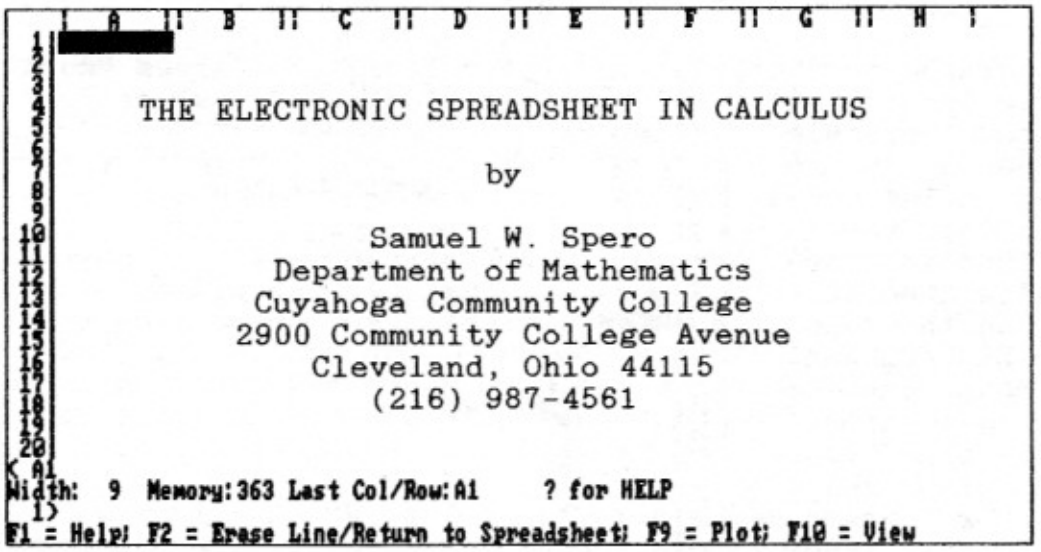


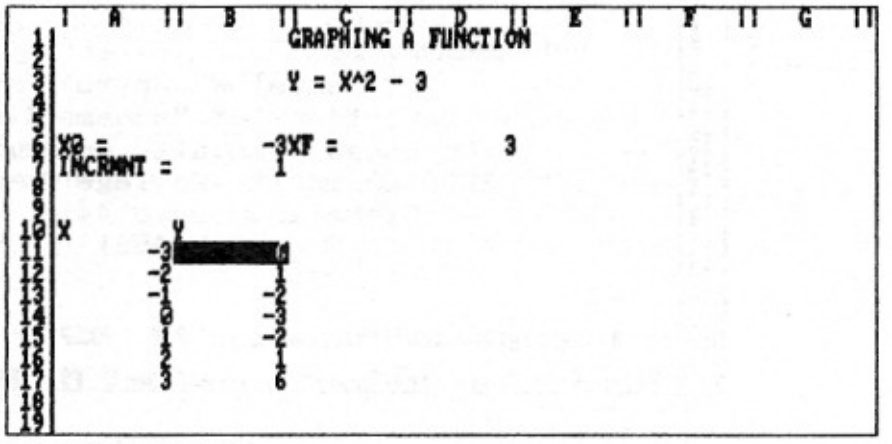
I. INTRODUCTION - GRAPHING FUNCTIONS IN CALCULUS

One of the most important applications of the computer in the study of Calculus is in the area of GRAPHING FUNCTIONS. From the very first chapter of almost every Calculus text, and then throughout the text, students are asked to graph functions. For example in the exercises in the text by Purcell and Varberg (published by Prentice-Hall) of the 126 sections in the text, in 56 of them - 44% of the total - the student is asked to graph functions or supply a sketch. In all of these exercises, sketching the graph does increase understanding of the underlying concepts of that particular section. Without computational help, no more than a few of the exercises can realistically be completed. On the other hand with computational help, a much more substantive learning experience can take place.

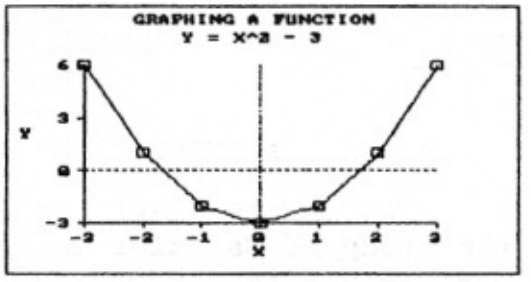
In this paper we will discuss the computer approach that we suggest for GRAPHING FUNCTIONS in the Calculus. This approach uses the electronic spreadsheet, in particular SUPERCALC 4 published by Computer Associates, for GRAPHING FUNCTIONS.

II. GRAPHING FUNCTIONS AND THE COMPUTER

To graph a function by hand a Table of Values must be computed. In the first column of this Table the values for the independent variable are set down. In the adjoining column the corresponding values of the function are then calculated. Depending on the function to be graphed, 5 or 10 points or more are calculated. If more than one function is being graphed, or parametric or polar functions are being evaluated more columns may be required.



Before the graph can be drawn a set of axes and an appropriate scale must be established. Once the scale has been established the points calculated in the Table can be graphed. In most cases the points should be connected in a smooth curve to complete the graph of the function. If the graph is to be handed in, the graph and the axes should be properly labeled.



The computer is an ideal tool to be used for graphing functions in the study of Calculus. The computer can be used to help set up the Table of Values, as well as graphing the values in the Table which includes scaling the axes, plotting and connecting the points, and providing the headings and labels. The computer also provides "hardcopy" of both the Table and the graph.

While there are many aspects of the above process that can be automated using a computer or calculator, it is this author's opinion that the computational method of choice should retain the above features of the "process" of graphing but should eliminate the "busywork." The electronic spreadsheet does that.

III. THE ELECTRONIC SPREADSHEET AS A GRAPHING TOOL

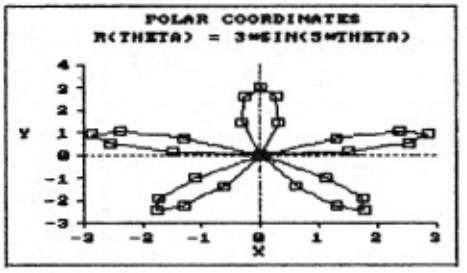
There are electronic spreadsheets available for all popular computers. In the present discussion we will be discussing software that runs on IBM PC's and compatibles which are readily available both on- and off-campus. Our approach is to have each student buy their own copy of the software which they then can

use anywhere and at anytime.

This is possible because electronic spreadsheet packages are reasonable in price. Almost all of the popular spreadsheet packages now offer student editions which sell for between $20 and $40. In fact Borland sells the complete QUATTRO package (an outstanding spreadsheet) to educators for that price.

Learning to use a spreadsheet is not just learning to graph. Spreadsheet skills can also be used in a broad spectrum of other courses as well as in one's personal life and in the workplace. For example, the author uses SUPERCALC 4 for his gradebook, for generating problem sets for students, and even for calculating his mortgage payments. The electronic spreadsheet is really a powerful computing language that is very easy to use.

The graphics - which we consider the most important application for our Calculus students - are especially strong and versatile. To prepare a graph the student specifies the function and its limits and sets up the procedure in a very intuitive manner. There is not a lot of typing involved. Especially nice are the printouts of both the Table and the graphs. Furthermore the flexibility is there to deal with parametric equations, polar equations, and in the newer packages even three-dimensional graphics.



Aside from graphics the electronic spreadsheet can be used in Calculus in the study of the solution of non-linear equations (Newton's Method), numerical integration, the numerical solution of differential equations, and the solution of simultaneous equations.

Because the electronic spreadsheet is being used very extensively in industry, it is now, and will continue to be, well supported. There is also extensive documentation available both from the manufacturer and from other sources.

IV. AN EXAMPLE

The various stages of graphing a function are easily accomplished with an electronic spreadsheet.

The electronic spreadsheet - in what follows we will be referring to SUPERCALC 4, or SC4, by Computer Associates - is a large electronic "sheet of paper" on which you can write using the keyboard as your electronic "pencil".

To type text into the spreadsheet, you "point" to where you

want to place the text and just type it in. No special command is needed. The same is true for numbers, you just "point" and type in the number. Even complex formulas can be typed in in a similar fashion.

To perform the tedious tasks associated with the process of computation and graphing there are simple commands.

For example, in the preparation of the Table of Values, the student has only to set up the calculation of the function at the first point in the domain, an SC4 command copies that formula and evaluates the function at all of the other points of the domain.

In the preparation of the graph, the student specifies the type of graph required and where on the spreadsheet the data to be graphed is. SC4 automatically sets up the axes and a scale appropriate to the points defined, graphs the function and connects the points in a smooth curve. Headings for the graph and labels for the axes are easily specified and pressing one key prints out the graph on the printer.

The spreadsheet for the function $Y = X^2 - 3$ and its graph are shown above. The spreadsheet with the equations in place instead of the numbers can be displayed with a simple command.

	A	B	C	D	E	F	G
1			GRAPHING A FUNCTION				
2							
3			Y = X^2 - 3				
4							
5							
6	XØ =	-3	XF =	3			
7	INCRMNT =	1					
8							
9							
10	X	Y					
11	B6	A11^2-3					
12	A11+B7	A12^2-3					
13	A12+B7	A13^2-3					
14	A13+B7	A14^2-3					
15	A14+B7	A15^2-3					
16	A15+B7	A16^2-3					
17	A16+B7	A17^2-3					
18							
19							
20							

Other graphing applications such as polar coordinates and parametric equations are no more difficult. For the function

$R(\theta) = 3SIN(5\theta)$

The graph has been displayed earlier in this paper. The spreadsheet is to the right.

	A	B	C	D	E
1			POLAR COORDINATES		
2					
3			R(THETA) = 3*SIN(5*THETA)		
4					
5	THETA	R	X	Y	
6	Ø	Ø	Ø	Ø	Ø
7	.1121997	1.596096	1.586060	.1787061	
8	.2243995	2.702907	2.635139	.6014533	
9	.3365992	2.981137	2.813845	.9846070	
10	.4487990	2.345494	2.113217	1.017672	
11	.5609987	.9908372	.8389658	.5271572	
12	.6731984	-.667563	-.521922	-.416219	
13	.7853982	-2.12132	-1.5	-1.5	
14	.8975979	-2.92478	-1.82357	-2.28669	
15	1.009798	-2.83165	-1.50653	-2.39763	
16	1.121997	-1.87047	-.811566	-1.68523	
17	1.234197	-.335893	-.110939	-.317044	
18	1.346397	1.301651	.2896446	1.269016	
19	1.458597	2.540173	.2844091	2.524201	
20	1.570796	3	Ø	3	

The author has described this process in greater detail in several articles[1] and also in a tutorial for students entitled GRAPHING FUNCTIONS which may be ordered from the author.

V. EXPERIENCES

The author has been using electronic spreadsheets - specifically the SUPERCALC series - in teaching Calculus since 1981.

SUPERCALC 2 was orginally selected for use with an 8-bit CPM computer because it was the only software available. When IBM technology was introduced, SUPERCALC 3 was selected because it was available in inexpensive student editions (SUPERCALC 3 by Lamont R. Lockwood, IBM PC Apprentice Personal Computer Learning Series, Prentice Hall,1984 and LEARNING TO USE SUPERCALC 3: AN INTRODUCTION by Gary Shelly and Thomas J. Cashman, Boyd and Fraser Publishing Company, 1986). Each student purchased their own software. This was very cost effective for the school, as well being very satisfying to the students since they could take the software to any IBM compatible machine.

Students need at least a two-hour orientation to SC4 which is usually sufficient to teach them to draw graphs. We have designed the above-mentioned tutorial on GRAPHING FUNCTIONS specifically for this two-hour orientation. Following this the students are able to undertake assignments from the Calculus.

The approach has been very successful. While we have not formally evaluated the use of the electronic spreadsheet, the students have indicated that they are more motivated when they can use SC4. The students are definitely completing more of those assignments which include graphing of functions. They have also acquired a new skill which they are using in their other courses.

FOOTNOTES:

1. a) The Electronic Spreadsheet as a Problem Solving Tool in Mathematics Instruction, paper presented at Fourth Annual Conference Applying New Technology in Higher Education, March 4-5, 1985, Orlando, Florida. Published in the PROCEEDINGS OF THE FOURTH ANNUAL CONFERENCE APPLYING NEW TECHNOLOGY IN HIGHER EDUCATION, National Issues in Higher Education, Kansas State University.

   b) Spreadsheets in the Classroom: Using SUPERCALC to teach Algorithms in Mathematics, CREATIVE COMPUTING, Volume 11, Number 10, October, 1985.

   c) The Electronic Spreadsheet as a Problem Solving Tool in Mathematics Instruction, paper presented at International Conference on Courseware Design and Evaluation, Ramat Gan, Israel, April 8-13, 1986. Published in the PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON COURSEWARE DESIGN AND EVALUATION, Israel Association for Computers in Education.

   d) The Electronic Spreadsheet as a Problem Solving Tool in Vocational Education, paper presented at the 24th National Conference on Technical Education of the American Technical Education Association, March 25-28, 1987, Cleveland, Ohio.