
- ☐ location C
- ☐ location D

3. The various forms of electromagnetic energy are distinguished from one another by their

- ☐ temperatures.
- ☐ wavelengths.
- ☐ longitudinal wave properties.
- ☐ speeds of travel.

4. Fish and other animals in the ocean take oxygen out of the ocean water. Much of the oxygen dissolved in the ocean water comes from

- ☐ oxidation.
- ☐ plants living in the water.
- ☐ chemical breakdown of water.
- ☐ decaying plants and animals.

5. A gene whose effect remains hidden when it is paired with a different gene is called

- ☐ codominant.
- ☐ dominant.
- ☐ mutant.
- ☐ recessive.

6. Soil is composed of

- ☐ minerals and water
- ☐ sand and minerals
- ☐ organic matter
- ☐ minerals and organic matter
- ☐ water and organic matter

7. The total number of atoms represented by the formula H_2SO_4, is

- ☐ two.
- ☐ three.
- ☐ four.
- ☐ six.
- ☐ seven.

Please continue on next page

8. If a concentrated solution of salt water is poured onto grass, the grass will die because salt water

- ☐ enters the leaves and prevents photosynthesis.
- ☐ enters the roots and blocks the conducting vessels.
- ☐ causes the dehydration of plant cells.
- ☐ prevents air from entering the spaces in the soil.

9. New oceanic crust, composed of basalt, is produced at

- ☐ transform boundaries.
- ☐ subduction zones.
- ☐ the center of the Earth.
- ☐ mid-ocean spreading centers.
- ☐ convergent plate boundaries.

10. If the resistance in a circuit is doubled while the voltage remains the same, how will the current change?

- ☐ It will not change.
- ☐ It will be twice as great.
- ☐ It will be half as great.
- ☐ It will be four times as great.
- ☐ It will be one-fourth as great.

11. The products of any neutralization reaction are

- ☐ carbon dioxide and water.
- ☐ an acid and a base.
- ☐ salt and water.
- ☐ sodium chloride and water.

12. The photoelectric effect can be described by which of the following?

- ☐ electrons striking the surface of a metal and atoms of the metal being emitted
- ☐ neutrons striking the surface of a metal and other neutrons being emitted
- ☐ photons striking the surface of a metal and electrons being emitted
- ☐ positive ions striking the surface of a metal and negative ions being emitted

13. Some aqueous solutions are strongly basic because

- ☐ they contain a high concentration of metallic ions.
- ☐ they contain a high concentration of hydrogen ions.
- ☐ they hardly dissociate into their constituent ions.
- ☐ they contain a high concentration of hydroxide ions.

14. The tendency of a pool ball to roll uniformly in a straight line is an example of

- ☐ Newton's first law of motion: inertia.
- ☐ Newton's second law of motion: F=ma.
- ☐ Newton's third law of motion: action-reaction.
- ☐ the law of gravity.
- ☐ the law of conservation.

Please continue on next page

15. If the amount of water vapor in the air remains the same, but there were a sudden drop in temperature, the relative humidity would

- ☐ go up.
- ☐ go down.
- ☐ stay the same.
- ☐ not be predictable.

16. BOTH cellular respiration and fermentation require

- ☐ enzymes.
- ☐ minerals.
- ☐ oxygen.
- ☐ nitrogen.

17. To become a calcium ion, Ca^{2+}, a calcium atom must

- ☐ gain two electrons.
- ☐ gain two protons.
- ☐ lose two electrons.
- ☐ lose two neutrons.

18. As temperatures drop in the mid-latitude areas as a result of the seasonal changes from autumn to winter, what happens to the surface waters of the ocean as their temperatures also drop?

- ☐ The density increases and surface water masses sink.
- ☐ Due to less evaporation, the salinity increases.
- ☐ Due to less evaporation, the density decreases.
- ☐ The density decreases and waves form.

19. A cell does not need to use energy in

- ☐ active transport.
- ☐ diffusion.
- ☐ metabolism.
- ☐ mitosis.

20. If thunder is heard 10 seconds after a lightning flash is seen, how far away is the lightning?

- ☐ about 1,300 meters away
- ☐ about 3,300 meters away
- ☐ about 5,900 meters away
- ☐ about 10,000 meters away

STOP

School Science Assessment

A Personalized test of

Science Understanding

for

Eve Winston

Supported by the National Science Foundation and the U.S. Office of Education

1. The BEST explanation of the Northern Lights is that they are produced by

- ☐ electrostatic induction.
- ☐ reflection from the polar ice caps.
- ☐ rotation of the Earth's magnetic field.
- ☐ energetic particles in the Earth's upper atmosphere.

2. If you pole vault 3 meters on Earth, how high could you pole vault on the Moon?

- ☐ 1 meter
- ☐ 2 meters
- ☐ 3 meters
- ☐ 6 meters
- ☐ 18 meters

3. The amount of oxygen in the atmosphere remains relatively constant because oxygen is given off by

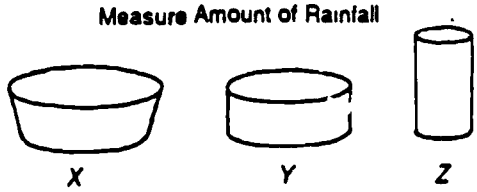
- ☐ rocks.
- ☐ animals.
- ☐ the ocean.
- ☐ plants.

4. The sun's energy is most apparent at which stage in the water cycle?

- ☐ transpiration
- ☐ evaporation
- ☐ rain
- ☐ surface flow

5. Would readings of water depth in the containers below, made immediately after a rain, at the same time and location, vary?

Containers Placed Outside to Measure Amount of Rainfall



- ☐ *Y* and *Z* would show the same reading; *X* would be lower.
- ☐ *X* and *Y* would show the same reading; *Z* would be higher.
- ☐ *X*, *Y*, and *Z* would have different readings; *X* would be highest and *Z* lowest.
- ☐ More information is needed to answer the question.

6. If you were looking for gold in a stream, where would it be found?

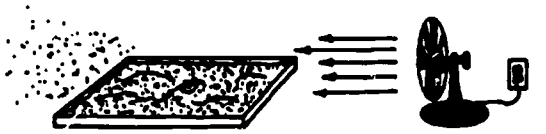
- ☐ at the lowest level of most of the material under the water
- ☐ at the top surface of the material under the water
- ☐ flowing with the water
- ☐ dissolved in the water
- ☐ all of these places

Please continue on next page

7. The minerals found in a sample of rock can best be identified by their

- ☐ ages.
- ☐ amounts and sizes.
- ☐ physical and chemical properties.
- ☐ locations in the rock.

8. What natural process on Earth's crust is represented by the model below?



PAN OF DRY SAND ELECTRIC FAN

- ☐ evaporation
- ☐ erosion
- ☐ fossil formation
- ☐ chemical change

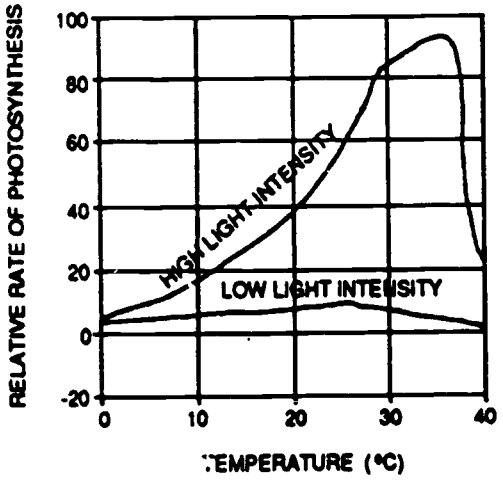
Please continue on next page

9. Starches are broken down into simple sugars by the action of

- ☐ enzymes.
- ☐ minerals.
- ☐ hormones.
- ☐ water.

10. Base your answer to the question below on the graph below which relates the rate of photosynthesis in a geranium plant to varying conditions of temperature and light intensity.

At a low light intensity, an increase in temperature will



- ☐ greatly slow down the rate of photosynthesis.
- ☐ greatly speed up the rate of photosynthesis.
- ☐ have no effect on the rate of photosynthesis.
- ☐ have little effect on the rate of photosynthesis.

11. The sequence that correctly describes the transmission of a nerve impulse is:

- ☐ effector, motor neuron, sensory neuron, receptor
- ☐ receptor, sensory neuron, motor neuron, effector
- ☐ effector, sensory neuron, motor neuron, receptor
- ☐ receptor, motor neuron, sensory neuron, effector

12. If a person who is a light eater has a tendency to be overweight, it is most likely due to

- ☐ too much exercise.
- ☐ a carefully balanced diet.
- ☐ a tendency toward nervousness.
- ☐ an excessive dosage of vitamins.
- ☐ food being used very efficiently.

13. Some seeds germinate (start to grow) best in the dark, others in the light, while others germinate equally well in the dark or the light. A girl wanted to find out by means of an experiment to which group a certain kind of seed belonged. She should put some of the seeds on damp newspaper and

- ☐ keep them in a warm place in the dark.
- ☐ keep one batch in the light and another in the dark.
- ☐ keep them in a warm place in the light.
- ☐ put some on dry newspaper and keep them in the light.
- ☐ put some on dry newspaper and keep them in the dark.

Please continue on next page

14. The results below are from experiments which were designed to find how long it took for newborn babies of different mammals to double in weight.

What do the results of these experiments suggest?

Mammal	Time in days to double the weight of the newborn baby	Percentage protein in the milk of the mother
human	180	1.6
horse	60	2.0
cow	47	3.5
pig	18	5.9
sheep	10	6.5
dog	8	7.1
rabbit	8	10.4

- ☐ The larger the mammal, the greater the protein concentration in the milk.
- ☐ The smaller the mammal, the greater the protein concentration in the milk.
- ☐ The greater the protein concentration in the mammal's milk, the slower the newborn baby will double its weight.
- ☐ The greater the protein concentration in the mammal's milk, the faster the newborn baby will double its weight.
- ☐ There appears to be no relationship between protein concentration in mammal's milk and time taken for a newborn baby to double its birth weight.

15. Reconstructing the way of life of an extinct organism is partly based on comparing its fossils to

- ☐ inorganic sediments.
- ☐ living organisms.
- ☐ minerals of the same age.
- ☐ traces of decomposers.

16. Here are four organisms that make up a food chain:

I. Snail

II. Cabbage

III. Small bird

IV. Owl

Which of the following lists is a correct food chain with the producer listed first?

- ☐ I, II, III and IV
- ☐ I, III, II and IV
- ☐ II, III, I and IV
- ☐ II, I, III and IV
- ☐ IV, III, II and I

STOP

Do not turn this page
until instructed to do so.

17. The mass of an atom depends mainly on the number of

- ☐ protons only.
- ☐ neutrons only.
- ☐ protons plus neutrons.
- ☐ protons plus electrons.

18. An ion of the element Al (aluminum) carries a charge of 3+. Which choice in the following table best describes this ion?

	ATOMIC No.	MASS No.	No. OF PROTONS	No. OF NEUTRONS	No. OF ELECTRONS
A	10	13	13	10	13
B	13	13	10	14	13
C	13	27	13	14	10
D	13	27	13	14	13

- ☐ A
- ☐ B
- ☐ C
- ☐ D

19. A catalyst in a chemical system may do all of the following EXCEPT

- ☐ speed up the reaction.
- ☐ slow down the reaction.
- ☐ make a reaction economically important.
- ☐ change the temperature used for the reaction.
- ☐ change the amounts of products and reactants present at equilibrium.

20. Tearing a piece of paper into small pieces is considered a physical change rather than a chemical change because

- ☐ no new substances are formed.
- ☐ no energy is wasted.
- ☐ very little heat is given off.
- ☐ paper contains no chemicals.

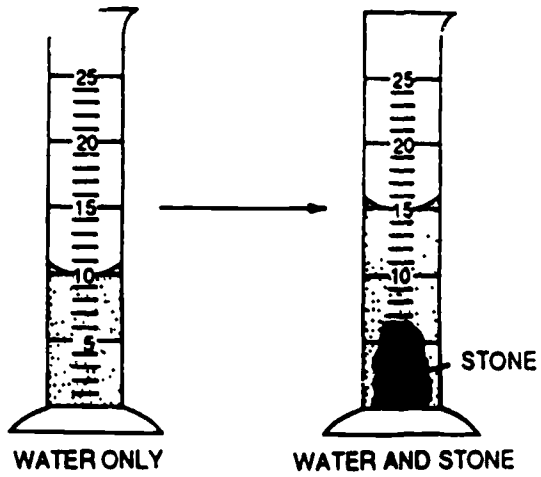
Please continue on next page

21. In each of five experiments, two objects were weighed four times each. Which experiment gives the strongest evidence that object I weighs more than object II?

	Object I	Object II
A Experiment A	80 lb.	70 lb.
	81 lb.	69 lb.
	80 lb.	71 lb.
	82 lb.	70 lb.
B Experiment B	69 lb.	81 lb.
	71 lb.	82 lb.
	70 lb.	80 lb.
	70 lb.	80 lb.
C Experiment C	70 lb.	80 lb.
	75 lb.	75 lb.
	77 lb.	73 lb.
	80 lb.	70 lb.
D Experiment D	80 lb.	70 lb.
	75 lb.	75 lb.
	73 lb.	77 lb.
	70 lb.	80 lb.
E Experiment E	80 lb.	77 lb.
	79 lb.	76 lb.
	78 lb.	75 lb.
	77 lb.	74 lb.

- ☐ A
- ☐ B
- ☐ C
- ☐ D
- ☐ E

22. A stone is placed in a graduated cylinder containing 10 milliliters of water, as shown in the diagram. What is the volume of this stone?



- ☐ 5 mL
- ☐ 10 mL
- ☐ 15 mL
- ☐ 16 mL

Please continue on next page

23. Which of the following illustrates an evaporation dish?

A B C D E

- ☐ A
- ☐ B
- ☐ C
- ☐ D
- ☐ E

24. The property of gases that accounts for pressure is

- ☐ the space between molecules.
- ☐ the density of the gas.
- ☐ the motion of the gas molecules.
- ☐ the identity of the gas.

Please continue on next page

25. The amount of work done to a lever is always

- ☐ less than the amount of work done by the lever.
- ☐ greater than the amount of work done by the lever.
- ☐ the same as the amount of work done by the lever.

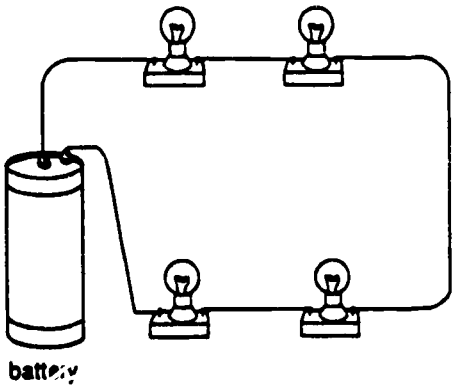
26. A boat travels at 18 km/h across a 40m wide stream in which there is a steady current running at 10 km/h. How far is the boat carried downstream before reaching the opposite shore if the boat starts out pointing directly across the stream?

- ☐ 22 m
- ☐ 7.0 m
- ☐ 4.5 m
- ☐ 72 m
- ☐ 50 m

27. An electric current in a copper wire involves mainly the movement of

- ☐ copper atoms.
- ☐ copper molecules.
- ☐ electrons.
- ☐ neutrons.

28. The graph below represents a(n)



- ☐ series circuit.
- ☐ parallel circuit.
- ☐ wet cell.
- ☐ electroscope.

29. Temperature is a measurement of the

- ☐ average kinetic energy of molecules.
- ☐ size of molecules.
- ☐ space between molecules.
- ☐ shape of molecules.

30. A 50 W light bulb operating for 20 s uses the same amount of energy as a 100 W bulb operating for

- ☐ 2.0 s
- ☐ 5.0 s
- ☐ 10 s
- ☐ 20 s
- ☐ 40 s

Please continue on next page

31. The table shows the results of an experiment in which the minimum wavelength of the X-rays produced by an X-ray machine is related to the voltage of the machine. The independent (manipulated) and dependent (responding) variables respectively are

Potential Difference (kV)	Minimum Wavelength (nm)
10	0 13
12	0 10
15	0 083
18	0.069
21	0 059

- ☐ wavelength and frequency.
- ☐ potential difference and voltage.
- ☐ wavelength and potential difference.
- ☐ potential difference and wavelength.

32. Bill is a long distance from Ann. He sees Ann hit a nail into a board before he hears the sound of the nail being hit. Which statement best explains Bill's observation?

- ☐ A gentle wind blowing from Bill toward Ann slowed the speed of the sound waves.
- ☐ Peoples eyes are in front of their ears; therefore, light reaches the eyes before sound reaches the ears.
- ☐ The speed of light is faster than the speed of sound.
- ☐ The speed of light is slower than the speed of sound.

Please continue on next page

500001

If you wish to receive a report of your performance on this test, please print your address in the spaces provided below.

Use block letters only. (Examples: A B C D E F G H I J K L M N O P Q R S T U V W X Y Z.) Please erase mistakes completely.

Street:

City:

State:

Zip:

STOP

500002

School Science Assessment

A Personalized test of

Science Understanding

for

Ivan Holbrook

Supported by the National Science Foundation and the U.S. Office of Education

INSTRUCTIONS

Please answer the questions in this booklet by marking an "X" in the boxes provided. Mark the boxes like this: ☒ If you wish to change an answer, erase the original mark completely.

Do not make blind guesses! If you are sure you do not know the answer to a question, just leave the question blank and go on to the next question.

There are two sets of questions on this test. Stop at the end of the first set and wait for the signal to start the second set. You have **20 minutes** to answer each set of questions.

If you have time at the end of each section, you may go back to the questions you have omitted in that section and try again to answer them. You may not go back to the first section once you have begun the second section.

Please wait for the signal to begin.

1. The BEST explanation of the Northern Lights is that they are produced by

- ☐ electrostatic induction.
- ☐ reflection from the polar ice caps.
- ☐ rotation of the Earth's magnetic field.
- ☐ energetic particles in the Earth's upper atmosphere.

2. If the Earth rotated from east to west, instead of west to east, the North Star would appear to

- ☐ rise in the south.
- ☐ remain stationary.
- ☐ set in the east.
- ☐ rise in the east.

3. Plants take nitrogen from the air. One way it is returned is by

- ☐ decaying plants and dead animals.
- ☐ the health of animals.
- ☐ plants giving it off during photosynthesis.
- ☐ water evaporating.

4. Warm air will rise through cooler air because warm air

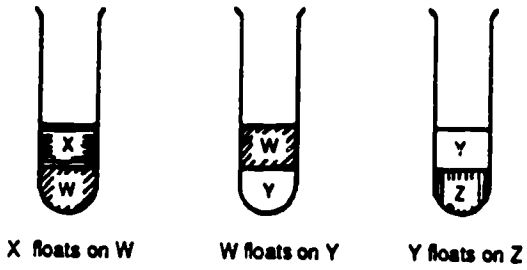
- ☐ has its molecules closer together.
- ☐ is less dense.
- ☐ has a lower percentage of lightweight atoms.
- ☐ is less likely to form a convection current.

5. If river deltas are used to determine how old the river is, it is assumed that the rate of depositing sediment

- ☐ is the same now as in the past.
- ☐ was faster in the past
- ☐ was slower in the past.
- ☐ is unimportant, as long as you know what it is now.
- ☐ is always the same for all materials.

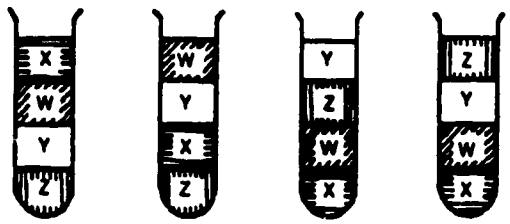
Please continue on next page

6. Four liquids, W, X, Y, and Z, do not mix with each other when they are poured into test tubes as shown below in (1). The four liquids are poured into one test tube. Which diagram in (2) shows how the liquids will float in the test tube?



X floats on W W floats on Y Y floats on Z

(1)



A B C D

(2)

- ☐ A
- ☐ B
- ☐ C
- ☐ D

7. The minerals found in a sample of rock can best be identified by their

- ☐ ages.
- ☐ amounts and sizes.
- ☐ physical and chemical properties.
- ☐ locations in the rock.

8. How do the effects of physical (mechanical) weathering differ most fundamentally from those of chemical weathering?

- ☐ Physical weathering changes the size of particles, whereas chemical weathering does not.
- ☐ Chemical weathering changes the size of particles, whereas physical weathering does not.
- ☐ Physical weathering changes the composition of particles, whereas chemical weathering does not.
- ☐ Chemical weathering changes the composition of particles, whereas physical weathering does not.

Please continue on next page

9. Terrestrial plants obtain the carbon dioxide they require for photosynthesis mostly from the

- ☐ soil water.
- ☐ soil gases.
- ☐ carbonates in the soil.
- ☐ the atmosphere.
- ☐ breakdown of stored starch.

10. Saliva was mixed with a starch suspension and divided into five parts. Each part was kept at a different temperature for 15 minutes. The amount of sugar produced at each temperature was measured.

Which of the following conclusions can be drawn from the experimental data below?

Temperature (°C)	0	20	40	60	80
Relative amount of sugar	10	60	90	30	2

- ☐ Enzyme activity stops at 0°C.
- ☐ A very high temperature reduces enzyme activity.
- ☐ Enzyme activity is unaffected by temperature.
- ☐ The optimum temperature for the reaction is 20°C.
- ☐ The higher the temperature the faster the rate of change of starch.

11. A MAJOR function of the kidney is the

- ☐ deamination of amino acids.
- ☐ chemical breakdown of urea.
- ☐ removal of glucose from the blood.
- ☐ removal of nitrogenous wastes from the blood.

12. Some doctors are now prescribing medications such as insulin and flu vaccines in the form of nasal sprays and nose drops. The advantages of using these methods include increased convenience and faster absorption. The reason for the rapid absorption of nasal sprays is that the nasal cavity has

- ☐ a close proximity to the control centers of the brain.
- ☐ many cilia that will transport the medication quickly.
- ☐ many odor receptors that absorb the medication.
- ☐ a high concentration of capillaries in its lining.

13. Which of the following best describes the information given on a gene map?

- ☐ the relative number of genes on the members of a pair of homologous chromosomes
- ☐ the potential for gene mutation
- ☐ the sequence and relative distance between the genes on a chromosome
- ☐ the position of abnormal genes
- ☐ the length of the chromosome in genetic units

Please continue on next page

14. The results below are from experiments which were designed to find how long it took for newborn babies of different mammals to double in weight.

What do the results of these experiments suggest?

Mammal	Time in days to double the weight of the newborn baby	Percentage protein in the milk of the mother
human	180	1.8
horse	60	2.0
cow	47	3.5
pig	18	5.9
sheep	10	8.5
dog	8	7.1
rabbit	8	10.4

- ☐ The larger the mammal, the greater the protein concentration in the milk.
- ☐ The smaller the mammal, the greater the protein concentration in the milk.
- ☐ The greater the protein concentration in the mammal's milk, the slower the newborn baby will double its weight.
- ☐ The greater the protein concentration in the mammal's milk, the faster the newborn baby will double its weight.
- ☐ There appears to be no relationship between protein concentration in mammal's milk and time taken for a newborn baby to double its birth weight.

15. Reconstructing the way of life of an extinct organism is partly based on comparing its fossils to

- ☐ inorganic sediments.
- ☐ living organisms.
- ☐ minerals of the same age.
- ☐ traces of decomposers.

16. The fossil record shows that dinosaurs existed in great numbers and in many different forms. From a scientific viewpoint, the most reasonable conclusion is that

- ☐ this was the reason for their respective extinctions.
- ☐ the many different species occupied many different ecological niches.
- ☐ they never became very specialized.
- ☐ they were the direct ancestors of animals that occupy the various niches today.
- ☐ they were resistant to diseases.

STOP

Do not turn this page
until instructed to do so.

17. Atoms with the same atomic number but different atomic mass are called

- ☐ isomers.
- ☐ isosceles.
- ☐ isobars.
- ☐ isotopes.

18. Atoms of element A have 2 electrons in their highest occupied energy level. Atoms of element B have 7 electrons in their highest occupied energy level. The formula of the compound formed between A and B is

- ☐ AB_3
- ☐ A_2B
- ☐ AB_2
- ☐ A_7B_2

19. The products of any neutralization reaction are

- ☐ carbon dioxide and water.
- ☐ an acid and a base.
- ☐ a salt and water.
- ☐ sodium chloride and water.

20. A certain reaction does not take place in the dark but proceeds explosively as soon as it is exposed to light. Which of the following is the best explanation of this observation?

- ☐ Light provides the energy which is released as heat in the explosion.
- ☐ Light initiates the reaction which then proceeds very rapidly.
- ☐ Light acts as a catalyst, being regenerated during the explosion.
- ☐ Light heats the unstable reactant(s) which then explode.
- ☐ The total reaction is endothermic and light initiates it by supplying much more than the required energy.

21. For a calorimetric experiment to determine the molar heat of combustion for a fuel, the information that would not be required is the

- ☐ time required to burn the fuel.
- ☐ heat capacity of the calorimeter.
- ☐ mass of the calorimeter and its contents.
- ☐ temperature change of the calorimeter and its contents.

22. The total number of atoms in 2 mol of $Na_2CO_3 \cdot 10H_2O$ is

- ☐ $2 \times 22.4 \times 6.02 \times 10^{23}$
- ☐ $2 \times 26 \times 6.02 \times 10^{23}$
- ☐ $2 \times 27 \times 6.02 \times 10^{23}$
- ☐ $2 \times 36 \times 6.02 \times 10^{23}$

Please continue on next page

23. A chemist working for a toothpaste firm wishes to prepare 250 cm^3 of a 0.010 M (mol/liter) aqueous solution of tin (II) fluoride. Fortunately for her, tin (II) fluoride is soluble in water. One mole of tin (II) fluoride weighs 156.7 g. Equipment available includes a 250 cm^3 volumetric flask, a 10 cm^3 pipette, a 0.01 g sensitivity balance, and a 400 cm^3 beaker.

Once the appropriate amount of tin (II) fluoride has been weighed, which one of the following procedures would be best?

- ☐ Place the tin (II) fluoride in the beaker and add exactly 250 cm^3 of water from the volumetric flask.
- ☐ Place the tin (II) fluoride in the volumetric flask, dissolve it in less than 250 cm^3 of water, and then dilute to the 250 cm^3 mark.
- ☐ Place the tin (II) fluoride in the beaker and add exactly 250 cm^3 of water from the pipette in 10 cm^3 portions.
- ☐ Using the beaker and balance, weigh out exactly 250 g of water and add the tin (II) fluoride to it.
- ☐ Dissolve the tin (II) fluoride in more than 250 cm^3 of water in the beaker and then fill the volumetric flask to the line with the solution.

24. The property of gases that accounts for pressure is

- ☐ the space between molecules.
- ☐ the density of the gas.
- ☐ the motion of the gas molecules.
- ☐ the identity of the gas.

Please continue on next page

25. A ball is thrown horizontally from the top of a cliff. Before the ball hits the ground, it (neglecting air resistance)

- ☐ accelerates vertically only.
- ☐ accelerates horizontally only.
- ☐ accelerates both vertically and horizontally.
- ☐ does not accelerate.

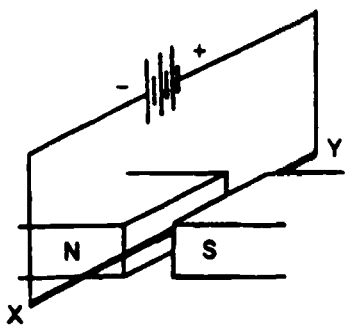
26. A boat travels at 18 km/h across a 40m wide stream in which there is a steady current running at 10 km/h. How far is the boat carried downstream before reaching the opposite shore if the boat starts out pointing directly across the stream?

- ☐ 22 m
- ☐ 7.0 m
- ☐ 4.5 m
- ☐ 72 m
- ☐ 50 m

27. Millikan was able to determine the charge of an electron by balancing which forces?

- ☐ Electric and magnetic
- ☐ Magnetic and centripetal
- ☐ Electric and gravitational
- ☐ Magnetic and gravitational

28. A wire with an electric current passing through it is placed in a magnetic field as shown in the diagram. In which direction will the wire move?



- ☐ towards the North pole
- ☐ towards the South pole
- ☐ vertically up
- ☐ vertically down
- ☐ in the direction of point Y

29. Scientists once thought that all matter existed forever. They now think that matter can be transformed and that energy will be released. Why has their understanding of matter changed?

- ☐ New knowledge was used to improve their understanding.
- ☐ Later experiments were not performed as carefully.
- ☐ There has been a change in the way matter and energy behave.
- ☐ Early scientists had no information about matter.

Please continue on next page

30. If the specific heat capacity of aluminum is 900 J/(kg-°C), the heat energy required to increase the temperature of 10.0 g of aluminum from 15°C to 20°C is

- ☐ 4.5×10^1 J
- ☐ 1.4×10^2 J
- ☐ 1.8×10^2 J
- ☐ 3.2×10^2 J
- ☐ 4.5×10^4 J

31. Which optical device may form an enlarged image?

- ☐ plane mirror
- ☐ glass plate
- ☐ converging lens
- ☐ diverging lens

32. The ether concept was ORIGINALLY introduced to explain the

- ☐ high speed of light.
- ☐ passage of light through outer space.
- ☐ existence of discrete photons in electromagnetic radiation.
- ☐ equality of speed of all forms of electromagnetic radiation in a vacuum.

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School Science Assessment

A Personalized test of

Science Understanding

for

Dennis Hobson

Supported by the National Science Foundation and the U.S. Office of Education

INSTRUCTIONS

Please answer the questions in this booklet by marking an "X" in the boxes provided. Mark the boxes like this: ☒. If you wish to change an answer, erase the original mark completely.

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Please wait for the signal to begin.

1. A meteor is best defined as

- ☐ the light produced by an exploding star.
- ☐ a comet-like object made of ice and dirt.
- ☐ a rock fragment entering Earth's atmosphere.
- ☐ a star entering Earth's atmosphere.

2. An astronaut who weighs 9.00×10^2 N on Earth travels to Planet X, which has the same radius as Earth. If the mass of Planet X is 1.98×10^{30} kg and the mass of the Earth is 5.98×10^{24} kg, then the factor by which the astronaut's weight has changed is expected to be

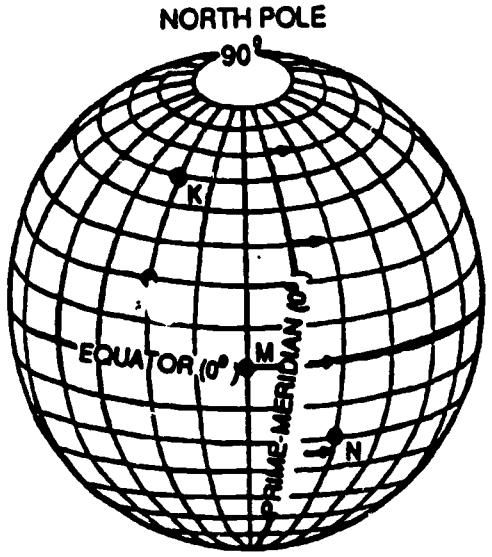
- ☐ 3.02×10^{-6}
- ☐ 2.72×10^{-3}
- ☐ 3.31×10^{6}
- ☐ 1.10×10^{11}

3. Infrared waves produced by the warmed materials of the earth's surface are absorbed in the atmosphere chiefly by

- ☐ water vapor and oxygen.
- ☐ water vapor and carbon dioxide.
- ☐ carbon dioxide and oxygen.
- ☐ oxygen and nitrogen.

4. The diagram below represents latitude and longitude lines on the surface of the Earth. Letters J through N represent sea level locations and the arrows show the direction of the Earth's rotation. The latitude lines shown are spaced 10° apart and the longitude lines are spaced 15° apart.

Which pair of locations (K, L, M, or N) would receive equal yearly insolation per square meter of surface if the atmosphere were completely transparent at each location?



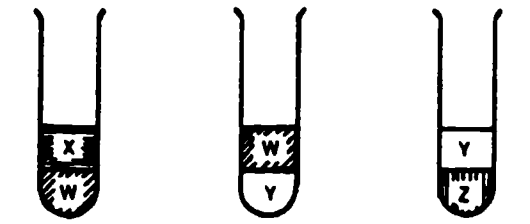
- ☐ M, N
- ☐ K, L
- ☐ L, N
- ☐ L, M
- ☐ K, N

5. Which of the following pieces of equipment could be used to monitor the effect of acid rain on lake water?

- ☐ A glass electrode.
- ☐ A platinum electrode.
- ☐ An oxygen electrode.
- ☐ A salt bridge.

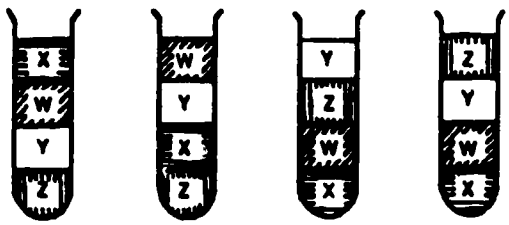
Please continue on next page

6. Four liquids, W, X, Y, and Z, do not mix with each other when they are poured into test tubes as shown below in (1). The four liquids are poured into one test tube. Which diagram in (2) shows how the liquids will float in the test tube?



X floats on W W floats on Y Y floats on Z

(1)



A B C D

(2)

- ☐ A
- ☐ B
- ☐ C
- ☐ D

7. Of the following, which type of igneous rock formation is most useful in interpreting the rock record?

- ☐ extrusive formations
- ☐ intrusive formations
- ☐ lava flows
- ☐ lavalith

8. One reason it is believed that the polar regions once had a tropical climate is that

- ☐ fossils of tropical plants have been found there.
- ☐ evidence shows that the polar continents were once at the equator.
- ☐ the temperature of polar regions sometimes are as high as in the tropics.
- ☐ evidence indicates that snow was absent at one time in the polar regions.

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9. Elongated epidermal cells present in the roots of plants function in the process of

- ☐ transpiration.
- ☐ photosynthesis.
- ☐ reproduction.
- ☐ absorption.

10. The two arms of a U-tube are separated by a barrier of dialysis membrane. If the left side of the tube contains a 6% sugar solution, and the right side contains a 10% sugar solution, then

- ☐ the level of the liquid will rise on the right side.
- ☐ the level of the liquid will rise on the left side.
- ☐ the concentrations of each side of the membrane will become equal, but the levels of the liquid will remain unchanged.
- ☐ the concentration of water molecules will increase on the left.
- ☐ sugar molecules will move from the left to the right.

11. Membranes of nerve axons are specialized to provide

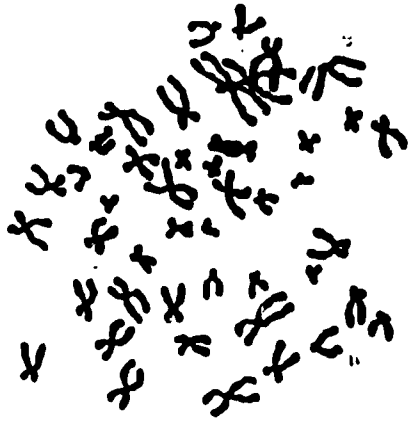
- ☐ a resting potential difference resulting in a polarized membrane.
- ☐ respiratory enzymes capable of supplying energy rapidly.
- ☐ storage places for glycogen molecules.
- ☐ electric currents which can travel along the membrane.
- ☐ transmitter molecules along their full length.

12. Some doctors are now prescribing medications such as insulin and flu vaccines in the form of nasal sprays and nose drops. The advantages of using these methods include increased convenience and faster absorption. The reason for the rapid absorption of nasal sprays is that the nasal cavity has

- ☐ a close proximity to the control centers of the brain.
- ☐ many cilia that will transport the medication quickly.
- ☐ many odor receptors that absorb the medication.
- ☐ a high concentration of capillaries in its lining.

13. The diagram below represents a photographic enlargement of replicated chromosomes from a fetal cell.

For which technique would this photograph be used to determine if the chromosomes of the fetus exhibit any genetic abnormalities?



- ☐ cleavage
- ☐ karyotyping
- ☐ chemosynthesis
- ☐ plasmolysis

Please continue on next page

14. Color blindness is an X-linked recessive condition. Which parental genotypes below would result in children who are all normal daughters and all color-blind sons? (B = allele for normal color vision; b = allele for color blindness.)

- ☐ $X^BX^b - X^BY$
- ☐ $X^BX^B - X^bY$
- ☐ $X^BX^b - X^bY$
- ☐ $X^bX^b - X^bY$
- ☐ $X^bX^b - X^BY$

15. Although fossils provide evidence that many organisms once lived on earth and are now extinct, there are still many gaps in the fossil record. This is due mainly to certain conditions that are necessary for fossilization to occur. These conditions include all of the following EXCEPT

- ☐ an organism becoming quickly buried by sediments before disintegrating.
- ☐ the organism having a hard and rigid skeleton.
- ☐ the activity of micro-organisms and scavengers being limited.
- ☐ the area not having much volcanic and earthquake activity.

16. Which structures would be considered homologous?

- ☐ the wing of a bat and the flipper of a whale
- ☐ the arm of a starfish and the foreleg of a horse
- ☐ the jointed appendages of a grasshopper and a human
- ☐ the wings of a bat and a butterfly

STOP

Do not turn this page
until instructed to do so.

17. The maximum number of electrons that a single orbital of the 3d sublevel may contain is

- ☐ 5
- ☐ 2
- ☐ 3
- ☐ 4

18. Within a family in the periodic table, why is the metal with the lowest ionization energy usually the one with the highest atomic number?

- ☐ Larger atoms are less likely to be spherical.
- ☐ Larger atoms are less likely to pack close together.
- ☐ The heaviest particles have the greatest kinetic energies.
- ☐ The distance between the nucleus and the electrons is greatest for the heaviest atoms.

19. When oxygen reacts with the food we eat, the processes that occur are

- ☐ endothermic reactions.
- ☐ exothermic reactions.
- ☐ neutralization reactions.
- ☐ combustion reactions.

20. An example of an oxidation process would be

- ☐ a chromium (II) ion forming a chromium (III) ion.
- ☐ a chlorine atom forming a chloride ion.
- ☐ oxygen gas, O_2, reacting to form ozone gas, O_3.
- ☐ a calcium ion forming a calcium atom.

21. A student prepared a solution of acidified $SnCl_2(aq)$ and then titrated this solution with $KMnO_4(aq)$. The student's data were recorded as shown in the table below. In order to calculate correctly the concentration of $MnO_4^-(aq)$, in addition to the balanced chemical equation, one would use

I. concentration of $SnCl_2$ (aq)	0.0790 mol/L
II. volume of $SnCl_2$ (aq) solution prepared	100.0 mL
III. volume of acid added to $SnCl_2$ (aq)	3.0 mL
IV. volume of $SnCl_2$ (aq) solution used in the titration	10.0 mL
V. volume of $KMnO_4$ (aq) solution used in the titration	12.8 mL

- ☐ I, II, and V.
- ☐ I, IV, and V.
- ☐ I, II, IV, and V.
- ☐ I, II, III, IV, and V.

22. If 1 L of a gas at STP has a mass of 2.86 g, the molar mass of the gas is

- ☐ 2.86 g
- ☐ 22.4 g
- ☐ 64.1 g
- ☐ 286 g

Please continue on next page

23. The acid-base indicator methyl red, may be represented by HMr, and its ionization equilibrium may be represented by the equation $HMr = H^+ + Mr^-$. The table shows the colors that methyl red exhibits in solution at given hydrogen ion concentrations. According to the results in the table, the equilibrium constant for the indicator is approximately

COLOR	$[H^+]$
red	10^{-1}
red	10^{-2}
red	10^{-3}
orange	10^{-4}
yellow	10^{-5}
yellow	10^{-6}
yellow	10^{-7}
yellow	10^{-8}

- ☐ 1.0×10^{-8} mol/L
- ☐ 1.0×10^{-6} mol/L
- ☐ 1.0×10^{-4} mol/L
- ☐ 1.0×10^{-3} mol/L

24. An aqueous acid or base is said to be strong if it is

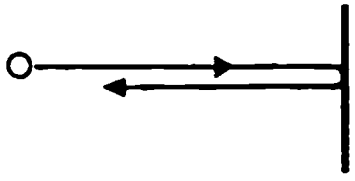
- ☐ highly concentrated.
- ☐ in a state of equilibrium.
- ☐ highly hydrated.
- ☐ highly dissociated.

Please continue on next page

25. A car with a mass of 100 kg is moving with a constant velocity of 4 m/sec. What is its kinetic energy?

- ☐ 200 joules
- ☐ 400 joules
- ☐ 800 joules
- ☐ 1,600 joules
- ☐ 20,000 joules

26. The ball of mass 2 kg moving with a horizontal velocity of 5 m/s to the right hits a vertical wall and rebounds with a horizontal velocity of 4 m/s to the left as shown in the diagram below. The magnitude of the change in momentum of the ball, in kilogram meters per second, is



- ☐ 2
- ☐ 5
- ☐ 9
- ☐ 10
- ☐ 18

27. Millikan was able to determine the charge of an electron by balancing which forces?

- ☐ Electric and magnetic
- ☐ Magnetic and centripetal
- ☐ Electric and gravitational
- ☐ Magnetic and gravitational

28. Whenever a net charge is placed on a neutral object by contact, the predicted sign of the charge on the object

- ☐ is opposite to the charge on the charging agent.
- ☐ is the same as the charge on the charging agent.
- ☐ returns to neutral once the charging agent is removed.
- ☐ depends on the kind of material making up the object.

29. Scientists once thought that all matter existed forever. They now think that matter can be transformed and that energy will be released. Why has their understanding of matter changed?

- ☐ New knowledge was used to improve their understanding.
- ☐ Later experiments were not performed as carefully.
- ☐ There has been a change in the way matter and energy behave.
- ☐ Early scientists had no information about matter.

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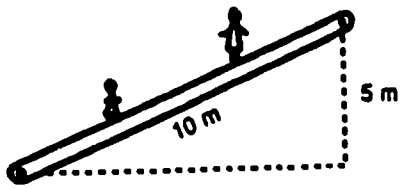
30. The escalator shown below is used to move 20 passengers a minute from the first floor of a department store to the second floor, 5 m above. If the average mass of the passengers is 60 kg, the power required to move them is approximately



- ☐ 100 W
- ☐ 200 W
- ☐ 1,000 W
- ☐ 2,000 W
- ☐ 60,000 W

31. The following are hypotheses concerning the nature of electromagnetic waves:

I. Electromagnetic waves carry energy.

II. Electromagnetic waves can be reflected.

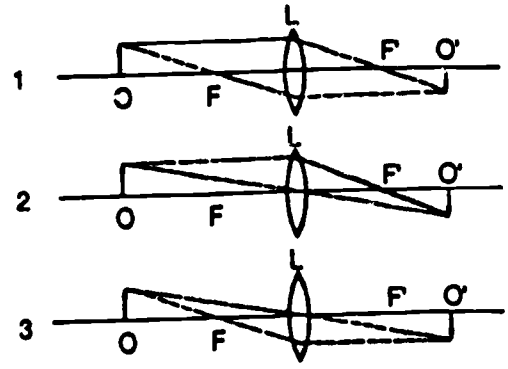
III. Electromagnetic waves travel through space as changing electric and magnetic fields.

IV. Electromagnetic waves travel at different speeds in a vacuum depending on their frequency.

The hypotheses consistent with experimental data are

- ☐ I and II only.
- ☐ II and III only.
- ☐ I, II, and III only.
- ☐ II, III, and IV only.

32. The three Diagrams 1, 2, 3, give the graphical construction for image O′ of object O as produced by the thin lens L with foci F and F′. Which, if any, of these three diagrams are correct?



- ☐ Only Diagrams 2 and 3 are correct.
- ☐ Only Diagrams 1 and 3 are correct.
- ☐ Only Diagrams 1 and 2 are correct.
- ☐ None of the diagrams is correct.
- ☐ All three diagrams are correct.

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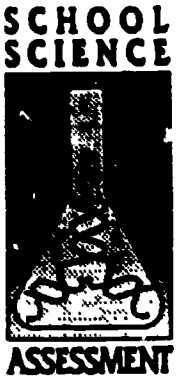
School Science Assessment



A Personalized test of

Science Understanding

for

Mary Dolman

Supported by the National Science Foundation and the U.S. Office of Education

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Please wait for the signal to begin.

1. The planet Neptune was discovered because

- ☐ of a photographic survey of the elliptic plane.
- ☐ of its proximity to Pluto.
- ☐ its gravitational effect caused small irregularities in the orbit of another planet.
- ☐ of the invention of a more powerful telescope.

2. A rocket is launched from the earth and travels to the upper limit of the earth's atmosphere. At this point its kinetic energy is 0.5×10^{10} J and its potential energy is -0.6×10^{10} J.

Which of the following statements is true?

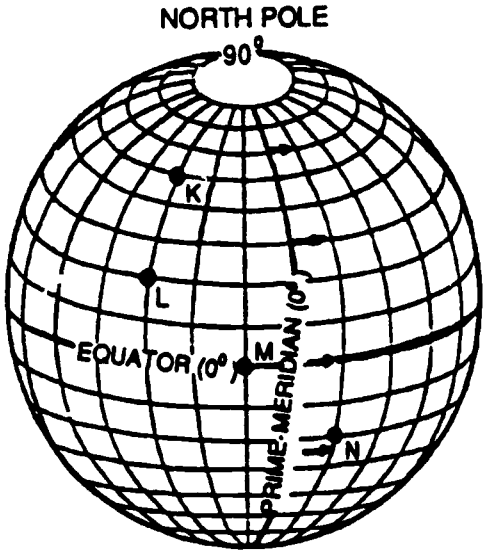
- ☐ The vehicle will escape and its binding energy is 1.1×10^{10} J.
- ☐ The vehicle will escape and its binding energy is 0.1×10^{10} J.
- ☐ The vehicle will escape and have a kinetic energy after escape of 0.1×10^{10} J.
- ☐ The vehicle will escape and have a binding energy of -0.1×10^{10} J.
- ☐ The vehicle will not escape because it has a binding energy of 0.1×10^{10} J.

3. Convectional precipitation is caused by

- ☐ warm air rising from a heated surface.
- ☐ air flowing up the side of a mountain.
- ☐ a clash of warm and cold air masses.
- ☐ warm air passing over a cold body of water.

4. The diagram below represents latitude and longitude lines on the surface of the Earth. Letters J through N represent sea level locations and the arrows show the direction of the Earth's rotation. The latitude lines shown are spaced 10° apart and the longitude lines are spaced 15° apart.

Which pair of locations (K, L, M, or N) would receive equal yearly insolation per square meter of surface if the atmosphere were completely transparent at each location?



- ☐ M, N
- ☐ K, L
- ☐ L, N
- ☐ L, M
- ☐ K, N

Please continue on next page

5. Four students determined the boiling point of pure water by boiling 5 beakers of water at sea level. The determinations were made during the same class period with the results shown below in °C. Which student obtained the most precise results?

Trial	Student A	Student B	Student C	Student D
1	101	100	104.5	105.15
2	99	99	97.5	102.85
3	102	100	101.5	102.25
4	98	98	100.0	97.95
5	100	98	101.0	101.80
Average reading	100	99	100.9	102.00
Spread	4	2	7.0	7.20

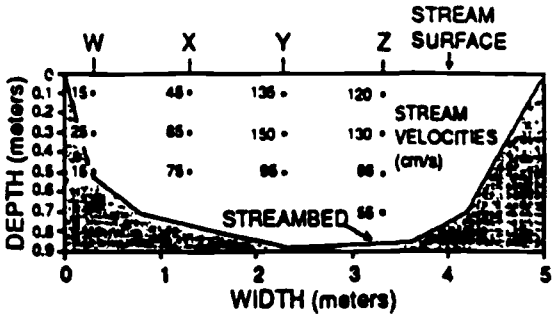
☐ A

☐ B

☐ C

☐ D

6. The diagram below represents a cross section of a shallow stream. Measured stream velocities, in centimeters per second, are shown at various points in the cross section. Which is the particle of largest size that the stream can keep in motion at location Z at a depth of 0.3 meter?



☐ silt

☐ sand

☐ pebbles

☐ cobblestones

7. An element having a long half-life that can be used for radioactive dating of rocks is

☐ thorium-14

☐ strontium-87

☐ carbon-14

☐ protactinium-234

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8. Which statement about earthquake waves best supports the inference that the Earth's outer core is liquid?

- ☐ The velocity of earthquake waves increases as the distance from an epicenter increases.
- ☐ Shear waves travel only through solids.
- ☐ Compressional waves travel faster than shear waves.
- ☐ The difference in arrival times for compressional and shear waves increases as the distance from an epicenter increases.

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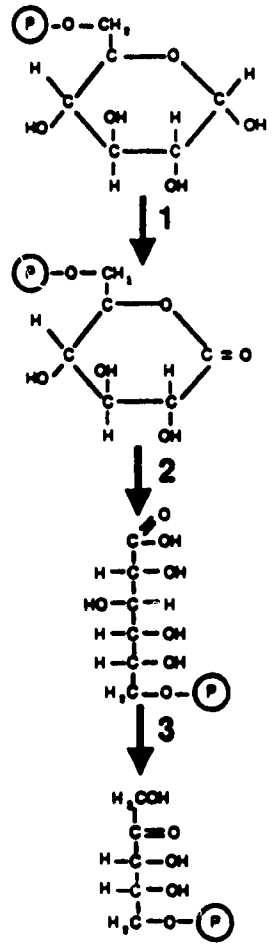
9. Elongated epidermal cells present in the roots of plants function in the process of

- ☐ absorption.
- ☐ photosynthesis.
- ☐ reproduction.
- ☐ transpiration.

10. The figure below shows three of a series of metabolic reactions occurring in cells. Where, in the sequence, would you expect NADP to be reduced as the reaction proceeds?

A SERIES OF CELLULAR METABOLIC REACTIONS



- ☐ reaction 1
- ☐ reaction 2
- ☐ reaction 3
- ☐ reaction 1 and also reaction 3
- ☐ reaction 1, reaction 2, and also reaction 3

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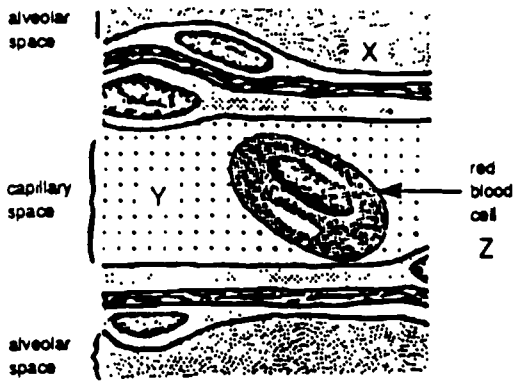
11. According to the table below, low levels of carbon monoxide in inhaled air cause SIGNIFICANTLY reduced oxygen levels in the area(s) labeled

A Diagram of a Capillary in a Human Lung



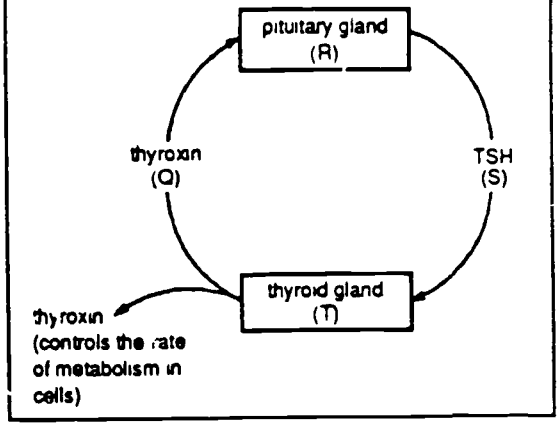
Hypothetical Data Based on the Above Diagram

Data Set	Substance Transferred From X to Y	Substance Transferred From Y to X	Substance Formed in Z	Effects of Transfer in Lung on Blood in Pulmonary Vein
I	CO_2	O_2	oxyhemoglobin	oxygen concentration is up
II	CO_2	O_2	carbamino-hemoglobin	oxygen concentration is down
III	O_2	CO_2	oxyhemoglobin	carbon dioxide concentration is down
IV	O_2	CO_2	carbamino-hemoglobin	carbon dioxide concentration is up

- ☐ X only.
- ☐ Z only.
- ☐ X and Y.
- ☐ X and Z.

12. A CORRECT interpretation of the diagram below is that a higher

Feedback Regulation of Pituitary and Thyroid Gland Secretions



- ☐ metabolic rate in cells induces T to produce more Q.
- ☐ metabolic rate in cells induces T to produce less Q.
- ☐ level of Q induces R to produce more S.
- ☐ level of Q induces R to produce less S.

13. If the cells in the meristematic region of a root tip are observed under a light microscope, it is possible to determine the stage of mitosis of each cell when the material was prepared.

Features which enable this to be determined include all of the following EXCEPT

- ☐ the presence or absence of centrioles in the cell.
- ☐ the presence of a nuclear membrane and nucleolus.
- ☐ the arrangement of any chromosomes visible.
- ☐ whether or not any distinct chromosomes are visible.

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14. In a certain species of animals, black fur (B) is dominant and white fur (b) is recessive. The percentage of white animals (bb) is 36 percent. According to the Hardy-Weinberg Principle, the percentage of heterozygous black animals would be

- ☐ 24%
- ☐ 48%
- ☐ 16%
- ☐ 36%
- ☐ 64%

15. Without knowing the common names of *Poa pratensis*, *Poa annua*, and *Poa autumnalis*, you know that these organisms are in the same

- ☐ class.
- ☐ family.
- ☐ genus.
- ☐ order.

16. Which of the following best represents the principle that ontogeny recapitulates phylogeny?

- ☐ the similarity of human and bird embryos at early stages of development
- ☐ the passing of inherited characteristics from one generation to the next
- ☐ the similarity of adult organisms sharing a common ancestor
- ☐ the classification of organisms into kingdoms, phyla, classes, and orders

STOP

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17. The Periodic Table, based on an octet pattern, led Mendeleev to predict the existence of an element which he referred to as eka-silicon. This element is now known as

- ☐ sodium.
- ☐ gallium.
- ☐ germanium.
- ☐ neptunium.

18. Within a family in the periodic table, why is the metal with the lowest ionization energy usually the one with the highest atomic number?

- ☐ Larger atoms are less likely to be spherical.
- ☐ Larger atoms are less likely to pack close together.
- ☐ The heaviest particles have the greatest kinetic energies.
- ☐ The distance between the nucleus and the electrons is greatest for the heaviest atoms.

19. An operating lead storage battery involves the two half-reactions listed below. When a lead storage battery is discharged,

$PbO_2(s) + SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$ $E^\circ = +1.68\ V$
$PbSO_4(s) + 2e^- \rightarrow Pb(s) + SO_4^{2-}(aq)$ $E^\circ = -0.36\ V$

- ☐ lead(IV) oxide is consumed.
- ☐ lead is produced.
- ☐ lead(II) sulfate is consumed.
- ☐ sulfuric acid concentration increases.

20. Which type of reaction is represented by the equation below?

$$C_6H_{12}O_6 \xrightarrow{\text{zymase}} 2C_2H_5OH + 2CO_2$$

- ☐ saponification
- ☐ fermentation
- ☐ esterification
- ☐ polymerization

21. A student prepared a solution of acidified $SnCl_2(aq)$ and then titrated this solution with $KMnO_4(aq)$. The student's data were recorded as shown in the table below. In order to calculate correctly the concentration of $MnO_4^-(aq)$, in addition to the balanced chemical equation, one would use

I. concentration of $SnCl_2$ (aq)	0.0790 mol/L
II. volume of $SnCl_2$ (aq) solution prepared	100.0 mL
III. volume of acid added to $SnCl_2$ (aq)	3.0 mL
IV. volume of $SnCl_2$ (aq) solution used in the titration	10.0 mL
V. volume of $KMnO_4$ (aq) solution used in the titration	12.8 mL

- ☐ I, II, and V.
- ☐ I, IV, and V.
- ☐ I, II, IV, and V.
- ☐ I, II, III, IV, and V.

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22. In an electrochemical cell with zinc and lead as electrodes, 3.0 A are generated for 6.0 h. The mass lost at the anode is

- ☐ 1.4×10^2 g
- ☐ 8.8×10^1 g
- ☐ 4.4×10^1 g
- ☐ 2.2×10^1 g

23. By what factor would the concentration of hydrogen (hydronium) ions be decreased if the pH of a solution changed from 2.0 to 4.0?

- ☐ 2
- ☐ 6
- ☐ 8
- ☐ 20
- ☐ 100

24. An ideal gas is compressed at constant temperature from 1.0 atm to 2.0 atm. What happens to the number of molecular collisions and to the average momentum per collision with the walls of the container?

	Number of Collisions	Average Momentum per Collision
A	increases	stays the same
B	increases	increases
C	decreases	stays the same
D	stays the same	stays the same

- ☐ A
- ☐ B
- ☐ C
- ☐ D

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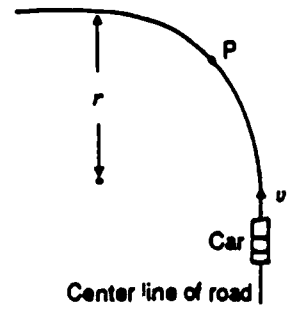
25. When a number of forces are applied to an object, the acceleration produced is

- ☐ equal to the numerical sum of the forces acting on the object.
- ☐ equal to the unbalanced force acting on the object.
- ☐ directly proportional to the mass of the object.
- ☐ directly proportional to the unbalanced force acting on the object.
- ☐ directly proportional to the product of the mass and the unbalanced force on the object.

26. A car is about to turn an unbanked corner of radius r, as shown, at constant speed v. Inside the car are two balloons. The lighter balloon is filled with a gas less dense than air and fastened by a string to the floor. The heavier balloon is filled with a gas more dense than air and hung by a string from the ceiling. Both balloons are located in the middle of the car when the car travels in a straight line. The balloons are free to swing right or left within the car.

When the car is at point P on the curve,



- ☐ both balloons are in the middle of the car.
- ☐ both balloons lean toward the inside of the curve.
- ☐ both balloons lean toward the outside of the curve.
- ☐ the lighter balloon leans toward the inside of the curve while the heavier balloon leans toward the outside.
- ☐ the heavier balloon leans toward the inside of the curve while the lighter balloon leans toward the outside.

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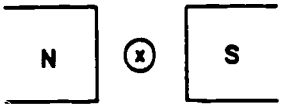
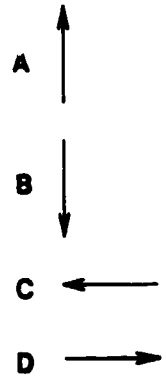
27. The conclusion from the Millikan oil drop experiment was that

- ☐ the mass to charge ratio of the electrons is very small.
- ☐ there exists a smallest electric charge.
- ☐ the electron has a negative charge.
- ☐ the proton has a positive charge.
- ☐ the speed of the electrons is very great.

28. The diagram below illustrates a straight wire conductor situated between the poles of a permanent magnet. The poles of the magnet are in the plane of the page, and the wire is perpendicular to the plane of the page. The wire is carrying an electron flow away from you into the plane of the page as indicated by the cross.

The direction of the magnetic force on the wire is





E the same as the electron flow

- ☐ A
- ☐ B
- ☐ C
- ☐ D
- ☐ E

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29. A student knows the specific heat capacity of water from previous experiments. During the laboratory determination of the specific heat capacity of a metal by the method of mixtures, the student measures the following:

1. the mass of cold water in a cup

2. the initial and final temperature of the water in the cup

3. the mass of the metal

What additional measurement is needed to determine the specific heat capacity of the metal?

- ☐ the volume of cold water in the cup
- ☐ the final temperature of the metal sample
- ☐ the initial temperature of the metal sample
- ☐ the mass of the boiling water
- ☐ the specific heat capacity of the water

30. The order of magnitude of the kinetic energy of a proton having mass 2×10^{-27} kg and traveling at 3×10^{8} m/s is

- ☐ 10^{-31} J
- ☐ 10^{-14} J
- ☐ 10^{-15} J
- ☐ 10^{-16} J
- ☐ 10^{-21} J

31. The interference pattern of monochromatic light is to be used to measure very small distances. Numerous clearly defined interference lines, as widely spaced as possible, are required.

Which of the following experimental conditions will produce the most suitable interference pattern?

- ☐ Green light incident on a wide single slit.
- ☐ Red light incident on a narrow single slit.
- ☐ Red light incident on a double slit which has a narrow slit width and a small distance between the slits.
- ☐ Red light incident on a double slit which has a wide slit width and a small distance between the slits.
- ☐ Blue light incident on a double slit which has a narrow slit width and a large distance between the slits.

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If you wish to receive a report of your performance on this test, please print your address in the spaces provided below.

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