A Report of the GRE Committee of Examiners
for the Advanced Test in Computer Science

The GRE Advanced Test in Computer Science

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This report describes the Advanced Test in Computer Science which was recently introduced in the Graduate Record Examination Program. The GRE program is described in general, and, the events leading to the establishment of the Advanced Computer Science Test are discussed. Content specifications and their rationale are given. A set of sample questions is included.

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1. Introduction

In the fall of 1972, the Graduate Record Examination (GRE) Board was asked to authorize and encourage the development of an Advanced Computer Science Test. Pertinent data were gathered from representatives of ACM, computer science educators, and GRE Program staff and a proposal was submitted to the GRE Board. In the spring of 1975, the Board approved the Advanced Test and appointed a Committee of Examiners whose responsibilities include the determination of the test's content and scope. Draft questions were collected during 1975, and the examinations were prepared in early 1976. Development of the examinations will be a continuing responsibility of the Committee.

The GRE Advanced Computer Science Test was given for the first time on October 16, 1976. Beginning in October 1977, the test will be available five times per year.

2. The GRE Program

The GRE Program is a coordinated effort to assist graduate schools and departments in admissions, guidance and placement, selection of fellowship recipients, and related areas as well as to assist students with the transition to graduate education. To achieve these purposes, the program offers tests, research, publications, and advisory services.

Testing has been the major vehicle for the GRE Program. Two types of examinations are offered: an Aptitude Test, consisting of two parts—verbal and quantitative, and Advanced Tests in 20 disciplines, now including computer science. These are administered on specified dates at GRE test centers in the

United States and other countries and at other times and places by special arrangement. Score reports are sent to the institutions designated by candidates taking the tests and to the candidates themselves.

Scores on the test are intended to indicate students' abilities and mastery of the subject matter emphasized in many undergraduate programs and, since past achievement is usually a good indicator of future performance, such scores can aid in predicting success in advanced study. A standardized test also allows comparison of the performance of students from different institutions with different programs on a single measure of competence in the field. Test scores should be used only in conjunction with other measures of competence in evaluating students for graduate admission such as prior academic grades, letters of recommendation, and previous experience. They should not be used for evaluations other than graduate admission.

3. Test Development

A. Background

Much of the early initiative leading to the establishment of the Advanced Computer Science Test can be attributed to John Hamblen of the University of Missouri-Rolla and ACM Secretary (1972–1976). In October, 1972 he requested the GRE Board to "authorize and encourage" the development of the test. In reply, he was asked to show that computer science satisfies the criteria used by the GRE Program to determine whether an advanced test should be developed for a new discipline. These criteria include the following:

(i) The field should be large enough, with a sufficient number of graduate programs, graduate faculty members, and matriculated graduate students. It should have one or more scholarly journals and professional associations willing to cooperate on test development.

(ii) There should be a need for the test and a high probability that it will be used.

(iii) It should be possible to construct a test to GRE standards. For example, the field must be reasonably homogeneous and amenable to a test which can be scored reliably, continually validated, and administered with standard procedures consistent with other Advanced Tests.

After sufficient data were supplied, no further action took place until the summer of 1974 when, at a meeting of chairmen of Ph.D. degree-granting computer science departments a resolution calling for a GRE Advanced Computer Science Test was passed. The resolution was sent to the GRE Program staff in time for the September 1974 GRE Board meeting and received favorable consideration there.

The GRE Program staff invited a group of computer science educators to meet on December 13, 1974 for the purpose of preparing tentative content specifications for the proposed test.[1] The content specifications were circulated to 120 graduate degree-granting computer science departments along with a questionnaire to gather data on possible utilization of the test both by students and graduate departments. Responses from 60 departments included few critical comments about the content specifications and indicated that 39 departments would require the GRE Advanced Computer Science Test.

The information collected from this questionnaire and other data gathered in 1972–1974 was presented to the GRE Board at its April 1975 meeting. The Board then approved the creation of a GRE Advanced Test in Computer Science.

B. Committee of Examiners

During the summer of 1975, a Committee of Examiners was appointed by Educational Testing Service (ETS) with the cooperation and assistance of ACM and was charged with the development of the Advanced Computer Science Test. The committee was initially appointed for one year (and subsequently reappointed for two more years ending in 1978) and was composed of the following members: Richard Austing, Chairman (University of Maryland), Michael Faiman (University of Illinois), Anthony Ralston (SUNY at Buffalo), Mary Shaw (Carnegie-Mellon University), and Peter Wegner (Brown University).

The role of the committee as well as the general nature of the test are explained in detail in the booklet "A Description of the Advanced Computer Science Test" available from GRE, Educational Testing Service, Princeton, N.J. 08540. Essentially the Committee has control over the content and scope of the examination. It writes or approves all test questions with advice and assistance from ETS staff members on the specific wording of questions. Each year the Committee will produce a new version of the test which will allow gradual evolution of the coverage of the discipline. Each new edition will be "equated" with previous ones; that is, scores will be related to those on previous editions by standard statistical methods.

C. Content Specifications

In determining the scope of the test, the committee considered the tentative content specifications previously sent to degree-granting departments. A revised version (Appendix A) was agreed upon after lengthy discussions. Various factors influenced the choices made in the Content Specifications of which the most significant are:

(1) Since undergraduate computer science curricula still vary a great deal from one institution to the next, the content focuses on material which should be common to all or almost all such programs.

[1] Attending this meeting were William F. Atchison (ACM Education Board Chairman), Richard Austing (University of Maryland), Michael Faiman (University of Illinois), John Hamblen (University of Missouri-Rolla), Jeffrey Ullman (Princeton University) and Peter Wegner (Brown University).

(2) In the content specifications and specifically in the examination questions themselves an attempt was made to define the subject matter spectrum of computer science broadly rather than narrowly.

(3) The Committee's belief in the centrality of Programming Systems and Methodology to the discipline of computer science is reflected in the emphasis given to this area in the content specifications.

(4) The Computer Systems section of the specifications might well be more extensive if it were not for the fact that other parts of the specifications contain aspects of this area (e.g. Operating Systems under Programming Systems and Methodology).

(5) The Theory of Computation is given a relatively small portion of the total at least in part because of the wide variation in approach to this area in undergraduate curricula.

(6) The Committee believes that any undergraduate curriculum in computer science should contain a significant component of Computational Mathematics.

(7) The short shrift given to the Special Topics reflects the great variability in whether they are covered or not in undergraduate curricula rather than a belief that they are of small importance. The Committee expects that some of these topics will "graduate" into other portions of the specifications in future years.

Test questions were solicited from a large number of computer scientists. Questions received and those questions supplied by the committee were reviewed. Using the content specifications as a guide, questions were categorized and then identified according to approximate degree of difficulty.

An experimental test consisting of 36 questions was prepared and was administered to 320 students in the fall of 1975. The results were analyzed for effectiveness and reliability by the same statistical methods used by ETS on all advanced tests in other fields and were found to be satisfactory.

The Committee then selected questions in proportions to match the content specifications and assembled two tests, one for October 1976 and the other for December 1976. Plans were made to solicit additional questions for the April 1977 test and then for each subsequent test. Sample questions, similar to those in the tests, are given in Appendix B. They are taken from the previously cited descriptive booklet on the Advanced Computer Science Test, but the content distribution in this sample does not match the percentages given in Appendix A.

4. Summary

The GRE Advanced Computer Science Test will affect undergraduate programs in colleges and universities currently offering baccalaureate degrees in computer science. It will also become a guideline, although not intended for that purpose, for course and curriculum development in institutions not now providing an undergraduate major in the field. Consequently, it is imperative that as many computer scientists as possible contribute to the continuing development of the test, either by critical comments to the committee concerning the content specifications or by writing questions for the test. In addition, educationally oriented groups within professional societies are welcome to provide questions, comments, or suggestions for future committee members. Although there are constraints on the amount of change which can occur from test-to-test, broad-based support and interest from concerned educators will insure the development of the Advanced Computer Test in a way that is consistent with the growth of the discipline.

Appendix A. Content Specifications, GRE Advanced Test in Computer Science

The items included in parentheses are intended to be examples of topics under the headings and not exhaustive lists.

I. PROGRAMMING SYSTEMS AND METHODOLOGY 40%

- **A. Programming Languages and their Processors**
  (evaluation of expressions, block structure, parameter passing and binding, control structures, assemblers, compilers, interpreters)
- **B. Programming Concepts**
  (iteration, recursion, modularity, abstraction, refinement, verification, documentation)
- **C. Properties of Algorithms**
  (time and space requirements of programs, especially of common processes such as sorting and searching; correctness of programs)
- **D. Data Structures**
  (linear data structures, list structures, strings, stacks, queues, trees)
- **E. Operating Systems**
  (scheduling, resource and storage allocation, interrupts, synchronization, addressing techniques, file structures, editors, batch/time sharing, networks/communications)

II. COMPUTER SYSTEMS 20%

- **A. Logic Design**
  (switching algebra, combinatorial and sequential networks)
- **B. Implementation of Computer Arithmetic**
  (codes, number representation, add/subtract/multiply/divide)
- **C. Processor Organization**
  (instruction sets, registers, data and control flow, storage)
- **D. System Architecture**
  (configurations of and communication among processors, memories, and I/O devices)

III. THEORY OF COMPUTATION 15%

- **A. Automata Theory**
  (sequential machines, transitions, regular expressions, Turing machines, nondeterministic finite automata)
- **B. Analysis of Algorithms**
  (complexity of specific algorithms, exact/asymptotic/lower bound analysis, analysis of time/space complexity, correctness)
- **C. Formal Languages**
  (regular and context-free grammars/languages, simple properties such as emptiness or ambiguity)

IV. COMPUTATIONAL MATHEMATICS 20%

A. Discrete Structures
(logic, sets, relations, functions, Boolean algebra, linear algebra, graph theory, combinatorics)

B. Numerical Mathematics
(arithmetic, number representation, numerical algorithms, error analysis, discrete probability and elementary statistics)

V. SPECIAL TOPICS 5%
(simulation and modeling, data management systems, information retrieval, artificial intelligence)

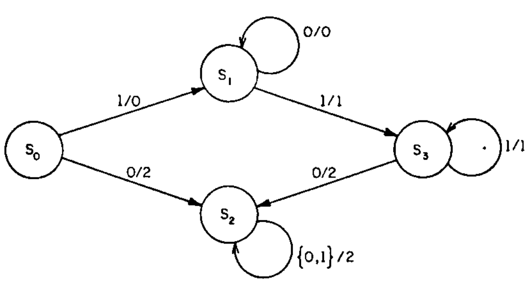
Appendix B. Sample Questions

The following questions will not appear in any of the GRE Advanced Tests in Computer Science, but are similar to actual test questions. These few examples do not illustrate the full range of the test in terms of the abilities measured, the subject-matter areas tested, or the difficulty of the questions posed.

1. Which of the following is true of interrupts?
(a) They are generated when memory cycles are "stolen".
(b) They are used in place of data channels.
(c) They can indicate completion of an I/O operation.
(d) They cannot be generated by arithmetic operations.
(e) None of the above

2. Which of the following is *not* a sentence that is generated by the grammar $A \to BC$, $B \to x \mid Bx$, $C \to B \mid D$, $D \to y \mid Ey$, $E \to z$?
(a) *xyz* (b) *xy* (c) *xxzy* (d) *xxxxy* (e) *xxx*

3.



If S_0 is the initial (start) state and S_3 is the final state, then which of the following regular expressions describes the set of strings recognized by the finite state machine represented above?
(a) 10*1* (b) 10*1 (c) (0 + 1)* (d) 0*(0 + 1)*0*
(e) 10*11*

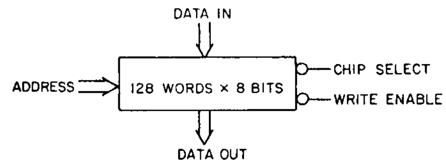
A certain computer represents floating point numbers by means of a signed magnitude fractional mantissa and an excess 16 base 4 exponent. The floating point format is illustrated below.

Exponent						Mantissa					
1	1	0	0	1	0	1	1	1	0	0	0

4. The decimal value of the number shown above is
(a) −0.0546875 (b) −0.5 (c) −2. (d) −3.5 (e) −14

5. Of the following, which best approximates the magnitude of the greatest number that can be represented in the floating point format above?
(a) 10^{18} (b) 3×10^3 (c) 4×10^9 (d) 4×10^{18} (e) 10^9

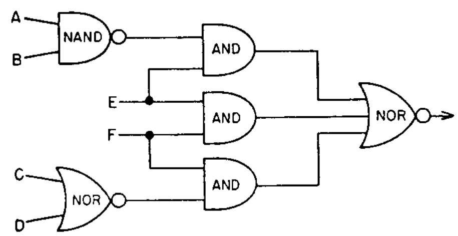
6.



The function generated by the network above is
(a) $\overline{AB}E + EF + \overline{CD}F$
(b) $(\bar{E} + AB\bar{F})(C + D + \bar{F})$
(c) $(\bar{A}\bar{B} + E)(\bar{E} + \bar{F})(C + D + \bar{F})$
(d) $(A + B)\bar{E} + \bar{E}\bar{F} + CD\bar{F}$
(e) $(\bar{A} + \bar{B})E + EF + \bar{C}\bar{D}F$

7. Let
$f(X)$ = **if** $x = 1$ **then** 0 **else** $[x * f(x - 1) + x^2]$
The value of $f(4)$ is
(a) 53 (b) 29 (c) 50 (d) 100 (e) 148

A random access, read/write semiconductor memory chip is organized into 128 words of 8 bits each. A block diagram of the chip is shown below.



8. Ignoring power supply connections, the minimum number of pin connections per chip is
(a) 23 (b) 25 (c) 26 (d) 138 (e) 146

9. A larger memory of 4K words of 16 bits each (K = 1024) may be obtained by connecting
(a) 32 chips in a 16 × 2 array
(b) 32 chips in a 32 × 1 array
(c) 64 chips in a 32 × 2 array
(d) 64 chips in a 8 × 8 array
(e) 32 chips in no special configuration

10. Of the following, which best approximates the ratio of the number of nonterminal nodes to the total number of nodes in a complete K-ary tree of depth N?
(a) $1/K$ (b) $K - 1/K$ (c) $\log_{10}(1/N)$ (d) $N - 1/N$ (e) $1/N$

11. In the following procedure

```
integer procedure P(X, Y);
integer X, Y; value X;
begin
  K ← 5; L ← 8;
  P ← X + Y
end
```

X is called by value and Y is called by name. If the procedure were invoked by the following program fragment

```
K ← 0;
L ← 0;
Z ← P(K, L),
```

then the value Z would be set equal to
(a) 5 (b) 8 (c) 13 (d) 0 (e) none of the above

Key

1. c **2.** a **3.** e **4.** d **5.** e **6.** b **7.** d **8.** b **9.** c **10.** a **11.** b

[*Editor's note:* the topic of the GRE Advanced Test in Computer Science has been discussed in an exchange of letters that appeared in a previous issue. The interested reader is referred to the August 1977 *Communications*, pp. 609–610.]