Committee of Examiners for the Physics Test

Selected with the advice of the
American Association of Physics Teachers and
The American Physical Society

Practice Tests Available

GRE Subject Test practice books are available for each of the Subject Tests. Each book **includes at least one test that was actually administered**, answer sheets, correct answers, and data on how students who took the test performed on each question. Score conversion information is also provided to enable you to calculate your scaled score. Practice books may be ordered with a credit card (VISA, MasterCard, or American Express only) by calling 1-800-537-3160. Outside the U.S. and Canada, call 1-609-771-7243. Practice books may also be ordered on the registration form in the *GRE Information and Registration Bulletin* or from the GRE Web site at **www.gre.org**.

You may want to keep this booklet until after you receive your score report. It contains important information about content specifications on which your scores are based.

Table of Contents

Purpose of the GRE Subject Tests

The GRE Subject Tests are designed to help graduate school admission committees and fellowship sponsors assess the qualifications of applicants in specific fields of study. The tests also provide you with an assessment of your own qualifications.

Scores on the tests are intended to indicate knowledge of the subject matter emphasized in many undergraduate programs as preparation for graduate study. Because past achievement is usually a good indicator of future performance, the scores are helpful in predicting success in graduate study. Because the tests are standardized, the test scores permit comparison of students from different institutions with different undergraduate programs. For some Subject Tests, subscores are provided in addition to the total score; these subscores indicate the strengths and weaknesses of your preparation, and they may help you plan future studies.

The GRE Board recommends that scores on the Subject Tests be considered in conjunction with other relevant information about applicants. Because numerous factors influence success in graduate school, reliance on a single measure to predict success is not advisable. Other indicators of competence typically include undergraduate transcripts showing courses taken and grades earned, letters of recommendation, the GRE Writing Assessment score, and GRE General Test scores. For information about the appropriate use of GRE scores, write to GRE Program, Educational Testing Service, Mail Stop 51-L, Princeton, NJ 08541.

Preparing for a Subject Test

GRE Subject Test questions are designed to measure skills and knowledge gained over a long period of time. Although you might increase your scores to some extent through preparation a few weeks or months before you take the test, last-minute cramming is unlikely to be of further help. The following information will help guide you if you decide to spend time preparing for the test.

- A general review of your college courses is probably the best preparation for the test. However, the test covers a broad range of subject matter, and no one is expected to be familiar with the content of every question.
- Use official GRE publications, published by ETS, to become familiar with questions used on the GRE Subject Tests. This descriptive booklet provides several sample questions. In addition, Subject Test practice books are available (see inside front cover).
- Become familiar with the types of questions used in the test, paying special attention to the directions. If you thoroughly understand the directions before you take the test, you will have more time during the test to focus on the questions themselves.

Test-Taking Strategies

The types of multiple-choice questions in the test are illustrated by the sample questions at the back of this booklet. When you take the test, you will mark your answers on a separate machine-scorable answer sheet. Total testing time is two hours and fifty minutes; there are no separately timed sections. Following are some general test-taking strategies you may want to consider.

- Read the test directions carefully, and work as rapidly as you can without being careless. For each question, choose the best answer from the available options.
- All questions are of equal value; do not waste time pondering individual questions you find extremely difficult or unfamiliar.
- You may want to work through the test quite rapidly, first answering only the questions about which you feel confident, then going back and answering questions that require more thought, and concluding with the most difficult questions if there is time.
- If you decide to change an answer, make sure you completely erase it and fill in the oval corresponding to your desired answer.
- Questions for which you mark no answer or more than one answer are not counted in scoring.
- As a correction for haphazard guessing, one-fourth of the number of questions you answer incorrectly is subtracted from the number of questions you answer correctly. It is improbable that mere guessing will improve your score significantly; it may even lower your score. If, however, you are not certain of the correct answer but have some knowledge of the question and are able to eliminate one or more of the answer choices, your chance of getting the right answer is improved, and it may be to your advantage to answer such a question.

- Record all answers on your answer sheet. Answers recorded in your test book will not be counted.
- Do not wait until the last five minutes of a testing session to record answers on your answer sheet.

Development of the Subject Tests

Each new edition of a Subject Test is developed by a committee of examiners composed of professors in the subject who are on undergraduate and graduate faculties in different types of institutions and in different regions of the United States and Canada. In selecting members for each committee, the GRE Program seeks the advice of the appropriate professional associations in the subject.

The content and scope of each test are specified and reviewed periodically by the committee of examiners. Test questions are written by the committee and by other faculty who are also subject-matter specialists and by subject-matter specialists at ETS. All questions proposed for the test are reviewed by the committee and revised as necessary. The accepted questions are assembled into a test in accordance with the content specifications developed by the committee to ensure adequate coverage of the various aspects of the field and at the same time to prevent overemphasis on any single topic. The entire test is then reviewed and approved by the committee.

Subject-matter and measurement specialists on the ETS staff assist the committee, providing information and advice about methods of test construction and helping to prepare the questions and assemble the test. In addition, each test question is reviewed to eliminate language, symbols, or content considered potentially offensive, inappropriate for major subgroups of the test-taking population, or likely to perpetuate any negative attitude that may be conveyed to these subgroups. The test as a whole is also reviewed to ensure that the test questions, where applicable, include an appropriate balance of people in different groups and different roles.

Because of the diversity of undergraduate curricula, it is not possible for a single test to cover all the material you may have studied. The examiners, therefore, select questions that test the basic knowledge and skills most important for successful graduate study in the particular field. The committee keeps the test up-to-date by regularly developing new editions and revising existing editions. In this way, the test content changes steadily but gradually, much like most curricula. In addition, curriculum surveys are conducted periodically to ensure that the content of a test reflects what is currently being taught in the undergraduate curriculum.

After a new edition of a Subject Test is first administered, examinees’ responses to each test question are analyzed in a variety of ways to determine whether each question functioned as expected. These analyses may reveal that a question is ambiguous, requires knowledge beyond the scope of the test, or is inappropriate for the total group or a particular subgroup of examinees taking the test. Answers to such questions are not used in computing scores.

Following this analysis, the new test edition is equated to an existing test edition. In the equating process, statistical methods are used to assess the difficulty of the new test. Then scores are adjusted so that examinees who took a difficult edition of the test are not penalized, and examinees who took an easier edition of the test do not have an advantage. Variations in the number of questions in the different editions of the test are also taken into account in this process.

Scores on the Subject Tests are reported as three-digit scaled scores with the third digit always zero. The maximum possible range for all Subject Test total scores is from 200 to 990. The actual range of scores for a particular Subject Test, however, may be smaller. The maximum possible range of Subject Test subscores is 20 to 99; however, the actual range of subscores for any test or test edition may be smaller than 20 to 99. Subject Test score interpretive information is provided in *Interpreting Your GRE Scores*, which you will receive with your GRE Report of Scores.

What Your Scores Mean

Your raw score, that is, the number of questions you answered correctly minus one-fourth of the number you answered incorrectly, is converted to the scaled score that is reported. This conversion ensures that a scaled score reported for any edition of a Subject Test is comparable to the same scaled score earned on any other edition of the same Subject Test. Thus, equal scaled scores on a particular Subject Test indicate essentially equal levels of performance regardless of the test edition taken. Test scores should be compared only with other scores on the same Subject Test. (For example, a 680 on the Computer Science Test is not equivalent to a 680 on the Mathematics Test.)

Before taking the test, you may find it useful to know approximately what raw scores would be required to obtain a certain scaled score. Several factors influence the conversion of your raw score to your scaled score, such as the difficulty of the test edition and the number of test questions included in the computation of your raw score. Based on recent editions of the Physics Test, the table on the next page gives the range of raw scores associated with selected scaled scores for three different test editions. (Note that when the number of scored questions for a given test is greater than the range of possible scaled scores, it is likely that two or more raw scores will convert to the same scaled score.) The three test editions in the table that follows were selected to reflect varying degrees of difficulty. Examinees should note that future test editions may be somewhat more or less difficult than those test editions illustrated in the table.

Range of Raw Scores* Needed to Earn Selected Scaled Scores
on Three Physics Test Editions That Differ in Difficulty

Scaled Score	Raw Scores		
	Form A	Form B	Form C
900	69	65	56
800	56	52	44
700	43	38-39	32
600	30	25	19-20
Number of Questions Used to Compute Raw Score	99	99	99

*Raw Score = Number of correct answers minus one-fourth the number of incorrect answers, rounded to the nearest integer.

For a particular test edition, there are many ways to earn the same raw score. For example, on the edition listed above as "Form A," a raw score of 43 would earn a scaled score of 700. Below are a few of the possible ways in which a scaled score of 700 could be earned on that edition.

Examples of Ways to Earn a Scaled Score of 700
on the Edition Labeled As "Form A"

Raw Score	Questions Answered Correctly	Questions Answered Incorrectly	Questions Not Answered	Number of Questions Used to Compute Raw Score
43	43	0	56	99
43	48	21	30	99
43	54	43	2	99

CONTENT OF THE PHYSICS TEST

The test consists of about 100 five-choice questions, some of which are grouped in sets and based on such materials as diagrams, graphs, experimental data, and descriptions of physical situations.

The aim of the test is to determine the extent of the students' grasp of fundamental principles and their ability to apply these principles in the solution of problems. Most test questions can be answered on the basis of a mastery of the first three years of undergraduate physics.

The International System (SI) of units is used predominantly in this test. A table of information (see page 10) representing various physical constants and a few conversion factors among SI units is presented in this test booklet.

The approximate percentages of the test on the major content topics have been set by the committee of examiners to reflect its judgment about the relative emphases placed on these topics in most undergraduate curricula as determined by a content representativeness survey of these curricula that was conducted in 1989. These percentages are given below along with the major subtopics included in each content category. In each category, the subtopics are listed roughly in order of decreasing importance for inclusion in the test. Nearly all the questions in the test will relate to material in this outline; however, there may be occasional questions on other topics not explicitly listed here.

Topic	*Percentage of Questions*
1. CLASSICAL MECHANICS (such as kinematics, Newton's laws, work and energy, oscillatory motion, rotational motion about a fixed axis, dynamics of systems of particles, central forces and celestial mechanics, three-dimensional particle dynamics, Lagrangian and Hamiltonian formalism, non-inertial reference frames, elementary topics in fluid dynamics)	20
2. ELECTROMAGNETISM (such as electrostatics, currents and DC circuits, magnetic fields in free space, Lorentz force, induction, Maxwell's equations and their applications, electromagnetic waves, AC circuits, magnetic and electric fields in matter)	18
3. OPTICS AND WAVE PHENOMENA (such as wave properties, superposition, interference, diffraction, geometrical optics, polarization, Doppler effect)	9

4. THERMODYNAMICS AND STATISTICAL MECHANICS (such as the laws of thermodynamics, thermodynamic processes, equations of state, ideal gases, kinetic theory, ensembles, statistical concepts and calculation of thermodynamic quantities, thermal expansion and heat transfer) 10

5. QUANTUM MECHANICS (such as fundamental concepts, solutions of the Schrödinger equation (including square wells, harmonic oscillators, and hydrogenic atoms), spin, angular momentum, wave function symmetry, elementary perturbation theory) 12

6. ATOMIC PHYSICS (such as properties of electrons, Bohr model, energy quantization, atomic structure, atomic spectra, selection rules, black-body radiation, x-rays, atoms in electric and magnetic fields) 10

7. SPECIAL RELATIVITY (such as introductory concepts, time dilation, length contraction, simultaneity, energy and momentum, four-vectors and Lorentz transformation, velocity addition) 6

8. LABORATORY METHODS (such as data and error analysis, electronics, instrumentation, radiation detection, counting statistics, interaction of charged particles with matter, lasers and optical interferometers, dimensional analysis, fundamental applications of probability and statistics) 6

9. SPECIALIZED TOPICS: Nuclear and Particle physics (such as nuclear properties, radioactive decay, fission and fusion, reactions, fundamental properties of elementary particles), Condensed Matter (such as crystal structure, x-ray diffraction, thermal properties, electron theory of metals, semiconductors, superconductors), Miscellaneous (such as astrophysics, mathematical methods, computer applications) 9

Students taking the test should be familiar with certain mathematical methods and their applications in physics. Such mathematical methods include single and multivariate calculus, coordinate systems (rectangular, cylindrical, and spherical), vector algebra and vector differential operators, Fourier series, partial differential equations, boundary value problems, matrices and determinants, and functions of complex variables. These methods may appear in the test in the context of various content categories as well as occasional questions concerning only mathematics, in the specialized topics category above.

TABLE OF INFORMATION

Rest mass of the electron	$m_e = 9.11 \times 10^{-31}$ kilogram $= 9.11 \times 10^{-28}$ gram
Magnitude of the electron charge	$e = 1.60 \times 10^{-19}$ coulomb $= 4.80 \times 10^{-10}$ statcoulomb (esu)
Avogadro's number	$N_0 = 6.02 \times 10^{23}$ per mole
Universal gas constant	$R = 8.31$ joules/(mole $\cdot$ K)
Boltzmann's constant	$k = 1.38 \times 10^{-23}$ joule/K $= 1.38 \times 10^{-16}$ erg/K
Speed of light	$c = 3.00 \times 10^{8}$ m/s $= 3.00 \times 10^{10}$ cm/s
Planck's constant	$h = 6.63 \times 10^{-34}$ joule $\cdot$ second $= 4.14 \times 10^{-15}$ eV $\cdot$ second
	$\hbar = h/2\pi$
Vacuum permittivity	$\epsilon_0 = 8.85 \times 10^{-12}$ coulomb^2/(newton $\cdot$ meter^2)
Vacuum permeability	$\mu_0 = 4\pi \times 10^{-7}$ weber/(ampere $\cdot$ meter)
Universal gravitational constant	$G = 6.67 \times 10^{-11}$ meter^3/(kilogram $\cdot$ second^2)
Acceleration due to gravity	$g = 9.80$ m/s^2 $= 980$ cm/s^2
1 atmosphere pressure	1 atm $= 1.0 \times 10^{5}$ newton/meter^2 $= 1.0 \times 10^{5}$ pascals (Pa)
1 angstrom	1 Å $= 1 \times 10^{-10}$ meter
	1 weber/m^2 $= 1$ tesla $= 10^{4}$ gauss

Moments of inertia about center of mass

Rod	$\frac{1}{12}M\ell^2$
Disc	$\frac{1}{2}MR^2$
Sphere	$\frac{2}{5}MR^2$

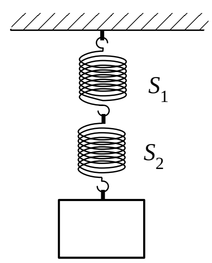
SAMPLE QUESTIONS

The following questions are similar to those in the test. The examples here serve to illustrate the range of the actual test in terms of the subject-matter areas included, the abilities measured, and the difficulty of the questions posed. An answer key appears after the sample questions.

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.

1. The weight of an object on the Moon is 1/6 of its weight on the Earth. A pendulum clock that ticks once per second on the Earth is taken to the Moon. On the Moon the clock would tick once every

   (A) 1/6 s (B) $1/\sqrt{6}$ s (C) 1 s (D) $\sqrt{6}$ s (E) 6 s



2. Two springs, S_1 and S_2, have negligible masses and the spring constant of S_1 is 1/3 that of S_2. When a block is hung from the springs as shown above and the springs come to equilibrium again, the ratio of the work done in stretching S_1 to the work done in stretching S_2 is

   (A) 1/9 (B) 1/3 (C) 1 (D) 3 (E) 9

Questions 3-4 relate to a particle of mass M that is moving in an attractive central force field. The potential energy function representing the attractive central force field can be written as $V(r) = -k/r$. At a certain time the particle has angular momentum $\mathbf{L}$ and total energy E.

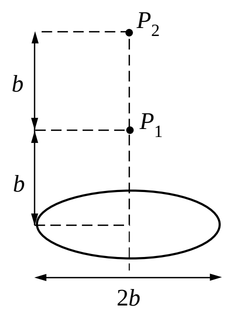
3. At some later time, which of the following statements will be true of the angular momentum $\mathbf{L}$ and total energy E of the particle?

(A) $\mathbf{L}$ will have changed, but E will not.
(B) E will have changed, but $\mathbf{L}$ will not.
(C) Neither $\mathbf{L}$ nor E will have changed.
(D) Both $\mathbf{L}$ and E will have changed.
(E) It is not possible to say what will happen to $\mathbf{L}$ and E.

4. For a given nonzero angular momentum, there is a minimum energy for which it is possible to find a solution to the equations of motion. At this minimum energy, the particle is moving in a

(A) circular orbit
(B) noncircular elliptical orbit
(C) parabolic orbit
(D) hyperbolic orbit
(E) straight line

<u>Questions 5-6</u> concern a uniformly charged wire that has the form of a circular loop with radius b. Consider two points on the axis of the loop. P_1 is at a distance b from the loop's center, and P_2 is at a distance $2b$ from the loop's center. The potential V is zero, very far from the loop. At P_1 and P_2 the potentials are V_1 and V_2, respectively.



5. What is V_2 in terms of V_1 ?

   (A) $\frac{V_1}{3}$ (B) $\frac{2V_1}{5}$ (C) $\frac{V_1}{2}$ (D) $\sqrt{\frac{2}{5}}\,V_1$ (E) $4\pi V_1$

6. How much work would be required to move a charge q from P_1 to P_2 ?

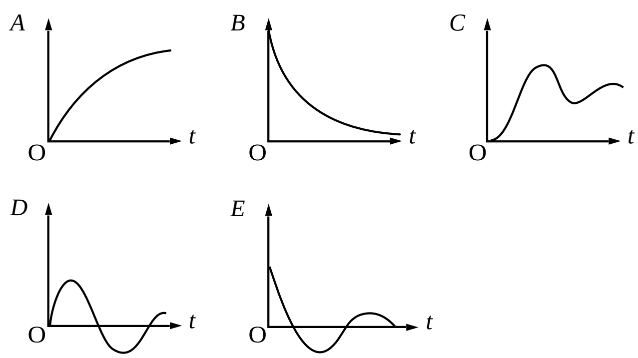
   (A) $\frac{qV_2}{V_1}$ (B) qV_2 (C) $q\log_e\left(\frac{V_2}{V_1}\right)$ (D) qV_1V_2 (E) $q(V_2 - V_1)$

7. In electrostatic problems, the electric field always satisfies the equation

   (A) $\nabla \cdot \mathbf{E} = \nabla \times \mathbf{E}$ (B) $\nabla \cdot \mathbf{E} = 0$ (C) $\nabla \times \mathbf{E} = 0$
   (D) $\nabla(E^2) = 0$ (E) $\nabla(\nabla \cdot \mathbf{E}) = \nabla \times \mathbf{E}$

Questions 8-9

The graphs below represent variables of an electrical circuit as functions of time t after the circuit switch is closed. In each case the circuit specified contains circuit elements connected in series with each other and with a battery. Any capacitor is uncharged at the beginning. Select the graph that most nearly shows the nature of the time dependence of the indicated variable.



8. Which graph represents the potential drop across the resistor as a function of time in an inductance-resistance circuit?

   (A) *A*
   (B) *B*
   (C) *C*
   (D) *D*
   (E) *E*

9. Which graph represents the charge on the capacitor as a function of time in an underdamped inductance-resistance-capacitance circuit?

   (A) *A*
   (B) *B*
   (C) *C*
   (D) *D*
   (E) *E*

10. Which of the following properties of the hydrogen atom can be predicted most accurately from the simple Bohr model?

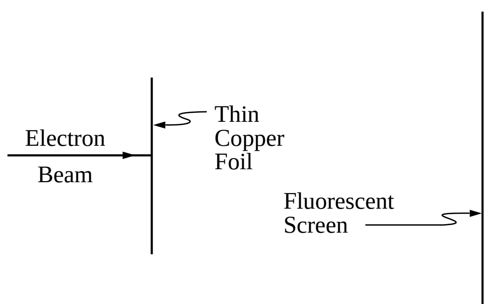
(A) Energy differences between states
(B) Angular momentum of the ground state
(C) Degeneracy of states
(D) Transition probabilities
(E) Selection rules for transitions

11. The ratio of the nuclear radius to the atomic radius of an element near the middle of the periodic table is most nearly

(A) 10^{-2} (B) 10^{-5} (C) 10^{-8} (D) 10^{-11} (E) 10^{-14}

12. The total energy necessary to remove all three electrons from a lithium atom is most nearly

(A) 2 MeV (B) 2 KeV (C) 200 eV (D) 20 eV (E) 2 eV



13. In order to observe a ring diffraction pattern on the screen shown above, which of the following conditions must be met?

(A) The electron beam must be polarized.
(B) The electron beam must be approximately monoenergetic.
(C) The copper foil must be a single crystal specimen.
(D) The copper foil must be of uniform thickness.
(E) The electron beam must strike the foil at normal incidence.

14. The speed of sound in an ideal gas is related to the temperature T of the gas. This speed is proportional to

(A) $T^{\frac{1}{4}}$

(B) $T^{\frac{1}{2}}$

(C) T

(D) $T^{\frac{4}{3}}$

(E) T^{2}

15. Two harmonic transverse waves of the same frequency with displacements at right angles to each other can be represented by the equations

$$y = y_0 \sin(\omega t - kx),$$

$$z = z_0 \sin(\omega t - kx + \phi),$$

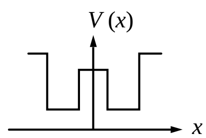
where y_0 and z_0 are nonzero constants.

The equations represent a plane-polarized wave if ϕ equals

(A) $\sqrt{2}$
(B) $3\pi/2$
(C) $\pi/2$
(D) $\pi/4$
(E) 0

Questions 16-17

The sketch below shows a one-dimensional potential for an electron. The potential is symmetric about the *V*-axis.



16. Which of the following statements correctly describes the ground state of the system with one electron present?

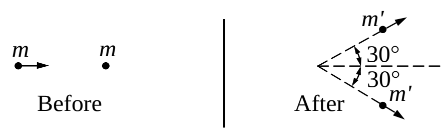
    (A) A single electron must be localized in one well.
    (B) The ground state will accommodate up to four electrons.
    (C) The kinetic energy of the ground state will be one-half its potential energy.
    (D) The wave function of the ground state will be antisymmetric with respect to the *V*-axis.
    (E) The wave function of the ground state will be symmetric with respect to the *V*-axis.

17. A second electron is now added to the system. If the electrons do not interact, which of the following statements is correct?

    (A) The second electron must be localized in the well not previously occupied.
    (B) In the ground state of the system, each of the two electrons will have the same spatial wave function.
    (C) In the ground state of the system, one electron will be in a spatially symmetric state and one will be in a spatially antisymmetric state.
    (D) The second electron will not be bound.
    (E) Pair annihilation will occur.

Questions 18-19

A particle with rest mass m and momentum $mc/2$ collides with a particle of the same rest mass that is initially at rest. After the collision, the original two particles have disappeared. Two other particles, each with rest mass m', are observed to leave the region of the collision at equal angles of 30° with respect to the direction of the original moving particle, as shown below.



18. What is the speed of the original moving particle?

(A) $c/5$
(B) $c/3$
(C) $c/\sqrt{7}$
(D) $c/\sqrt{5}$
(E) $c/2$

19. What is the momentum of each of the two particles produced by the collision?

(A) $mc/5$
(B) $mc/2\sqrt{3}$
(C) $mc/\sqrt{5}$
(D) $mc/2$
(E) $mc/\sqrt{3}$

Questions 20-21

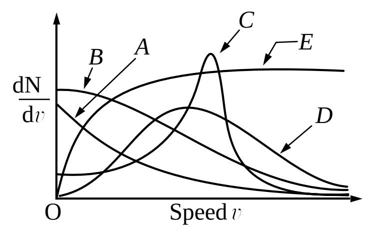
An ideal diatomic gas is initially at temperature T and volume V. The gas is taken through three reversible processes in the following cycle: adiabatic expansion to the volume $2V$, constant volume process to the temperature T, isothermal compression to the original volume V.

20. For the complete cycle described above, which of the following is true?

(A) Net thermal energy is transferred from the gas to the surroundings.
(B) The net work done by the gas on the surroundings is positive.
(C) The net work done by the gas on the surroundings is zero.
(D) The internal energy of the gas increases.
(E) The internal energy of the gas decreases.

21. Which of the following statements about entropy changes in this cycle is true?

(A) The entropy of the gas remains constant during each of the three processes.
(B) The entropy of the surroundings remains constant during each of the three processes.
(C) The combined entropy of the gas and surroundings remains constant during each of the three processes.
(D) For the complete cycle, the combined entropy of the gas and surroundings increases.
(E) For the complete cycle, the entropy of the gas increases.



22. Which of the curves in the graph above best represents the distribution of speeds of the molecules in an ideal gas at thermal equilibrium?

    (A) *A* (B) *B* (C) *C* (D) *D* (E) *E*

23. Which of the following is most useful for measuring temperatures of about 3,000 K?

    (A) Optical pyrometer (B) Carbon resistor (C) Gas-bulb thermometer
    (D) Mercury thermometer (E) Thermocouple

24. A counter near a long-lived radioactive source measures an average of 100 counts per minute. The probability that more than 110 counts will be recorded in a given one-minute interval is most nearly

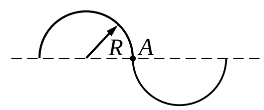
    (A) zero (B) 0.001 (C) 0.025 (D) 0.15 (E) 0.5

25. Materials that are good electrical conductors also tend to be good thermal conductors because

    (A) they have highly elastic lattice structures
    (B) they have energy gaps between the allowed electron energy bands
    (C) impurities aid both processes
    (D) surface states are important in both processes
    (E) conduction electrons contribute to both processes

26. The nonconservation of parity in the decay $\pi^+ \rightarrow \mu^+ + \nu$ can be verified by measuring the

(A) Q-value of the decay
(B) longitudinal polarization of the μ^+
(C) longitudinal polarization of the π^+
(D) angular correlation between the μ^+ and the ν
(E) time dependence of the decay process



27. The S-shaped wire shown above has a mass M, and the radius of curvature of each half is R. The moment of inertia about an axis through A and perpendicular to the plane of the paper is

(A) $\frac{1}{2}MR^2$

(B) $\frac{3}{4}MR^2$

(C) MR^2

(D) $\frac{3}{2}MR^2$

(E) $2\,MR^2$

Questions 28-29 are based on the following information.

A long, thin, vertical wire has a net positive charge λ per unit length. In addition, there is a current I in the wire. A charged particle moves with speed u in a straight-line trajectory, parallel to the wire and at a distance r from the wire. Assume that the only forces on the particle are those that result from the charge on and the current in the wire and that u is much less than c, the speed of light.

28. Suppose that the current in the wire is reduced to $I/2$. Which of the following changes, made simultaneously with the change in the current, is necessary if the same particle is to remain in the same trajectory at the same distance r from the wire?

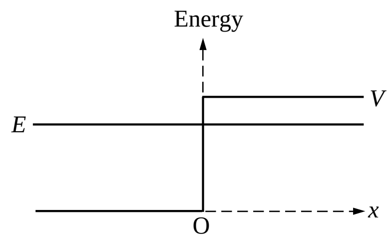
    (A) Doubling the charge per unit length on the wire only
    (B) Doubling the charge on the particle only
    (C) Doubling both the charge per unit length on the wire and the charge on the particle
    (D) Doubling the speed of the particle
    (E) Introducing an additional magnetic field parallel to the wire

29. The particle is later observed to move in a straight-line trajectory, parallel to the wire but at a distance $2r$ from the wire. If the wire carries a current I and the charge per unit length is still λ, the speed of the particle is

    (A) $4u$
    (B) $2u$
    (C) u
    (D) $u/2$
    (E) $u/4$

30. An energy level of a certain isolated atom is split into three components by the hyperfine interaction coupling of the electronic and nuclear angular momenta. The quantum number j, specifying the magnitude of the total electronic angular momentum for the level, has the value $j = 3/2$. The quantum number i, specifying the magnitude of the nuclear angular momentum, must have the value

(A) 1/2 (B) 1 (C) 3/2 (D) 2 (E) 3



31. An electron with energy E and momentum $k\hbar$ is incident from the left on a potential step of height $V > E$ at $x = 0$. For $x > 0$, the space part of the electron's wave function has the form

(A) e^{ikx} (B) $e^{-ik'x}; k' < k$ (C) $e^{-\alpha x}$, where α is real and positive
(D) $\sin kx$ (E) identically zero

Answer Key

1. D	8. A	15. E	22. D	29. C
2. D	9. C	16. E	23. A	30. B
3. C	10. A	17. B	24. D	31. C
4. A	11. B	18. D	25. E	
5. D	12. C	19. B	26. B	
6. E	13. B	20. A	27. E	
7. C	14. B	21. C	28. D	