A GRAPHIC SIMULATION PROGRAM FOR MICROCOMPUTERS, ELECTRON CONFIGURATION

By

BETTY McNEIL BRANSTETTER

Bachelor of Science in Education
Southwestern Oklahoma State University
Weatherford, Oklahoma
1950

Bachelor of Science
Central State University
Edmond, Oklahoma
1971

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
December, 1980

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Thesis Approved:

Thesis Adviser

Dean of Graduate College

PREFACE

If the computer is going to be an aid in the public school education process, the classroom teacher will need to become acquainted with and feel comfortable with the computer and its many applications. The objectives of this program development were to determine if the average classroom teacher without prior computer background work could become computer-literate enough to develop programs and to adapt existing programs to fit his or her classroom educational needs; also to determine if simulation programs on the microcomputer are acceptable to the classroom students which in turn would be an aid to their educational process.

I wish to express my appreciation to my advisers, Dr. Tom Johnsten and Dr. John Gelder, for their continual encouragement and assistance throughout the development of this program. A special thanks goes to Dr. Gelder for his many hours of patient instructions and invaluable assistance with the microcomputer. In addition, I want to extend my appreciation to Sharon Higgins for her excellence in preparation of the final copy of this manuscript.

Finally, my special thanks is expressed to my husband, Max, and our children for their understanding, encouragement, and sacrifices while my time and energies have been directed to this project.

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CHAPTER I

INTRODUCTION

Educators are excited by the greatly expanded possibilities that microcomputers provide for computer applications in chemical education. Using graphic simulation to enhance the presentation of scientific concepts is one application of the use of this new technology. Electron Configuration is a graphic simulation program designed as a supplement to the teacher's total class program in an introductory chemistry course.

Rationale

The revolution in the computer industry brought on by microcomputers has begun to make an impact on education. Education should not ignore the implications of the microcomputer revolution, but should deal with the educational applications of this new technology in its variety of disciplines.

The rate at which new discoveries and developments are being made is accelerating rapidly and the cost of equipment and time needed to acquire and use the microcomputers in the classroom continues to decline. Educators are at a time of transition from the computer as a curiosity to the computer as a tool that should be employed at least occasionally by most educators (1).

> Joseph Weisenbaum has pointed out that certain devices given us by technology - the microscope and the telescope for example - have led to profound changes in mankind's view of himself and the universe. These devices have been like special windows which have enlarged man's view of the world around him. The computer, working through special graphics equipment, is likely to become another such window; in this case, however, it will be an inward view. Through the medium of computer graphics, the computer can give pictoral form to abstract formulations of the human intellect (2, p. 644).

The first year chemistry student is inundated with numerous physical and chemical concepts of matter. One of these important concepts is concerned with electrons, their probable locations and energy levels within the atom. A model simulated on the computer may help the students to visualize this complex abstract concept and better understand electron configuration and its application to chemical bonding.

Background Information

The electrons in an atom are of primary interest to the chemist. To be able to describe fully what an electron does, the chemist must know where it is and its velocity. Based on Schrodinger wave equation, there is a set of four quantum numbers of an electron used to establish its state, fixing both its energy and position. The electron configuration of an atom is a statement giving the population and probable location and energy of the electrons.

The first or principal quantum number determines the energy of the electron. It may have any integral value except zero. Electrons of an atom moving about in roughly the same region are said to be in the same principal level or shell.

As the quantum number increases, the energy of the electron increases, and the average distance of the electron cloud from the nucleus also increases.

Each level of electrons in an atom include one or more sublevels or subshells. The subshells are denoted by the second quantum number. Traditionally subshells are expressed by the symbols s, p, d, and f which come from the sharp, principal, diffuse, and fundamental series observed in atomic spectral early in this century. Electrons in sublevels within a given principal level will have energies which increase slightly with increasing value.

Each sublevel contains one or more orbitals which is designated by the third quantum number. This quantum number is associated with the orientations of the electron cloud with respect to a given direction. Each of these orbitals will have essentially the same energy. Each electron in an atom will be in an orbital within a sublevel within a principal level.

The fourth quantum number is called the spin quantum number. The spin quantum number can be associated with the spin of the electron about its own axis. An electron can have one of two possible spins, clockwise or counterclockwise. Two electrons in the same orbital having opposite spins are said to be paired; both of these electrons would have the same amount of energy. It is a rule that no more than two electrons can fit into any atomic orbital. This agrees with the Pauli exclusion principle which states that no two electrons in an atom can have the same set of four quantum numbers.

To arrive at the electron configuration of atoms, the order in which the various sublevels become populated must be known. The electrons are added to sublevels in order of increasing energy, in general filling each sublevel to capacity before beginning the next. This general approach can be used to find the electron configuration of most atoms. This method is sometimes called the Aufbau, or building up, principle, adding electrons one by one as the atomic number increases. The order of sublevels are listed in proper order as follows:

1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s,
4d, 5p, 6s, 4f, 5d, 6p, 7s, 5f, 6d.

Description of the Program

Electron Configuration (Appendix A) is a graphic simulation program illustrating the filling of the different energy shells and orbitals with electrons. The program is written in BASIC computer language for the Apple II microcomputer. The design of the program makes it suitable to be used with a class lecture format.

At the beginning of the program the s, p, d sublevels through the 4d level are graphically shown in white to illustrate some of the possible energy levels that can exist. Energy levels, sublevels, or orbitals are not in existence until they actually contain an electron. As the first electron is placed in a shell, the shell will turn green to show that it is now in existence. (An electron can be added by depression of the space bar or any key.) Two different colors are used to represent an electron pair; the bluish color represents the first electron in an orbital with its clockwise spin, and the pinkish color represents the second electron with its counterclockwise spin.

As stated in the background information, the orbitals of the sublevels will have essentially the same energies. Through experimentation of the properties of the carbon atom, it was indicated that there was an energy difference between the different possible electronic arrangements in the p and d orbitals. The most stable configuration was the one in which electrons are unpaired, with parallel spins. Hund's rule states that in an atom in which orbitals of equal energy are to be filled by electrons, the order of filling is such that as many electrons remain unpaired as possible. In the p and d orbitals in compliance with this rule, the electrons with the clockwise spin are all filled first before they are paired with the opposite spin electrons.

The configuration of electrons generally follow the Aufbau principle. The major exceptions occur for the elements of medium to high atomic number in which a sublevel is close to being filled or half-filled. Having a full or half-full sublevel confers a measure of stability on the electronic structure of an atom. Where 3d sublevels are involved, with energies close to those of the 4s sublevels, the effect is large enough in chromium to allow a 4s electron to move to the 3d sublevel, giving chromium five 3d electrons. In the copper atom a 4s electron is also placed in the 3d sublevel, thereby filling that sublevel. These anomalies of chromium and copper are taken into account and illustrated in the program.

As each electron is added, the symbol for that particular element with its atomic number will appear on the screen. Also along the bottom of the screen, typed out, will be the total electron configuration notation for the element symbolized above.

As each electron is added by the depression of a key, the program can proceed at a rate determined by the lecturer and the class. When the program has been completed, it can easily be run again for reinforcement of the concepts or for review.

Limitations

Due to the availability of space on the television screen, the 5p through the 7s electron orbitals could not be incorporated into the program. Also the differences of relative energies of the atomic orbitals, especially the difference of energy levels of the 1s and the 2s orbitals, could not be accurately illustrated because of limited space on the screen.

Another limitation is the portraying of the correct capitalization of the element symbols due to the graphic nature of drawing the letters. When the symbol is composed of two letters, the second letter is drawn to smaller dimensions to illustrate the correct capitalization procedure. Sometimes models can be useful even if they are not quite right.

Summary

Most educators accept the premise that students learn best by direct experiences. If educators accept this premise, then the microcomputer used as a simulator and enhanced by color graphics can save students a lot of time in getting that experience. To cite an example, the Milligan oil-drop experiment used in physics and chemistry courses requires several weeks of work and extensive equipment for students to become proficient enough to set up and run (3). Titration is another example of a computer simulated experiment program used to replace time consuming experiments (4). Now these experiments can be shared with a large group of students through a program graphically simulated on a microcomputer.

The Gas Laws is a computer simulation laboratory experiment that is designed to teach concepts rather than manipulative skills (5). The program saves much student time as well as cost associated with actually performing the experiments. Extensive use of graphics and sound not only add to the realism of the simulation, but also enhances the student's interest in the exercise.

With the development of the microprocessor, the cost/benefit ratio is now within the range for computer-based education to be brought into the school systems on a broad basis.

The problem of hardware cost is receding, and with graphic possibilities of these microcomputers, low-cost simulations are now a reality. Educators now have the means of simulating physical events, experiments, and other learning scenes that lend themselves to graphical presentations.

CHAPTER II

REVIEW OF LITERATURE

Rapid advances in technology and the range of possible uses of technology in science education is overwhelming. New technology represents a considerable resource, but it is a largely unrealized potential. It seems likely that technological advances will continue which can have a dramatic effect on teaching methodology (6).

History of Computers in Education

Beginning about 1960 there was a concerted effort by many people to explore and to demonstrate the value of digital computers in the learning environment. The educational community largely ignored all these efforts. There were many reasons for this, such as the cost and the unavailability. The expenditures for textbooks, films, and other instructional material measured in pennies per student per hour as compared to two to five dollars per student per hour for computer time. Also the learners had to be transported to the computers rather than the computer brought into the learning environment due to the size and weight of the computers and the peripheral devices.

The flexibility of computer use was also hindered because of the complexity of interconnections of most time-sharing systems (the primary source of computing power at that time). This resulted in many interruptions and wasted class periods. Many teachers rejected computers as unreliable for class use.

In the late 1960's computer-aided instruction was going to revolutionize the learning process; the best teachers were going to write courseware that would be nationally distributed. Students would learn rapidly and efficiently. However, the educational community had not overcome its reluctance to adopt computer-aided instruction on a wide scale; so reality turned out to be quite different from the dream.

> The lure of computer-aided instruction is once again being felt by those who have maintained their interest in this problem-ridden educational tool and believe that advances in technology will give it another chance (7, p. 29).

Future of Computers in Education

According to the National Science Foundation, the future for computer-aided instruction is exploration aimed at learning about learning through interactive computer use rather than at achieving specific learning goals (7). Since learning is still in its infancy as a cognitive science, with or without computers, many educators have responded by using computers as a complement to regular course offerings rather than as a complete self-paced course where the traditional student-teacher dialogue is replaced with a student-computer interaction. As machines communicate faster than humans, they should be able to provide more and better communications. This objective has been achieved in drill and practice but not in the larger fraction of educational environment (3).

New approaches for computer-aided instruction are not based on the existence of a general-purpose communications model. Instead, they implore the computer to develop the model.

> After a decade of allowing children mainly to play games, draw pictures, and learn geometry on their computers, educators working at the Massachusetts Institute of Technology and elsewhere are expending their efforts in other areas. In the past year, the M.I.T. group has deployed computers to provide a creative learning environment in a public school setting, to design new course material that allows graphical interaction in high school mathematics and physics, and to augment the sensory environment of handicapped children (3, pp. 44-45).

The future for computer technology in the educational environment may be in the personal computers. The personal computer defies exact definition, but may be broadly defined as any general purpose computer affordable by an individual or a small group which may be designed for a specific area of application. In the home, in business, in science, and in education, the personal computer is an increasingly available resource, prompting widespread attention to both its use and its impact. The widespread availability of inexpensive computing systems will bring information processing to large numbers of burgeoning society more and more preoccupied with education, entertainment, science, and business. Worldwide communications will be readily accessible via the computer--as the printed book brought reading to large numbers of people in early industrial society (8).

The rapid technological evolution which has brought us time-shared, interactive computing, pocket calculators, video games, and home computers is now having its effect on computer graphics. Modern graphic devices support two-way interaction between the user and the computer. This capability has stimulated a wide variety of graphic applications in many fields, including education.

> We are in a true microelectric revolution. Pocket calculators that are cheaper, more accurate, and more versatile than slide rules; smart scientific instruments that can control experiments, analyze data; and small inexpensive microcomputer systems that rival in computing with the large machines of only a decade ago are having a profound effect on how chemists learn, teach, do research, store, and access information. Over the next decade microprocessors and similar microelectric devices are certain to have an impact on almost every facet of chemists' professional lives (9, p. 701).

CHAPTER III

RESULTS

While no one has proven the merit of using computer simulation for education, arguments for it are a lot easier to appreciate than those for conventional Computer-Aided Instruction (3). Electron Configuration program (Appendix A) was used as a supplement to the teacher's lecture in a college first semester summer term chemistry course as well as in a high school class. The total student number for both classes was 48. The students that made up the high school class were juniors and seniors; the students in the college chemistry class were freshmen through seniors. The range of ages for the total number of students was from 16 to approximately 21 years.

The program was used as a review after the basic concepts had been presented in the teacher's usual techniques. After the testing over the unit, the students were administered an evaluation survey instrument (Appendix B).

Evaluation Instrument

The evaluation instrument was designed in two parts. One part permitted the students to briefly rank the program on a ranking scale. The second part of the instrument provided questions which allowed the students to express their opinions concerning the use of microcomputer simulation programs as a supplement to the overall class program.

The second part of the instrument had four questions; one was concerned with the design of the program. Was the design of the program such that you could clearly understand what it was trying to represent? The second question addressed itself to the benefit which the program had in the students' understanding of the concept that was being presented. The third question asked the students to comment about the effectiveness of simulation programs when used in conjunction with the class lecture format. The last question was concerned with the general interest that the students had about microcomputers and their desire to have access to microcomputers for future class work.

Of the 48 evaluation instruments issued, 34 were returned with both sections completely answered and 14 papers were returned with only the two ranking questions answered. Table I shows the ranking scale results from this instrument.

Of the 34 students who expressed their opinions concerning the graphic simulation program, most were highly receptive and felt it was a definite aid in learning the concepts. They also expressed approval of the use of computer simulation programs as a supplement to class lectures. But only slightly more than half the students who responded wanted to learn to use and to personally interact with the computer. The students who responded less than enthusiastically about their personal use of the computer were of the college group; all the high school students were eager to have access to the computer and were highly motivated to learn more. They felt that the computer had many opportunities for enhancing classroom instruction.

TABLE I

RESULTS OBTAINED FROM THE EVALUATION INSTRUMENTS ON THE RANKING SCALE

Scale	Low 1	2	3	4	Average 5	6	7	8	9	High 10
Results:										
Question 1						2	8	9	13	16
Question 2				1	4	2	11	8	10	12
Total Number of Subjects										48

Conclusions and Summary

The low cost of microcomputer hardware of all kinds provides opportunities for chemistry teachers from high school through graduate school level to incorporate computer-aided instruction into their courses, provided, of course, that they are willing to spend the time necessary to write or acquire and adapt necessary software for their classes (10).

Computer graphics as an instructional tool is making rapid progress with developments in hardware and software coming rapidly. It appears that society may be on the verge of a new era of computing in which the powers of the computer, through its graphic capabilities, will have many and varied applications in education, especially science education.

> The pressures of the marketplace in the area of microprocessor based TV games and home computers are going to produce new, more powerful, less expensive display methods. High resolution dynamic color displays with easy graphic input as well as output coupled with transparent graphics software will make interactive computer graphics a new kind of window, expanding our visual horizons. We chemistry educators--whose job it is to help students see in their minds' eyes potential energy surfaces, conformational isomerism, orbitals--we should be able to take special advantage of the emerging graphics technology to help our students achieve concrete visualization of these abstract concepts (2, p. 649).

The answer, at the moment, resides in specialized uses of the computer for supplementing the teacher. Computer as a low cost simulator presents educators with a means of simulating physical events, experiments, and other learning scenes that lend themselves to graphical presentations. Classroom use of computer graphics offers opportunities for enhancing elementary and secondary teaching in many subject areas.

Summary

Computers are here to stay. Computer usage is no longer a skill needed only in certain professions and occupations. Many opportunities are being missed because teachers do not know how to use computers in the classroom and know very little about the potential for computer applications (11).

Technical obsolescence is not something that happens only to machines and hardware--it happens to teachers also. Many educators do not seem to feel the relevance of computing in the curriculum and therefore give it low priority. Often high school and college students are far ahead of faculty in organizing microcomputer clubs, developing and evaluating hardware and software; as Milner (11) states, students may well become more computer literate than their teachers.

The revolution in the computer industry brought on by microcomputers has begun to make an impact on education. Many schools are likely to own at least one microcomputer within the next few years. Educators should not ignore the implications of the microcomputer revolution.

> Andrew Molnar of the National Science Foundation sees computer literacy as the next crisis in American education. Only a few years ago most educators felt that the role of computers in education would be defined some time in the future. Microcomputers have changed all that--the future is now (11, p. 546).

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APPENDIX A

A GRAPHIC SIMULATION PROGRAM FOR MICROCOMPUTERS, ELECTRON CONFIGURATION

```
LIST

90  REM  ELECTRON CONFIGURATIONS
95  HOME : VTAB 24
100  GR :X = 26:Y = 26
101  GOSUB 6000
106  GOSUB 2000:X = 26:Y = 26
110  COLOR= 4
120  HLIN 6,9 AT 39
130  VLIN 37,39 AT 6: VLIN 37,39 AT 9
140  VTAB 23: HTAB 1: PRINT "1S"
145  COLOR= 2: PLOT 7,38
150  VTAB 22: HTAB 3: PRINT "1"
155  COLOR= 8: GOSUB 5010: GOSUB 7000
160  GOSUB 2000: COLOR= 9: PLOT 8,38
166  VTAB 22: HTAB 3: PRINT "2"
167  COLOR= 0: GOSUB 7000: COLOR= 8: GOSUB 5020: GOSUB
     7010
169  GOSUB 2000: COLOR= 2: PLOT 7,30
170  COLOR= 4: HLIN 6,9 AT 31
180  VLIN 29,31 AT 6: VLIN 29,31 AT 9
185  VTAB 23: HTAB 5: PRINT "2S"
195  VTAB 22: HTAB 7: PRINT "1"
196  COLOR= 0: GOSUB 5010: GOSUB 7010: GOSUB 5020: COLOR=
     8: GOSUB 5030: GOSUB 7020
200  GOSUB 2000: COLOR= 9: PLOT 8,30
201  VTAB 22: HTAB 7: PRINT "2"
202  COLOR= 0: GOSUB 5030: GOSUB 7020: COLOR= 8: GOSUB
     5040: GOSUB 5020: GOSUB 7030
205  GOSUB 2000: COLOR= 2: PLOT 15,27
208  REM  2P
210  COLOR= 4: HLIN 14,21 AT 28
220  VLIN 26,28 AT 14: VLIN 26,28 AT 21
225  VTAB 23: HTAB 8: PRINT "2P"
231  VTAB 22: HTAB 10: PRINT "1"
232  COLOR= 0: GOSUB 5040: GOSUB 5020: GOSUB 7030: COLOR=
     8: GOSUB 5040: GOSUB 7040
235  GOSUB 2000: COLOR= 2: PLOT 17,27
236  VTAB 22: HTAB 10: PRINT "2"
```

```
237  COLOR= 0: GOSUB 5040: GOSUB 7040: COLOR= 8: GOSUB
     5050: GOSUB 7050
238  GOSUB 2000: COLOR= 2: PLOT 19,27
240  VTAB 22: HTAB 10: PRINT "3"
241  COLOR= 0: GOSUB 5050: GOSUB 7050: COLOR= 8: GOSUB
     5060: GOSUB 7060
245  GOSUB 2000: COLOR= 9: PLOT 16,27
246  VTAB 22: HTAB 10: PRINT "4"
247  COLOR= 0: GOSUB 5060: GOSUB 7060: COLOR= 8: GOSUB
     5070: GOSUB 7070
250  GOSUB 2000: COLOR= 9: PLOT 18,27
251  VTAB 22: HTAB 10: PRINT "5"
252  COLOR= 0: GOSUB 5070: GOSUB 7070: COLOR= 8: GOSUB
     5080: GOSUB 7080
254  GOSUB 2000: COLOR= 9: PLOT 20,27
255  VTAB 22: HTAB 10: PRINT "6"
256  COLOR= 0: GOSUB 5080: GOSUB 7080: COLOR= 8: GOSUB
     5060: GOSUB 5020: GOSUB 7090
260  GOSUB 2000: COLOR= 2: PLOT 7,22
270  COLOR= 4: HLIN 6,9 AT 23
280  VLIN 21,23 AT 6: VLIN 21,23 AT 9
285  VTAB 23: HTAB 12: PRINT "3S"
295  VTAB 22: HTAB 14: PRINT "1"
296  COLOR= 0: GOSUB 5060: GOSUB 5020: GOSUB 7090: COLOR=
     8: GOSUB 5060: GOSUB 5090: GOSUB 7100
300  GOSUB 2000: COLOR= 9: PLOT 8,22
305  VTAB 22: HTAB 14: PRINT "2"
310  COLOR= 0: GOSUB 5060: GOSUB 5090: GOSUB 7100: COLOR=
     8: GOSUB 5100: GOSUB 5110: GOSUB 8000: GOSUB 701
     0
320  GOSUB 2000: COLOR= 2: PLOT 15,19
330  COLOR= 4: HLIN 14,21 AT 20
340  VLIN 18,20 AT 14: VLIN 18,20 AT 21
345  VTAB 23: HTAB 15: PRINT "3P"
355  VTAB 22: HTAB 17: PRINT "1"
356  COLOR= 0: GOSUB 5100: GOSUB 5110: GOSUB 7010: COLOR=
     8: GOSUB 5120: GOSUB 7020
360  GOSUB 2000: COLOR= 2: PLOT 17,19
361  VTAB 22: HTAB 17: PRINT "2"
362  COLOR= 0: GOSUB 5120: GOSUB 7020: COLOR= 8: GOSUB
     5130: GOSUB 5140: GOSUB 7030
365  GOSUB 2000: COLOR= 2: PLOT 19,19
370  VTAB 22: HTAB 17: PRINT "3"
375  COLOR= 0: GOSUB 5130: GOSUB 5140: GOSUB 7030: COLOR=
     8: GOSUB 5150: GOSUB 7040
380  GOSUB 2000: COLOR= 9: PLOT 16,19
385  VTAB 22: HTAB 17: PRINT "4"
386  COLOR= 0: GOSUB 5150: GOSUB 7040: COLOR= 8: GOSUB
     5130: GOSUB 7050
390  GOSUB 2000: COLOR= 9: PLOT 18,19
395  VTAB 22: HTAB 17: PRINT "5"
396  COLOR= 0: GOSUB 5130: GOSUB 7050: COLOR= 8: GOSUB
     5160: GOSUB 7060
400  GOSUB 2000: COLOR= 9: PLOT 20,19
```

```
405  VTAB 22: HTAB 17: PRINT "6"
406  COLOR= 0: GOSUB 5160: GOSUB 7060: COLOR= 8: GOSUB
     5170: GOSUB 7070
410  GOSUB 2000: COLOR= 2: PLOT 7,15
420  COLOR= 4: HLIN 6,9 AT 16
430  VLIN 14,16 AT 6: VLIN 14,16 AT 9
435  VTAB 23: HTAB 19: PRINT "4S"
445  VTAB 22: HTAB 21: PRINT "1"
446  COLOR= 0: GOSUB 5170: GOSUB 7070: COLOR= 8: GOSUB
     5180: GOSUB 7080
450  GOSUB 2000: COLOR= 9: PLOT 8,15
455  VTAB 22: HTAB 21: PRINT "2"
500  COLOR= 0: GOSUB 5180: GOSUB 8000: GOSUB 7080: COLOR=
     8: GOSUB 5050: GOSUB 5090: GOSUB 8010: GOSUB 802
     0
510  GOSUB 2000: COLOR= 2: PLOT 25,12
520  COLOR= 4: HLIN 24,35 AT 13
530  VLIN 11,13 AT 24: VLIN 11,13 AT 35
535  VTAB 23: HTAB 23: PRINT "3D"
545  VTAB 22: HTAB 25: PRINT "1"
546  COLOR= 0: GOSUB 5050: GOSUB 8020: GOSUB 5090: GOSUB
     8010: COLOR= 8: GOSUB 5130: GOSUB 5190: GOSUB 80
     30: GOSUB 7000
550  GOSUB 2000: COLOR= 2: PLOT 27,12
551  VTAB 22: HTAB 25: PRINT "2"
552  COLOR= 0: GOSUB 5130: GOSUB 5190: GOSUB 8030: GOSUB
     7000: COLOR= 8: GOSUB 5200: GOSUB 5140: GOSUB 80
     10: GOSUB 7010
555  GOSUB 2000: COLOR= 2: PLOT 29,12
556  VTAB 22: HTAB 25: PRINT "3"
557  COLOR= 0: GOSUB 5200: GOSUB 5140: GOSUB 7010: COLOR=
     8: GOSUB 5210: GOSUB 7020
558  GOSUB 2000: COLOR= 0: PLOT 8,15
559  VTAB 22: HTAB 21: PRINT "1"
560  COLOR= 2: PLOT 31,12: PLOT 33,12
561  VTAB 22: HTAB 25: PRINT "5"
562  COLOR= 0: GOSUB 5210: GOSUB 7020: COLOR= 8: GOSUB
     5050: GOSUB 5220: GOSUB 7030
563  GOSUB 2000: COLOR= 9: PLOT 8,15
564  VTAB 22: HTAB 21: PRINT "2"
565  COLOR= 2: PLOT 33,12
570  COLOR= 0: GOSUB 5050: GOSUB 5220: GOSUB 7030: COLOR=
     8: GOSUB 5100: GOSUB 5230: GOSUB 7040
580  GOSUB 2000: COLOR= 9: PLOT 26,12
585  VTAB 22: HTAB 25: PRINT "6"
586  COLOR= 0: GOSUB 5100: GOSUB 5230: GOSUB 7040: COLOR=
     8: GOSUB 5240: GOSUB 5020: GOSUB 7050
590  GOSUB 2000: COLOR= 9: PLOT 28,12
591  VTAB 22: HTAB 25: PRINT "7"
592  COLOR= 0: GOSUB 5240: GOSUB 5020: GOSUB 7050: COLOR=
     8: GOSUB 5050: GOSUB 5250: GOSUB 7060
595  GOSUB 2000: COLOR= 9: PLOT 30,12
596  VTAB 22: HTAB 25: PRINT "8"
597  COLOR= 0: GOSUB 5050: GOSUB 5250: GOSUB 7060: COLOR=
```

```
    8: GOSUB 5060: GOSUB 5140: GOSUB 7070
600 GOSUB 2000: COLOR= 9: PLOT 32,12: PLOT 34,12: COLOR=
    0: PLOT 8,15
602 VTAB 22: HTAB 21: PRINT "1"
605 VTAB 22: HTAB 25: PRINT "10"
606 COLOR= 0: GOSUB 5060: GOSUB 5140: GOSUB 7070: COLOR=
    8: GOSUB 5050: GOSUB 5260: GOSUB 7080
608 GOSUB 2000: COLOR= 9: PLOT 34,12
610 VTAB 22: HTAB 21: PRINT "2": COLOR= 9: PLOT 8,15

612 COLOR= 0: GOSUB 5050: GOSUB 5260: GOSUB 8010: GOSUB
    7080: COLOR= 8: GOSUB 5270: GOSUB 5230: GOSUB 80
    40: GOSUB 8020
620 GOSUB 2000: COLOR= 2: PLOT 15,9
630 COLOR= 4: HLIN 14,21 AT 10
640 VLIN 8,10 AT 14: VLIN 8,10 AT 21
645 VTAB 23: HTAB 28: PRINT "4P"
655 VTAB 22: HTAB 30: PRINT "1"
656 COLOR= 0: GOSUB 5270: GOSUB 5230: GOSUB 8040: GOSUB
    8020: COLOR= 8: GOSUB 5280: GOSUB 5090: GOSUB 80
    50: GOSUB 7000
660 GOSUB 2000: COLOR= 2: PLOT 17,9
661 VTAB 22: HTAB 30: PRINT "2"
662 COLOR= 0: GOSUB 5090: GOSUB 8050: GOSUB 7000: COLOR=
    8: GOSUB 5020: GOSUB 8040: GOSUB 7010
665 GOSUB 2000: COLOR= 2: PLOT 19,9
666 VTAB 22: HTAB 30: PRINT "3"
668 COLOR= 0: GOSUB 5280: GOSUB 5020: GOSUB 7010: COLOR=
    8: GOSUB 5290: GOSUB 7020
670 GOSUB 2000: COLOR= 9: PLOT 16,9
675 VTAB 22: HTAB 30: PRINT "4"
676 COLOR= 0: GOSUB 5290: GOSUB 7020: COLOR= 8: GOSUB
    5130: GOSUB 5020: GOSUB 7030
680 GOSUB 2000: COLOR= 9: PLOT 18,9
682 VTAB 22: HTAB 30: PRINT "5"
683 COLOR= 0: GOSUB 5130: GOSUB 5020: GOSUB 7030: COLOR=
    8: GOSUB 5040: GOSUB 5220: GOSUB 7040
685 GOSUB 2000: COLOR= 9: PLOT 20,9
690 VTAB 22: HTAB 30: PRINT "6"
695 COLOR= 0: GOSUB 5040: GOSUB 5220: COLOR= 8: GOSUB
    5180: GOSUB 5220
697 COLOR= 0: GOSUB 5040: GOSUB 7040: COLOR= 8: GOSUB
    5180: GOSUB 7050:
699 END
700 GOSUB 2000: COLOR= 2: PLOT 7,6
710 COLOR= 4: HLIN 6,9 AT 7
720 VLIN 5,7 AT 6: VLIN 5,7 AT 9
725 VTAB 23: HTAB 32: PRINT "5S"
735 VTAB 22: HTAB 34: PRINT "1"
736 COLOR= 0: GOSUB 5180: GOSUB 5220: COLOR= 8: GOSUB
    5300
740 GOSUB 2000: COLOR= 9: PLOT 8,6
745 VTAB 22: HTAB 34: PRINT "2"
750 COLOR= 0: GOSUB 5300: COLOR= 8: GOSUB 5130: GOSUB
```

```
     5220
760  GOSUB 2000: COLOR= 2: PLOT 25,3
770  COLOR= 4: HLIN 24,35 AT 4
780  VLIN 2,4 AT 24: VLIN 2,4 AT 35
785  VTAB 23: HTAB 36: PRINT "4D"
795  VTAB 22: HTAB 38: PRINT "1"
796  COLOR= 0: GOSUB 5130: GOSUB 5220: COLOR= 8: GOSUB
     5310
800  GOSUB 2000: COLOR= 2: PLOT 27,3
801  VTAB 22: HTAB 38: PRINT "2"
802  COLOR= 0: GOSUB 5310: COLOR= 8: GOSUB 5270: GOSUB
     5220
805  GOSUB 2000: COLOR= 2: PLOT 29,3
806  VTAB 22: HTAB 38: PRINT "3"
808  COLOR= 0: GOSUB 5270: GOSUB 5220: COLOR= 8: GOSUB
     5060: GOSUB 5320
810  GOSUB 2000: COLOR= 2: PLOT 31,3
812  VTAB 22: HTAB 38: PRINT "4"
814  COLOR= 0: GOSUB 5060: GOSUB 5320: COLOR= 8: GOSUB
     5100: GOSUB 5250
815  GOSUB 2000: COLOR= 2: PLOT 33,3
816  VTAB 22: HTAB 38: PRINT "5"
818  COLOR= 0: GOSUB 5100: GOSUB 5250: COLOR= 8: GOSUB
     5200: GOSUB 5190
820  GOSUB 2000: COLOR= 9: PLOT 26,3
825  VTAB 22: HTAB 38: PRINT "6"
828  COLOR= 0: GOSUB 5200: GOSUB 5190: COLOR= 8: GOSUB
     5330: GOSUB 5260
830  GOSUB 2000: COLOR= 9: PLOT 28,3
832  VTAB 22: HTAB 38: PRINT "7"
833  COLOR= 0: GOSUB 5330: GOSUB 5260: COLOR= 8: GOSUB
     5330: GOSUB 5340
835  GOSUB 2000: COLOR= 9: PLOT 30,3
836  VTAB 22: HTAB 38: PRINT "8"
838  COLOR= 0: GOSUB 5330: GOSUB 5340: COLOR= 8: GOSUB
     5150: GOSUB 5350
840  GOSUB 2000: COLOR= 9: PLOT 32,3
845  VTAB 22: HTAB 38: PRINT "9"
848  COLOR= 0: GOSUB 5150: GOSUB 5350: COLOR= 8: GOSUB
     5360: GOSUB 5110
850  GOSUB 2000: COLOR= 9: PLOT 34,3
855  VTAB 22: HTAB 38: PRINT "10"
858  COLOR= 0: GOSUB 5290: GOSUB 5110: COLOR= 8: GOSUB
     5050: GOSUB 5350
860  CALL  - 380: END
2000  POKE  - 16368,0
2010  IF  PEEK ( - 16384) > 128 THEN  POKE  - 16368,0
     : RETURN
2020  GOTO 2010
3050  COLOR= 0
5010  HLIN X,X + 4 AT Y + 3: VLIN Y,Y + 6 AT X: VLIN
     Y,Y + 6 AT X + 4
5015  REM H
5018  RETURN
```

```
5020  HLIN X + 6,X + 9 AT Y + 2: HLIN X + 6,X + 9 AT
     Y + 4: HLIN X + 6,X + 9 AT Y + 6: VLIN Y + 2,Y +
     6 AT X + 6: VLIN Y + 2,Y + 4 AT X + 9
5025  REM LE
5028  RETURN
5030  VLIN Y,Y + 6 AT X: HLIN X,X + 4 AT Y + 6: PLOT
     X + 6,Y + 1: VLIN Y + 3,Y + 6 AT X + 6
5035  REM L LI
5038  RETURN
5040  HLIN X,X + 4 AT Y: HLIN X,X + 4 AT Y + 3: HLIN
     X,X + 4 AT Y + 6: VLIN Y,Y + 6 AT X: VLIN Y,Y +
     6 AT X + 4
5045  REM B
5048  RETURN
5050  HLIN X,X + 4 AT Y: HLIN X,X + 4 AT Y + 6: VLIN
     Y,Y + 6 AT X: PLOT X + 4,Y + 1: PLOT X + 4,Y + 5

5055  REM C
5058  RETURN
5060  VLIN Y,Y + 6 AT X: VLIN Y,Y + 6 AT X + 4: VLIN
     Y + 1,Y + 2 AT X + 1: PLOT X + 2,Y + 3: VLIN Y +
     4,Y + 5 AT X + 3
5065  REM N
5068  RETURN
5070  HLIN X,X + 4 AT Y: HLIN X,X + 4 AT Y + 6: VLIN
     Y,Y + 6 AT X: VLIN Y,Y + 6 AT X + 4
5075  REM O
5078  RETURN
5080  HLIN X,X + 4 AT Y: HLIN X,X + 3 AT Y + 3: VLIN
     Y,Y + 6 AT X
5085  REM F
5088  RETURN
5090  HLIN X + 7,X + 10 AT Y + 2: HLIN X + 7,X + 10 AT
     Y + 4: HLIN X + 7,X + 10 AT Y + 6: VLIN Y + 2,Y +
     6 AT X + 10: VLIN Y + 4,Y + 6 AT X + 7
5095  REM  LA
5098  RETURN
5100  VLIN Y,Y + 6 AT X: VLIN Y,Y + 6 AT X + 4: VLIN
     Y + 1,Y + 2 AT X + 1: PLOT X + 2,Y + 3: VLIN Y +
     1,Y + 2 AT X + 3
5105  REM M
5108  RETURN
5110  HLIN X + 6,X + 9 AT Y + 4: HLIN X + 6,X + 9 AT
     Y + 6: HLIN X + 6,X + 9 AT Y + 9: VLIN Y + 4,Y +
     6 AT X + 6: VLIN Y + 4,Y + 9 AT X + 9
5115  REM LG
5118  RETURN
5120  HLIN X,X + 4 AT Y: HLIN X,X + 4 AT Y + 3: VLIN
     Y,Y + 6 AT X: VLIN Y,Y + 6 AT X + 4: VLIN Y,Y +
     6 AT X + 6
5125  REM A LL
5128  RETURN
5130  HLIN X,X + 4 AT Y: HLIN X,X + 4 AT Y + 3: HLIN
     X,X + 4 AT Y + 6: VLIN Y,Y + 3 AT X: VLIN Y + 5,
```

```
     Y + 6 AT X: VLIN Y,Y + 1 AT X + 4: VLIN Y + 3,Y +
     6 AT X + 4
5135  REM S
5138  RETURN
5140  PLOT X + 6,Y + 1: VLIN Y + 3,Y + 6 AT X + 6
5145  REM L I
5148  RETURN
5150  HLIN X,X + 4 AT Y: HLIN X,X + 4 AT Y + 3: VLIN
     Y,Y + 6 AT X: VLIN Y,Y + 3 AT X + 4
5155  REM P
5158  RETURN
5160  HLIN X,X + 4 AT Y: HLIN X,X + 4 AT Y + 6: VLIN
     Y,Y + 6 AT X: PLOT X + 4,Y + 1: PLOT X + 4,Y + 5
     : VLIN Y,Y + 6 AT X + 6
5165  REM C L L
5168  RETURN
5170  HLIN X,X + 4 AT Y: HLIN X,X + 4 AT Y + 3: VLIN
     Y,Y + 6 AT X: VLIN Y,Y + 6 AT X + 4: VLIN Y + 2,
     Y + 6 AT X + 6: HLIN X + 6,X + 8 AT Y + 3
5175  REM A LR
5178  RETURN
5180  VLIN Y,Y + 6 AT X: PLOT X + 2,Y + 2: PLOT X + 2
     ,Y + 4: HLIN X,X + 1 AT Y + 3: PLOT X + 3,Y + 1:
      PLOT X + 4,Y:: PLOT X + 3,Y + 5: PLOT X + 4,Y +
     6
5185  REM K
5188  RETURN
5190  HLIN X + 6,X + 9 AT Y + 2: VLIN Y + 2,Y + 6 AT
     X + 6: VLIN Y + 2,Y + 3 AT X + 9: VLIN Y + 5,Y +
     6 AT X + 9: HLIN X + 6,X + 9 AT Y + 6
5195  REM L C
5198  RETURN
5200  HLIN X,X + 4 AT Y: VLIN Y,Y + 6 AT X + 2
5205  REM T
5208  RETURN
5210  VLIN Y,Y + 4 AT X: VLIN Y,Y + 4 AT X + 4: HLIN
     X + 1,X + 3 AT Y + 5: PLOT X + 2,Y + 6
5215  REM V
5218  RETURN
5220  VLIN Y + 2,Y + 6 AT X + 6: HLIN X + 6,X + 8 AT
     Y + 3
5225  REM L R
5228  RETURN
5230  VLIN Y + 2,Y + 6 AT X + 6: HLIN X + 7,X + 9 AT
     Y + 3: VLIN Y + 3,Y + 6 AT X + 9
5235  REM  L N
5238  RETURN
5240  HLIN X,X + 4 AT Y: HLIN X,X + 3 AT Y + 3: VLIN
     Y,Y + 6 AT X
5245  REM F
5248  RETURN
5250  HLIN X + 6,X + 9 AT Y + 2: HLIN X + 6,X + 9 AT
     Y + 6: VLIN Y + 2,Y + 6 AT X + 6: VLIN Y + 2,Y +
     6 AT X + 9
```

```
5255  REM L O
5258  RETURN
5260  VLIN Y + 2,Y + 6 AT X + 6: VLIN Y + 2,Y + 6 AT
     X + 9: HLIN X + 6,X + 9 AT Y + 6
5265  REM L U
5268  RETURN
5270  HLIN X,X + 4 AT Y: HLIN X,X + 4 AT Y + 6: PLOT
     X,Y + 5: PLOT X + 1,Y + 4: PLOT X + 2,Y + 3: PLOT
     X + 3,Y + 2: PLOT X + 4,Y + 1
5275  REM Z
5278  RETURN
5280  HLIN X,X + 4 AT Y: HLIN X,X + 4 AT Y + 6: HLIN
     X + 2,X + 4 AT Y + 3: VLIN Y,Y + 6 AT X: VLIN Y +
     3,Y + 6 AT X + 4: PLOT X + 4,Y + 1
5285  REM G
5288  RETURN
5290  HLIN X,X + 4 AT Y: HLIN X,X + 4 AT Y + 3: VLIN
     Y,Y + 6 AT X: VLIN Y,Y + 6 AT X + 4
5291  REM A
5292  HLIN X + 6,X + 9 AT Y + 2: HLIN X + 6,X + 9 AT
     Y + 4: HLIN X + 6,X + 9 AT Y + 6: PLOT X + 6,Y +
     3: PLOT X + 9,Y + 5
5293  REM L S
5298  RETURN
5300  HLIN X,X + 4 AT Y: HLIN X,X + 4 AT Y + 3: VLIN
     Y,Y + 6 AT X: VLIN Y,Y + 3 AT X + 4: VLIN Y,Y +
     6 AT X + 6: VLIN Y + 4,Y + 6 AT X + 9: HLIN X +
     7,X + 9 AT Y + 4: HLIN X + 7,X + 9 AT Y + 6
5301  PLOT X + 1,Y + 4: PLOT X + 2,Y + 5: PLOT X + 3,
     Y + 6
5305  REM R L B
5308  RETURN
5310  VLIN Y,Y + 3 AT X: VLIN Y,Y + 3 AT X + 4: HLIN
     X,X + 4 AT Y + 3: VLIN Y + 4,Y + 6 AT X + 2
5315  REM Y
5318  RETURN
5320  VLIN Y,Y + 6 AT X + 6: HLIN X + 6,X + 9 AT Y +
     4: HLIN X + 6,X + 9 AT Y + 6: VLIN Y + 4,Y + 6 AT
     X + 9
5325  RETURN
5328  RETURN
5330  HLIN X,X + 4 AT Y: VLIN Y,Y + 6 AT X: HLIN X,X +
     4 AT Y + 3: VLIN Y,Y + 3 AT X + 4: PLOT X + 1,Y +
     4: PLOT X + 2,Y + 5: PLOT X + 3,Y + 6
5335  REM R
5338  RETURN
5340  VLIN Y,Y + 6 AT X + 6: VLIN Y + 4,Y + 6 AT X +
     9: HLIN X + 6,X + 9 AT Y + 4
5345  REM L H
5348  RETURN
5350  VLIN Y,Y + 6 AT X + 9: HLIN X + 6,X + 9 AT Y +
     4: HLIN X + 6,X + 9 AT Y + 6: VLIN Y + 4,Y + 6 AT
     X + 6
5355  REM L D
```

```
5358  RETURN
5360  HLIN X,X + 4 AT Y: HLIN X,X + 4 AT Y + 3: VLIN
     Y,Y + 6 AT X: VLIN Y,Y + 6 AT X + 4
5365  REM A
5368  RETURN
6000  COLOR= 15: HLIN 6,9 AT 39: VLIN 37,39 AT 6: VLIN
     37,39 AT 9: HLIN 6,9 AT 31: VLIN 29,31 AT 6: VLIN
     29,31 AT 9
6010  HLIN 14,21 AT 28: VLIN 26,28 AT 14: VLIN 26,28 AT
     21: HLIN 6,9 AT 23: VLIN 21,23 AT 6: VLIN 21,23 AT
     9
6020  HLIN 14,21 AT 20: VLIN 18,20 AT 14: VLIN 18,20 AT
     21: HLIN 6,9 AT 16: VLIN 14,16 AT 6: VLIN 14,16 AT
     9
6030  HLIN 24,35 AT 13: VLIN 11,13 AT 24: VLIN 11,13 AT
     35: HLIN 14,21 AT 10: VLIN 8,10 AT 14: VLIN 8,10
      AT 21
6040 X = 0:Y =  - 2: GOSUB 5292
6050 X = 16:Y = 2: HLIN X,X + 3 AT Y: HLIN X,X + 3 AT
     Y + 2: VLIN Y,Y + 4 AT X: VLIN Y,Y + 2 AT X + 3
6060 X = 28:Y = 0: HLIN X,X + 3 AT Y + 2: HLIN X,X +
     3 AT Y + 4: VLIN Y + 2,Y + 4 AT X: VLIN Y,Y + 4 AT
     X + 3
6080  REM  L SPDF
6090  RETURN
7000  VLIN Y + 5,Y + 9 AT X - 2: RETURN : REM  1
7010  FOR D = 0 TO 4 STEP 2: HLIN X - 4,X - 2 AT Y +
     5 + D: NEXT : VLIN Y + 5,Y + 7 AT X - 2: VLIN Y +
     7,Y + 9 AT X - 4: RETURN : REM    2
7020  HLIN X - 4,X - 2 AT Y + 5: HLIN X - 4,X - 2 AT
     Y + 9: HLIN X - 3,X - 2 AT Y + 7: VLIN Y + 5,Y +
     9 AT X - 2: RETURN : REM  3
7030  VLIN Y + 5,Y + 7 AT X - 4: VLIN Y + 5,Y + 9 AT
     X - 2: HLIN X - 4,X - 2 AT Y + 7: RETURN : REM
     4
7040  FOR D = 0 TO 4 STEP 2: HLIN X - 4,X - 2 AT Y +
     5 + D: NEXT : VLIN Y + 5,Y + 7 AT X - 4: VLIN Y +
     7,Y + 9 AT X - 2: RETURN : REM   5
7050  VLIN Y + 5,Y + 9 AT X - 4: HLIN X - 4,X - 2 AT
     Y + 7: HLIN X - 4,X - 2 AT Y + 9: VLIN Y + 7,Y +
     9 AT X - 2: RETURN : REM  6
7060  VLIN Y + 5,Y + 9 AT X - 2: HLIN X - 4,X - 2 AT
     Y + 5: RETURN : REM  7
7070  FOR D = 0 TO 4 STEP 2: HLIN X - 4,X - 2 AT Y +
     5 + D: NEXT : FOR D = 0 TO 2 STEP 2: VLIN Y + 5,
     Y + 9 AT X - 2 - D: NEXT : RETURN : REM  8
7080  VLIN Y + 5,Y + 7 AT X - 4: VLIN Y + 5,Y + 9 AT
     X - 2: HLIN X - 4,X - 2 AT Y + 5: HLIN X - 4,X -
     2 AT Y + 7: RETURN : REM  9
7090  FOR D = 0 TO 4 STEP 2: VLIN Y + 5,Y + 9 AT X -
     6 + D: NEXT : FOR D = 0 TO 4 STEP 4: HLIN X - 4,
     X - 2 AT Y + 5 + D: NEXT : RETURN : REM   10
7100  VLIN Y + 5,Y + 9 AT X - 4: VLIN Y + 5,Y + 9 AT
     X - 2: RETURN : REM  11
```

```
8000 X = 22: VLIN Y + 5,Y + 9 AT X - 2:X = 26: RETURN
     : REM   1
8010 X = 22: FOR D = 0 TO 4 STEP 2: HLIN X - 4,X - 2 AT
     Y + 5 + D: NEXT : VLIN Y + 5,Y + 7 AT X - 2: VLIN
     Y + 7,Y + 9 AT X - 4:X = 26: RETURN : REM  2
8020  FOR D = 0 TO 2 STEP 2: VLIN Y + 5,Y + 9 AT X -
     4 + D: NEXT : FOR D = 0 TO 4 STEP 4: HLIN X - 4,
     X - 2 AT Y + 5 + D: NEXT : RETURN : REM     0

8030 X = 24: FOR D = 0 TO 4 STEP 2: HLIN X - 4,X - 2 AT
     Y + 5 + D: NEXT : VLIN Y + 5,Y + 7 AT X - 2: VLIN
     Y + 7,Y + 9 AT X - 4:X = 26: RETURN : REM
          2
8040 X = 22: HLIN X - 4,X - 2 AT Y + 5: HLIN X - 4,X -
     2 AT Y + 9: HLIN X - 3,X - 2 AT Y + 7: VLIN Y +
     5,Y + 9 AT X - 2:X = 26: RETURN : REM  3
8050 X = 24: HLIN X - 4,X - 2 AT Y + 5: HLIN X - 4,X -
     2 AT Y + 9: HLIN X - 3,X - 2 AT Y + 7: VLIN Y +
     5,Y + 9 AT X - 2:X = 26: RETURN : REM   3

]
```

APPENDIX B

COMPUTER EVALUATION

SURVEY INSTRUMENT

Electron Configuration

Rank questions 1 and 2 using this scale

1 Low	2	3	4	5 Average	6	7	8	9	10 High

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1. Overall evaluation of the Electron Configuration program_____.
2. I would like to see more use of Microcomputer programs in lecture_____.

COMMENTS:

3. Was the <u>design</u> of the program such that you could clearly understand what it was trying to represent?
4. Did the graphic simulation <u>aid</u> in your understanding of the concepts?
5. Do you feel that this type of program can be effective when used in conjunction with the class lecture format?
6. Would you prefer having access to a microcomputer such that you could interact with it individually rather than through someone else?

APPENDIX C

DEFINITION OF TERMS

1. Basic - one of the high-level computer languages.
2. Computer - digital computer, one that performs its task using discrete signals.
3. Courseware - interactive educational computer programs.
4. Electron Configuration - a statement of the populations of the electronic energy sublevels in an atom.
5. Floppy disk - disk make of plastic used for memory storage.
6. Hardware - physical devices that perform the input, output, arithmetic-logic, storage and control functions.
7. Memory - storage of a computer (1K=2^{10}=1024; 1 byte-8 bits).
8. Microcomputer - a microprocessor combined with other micro-electric circuit components that provide timing, storage or memory, input, output, and other functions.
9. Microprocessor - central processing unit of a computer, miniaturized to fit a silicon chip.
10. Software - collection of programs available to the computer such as compilers, text editors, graphic package and interpreters.

VITA

Betty McNeil Branstetter

Candidate for the Degree of

Master of Science

Thesis: A GRAPHIC SIMULATION PROGRAM FOR MICROCOMPUTERS, ELECTRON CONFIGURATION

Major Field: Curriculum and Instruction

Biographical:

Personal Data: Born in Lawton, Oklahoma, January 24, 1929, the daughter of Mr. and Mrs. C. R. McNeil; Married Max H. Branstetter, 1952; four children: Roy (1956), Beth (1962), Karen (1965), Rex (1967).

Education: Graduated from Lawton High School, Lawton, Oklahoma, in May, 1946; attended Cameron College, 1946-48; received Bachelor of Science in Education degree in Biology from Southwestern Oklahoma State University, 1950; received Bachelor of Science degree in Public Health Services from Central State University, 1971; completed requirements for Master of Science degree at Oklahoma State University, December, 1980.

Professional Experience: High school science teacher for 13 years, 1950-52 (Oklahoma), 1959-61 (Missouri), 1962-64 (Illinois), 1971-80 (Oklahoma); instructor for adult education, 1966 and 1971; instructor for Emergency Medical Self-help, 1964-65, Illinois; Embalming and Funeral Service In-Service and Practicum, 1969-70, Oklahoma; graduate teaching assistant, 1978-79, General Chemistry Department, Oklahoma State University.