



Taking the SAT[®] II: Subject Tests

Mathematics

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The College Board: Expanding College Opportunity

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Each year, the College Board serves over three million students and their parents, 23,000 high schools, and 3,500 colleges through major programs and services in college admissions, guidance, assessment, financial aid, enrollment, and teaching and learning. Among its best-known programs are the SAT[®], the PSAT/NMSQT[®], and the Advanced Placement Program[®] (AP[®]). The College Board is committed to the principles of excellence and equity, and that commitment is embodied in all of its programs, services, activities, and concerns.

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Mathematics

one-hour subject tests

PURPOSE

- Measure students' knowledge of mathematics through the first three years of college-preparatory mathematics for Level IC and through precalculus for Level IIC

FORMAT

- 50 multiple-choice questions
- The tests cover content typically taught in the first three years (for Level IC) or four years (for Level IIC) of college-preparatory mathematics. Students are not expected to have studied every topic on either test.

CALCULATORS

- Both tests require the use of a scientific or graphing calculator. It is not necessary to use a calculator to solve every question, but it is important to know when and how to use one. Students who take these tests without a calculator will be at a disadvantage.
- Both tests are developed with the expectation that most students are using graphing calculators. A graphing calculator may provide an advantage over a scientific calculator on some questions. However, you should bring the calculator with which you are most familiar.
- For 50–60% of the questions on Level IC and 35–45% of the questions on Level IIC, there is no advantage, perhaps even a disadvantage, to using a calculator. For 40–50% of the questions on Level IC and 55–65% of the questions on Level IIC, a calculator may be useful or necessary.

RECOMMENDED PREPARATION

Mathematics Level IC

- Three years of college-preparatory mathematics, including two years of algebra and one year of geometry

Mathematics Level IIC

- More than three years of college-preparatory mathematics, including two years of algebra, one year of geometry, and elementary functions (precalculus) and/or trigonometry
- If you have had preparation in trigonometry and elementary functions and have attained grades of B or better in these courses, select Level IIC. If you are sufficiently prepared to take Level IIC but take Level IC in hopes of receiving a higher score, you may not do as well as you expect.

COMPARISONS BETWEEN THE TESTS

CONTENT	Approximate % of Test	
	IC	IIC
Topics Covered*		
Number and Operations Operations, ratio & proportion, complex numbers, counting, elementary number theory, matrices, sequences, <i>series, vectors</i>	10–14	10–14
Algebra and Functions Expressions, equations, inequalities, representation and modeling, properties of functions (linear, polynomial, rational, exponential, <i>logarithmic, trigonometric, inverse trigonometric, periodic, piecewise, recursive, parametric</i>)	38–42	48–52
Geometry and Measurement	38–42	28–32
Plane Euclidean/Measurement	18–22	----
Coordinate Lines, parabolas, circles, <i>ellipses, hyperbolas</i> , symmetry, transformations, <i>polar coordinates</i>	8–12	10–14
Three-dimensional Solids, surface area & volume (cylinders, cones, pyramids, spheres, prisms), <i>coordinates in three dimensions</i>	4–6	4–6
Trigonometry Right triangles, identities, <i>radian measure, law of cosines, law of sines, equations, double angle formulas</i>	6–8	12–16
Data Analysis, Statistics, and Probability Mean, median, mode, range, interquartile range, <i>standard deviation</i> , graphs and plots, regression (linear, <i>quadratic, exponential</i>), probability	6–10	6–10

*Topics in italics are tested on the Level IIC Test only. The content of Level IC overlaps somewhat with that on Level IIC, but the emphasis on Level IIC is on more advanced content. Plane Euclidean Geometry is not tested directly on Level IIC.

SCORE

- Total score: 200-to-800 scale
- Because the content measured by the two tests differs considerably, you should not use your score on one test to predict your score on the other.

GEOMETRIC FIGURES

Figures that accompany problems are intended to provide information useful in solving the problems. They are drawn as accurately as possible EXCEPT when it is stated in a particular problem that the figure is not drawn to scale. Even when figures are not drawn to scale, the relative positions of points and angles may be assumed to be in the order shown. Also, line segments that extend through points and appear to lie on the same line may be assumed to be on the same line. The text “Note: Figure not drawn to scale.” is included on the test when degree measures may not be accurately shown and specific lengths may not be drawn proportionally.

MORE ABOUT CALCULATOR USE

You may NOT use a calculator on any Subject Test EXCEPT the Mathematics Level IC and Mathematics Level IIC Tests.

What Type of Calculator Should I Bring?

- Bring a calculator that you are used to using. It may be a scientific or a graphing calculator. If you're comfortable with both a scientific and a graphing calculator, bring a graphing calculator.
- Verify that your calculator is in good working condition before you take the test. You may bring batteries and a backup calculator to the test center.
- No substitute calculators or batteries will be available at the test center. Students may not share calculators.
- If your calculator malfunctions during the Level IC or Level IIC Tests and you do not have a backup calculator, you must tell your test supervisor when the malfunction occurs in order to cancel scores on these tests only.

The Following Are NOT Permitted:

- Calculators with QWERTY (typewriter-like) keypads
- Calculators with paper tape
- Calculators that make noise or “talk”
- Calculators that require an electrical outlet
- Pocket organizers
- Handheld and laptop computers
- Electronic writing pads and pen-input devices
- Cell phones that contain calculators

Using the Calculator

- Remember, only some questions on these tests require the use of a calculator. First decide how you will solve a problem; then determine whether the calculator is needed.
- Do not round any intermediate calculations. If you get a result from the calculator for the first step of a solution, keep the result in the calculator and use it for the second step. If you round the result from the first step, your answer may not be one of the choices.

For more information about the Mathematics Subject Tests, visit the College Board's SAT II Learning Center at www.collegeboard.com.

Sample Questions

All questions in the Mathematics Level IC and Mathematics Level IIC Tests are multiple-choice questions in which you are asked to choose the **BEST** response from the five choices offered. The directions for the tests are below:

Directions: For each of the following problems, decide which is the BEST of the choices given. If the exact numerical value is not one of the choices, select the choice that best approximates this value. Then fill in the corresponding oval on the answer sheet.

Notes: (1) A scientific or graphing calculator will be necessary for answering some (but not all) of the questions in this test. For each question you will have to decide whether or not you should use a calculator.

IC: (2) The only angle measure used on this test is degree measure. Make sure your calculator is in the degree mode.

IIC: (2) For some questions in this test you may have to decide whether your calculator should be in the radian mode or the degree mode.

(3) Figures that accompany problems in this test are intended to provide information useful in solving the problems. They are drawn as accurately as possible EXCEPT when it is stated in a specific problem that its figure is not drawn to scale. All figures lie in a plane unless otherwise indicated.

(4) Unless otherwise specified, the domain of any function f is assumed to be the set of all real numbers x for which $f(x)$ is a real number.

(5) Reference information that may be useful in answering the questions in this test can be found on the page preceding Question 1.

Reference Information. The following information is for your reference in answering some of the questions in this test.

Volume of a right circular cone with radius r and height h : $V = \frac{1}{3}\pi r^2 h$

Lateral Area of a right circular cone with circumference of the base c and slant height ℓ : $S = \frac{1}{2}c\ell$

Volume of a sphere with radius r : $V = \frac{4}{3}\pi r^3$

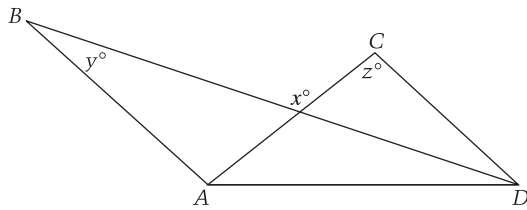
Surface Area of a sphere with radius r : $S = 4\pi r^2$

Volume of a pyramid with base area B and height h :
 $V = \frac{1}{3}Bh$

MATHEMATICS LEVEL IC

1. A band wants to distribute its music on compact discs (CD's). The equipment to produce the CD's costs \$250, and blank CD's cost \$5.90 for a package of 10. Which of the following represents the total cost, in dollars, to produce n CD's, where n is a multiple of 10?

- (A) $(250 + 0.59)n$ (B) $250 + 0.59n$
 (C) $(250 + 5.90)n$ (D) $250 + 5.90n$
 (E) $250n + 5.90$



2. In the figure above, \overline{AB} and \overline{CD} are parallel. What is x in terms of y and z ?

- (A) $y + z$
 (B) $2y + z$
 (C) $2y - z$
 (D) $180 - y - z$
 (E) $180 + y - z$

3. A number n is increased by 8. If the cube root of that result equals -0.5 , what is the value of n ?

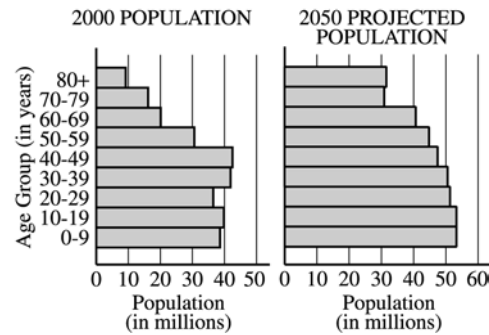
- (A) -15.625
 (B) -8.794
 (C) -8.125
 (D) -7.875
 (E) 421.875

4. If a and b are real numbers, $i^2 = -1$, and $(a + b) + 5i = 9 + ai$, what is the value of b ?

- (A) 4 (B) 5 (C) 9
 (D) $4 + 5i$ (E) $5 + 4i$

5. What are all values of x for which $4 - x^2 \geq x - 2$?

- (A) $x \geq -3$
 (B) $-5 \leq x \leq 0$
 (C) $-3 \leq x \leq 2$
 (D) $x \leq -3$ or $x \geq 2$
 (E) $-2 \leq x \leq 3$



6. The graphs above show United States Census Bureau population figures for the year 2000 for various age groups, together with projections for the year 2050. Of the following age groups, for which is the projected percent increase in population from 2000 to 2050 greatest?

- (A) 30–39
 (B) 40–49
 (C) 50–59
 (D) 60–69
 (E) 70–79

7. If $\log_c a = x$, which of the following must be true?

- (A) $a^c = x$ (B) $a^x = c$ (C) $c^a = x$
 (D) $c^x = a$ (E) $x^c = a$

8. If $f(x) = x + 3$ and $g(x) = \frac{x^2 - 9}{x - 3}$, how are the graphs of f and g related?

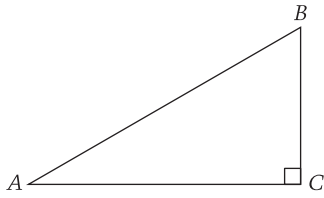
- (A) They are exactly the same.
 (B) They are the same except when $x = 3$.
 (C) They are the same except when $x = -3$.
 (D) They have the same shape but only a finite number of points in common.
 (E) They have no points in common.

9. If line ℓ is the perpendicular bisector of the line segment with endpoints $(2, 0)$ and $(0, -2)$, what is the slope of line ℓ ?

- (A) 2 (B) 1 (C) 0 (D) -1 (E) -2

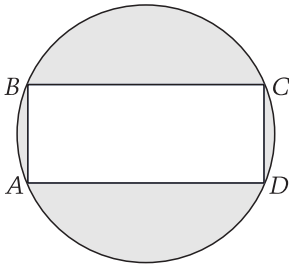
10. Twenty students have each sampled one or more of three kinds of candy bars that a school store sells. If 3 students have sampled all three kinds, and 5 have sampled exactly two kinds, how many of these students have sampled only one kind?

- (A) 8 (B) 12 (C) 15 (D) 17 (E) 18



Note: Figure not drawn to scale.

11. In the figure above, $\triangle ABC$ has a right angle at C . If the length of side AC is 10 and the measure of $\angle BAC$ is 22° , what is the length of side BC ?
 (A) 3.7 (B) 4.0 (C) 5.8 (D) 6.8 (E) 9.3
12. In a certain community, 70 percent of the families reported household incomes equal to or greater than \$25,000 per year. Which of the following must be greater than or equal to \$25,000?
 I. The mean income
 II. The mode of the incomes
 III. The median income
 (A) I only (B) II only (C) III only
 (D) I and III (E) II and III
13. The front, side, and bottom faces of a rectangular solid have areas of 24 square centimeters, 8 square centimeters, and 3 square centimeters, respectively. What is the volume of the solid, in cubic centimeters?
 (A) 24 (B) 96 (C) 192 (D) 288 (E) 576

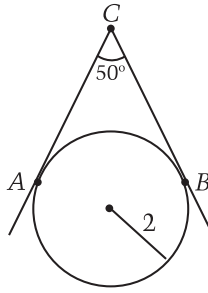


14. Rectangle $ABCD$ is inscribed in the circle shown above. If the length of side AB is 5 and the length of side BC is 12, what is the area of the shaded region?
 (A) 40.8 (B) 53.1 (C) 72.7 (D) 78.5 (E) 81.7
15. If $f(x) = x^4 - 3x^3 - 9x^2 + 4$, for how many real numbers k does $f(k) = 2$?
 (A) None (B) One (C) Two
 (D) Three (E) Four

16. If the measure of one angle of a rhombus is 60° , then the ratio of the length of its longer diagonal to the length of its shorter diagonal is
 (A) 2 (B) $\sqrt{3}$ (C) $\sqrt{2}$ (D) $\frac{\sqrt{3}}{2}$ (E) $\frac{\sqrt{2}}{2}$

MATHEMATICS LEVEL IIC

17. What is the distance in space between the points with coordinates $(-3, 6, 7)$ and $(2, -1, 4)$?
 (A) 4.36 (B) 5.92 (C) 7.91 (D) 9.11 (E) 22.25
18. If $f(x) = \frac{3x + 12}{2x - 12}$, what value does $f(x)$ approach as x gets infinitely larger?
 (A) -6 (B) $-\frac{3}{2}$ (C) -1 (D) $\frac{2}{3}$ (E) $\frac{3}{2}$
19. In January 1990 the world's population was 5.3 billion. Assuming a growth rate of 2 percent per year, the world's population, in billions, for t years after 1990 can be modeled by the equation $P = 5.3(1.02)^t$. According to the model, the population growth from January 1995 to January 1996 was
 (A) 106,000,000
 (B) 114,700,000
 (C) 117,000,000
 (D) 445,600,000
 (E) 562,700,000
20. What is the measure of one of the larger angles of a parallelogram in the xy -plane that has vertices with coordinates $(2, 1)$, $(5, 1)$, $(3, 5)$, and $(6, 5)$?
 (A) 93.4° (B) 96.8° (C) 104.0°
 (D) 108.3° (E) 119.0°
21. For some real number t , the first three terms of an arithmetic sequence are $2t$, $5t - 1$, and $6t + 2$. What is the numerical value of the fourth term?
 (A) 4 (B) 8 (C) 10 (D) 16 (E) 19
22. The diameter and height of a right circular cylinder are equal. If the volume of the cylinder is 2, what is the height of the cylinder?
 (A) 1.37 (B) 1.08 (C) 0.86 (D) 0.80 (E) 0.68
23. If $\sin \theta = 0.57$, then $\sin(\pi - \theta) =$
 (A) -0.57 (B) -0.43 (C) 0 (D) 0.43 (E) 0.57
24. In a group of 10 people, 60 percent have brown eyes. Two people are to be selected at random from the group. What is the probability that neither person selected will have brown eyes?
 (A) 0.13 (B) 0.16 (C) 0.25 (D) 0.36 (E) 0.64



25. In the figure above, two lines are tangent to a circle of radius 2 at points A and B . What is the length of segment AB (not shown)?

- (A) 1.37 (B) 1.69 (C) 3.06 (D) 3.63 (E) 4

26. If $x - 2$ is a factor of $x^3 + kx^2 + 12x - 8$, then $k =$

- (A) -6 (B) -3 (C) 2 (D) 3 (E) 6

27. If $f(x) = \sqrt[3]{x^3 + 1}$, what is $f^{-1}(1.5)$?

- (A) 3.4 (B) 2.4 (C) 1.6 (D) 1.5 (E) 1.3

$$C = -1.02F + 93.63$$

28. The linear regression model above is based on an analysis of nutritional data from 14 varieties of cereal bars to relate the percent of calories from fat (F) to the percent of calories from carbohydrates (C). Based on this model, which of the following statements must be true?

- I. There is a positive correlation between C and F .
- II. When 20 percent of calories are from fat, the predicted percent of calories from carbohydrates is approximately 73.
- III. The slope indicates that as F increases by 1, C decreases by 1.02.

- (A) II only (B) I and II only (C) I and III only
(D) II and III only (E) I, II, and III

29. A line has parametric equations $x = 5 + t$ and $y = 7 + t$, where t is the parameter. The slope of the line is

- (A) $\frac{5}{7}$ (B) 1 (C) $\frac{7+t}{5+t}$ (D) $\frac{7}{5}$ (E) 7

30. What is the range of the function defined by

$$f(x) = \frac{1}{x} + 2?$$

- (A) All real numbers
(B) All real numbers except $-\frac{1}{2}$
(C) All real numbers except 0
(D) All real numbers except 2
(E) All real numbers between 2 and 3

31. The number of hours of daylight, d , in Hartsville can be modeled by $d = \frac{35}{3} + \frac{7}{3} \sin\left(\frac{2\pi}{365}t\right)$,

where t is the number of days after March 21. The day with the greatest number of hours of daylight has how many more daylight hours than May 1? (March and May have 31 days each. April and June have 30 days each.)

- (A) 0.8 hr (B) 1.5 hr (C) 2.3 hr (D) 3.0 hr (E) 4.7 hr

	Day 1	Day 2	Day 3
Model X	20	18	3
Model Y	16	5	8
Model Z	19	11	10

32. The table above shows the number of digital cameras that were sold during a three-day sale. The prices of models X, Y, and Z are \$99, \$199, and \$299, respectively. Which of the following matrix representations gives the total income, in dollars, received from the sale of the cameras for each of the three days?

(A) $\begin{bmatrix} 20 & 18 & 3 \\ 16 & 5 & 8 \\ 19 & 11 & 10 \end{bmatrix} \begin{bmatrix} 99 & 199 & 299 \end{bmatrix}$

(B) $\begin{bmatrix} 20 & 18 & 3 \\ 16 & 5 & 8 \\ 19 & 11 & 10 \end{bmatrix} \begin{bmatrix} 99 \\ 199 \\ 299 \end{bmatrix}$

(C) $\begin{bmatrix} 99 & 199 & 299 \end{bmatrix} \begin{bmatrix} 20 & 18 & 3 \\ 16 & 5 & 8 \\ 19 & 11 & 10 \end{bmatrix}$

(D) $\begin{bmatrix} 99 \\ 199 \\ 299 \end{bmatrix} \begin{bmatrix} 20 & 18 & 3 \\ 16 & 5 & 8 \\ 19 & 11 & 10 \end{bmatrix}$

(E) $99 \begin{bmatrix} 20 & 18 & 3 \\ 16 & 5 & 8 \\ 19 & 11 & 10 \end{bmatrix} + 199 \begin{bmatrix} 20 & 18 & 3 \\ 16 & 5 & 8 \\ 19 & 11 & 10 \end{bmatrix} + 299 \begin{bmatrix} 20 & 18 & 3 \\ 16 & 5 & 8 \\ 19 & 11 & 10 \end{bmatrix}$

ANSWERS

The estimated difficulty level, on a scale of 1 to 5, with 1 the easiest and 5 the most difficult, is in parentheses.

Level I C

- | | | | |
|----------|----------|-----------|-----------|
| 1. B (2) | 5. C (3) | 9. D (4) | 13. A (4) |
| 2. A (2) | 6. D (4) | 10. B (3) | 14. C (4) |
| 3. C (2) | 7. D (3) | 11. B (3) | 15. E (3) |
| 4. A (3) | 8. B (4) | 12. C (4) | 16. B (5) |

Level II C

- | | | | |
|-----------|-----------|-----------|-----------|
| 17. D (2) | 21. E (4) | 25. D (4) | 29. B (3) |
| 18. E (2) | 22. A (3) | 26. A (2) | 30. D (3) |
| 19. C (4) | 23. E (3) | 27. E (4) | 31. A (4) |
| 20. C (4) | 24. A (4) | 28. D (4) | 32. C (3) |



Taking the SAT® II: Subject Tests

Biology E/M

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Biology E/M

one-hour subject test

PURPOSE

- measure knowledge of biology at a college-preparatory level with either an ecological emphasis (Biology E) or a molecular emphasis (Biology M)

How To Choose Biology E or M

- Take Biology E if you feel more comfortable answering questions pertaining to biological communities, populations, and energy flow.
- Take Biology M if you feel more comfortable answering questions pertaining to biochemistry, cellular structure and processes, such as respiration and photosynthesis.
- Indicate choice of Biology E or Biology M on your answer sheet on test day.

FORMAT

Both Biology E and M have:

- 80 multiple-choice questions
- 60 of the 80 questions are common to both Biology E and M, followed by 20 specialized questions for each section

RECOMMENDED PREPARATION

- one-year course in biology
- one-year course in algebra and familiarity with simple algebraic concepts such as ratios and direct and inverse proportions
- laboratory experience

Ability To:

- recall and understand the major concepts of biology and to apply the principles
- organize and interpret results obtained by observation and experimentation
- draw conclusions or make inferences from experimental data, including data presented in graphic or tabular form

OTHER

- calculator use is not permitted
- problem solving requires simple numerical calculations using the metric system

SCORE

- Total score: 200-to-800 scale

CONTENT

	Approximate % of E Test	Approximate % of M Test
Cellular and Molecular Biology <i>Cell structure and organization, mitosis, photosynthesis, cellular respiration, enzymes, biosynthesis, biological chemistry</i>	15	27
Ecology <i>Energy flow, nutrient cycles, populations, communities, ecosystems, biomes, conservation biology, biodiversity, effects of human intervention</i>	23	13
Genetics <i>Meiosis, Mendelian genetics, inheritance patterns, molecular genetics, population genetics</i>	15	20
Organismal Biology <i>Structure, function, and development of organisms (with emphasis on plants and animals), animal behavior</i>	25	25
Evolution and Diversity <i>Origin of life, evidence of evolution, patterns of evolution, natural selection, speciation, classification and diversity of organisms</i>	22	15

BIOLOGY-E AND BIOLOGY-M

	Approximate % of Test
Skills Specifications	
Knowledge of Fundamental Concepts: <i>remembering specific facts; demonstrating straightforward knowledge of information and familiarity with terminology</i>	30
Application: <i>understanding concepts and reformulating information into other equivalent forms; applying knowledge to unfamiliar and/or practical situations; solving problems using mathematical relationships</i>	35
Interpretation: <i>inferring and deducing from qualitative and quantitative data and integrating information to form conclusions; recognizing unstated assumptions</i>	35

Sample Questions

All of the questions in the test are multiple-choice questions for which you must choose the best response from the five choices offered. Some questions are grouped in sets that refer to a common figure, table, or laboratory experiment.

BIOLOGY E/M CORE SECTION

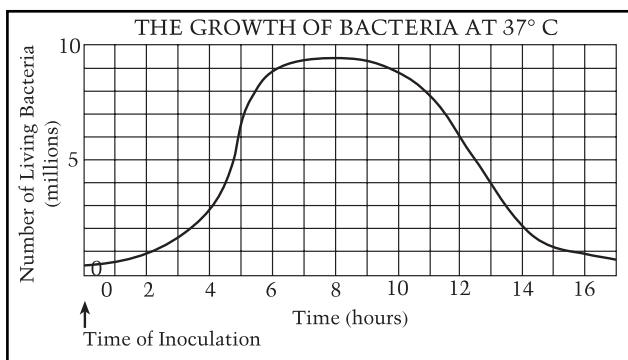
Directions: Each set of lettered choices below refers to the numbered statements immediately following it. Select the one lettered choice that best fits each statement and then fill in the corresponding oval on the answer sheet. A choice may be used once, more than once, or not at all in each set.

Questions 1–2

- (A) Decomposers (e.g., bacteria)
- (B) Producers (e.g., grasses)
- (C) Primary consumers (e.g., mice)
- (D) Secondary consumers (e.g., snakes)
- (E) Tertiary consumers (e.g., hawks)

1. Organisms that comprise the greatest mass of living substance (biomass) in a terrestrial food chain
2. Organisms that convert nitrogen-containing organic molecules into nitrates

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and then fill in the corresponding oval on the answer sheet.

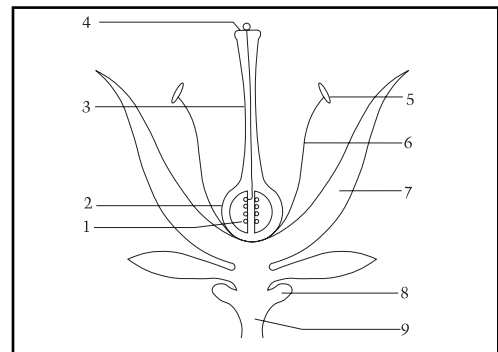


3. In the graph above, the time when the number of living bacteria is increasing at the greatest rate occurs
 - (A) during the first 2 hours
 - (B) between the 2nd and the 4th hour
 - (C) between the 4th and the 6th hour
 - (D) between the 6th and the 10th hour
 - (E) between the 11th and the 13th hour

4. ATP is produced during which of the following processes?
 - I. Photosynthesis
 - II. Aerobic respiration
 - III. Fermentation
 - (A) I only
 - (B) II only
 - (C) I and III only
 - (D) II and III only
 - (E) I, II, and III
5. All of the following are population characteristics EXCEPT
 - (A) number of individuals
 - (B) phenotype
 - (C) sex ratio
 - (D) age distribution
 - (E) death rate

6. True statements about the development of the frog and mouse embryos include which of the following?
 - I. Both the frog and the mouse embryos develop in an aqueous environment.
 - II. Both the frog and the mouse embryos depend on a large supply of yolk to sustain the developing embryo.
 - III. Both the frog and the mouse embryos develop a 4-chambered heart.
 - (A) I only
 - (B) III only
 - (C) I and II only
 - (D) II and III only
 - (E) I, II, and III

Questions 7–8 refer to the following diagram:



7. Commonly, the fruit is derived from
 - (A) 2
 - (B) 4
 - (C) 7
 - (D) 8
 - (E) 9
8. Pollination involves a transfer of pollen from
 - (A) 4 to 1
 - (B) 4 to 2
 - (C) 4 to 5
 - (D) 5 to 4
 - (E) 5 to 9

Directions: Each group of questions below concerns a laboratory or experimental situation. In each case, first study the description of the situation. Then choose the one best answer to each question following it and fill in the corresponding oval on the answer sheet.

Questions 9–10

In a breeding experiment using gray and white mice of unknown genotypes, the following results were obtained.

CROSS	Parents		Offspring		
	FEMALE	MALE	GRAY	WHITE	
I	Gray	x	White	82	78
II	Gray	x	Gray	118	39
III	White	x	White	0	50
IV	Gray	x	White	74	0

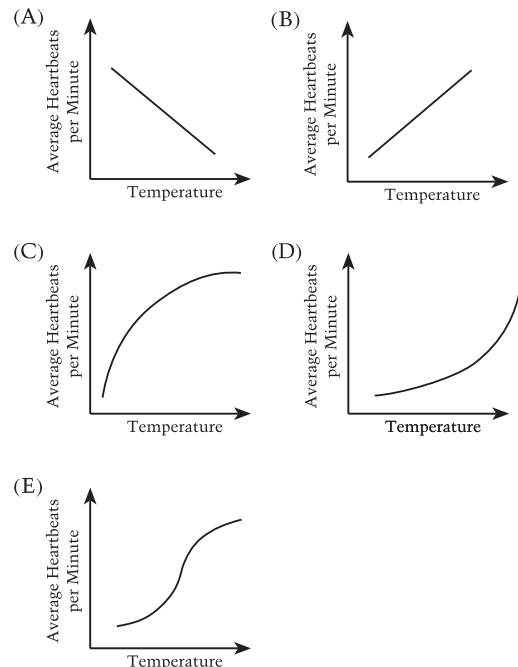
9. If the gray female from cross IV were mated with the gray male from cross II, then which of the following would most likely be true?
- (A) All of the offspring would be gray.
 (B) All of the offspring would be white.
 (C) Half of the offspring would be gray.
 (D) One-quarter of the offspring would be gray.
 (E) One-quarter of the offspring would be white.
10. If two gray progeny of cross IV mate with each other, what is the probability that any one individual offspring will be gray?
- (A) 100% (B) 75% (C) 50% (D) 25% (E) 0

Questions 11–12

Three students added equal volumes of pond water to each of four beakers (I–IV) and placed each in a different constant temperature bath, maintained at 5°C, 15°C, 25°C, and 35°C, respectively. The students then added 6 water fleas, *Daphnia pulex*, to each of the four beakers and recorded the time in each case. After 1 hour, the students removed 3 *Daphnia pulex* from each beaker and each student immediately observed one *Daphnia pulex* under low-power magnification of a light microscope. (The transparent body of the *Daphnia pulex* can be seen easily under a light microscope.) Heart rates were recorded as beats per minute. The results of the experiment are summarized in the chart below.

BEAKER	TEMPERATURE	TIME	TIME	HEARTBEATS PER MINUTE (average of 3 <i>Daphnia</i>)
		DAPHNIA ADDED	DAPHNIA REMOVED	
I	5°C	2:00 p.m.	3:00 p.m.	41
II	15°C	2:10 p.m.	3:10 p.m.	119
III	25°C	2:20 p.m.	3:20 p.m.	202
IV	35°C	2:30 p.m.	3:30 p.m.	281

11. The independent variable in this experiment is the
- (A) amount of light
 (B) number of water fleas
 (C) pH of the water
 (D) temperature of the water
 (E) average heart rate
12. If a graph is constructed using the data given in the table, it will most closely resemble which of the following?



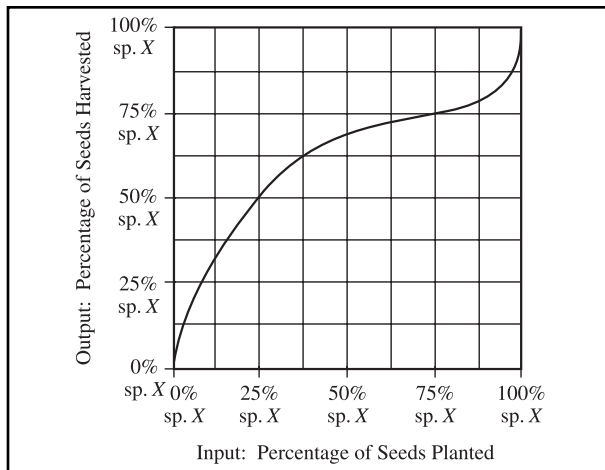
BIOLOGY E SECTION

13. Which of the following individuals is most fit in evolutionary terms?
- (A) A child who does not become infected with any of the usual childhood diseases, such as measles or chicken pox
 (B) A woman of 40 with seven adult offspring
 (C) A woman of 80 who has one adult offspring
 (D) A 100-year old man with no offspring
 (E) A childless man who can run a mile in less than five minutes

(More Biology E questions on next page.)

Questions 14–15

Known numbers of seeds from two species (*X* and *Y*) of annual plants are mixed together in different proportions and planted in five small plots of soil in the spring. The plants grow, flower, and produce seeds. It is found that the percentage of seeds of species *X* and species *Y* in the harvest is usually different from the proportion that was planted, although the total number of seeds produced is the same as the number of seeds planted. The data are plotted on the graph below.



14. What mixture of seeds was harvested in the plot that was planted with 25 percent species *X* and 75 percent species *Y*?

	X	Y
(A)	25%	75%
(B)	40%	60%
(C)	50%	50%
(D)	60%	40%
(E)	75%	25%

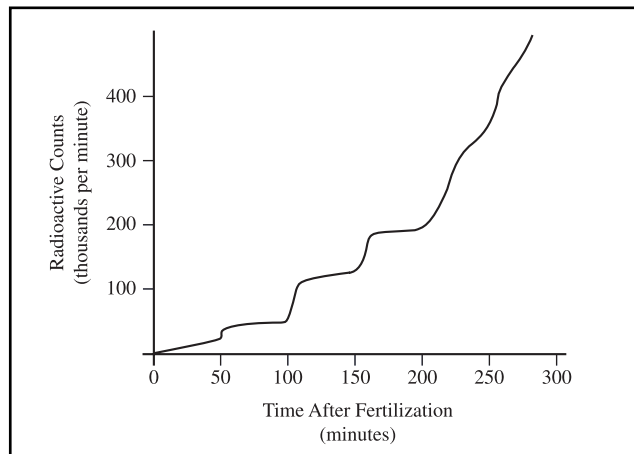
15. What do the data indicate about the ecological relationship between species *X* and species *Y*?
- (A) *X* and *Y* are mutualistic for low percentages of *X* seeds.
 (B) *X* and *Y* are mutualistic for high percentages of *X* seeds.
 (C) *X* and *Y* compete when both *X* and *Y* seeds are present.
 (D) *Y* competes successfully against *X* at all percentages of *X* and *Y* seeds.
 (E) *X* is parasite of *Y* when *Y* is rare.

BIOLOGY M SECTION

16. Which of the following most accurately reveals common ancestry among many different species of organisms?
- (A) The amino acid sequence of their cytochrome C
 (B) Their ability to synthesize hemoglobin
 (C) The percentage of their body weight that is fat
 (D) The percentage of their body surface that is used in gas exchange
 (E) The mechanism of their mode of locomotion

Questions 17–18

Thymine is used by animal cells primarily for the synthesis of DNA. A group of sea urchin eggs was fertilized in sea water containing radioactive thymine. Following fertilization, samples of embryos were removed at regular intervals and the radioactivity in the nucleic acid was measured in counts per minute. The results obtained are shown in the figure below.



17. The increase in radioactivity of the embryos with time probably results from
- (A) synthesis of new proteins by the developing embryos
 (B) synthesis of radioactive thymine by the developing embryos
 (C) oxidation of radioactive thymine
 (D) incorporation of radioactive thymine in new cell membranes
 (E) incorporation of radioactive thymine in new DNA during replication
18. An appropriate control to show that this experiment measures DNA synthesis and not RNA synthesis would be to perform the same procedures but
- (A) not fertilize the eggs
 (B) sample the embryos at longer time intervals
 (C) add radioactive uracil instead of radioactive thymine
 (D) fertilize the eggs in sea-water that does not contain radioactive thymine
 (E) count the number of cells in the embryos at the beginning and at the end of the experiment

ANSWERS

The estimated difficulty level, on a scale of 1 to 5, with 1 the easiest and 5 the most difficult, is in parentheses.

1. B (1)	6. A (4)	11. D (3)	16. A (2)
2. A (3)	7. A (1)	12. B (4)	17. E (4)
3. C (3)	8. D (3)	13. B (3)	18. C (3)
4. E (2)	9. A (4)	14. C (3)	
5. B (2)	10. B (4)	15. C (5)	



Taking the SAT® II: Subject Tests

Chemistry

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Chemistry

one-hour subject test

PURPOSE

- measure understanding of chemistry at a level suitable for college preparation independent of the particular textbook used or instructional approach

FORMAT

- 85 multiple-choice questions
- topics that are covered in most high school courses are emphasized
- differences in high school courses make it likely that most students will encounter some questions on unfamiliar topics
- every edition of the test contains approximately five questions on equation balancing and/or predicting products of chemical reactions; these are distributed among the various content categories

RECOMMENDED PREPARATION

- one-year introductory chemistry course at the college-preparatory level
- laboratory experience is a significant factor in developing reasoning and problem-solving skills and should help in test preparation even though laboratory skills can be tested only in a limited way in a multiple-choice test
- mathematics preparation that enables handling simple algebraic relationships and applying these to solving word problems
- familiarity with the concepts of ratio and direct and inverse proportions, exponents, and scientific notation

Ability To:

- recall and understand the major concepts of chemistry and to apply the principles to solve specific problems in chemistry
- organize and interpret results obtained by observation and experimentation and to draw conclusions or make inferences from experimental data, including data presented in graphic and/or tabular form

Other

- a periodic table indicating the atomic numbers and masses of elements is provided for all test administrations
- calculator use is not allowed during the test
- problem solving requires simple numerical calculations
- the metric system of units is used

SCORE

- Total score: 200-to-800 scale

CONTENT

Approximate
% of Test

Topics Covered

I. Structure of Matter	25
<i>Including atomic theory and structure, periodic relationships; chemical bonding and molecular structure; nuclear reactions</i>	
II. States of Matter	15
<i>Including kinetic molecular theory of gases, gas laws, liquids, solids, and phase changes; solutions, concentration units, solubility, conductivity, and colligative properties</i>	
III. Reaction Types	14
<i>Including acids and bases, oxidation-reduction, and precipitation</i>	
IV. Stoichiometry	12
<i>Including the mole concept, Avogadro's number, empirical and molecular formulas, percentage composition, stoichiometric calculations, and limiting reagents</i>	
V. Equilibrium and Reaction Rates	7
<i>Including gas equilibria, ionic equilibria, Le Chatelier's principle, equilibrium expressions; factors affecting rates of reaction</i>	
VI. Thermodynamics	6
<i>Including energy changes in chemical reactions and physical processes, Hess's Law, and randomness</i>	
VII. Descriptive Chemistry	13
<i>Including physical and chemical properties of elements and their more familiar compounds, chemical reactivity and products of chemical reactions, simple examples from organic chemistry and environmental chemistry</i>	
VIII. Laboratory	8
<i>Including equipment, measurement, procedures, observations, safety, calculations, and interpretation of results</i>	

Skills Specifications

Recall of Knowledge	20
<i>Remembering fundamental concepts and specific information; demonstrating familiarity with terminology</i>	
Application of Knowledge	45
<i>Applying a single principle to unfamiliar and/or practical situations to obtain a qualitative result or solve a quantitative problem</i>	
Synthesis of Knowledge	35
<i>Inferring and deducing from qualitative and/or quantitative data; integrating two or more relationships to draw conclusions or solve problems</i>	

Sample Questions

Three types of questions are used in the Chemistry Test: classification questions, relationship analysis questions, and five-choice completion questions. The directions that follow are identical to those that are in the test.

Note: For all questions involving solutions and/or chemical equations, assume that the system is in pure water unless otherwise stated.

Directions: Each set of lettered choices below refers to the numbered statements or questions immediately following it. Select the one lettered choice that best fits each statement or answers each question and then fill in the corresponding oval on the answer sheet. A choice may be used once, more than once, or not at all in each set.

Questions 1–3 refer to the following aqueous solutions.

- (A) 0.1 M HCl
- (B) 0.1 M NaCl
- (C) 0.1 M HC₂H₃O₂
- (D) 0.1 M CH₃OH
- (E) 0.1 M KOH

1. Is weakly acidic
2. Has the highest pH
3. Reacts with an equal volume of 0.05 M Ba(OH)₂ to form a solution with pH = 7

Questions 4–6 refer to the following ionic species.

- (A) X⁺
- (B) X²⁺
- (C) X³⁺
- (D) XO₃²⁻
- (E) XO₄²⁻

4. A type of ion found in sodium acetate
5. A type of ion found in aluminum oxide
6. A type of ion found in potassium phosphate

On the actual Chemistry Test, the following type of question must be answered on a special section (labeled “chemistry”) at the lower left-hand corner of page 2 of your answer sheet. These questions will be numbered beginning with 101 and must be answered according to the following directions.

Sample Answer Grid

	I	II	CE*
101	<input type="radio"/> T <input type="radio"/> F	<input type="radio"/> T <input type="radio"/> F	<input type="radio"/>

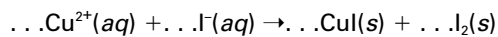
Directions: Each question below consists of two statements, I in the left-hand column and II in the right-hand column. For each question, determine whether statement I is true or false and whether statement II is true or false and fill in the corresponding T or F ovals on your answer sheet. Fill in oval CE only if statement II is a correct explanation of the true statement I.

	I	II
101.	The rate at which sugar dissolves in water increases with stirring	BECAUSE stirring exposes the surface of a solute crystal to a less concentrated layer of solution.
102.	Diamond has a high melting point	BECAUSE in a diamond crystal, the carbon atoms are held in place by ionic bonds.
103.	Potassium has a lower first ionization energy than lithium has	BECAUSE potassium has more protons in its nucleus than lithium has.
104.	Zinc metal will reduce Cu ²⁺ in solution	BECAUSE zinc is a more active metal than copper is.
	$\text{HC}_2\text{H}_3\text{O}_2 + \text{H}_2\text{O} \rightleftharpoons \text{C}_2\text{H}_3\text{O}_2^- + \text{H}_3\text{O}^+$	
105.	If some acetic acid, HC ₂ H ₃ O ₂ , is added to the equilibrium mixture represented by the equation above, the concentration of H ₃ O ⁺ decreases	BECAUSE the equilibrium constant of a reaction changes as the concentration of the reactants changes.

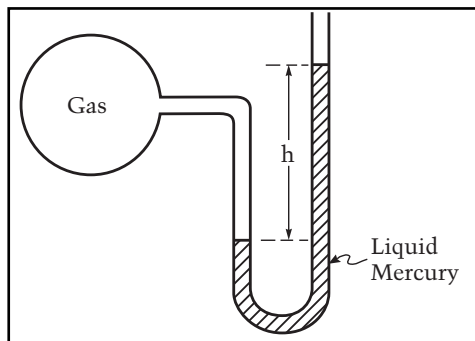
On the actual Chemistry Test, the remaining questions must be answered by returning to the section of your answer sheet you started for the Chemistry Test.

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and then fill in the corresponding oval on the answer sheet.

7. The hydrogen ion concentration of a solution prepared by diluting 50. mL of 0.10 M $\text{HNO}_3(aq)$ with water to 500. mL of solution is
 (A) 0.0010 M (B) 0.0050 M (C) 0.010 M
 (D) 0.050 M (E) 1.0 M

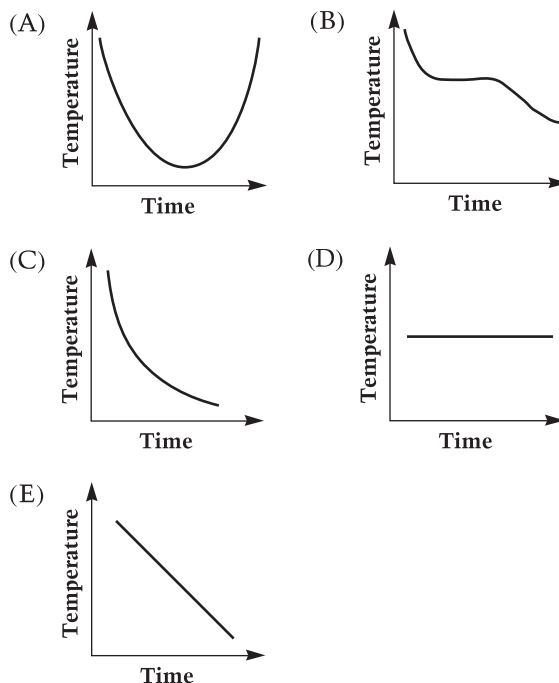


8. When the equation above is balanced and all coefficients are reduced to lowest whole-number terms, the coefficient for $\text{I}^{-}(aq)$ is
 (A) 1 (B) 2 (C) 3 (D) 4 (E) 5

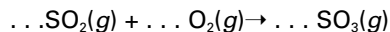


9. The bulb of the open-end manometer shown above contains a gas. True statements about this system include which of the following?
- Only atmospheric pressure is exerted on the exposed mercury surface in the right side of the tube.
 - The gas pressure is greater than atmospheric pressure.
 - The difference in the height, h , of mercury levels is equal to the pressure of the gas.
- (A) II only
 (B) III only
 (C) I and II only
 (D) I and III only
 (E) I, II, and III

10. A thermometer is placed in a test tube containing a melted pure substance. As slow cooling occurs, the thermometer is read at regular intervals until well after the sample has solidified. Which of the following types of graphs is obtained by plotting temperature *versus* time for this experiment?

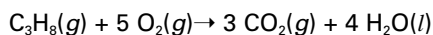


11. From their electron configurations, one can predict that the geometric configuration for which of the following molecules is NOT correct?
 (A) PF_3 trigonal planar
 (B) CF_4 tetrahedral
 (C) CHCl_3 irregular tetrahedron
 (D) OF_2 bent (v-shaped)
 (E) HF linear



12. According to the reaction represented by the unbalanced equation above, how many moles of $\text{SO}_2(g)$ are required to react completely with 1 mole of $\text{O}_2(g)$?
 (A) 0.5 mol (B) 1 mol (C) 2 mol
 (D) 3 mol (E) 4 mol

13. Analysis by mass of a certain compound shows that it contains 14 percent hydrogen and 86 percent carbon. Which of the following is the most informative statement that can properly be made about the compound on the basis of these data?
- (A) It is a hydrocarbon.
 (B) Its empirical formula is CH_2 .
 (C) Its molecular formula is C_2H_4 .
 (D) Its molar mass is 28 g/mol.
 (E) It contains a triple bond.



14. The combustion of propane, $\text{C}_3\text{H}_8(g)$, proceeds according to the equation above. How many grams of water will be formed in the complete combustion of 44.0 grams of propane?
- (A) 4.50 g (B) 18.0 g (C) 44.0 g
 (D) 72.0 g (E) 176 g
15. The number of oxygen atoms in 0.50 mole of KHSO_4 is
- (A) 1.2×10^{23} (B) 2.4×10^{23} (C) 3.0×10^{23}
 (D) 1.2×10^{24} (E) 2.4×10^{24}
16. All of the following statements about carbon dioxide are true EXCEPT:
- (A) It can be prepared by the action of acid on limestone.
 (B) It is used to extinguish fires.
 (C) It dissolves in water at room temperature.
 (D) It sublimes rather than melts at 20°C and 1 atmosphere pressure.
 (E) It is less dense than air at a given temperature and pressure.

17. For elements in the left-most column of the periodic table, properties that have increasing values as the atomic number increases include which of the following?
- I. Ionization energy (potential)
 II. Atomic radius
 III. Atomic mass
- (A) I only
 (B) III only
 (C) I and II only
 (D) II and III only
 (E) I, II, and III

18. All of the following can act as Brønsted-Lowry acids (proton donors) in aqueous solution EXCEPT
- (A) HI (B) NH_4^+ (C) HCO_3^- (D) H_2S (E) NH_3
19. What is the minimum number of moles of PbSO_4 that must be used to prepare 1 liter of saturated PbSO_4 solution at 25°C ? (K_{sp} at 25°C for $\text{PbSO}_4 = 1 \times 10^{-8}$)
- (A) 1×10^{-16} mol (B) 1×10^{-8} mol
 (C) 1×10^{-4} mol (D) 1×10^{-2} mol
 (E) 1×10^{-1} mol

ANSWERS

The estimated difficulty level, on a scale of 1 to 5, with 1 the easiest and 5 the most difficult, is in parentheses.

1. C (2) 3. A (4) 5. C (1)
 2. E (3) 4. A (3) 6. A (2)

Questions 101-105: See box for difficulty level.

	I	II	CE*	Diff. Level
101	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	3
102	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	3
103	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	3
104	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	4
105	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	5

7. C (3) 12. C (2) 16. E (3)
 8. D (2) 13. B (3) 17. D (3)
 9. C (4) 14. D (2) 18. E (4)
 10. B (3) 15. D (1) 19. C (5)
 11. A (3)



Taking the SAT® II: Subject Tests

Physics

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Physics

one-hour subject test

PURPOSE

- measure understanding of physics at the college-preparatory level

FORMAT

- 75 multiple-choice questions
- questions cover topics emphasized in most high school courses; because of course differences, most students will find that there are some questions on topics with which they are not familiar

RECOMMENDED PREPARATION

- one-year introductory physics course on the college-preparatory level
- laboratory experience — a significant factor in developing reasoning and problem-solving skills — even though this test can only measure lab skills in a limited way, such as data analysis

Ability To:

- recall and understand the major concepts of physics and to apply these physical principles to solve specific problems
- understand simple algebraic, trigonometric, and graphical relationships and the concepts of ratio and proportion, and apply these to physics problems

Other

- *the direction of any current is the direction of flow of positive charge (conventional current)*
- *calculator use is not allowed during the test*
- *numerical calculations are not emphasized and are limited to simple arithmetic*
- *predominantly uses the metric system*

SCORE

- Total score: 200-to-800 scale

CONTENT

Level of Concept Application

	Approximate % of Test
Recall <i>generally involves remembering and understanding concepts or information</i>	20-33
Single-Concept Problem <i>recall and use of a single physical relationship</i>	40-53
Multiple-Concept Problem <i>recall and integration of two or more physical relationships</i>	20-33

Topics Covered*

Approximate % of Test

I. Mechanics	36-42
<ul style="list-style-type: none"> A. Kinematics, such as velocity, acceleration, motion in one dimension, and motion of projectiles B. Dynamics, such as force, Newton's laws, and statics C. Energy and Momentum, such as potential and kinetic energy, work, power, impulse, and conservation laws D. Circular Motion, such as uniform circular motion and centripetal force E. Simple Harmonic Motion, such as mass on a spring and the pendulum F. Gravity, such as the law of gravitation, orbits, and Kepler's Laws 	
II. Electricity and Magnetism	18-24
<ul style="list-style-type: none"> A. Electric Fields, Forces, and Potentials, such as Coulomb's law, induced charge, field and potential of groups of point charges, and charged particles in electric fields B. Capacitance, such as parallel-plate capacitors and transients C. Circuit Elements and DC Circuits, such as resistors, light bulbs, series and parallel networks, Ohm's law, and Joule's law D. Magnetism, such as permanent magnets, fields caused by currents, particles in magnetic fields, Faraday's law, Lenz's law 	
III. Waves and Optics	15-19
<ul style="list-style-type: none"> A. General Wave Properties, such as wave speed, frequency, wavelength, superposition, standing waves, and Doppler effect B. Reflection and Refraction, such as Snell's law and changes in wavelength and speed C. Ray Optics, such as image formation using pinholes, mirrors, and lenses D. Physical Optics, such as single-slit diffraction, double-slit interference, polarization, and color 	
IV. Heat and Thermodynamics	6-11
<ul style="list-style-type: none"> A. Thermal Properties, such as temperature, heat transfer, specific and latent heats, and thermal expansion B. Laws of Thermodynamics, such as first and second laws, internal energy, entropy, and heat engine efficiency 	

Topics Covered (continued)	Approximate % of Test
V. Modern Physics	6-11
A. Quantum Phenomena , such as photons and photoelectric effect	
B. Atomic , such as the Rutherford and Bohr models, atomic energy levels, and atomic spectra	
C. Nuclear and Particle Physics , such as radioactivity, nuclear reactions, and fundamental particles	
D. Relativity , such as time dilation, length contraction, and mass-energy equivalence	
VI. Miscellaneous	4-9
A. General , such as history of physics and general questions that overlap several major topics	
B. Analytical Skills , such as graphical analysis, measurement, and math skills	
C. Contemporary Physics , such as astrophysics, superconductivity, and chaos theory	
*Laboratory Skills: In each of the six major topics above, some questions may deal with laboratory skills in context.	

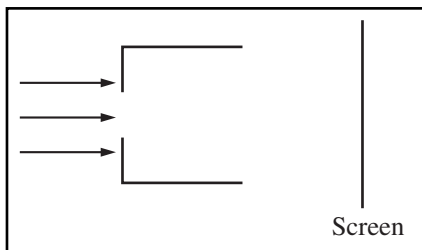
Sample Questions

Two types of questions are used in the Physics Test. The directions that follow are identical to those that are in the test. All questions in the test are multiple-choice questions in which you must choose the **BEST** response from the five choices offered.

PART A

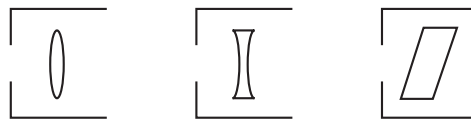
Directions: Each set of lettered choices below refers to the numbered questions immediately following it. Select the one lettered choice that best answers each question or best fits each statement and then fill in the corresponding oval on the answer sheet. A choice may be used once, more than once, or not at all in each set.

Questions 1–2



A beam of light is incident on a rectangular opening in the front of a box, as shown in the side view above. The back of the box is open. After passing through the box, the light is incident on a screen. The following devices may be in the box, positioned as shown at the top of the next column.

- (A) A convex lens (B) A concave lens (C) A thick sheet of glass

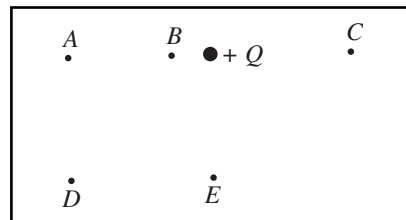


- (D) An opaque card with a very narrow slit (E) A prism with vertex pointing downward



- Which device could produce a tiny spot of light on the screen?
- Which device could produce a diffraction pattern consisting of a central bright fringe with parallel secondary fringes that decrease in intensity with increasing distance from the center of the screen?

Questions 3–4 relate to a point charge $+Q$ fixed in position, as shown below. Five points near the charge and in the plane of the page are shown.

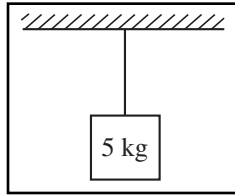


- At which point will the magnitude of the electric field be least?
- At which point will an electron experience a force directed toward the top of the page?

PART B

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and then fill in the corresponding oval on the answer sheet.

- When a vector of magnitude 6 units is added to a vector of magnitude 8 units, the magnitude of the resultant vector will be
 - exactly 2 units
 - exactly 10 units
 - exactly 14 units
 - 0 units, 10 units, or some value between them
 - 2 units, 14 units, or some value between them



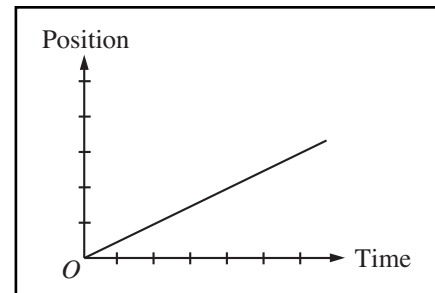
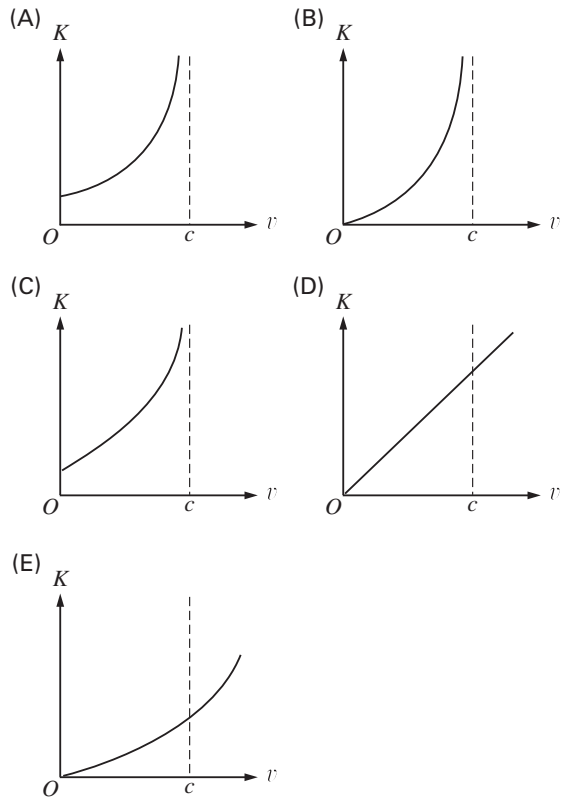
6. A 5-kilogram block is suspended by a cord from the ceiling, as shown above. The force exerted on the block by the cord is most nearly
 (A) zero (B) 25 N (C) 50 N (D) 100 N (E) 200 N

7. An experiment is performed to measure the specific heat of copper. A lump of copper is heated in an oven, then dropped into a beaker of water. To calculate the specific heat of copper, the experimenter must know or measure the value of all of the quantities below EXCEPT the
 (A) mass of the water
 (B) original temperatures of the copper and the water
 (C) final (equilibrium) temperature of the copper and the water
 (D) time taken to achieve equilibrium after the copper is dropped into the water
 (E) specific heat of the water

8. Which of the following is true of the magnetic field produced by a current in a long, straight wire?
 (A) The field is uniform.
 (B) The field increases in strength as the distance from the wire increases.
 (C) The field lines are directed parallel to the wire, but opposite to the direction of the current.
 (D) The field lines are directed radially outward from the wire.
 (E) The field lines form circles about the wire.

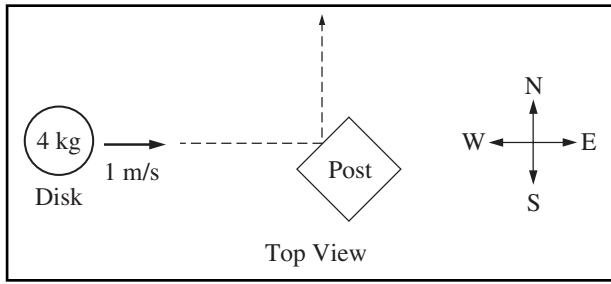
9. In a given process, 12 joules of heat is added to an ideal gas and the gas does 8 joules of work. Which of the following is true about the internal energy of the gas during this process?
 (A) It has increased by 20 joules.
 (B) It has increased by 4 joules.
 (C) It has not changed.
 (D) It has decreased by 4 joules.
 (E) It has decreased by 20 joules.

10. Which of the following graphs best represents the kinetic energy K of an elementary particle as a function of its speed v , where c is the speed of light?



11. The graph of position *versus* time for an object moving along a straight line is given above. During the time shown on the graph, the speed and acceleration of the object will have which of the following characteristics?

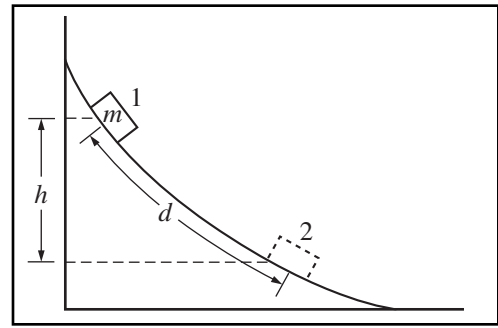
<u>SPEED</u>	<u>ACCELERATION</u>
(A) Increasing	Increasing
(B) Increasing	Constant but not zero
(C) Constant but not zero	Increasing
(D) Constant but not zero	Zero
(E) Zero	Constant but not zero



12. A 4-kilogram disk slides over level ice toward the east at a velocity of 1 meter per second, as shown above. The disk strikes a post and rebounds toward the north at the same speed. The change in the magnitude of the momentum of the disk is
- (A) $-4 \text{ kg} \cdot \text{m/s}$
 (B) $-1 \text{ kg} \cdot \text{m/s}$
 (C) $0 \text{ kg} \cdot \text{m/s}$
 (D) $1 \text{ kg} \cdot \text{m/s}$
 (E) $4 \text{ kg} \cdot \text{m/s}$

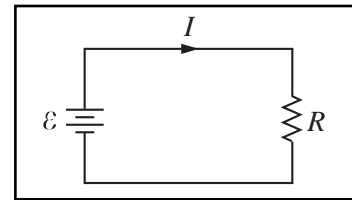
n	Energy Above Ground State
3	7 eV
2	4 eV
1	0 eV

13. Three energy levels of an atom are shown above. Atoms in the $n = 2$ state can spontaneously emit photons having which of the following energies?
- (A) 4 eV only
 (B) 7 eV only
 (C) 3 eV and 4 eV only
 (D) 3 eV and 7 eV only
 (E) 3 eV, 4 eV, and 7 eV



14. A box of mass m is released from rest at position 1 on the frictionless curved track shown above. It slides a distance d along the track in time t to reach position 2, dropping a vertical distance h . Let v and a be the instantaneous speed and instantaneous acceleration, respectively, of the box at position 2. Which of the following equations is valid for this situation?
- (A) $h = vt$ (B) $h = \frac{1}{2}gt^2$ (C) $d = \frac{1}{2}at^2$
 (D) $v^2 = 2ad$ (E) $mgh = \frac{1}{2}mv^2$

Questions 15–16 relate to the following circuit.



A single resistor R is connected to a battery as shown above. The current is I and the power dissipated as heat is P . The circuit is changed by doubling the emf \mathcal{E} of the battery while R is kept constant.

15. After the change, the current is
- (A) $\frac{I}{4}$ (B) $\frac{I}{2}$ (C) I (D) $2I$ (E) $4I$
16. After the change, the power dissipated in R is
- (A) $\frac{P}{4}$ (B) $\frac{P}{2}$ (C) P (D) $2P$ (E) $4P$
17. Which of the following may transmit energy from one point to another?
- I. Electromagnetic radiation
 II. Sound waves
 III. Convection currents
- (A) I only
 (B) III only
 (C) I and II only
 (D) II and III only
 (E) I, II, and III

18. The Earth has a radius of 6,400 kilometers. A satellite orbits the Earth at a distance of 12,800 kilometers from the center of the Earth. If the weight of the satellite on Earth is 100 kilonewtons, the gravitational force on the satellite in orbit is
- (A) 11 kilonewtons
 - (B) 25 kilonewtons
 - (C) 50 kilonewtons
 - (D) 100 kilonewtons
 - (E) 200 kilonewtons

Questions 19–20

A piece of chalk is thrown vertically upward and caught during its descent at the same height from which it was thrown. Position is measured from the location of the chalk when it left the hand. The positive direction for position, velocity, and acceleration is upward.

19. What are the signs of the position, velocity, and acceleration during the ascending part of the trajectory?

<u>POSITION</u>	<u>VELOCITY</u>	<u>ACCELERATION</u>
(A) Positive	Positive	Positive
(B) Positive	Positive	Negative
(C) Positive	Negative	Negative
(D) Negative	Positive	Negative
(E) Negative	Negative	Negative

20. What are the signs of the position, velocity, and acceleration during the descending part of the trajectory?

<u>POSITION</u>	<u>VELOCITY</u>	<u>ACCELERATION</u>
(A) Positive	Positive	Positive
(B) Positive	Positive	Negative
(C) Positive	Negative	Negative
(D) Negative	Positive	Negative
(E) Negative	Negative	Negative

ANSWERS

The estimated difficulty level, on a scale of 1 to 5, with 1 the easiest and 5 the most difficult, is in parentheses.

- | | | | |
|----------|-----------|-----------|-----------|
| 1. A (3) | 6. C (1) | 11. D (2) | 16. E (5) |
| 2. D (3) | 7. D (3) | 12. A (4) | 17. E (4) |
| 3. D (1) | 8. E (3) | 13. A (4) | 18. B (5) |
| 4. E (2) | 9. B (3) | 14. E (4) | 19. B (4) |
| 5. E (2) | 10. B (2) | 15. D (3) | 20. C (5) |