

ENGINEERING MATH II PROGRAM

ENGINEERING MATH II

COMPLEX

$$j^2 = -1$$

$$\sin |1+2j| = 3.16578 + 1.9596j$$

$$\sin |2x-y+z| = 1.73205$$

VECTOR

$$|1x+2y+3z| \cdot |2x-y+z| = 1.73205$$

COT

SIN

ACSCH

SEC

TAN

ADVMATH

INSTRUCTION MANUAL

CAT. NO. 26-3526

Radio Shack

TRS-80

POCKET
COMPUTER
SOFTWARE

Engineering Math II

Radio Shack®

A DIVISION OF TANDY CORPORATION
FORT WORTH, TEXAS 76102

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10 9 8 7 6 5 4 3 2 1

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Introduction

Engineering Math II consists of three programs:

Program	Description
VECTOR	Vector arithmetic
COMPLEX	Complex arithmetic
ADMATH	Advanced trig and exponentials

The functions of the programs are as follows:

VECTOR provides all common vector operations in three dimensions in both Cartesian and polar coordinates: addition, subtraction, dot product, cross product, angle between two vectors, and direct conversion of a vector between rectangular and polar coordinate systems. Chain operations are allowed. The mode may be changed between polar and rectangular at any point during program execution without adversely affecting intermediate results.

COMPLEX provides for the most common complex number arithmetic operations: addition, subtraction, multiplication, division, calculation of magnitude, conjugation, base-e logarithms, e to complex powers, sines, cosines, arc sines, and arc cosines. Chain operations are allowed.

ADMATH provides 24 common trig functions in degree or radian measure. It also provides logarithms to any base and an exponentiation function which can raise negative numbers to positive or integral negative powers.

At the end of each section of the manual, there is a description of the program variables. These may be useful if you want to examine intermediate results. Use the Backup instructions in Appendix B to make a working copy of the tape. See Appendix C for Maintenance instructions.

Vector Arithmetic

This program will perform most common vector operations in three dimensions. It can use either rectangular or polar coordinates, and in the polar mode can use radian, degree, or grad units of arc.

To load VECTOR, insert the tape in the recorder and press the "Play" key. Turn the computer on, make sure the mode is set to DEF, then type:

C**L****O****A****D****←****V****E****C****T****O****R****←** and press **ENTER**. After the prompt sign (>) appears, press **S****H****F****T****←****S****P****C**.

The program will start itself in the rectangular mode. First, it will display the program title: VECTOR ARITHMETIC. Press **ENTER** and the copyright notice will be shown briefly before the menu starts.

Press **ENTER** to see the available operations one at a time, along with the shift-letter command which will start each operation. These are:

CLEAR: SHFT-C
ADD: SHFT-A
SUBTRACT: SHFT-S
DOT PRODUCT: SHFT-D
CROSS PRODUCT: SHFT-X
ANGLE COMPUTATION: SHFT-V
POLAR TO RECT: SHFT-F

RECT TO POLAR: SHFT-G
CHANGE MODE: SHFT-M
SHFT-K TO RE-ENTER MENU

If the end of the menu is reached, the program will end. This is to prevent repeated listings of the menu if the Pocket Computer has a printer attached.

S**H****F****T****←****K** will restart the menu without restarting the program.

The same input routine is used for all operations. The first display will be: FIRST VECTOR. It will then ask for X, Y, and Z (rectangular mode) or MAGNITUDE, PHI, and THETA (polar mode). SECOND VECTOR will be displayed and the input routine will be repeated.

Starting any option will cause the program to ask for any needed information, display the results, then stop and await the next command. For chained operations, such as a series of additions, press **ENTER** in response to the first input question (X? or MAGNITUDE?, depending on the mode). This will cause the result of the last calculation to be loaded as the first operand.

Clear

Press **S****H****F****T****←****C** to clear the entire program. This will also reset the mode to rectangular.

Add

Press **(SHIFT)(A)** to add one vector to another.

Subtract

Press **(SHIFT)(S)** to subtract one vector from another.

Dot Product

Press **(SHIFT)(D)** to calculate the dot product of two vectors.

Cross Product

Press **(SHIFT)(X)** to calculate the cross product of two vectors.

Angle Computation

Press **(SHIFT)(V)** to calculate the angle between two vectors.

Polar to Rectangular Coordinate Conversion

Press **(SHIFT)(F)** to convert a vector from polar to rectangular coordinates. This operation is independent of the set mode and does not affect any of the temporary results held by the computer.

Note: This routine will call the input routine for a single vector. You **must** enter the vector you want to convert in response to the FIRST VECTOR statement.

Rectangular to Polar Coordinate Conversion

Press **(SHIFT)(G)** to convert a vector from rectangular to polar coordinates. This operation is independent of the set mode and does not affect any of the temporary results held by the computer.

Change Mode

Press **(SHIFT)(M)** to switch modes from rectangular to polar or from polar to rectangular. The new mode will be displayed briefly. This operation does not affect the contents of the accumulator. In

rectangular mode, all input and output is in terms of magnitude, phi, and theta, where phi is the clockwise angle from the X axis to the projection of the vector on the XY plane, and theta is the angle from the XY plane to the vector.

Example

$$(1x + 2y + 3z) + (-2x + 1y - z) = (-1x + 3y + 2z)$$

Computer displays:

>
FIRST VECTOR
X?
Y?
Z?
SECOND VECTOR
X?
Y?
Z?
X=-1.
Y=3.
Z=2.
>

You type:

(SHIFT) (A)
Displays briefly
(1) (ENTER)
(2) (ENTER)
(3) (ENTER)
Displays briefly
(-) (2) (ENTER)
(1) (ENTER)
(-) (1) (ENTER)
(ENTER)
(ENTER)
(ENTER)

Variable List

A—X In Accum
B—Y In Accum
C—Z In Accum
X—X
Y—Y
Z—Z
G-I—Dummies and Holders
J—Magnitude
K—THETA
L—PHI
M—Mode: 0 = RECTANGULAR, 1 = POLAR
N-P—Holders
Q—Early Return Flag
R—Holder

Complex Arithmetic for the Pocket Computer

This program allows complex numbers to be added, subtracted, multiplied, divided, or conjugated. It also allows for the calculation of natural (base-e) logarithms, natural anti-logarithms, sines, cosines, arc sines, and arc cosines. These functions may be used in conjunction with the program's chaining capability to complete almost any calculation.

Please note that this program starts and runs **only** in RADIAN mode. All trig and exponential functions assume radian input and display radian results. Attempting to reset the mode to DEGREE or GRAD will result in inaccuracies in trig and exponential functions.

To load COMPLEX, insert the tape in the recorder and press the "Play" key. Turn the computer on, make sure the mode is set to DEF, then type:
CLOAD"COMPLEX" and press **(ENTER)**. After the prompt sign (>) appears, press **(SHIFT)(SPC)**. The program title will be displayed: COMPLEX ARITHMETIC. Press **(ENTER)** and the copyright notice will be displayed for about a second, then the command prompt will appear:
>READY.

The desired operation is selected by pressing the **(SHIFT)** key followed by a letter:

to ADD, press **(SHIFT)(A)**
to SUBTRACT, press **(SHIFT)(S)**
to MULTIPLY, press **(SHIFT)(M)**
to DIVIDE, press **(SHIFT)(D)**
to CONJUGATE, press **(SHIFT)(C)**
to calculate MAGNITUDE, press **(SHIFT)(Z)**
to calculate Natural LOGARITHM, press **(SHIFT)(L)**
to calculate Natural ANTILOG, press **(SHIFT)(K)**
to calculate SINE, press **(SHIFT)(F)**
to calculate COSINE, press **(SHIFT)(G)**
to calculate ARC SINE, press **(SHIFT)(H)**
to calculate ARC COSINE, press **(SHIFT)(J)**
to return to >READY, press **(SHIFT)(X)**
to REDISPLAY LAST ANSWER, press **(SHIFT)(=)**

The same input routine is used for all operations. In rectangular mode, the first question is: 1ST NUMBER REAL? Enter the real portion of the first number. Next is: 1ST NUMBER IMAGINARY? Reply with the imaginary part of the first number. If the chosen operation is monadic (one that requires only one operand), the input routine will end at this point.

In polar mode, you are asked for magnitude and phase angle rather than real and imaginary components.

Note: You may use the result of the last computation as an operand by pressing **(ENTER)** in response to: 1ST NUMBER REAL? If this is done, the input routine will load the result of the last computation as the first operand of the new operation and skip to: 2ND NUMBER REAL?

Next comes: 2ND NUMBER REAL? and 2ND NUMBER IMAGINARY? When all data has been entered, the computer will beep once when the answer is ready and display the result with the real portion on the left half of the display and the imaginary portion on the right.

The real and/or imaginary part of the second number may be kept unchanged by pressing **(ENTER)** in response to either: 2ND NUMBER REAL? or: 2ND NUMBER IMAGINARY? In either case, when **(ENTER)** is pressed, the old value of the number asked for will be displayed briefly and retained.

Computation of magnitude does not change the numbers stored by the program. Instead, magnitude is calculated and displayed separately. The magnitude is not kept as a new "1st number"; instead the complex number whose magnitude was computed is kept.

You can combine the functions available in this program to evaluate many other factors. For example,

in raising a complex number to a complex power, recall that if we take the log of the first number, multiply that by the second, and raise e to the resulting power, we've effectively raised the first number to the second power. To raise $2 + 3i$ to the $5 + 2i$ power, we could conduct the following operations:

Computer displays:

You type:

> READY
LOGARITHM
1ST NUMBER REAL?
1ST NUMBER IMAGINARY?
(BEEP)
1.282474679 9.82793E-01
MULTIPLY
1ST NUMBER REAL?
2ND NUMBER REAL?
2ND NUMBER IMAGINARY?
(BEEP)
4.446785949 7.478917974
 E^X
1ST NUMBER REAL?
(BEEP)
31.26721338 79.41886041

(SHIFT)L
Displays briefly
(2)ENTER
(3)ENTER

(SHIFT)M
Displays briefly
(ENTER)
(5)ENTER
(2)ENTER

(SHIFT)K
Displays briefly
(ENTER)

Your Answer: $31.267 + 79.419i$

With this method and the COMPLEX program's ability to chain easily (as demonstrated above), it can complete just about any calculation.

Note: Not all complex math problems have unique answers. Operations such as logarithm have multiple but equally correct solutions; hence when this program conducts extraction of logs or an inverse trig function (which uses logarithms) the answer may not be the obvious one. Usually it will be—but the answer will **always** be a correct one. Just remember that it may not be **the** correct answer!

The following algorithms are used:

Conjugation: $(A + Bi) = (A - Bi)$

Magnitude: $= \text{SQR}(AA + BB)$

Addition: $(A + Bi) + (C + Di) = (A + C) + (B + D)i$

Subtraction: $(A + Bi) - (C + Di) = (A - C) + (B - D)i$

Multiplication: $(A + Bi) * (C + Di) = (AC - BD) + (AD + BC)i$

Division: $(A + Bi) / (C + Di) = ((AC + BD)/(CC + DD) + (BC - AD)/(CC + DD))i$

Logarithm: (complex—examine code if interested)

e to the z: $e^{(A + Bi)} = e^A \cos(B) + e^A i \sin(B)$

Sine: $\text{SIN}(A + Bi) = (\text{SIN}(A) * (e^B - e^{-B})/2 + (\text{COS}(A) * (e^B + e^{-B})/2 i$

Cosine: $\text{COS}(A + Bi) = (\text{COS}(A) * (e^B - e^{-B})/2 + (\text{SIN}(A) * (e^B + e^{-B})/2 i$

Arc sine: $\text{ASIN}(Z) = -i \ln(i(Z + \text{SQR}(ZZ - 1)))$

Arc cosine: $\text{ACOS}(Z) = -i \ln(Z + \text{SQR}(ZZ - 1))$

When the result of the last computation is used as an operand, it is used as the first (A + Bi in the algorithms).

Variable List

A—1st Number Real and Result Real

B—1st Number Imaginary and Result Imaginary

C—2nd Number Real

D—2nd Number Imaginary

E—Holder for Incomplete Calculations and Magnitude

F—Holder for Incomplete Calculations and Return Flag

G—Holder for Incomplete Calculations: Real

H—Holder for Incomplete Calculations: Imaginary

I—Error-Present Flag

J—Single-Operand Flag

K—Sign Flag in Inverse Sine/Cosine Computations

Advanced Trig and Exponentiation

This program allows the Pocket Computer to evaluate advanced trigonometric and exponential functions.

To load ADVMATH, insert the tape in the recorder and press the "Play" key. Turn the computer on, make sure the mode is set to DEF, then type:

C**L****O****A****D****"****A****D****V****M****A****T****H****"**
and press **ENTER**. After the prompt sign (>) appears, press **SHIFT****SPC**. The program name will be displayed first: ADVANCED MATH. Press **ENTER** to clear this display and start the menu, from which functions are called by number:

(C) 1981 TANDY CORP.
SELECT FUNCTION BY NUMBER:
CHANGE MODE (RAD/DEG)0

Note: This program does not send the menu to the printer.

The following functions are provided:

Number	Function	Abbreviation
0 0	Change Modes, DEG/RAD	None
0 1	Sine	SIN
0 2	Cosine	COS

0 3	Tangent	TAN
0 4	Cotangent	COT
0 5	Secant	SEC
0 6	Cosecant	CSC
0 7	Arc Sine	ASIN
0 8	Arc Cosine	ACOS
0 9	Arc Tangent	ATAN
1 0	Arc Cotangent	ACOT
1 1	Arc Secant	ASEC
1 2	Arc Cosecant	ACSC
1 3	Hyperbolic Sine	SINH
1 4	Hyperbolic Cosine	COSH
1 5	Hyperbolic Tangent	TANH
1 6	Hyperbolic Cotangent	COTH
1 7	Hyperbolic Secant	SECH
1 8	Hyperbolic Cosecant	CSCH
1 9	Arg Hyperbolic Sine	ASINH
2 0	Arg Hyperbolic Cosine	ACOSH
2 1	Arg Hyperbolic Tangent	ATANH
2 2	Arg Hyperbolic Cotangent	ACOTH
2 3	Arg Hyperbolic Secant	ASECH
2 4	Arg Hyperbolic Cosecant	ACSCH
2 5	LOGn(x)	LOGN
2 6	X to the Y	none

Any function may be called from any line of the menu.

Modes

The 12 circular trig functions may be evaluated in either degrees or radians, as set through program option 0. The 12 hyperbolic functions are always evaluated in radian measure, regardless of the mode. The current mode (DEG or RAD) is displayed near the top left of the Pocket Computer display window.

Changing the Mode

Enter option (0). The mode will be changed. If it is RADian, it will change to DEGree. If the mode is DEGree, it will change to RADian. The new mode will appear in the top left of the display window.

Using the Trig Functions

Just call the function by number. The program will ask for the number to be evaluated: ARGUMENT?, then beep after calculations are completed (this may take a couple of seconds) and display the answer. Pressing (ENTER) will end the answer display and return to the menu.

You may reuse the last argument entered by pressing (ENTER) when asked for the argument. The

program will display: * and the old argument. You may also use the result of the last computation as the new argument by entering (A) in response to: ARGUMENT?

Using the Logarithm Function

Call it by entering (2)(5). The program will first ask: ARGUMENT? Answer with the positive number whose logarithms you want. Next it will ask: BASE? Reply with a positive number. The program will then perform the required calculations and display the answer.

Example

Find log (9).

Computer displays:

ARGUMENT?
BASE?
(BEEP)
3.

You type:

(9)(ENTER)
(3)(ENTER)

Find log (10).

Computer displays:

ARGUMENT?

BASE?

(BEEP)

1.430676558

You type:

1 0 ENTER

5 ENTER

Exponentiation

This function allows you to raise any positive number to any power, and a negative number to a positive or integral negative power. First, the program will ask: ARGUMENT? Enter the number you wish to exponentiate. Next, it will ask: EXPONENT? Reply with the power to which you wish to raise the argument. The program will then display the answer.

Permissible Numerical Ranges for Functions

Entry of an argument for which the function called cannot be evaluated will cause the program to beep three times and display: ILLEGAL, then return to the menu.

The following list details the numerical range of arguments for which each function is defined:

Function	Defined Range	Undefined Points Within Range
----------	---------------	-------------------------------

SIN	No Limits	None
COS	No Limits	None
TAN	No Limits	$\pi/2 + n \cdot \pi$
COT	No Limits	$0, n \cdot \pi$
SEC	No Limits	$\pi/2 + n \cdot \pi$
CSC	No Limits	$0, n \cdot \pi$
ASIN	$ABS(X) \leq 1$	None
ACOS	$ABS(X) \leq 1$	None
ATAN	No Limits	None
ACOT	No Limits	None
ASEC	$ABS(X) \geq 1$	None
ACSC	$ABS(X) \geq 1$	None
SINH	No Limits	None
COSH	No Limits	None
TANH	No Limits	None
COTH	No Limits	0
SECH	No Limits	None
CSCH	No Limits	0
ASINH	No Limits	None
ACOSH	$X \geq 1$	None
ATANH	$ABS(X) < 1$	None
ACOTH	$ABS(X) > 1$	None
ASECH	$0 < X \leq 1$	0
ACSCH	No Limits	0

Variable List

A—Result Holder

B—Argument

C—Mode Flag

D—Branching Dummy

R,S—Sign Flags for Exponentiation

Appendix A

The four Engineering Math packages consist of nine programs designed to handle a variety of algebraic and elementary calculus problems. The contents of the packages are:

Package	Program	Description
Engineering Math I (26-3525)	GAUSS	Gaussian matrix reduction
	MATMUL	Matrix multiplication
	MATINV	Matrix inversion
Engineering Math II (26-3526)	VECTOR	Vector arithmetic
	COMPLEX	Complex arithmetic
	ADVMATH	Advanced trig and exponentials
Engineering Math III (26-3527)	SIMEQ	Linear simultaneous equations
	PCALC	Polynomial math and calculus
Engineering Math IV (26-3528)	TRIANG	Solution of triangles

The functions of the programs are as follows:

GAUSS—Can complete a Gaussian reduction of a square matrix from 3×3 to 10×10 , display the reduced matrix, and calculate its determinant.

MATMUL—Will multiply an $I \times J$ matrix by a $J \times K$ matrix, displaying an $I \times K$ matrix as the product. $IJ + JK$ must be less than or equal to 108.

MATINV—Will calculate the inverse of a square matrix, from 3×3 to 6×6 .

VECTOR—Provides all common vector operations in three dimensions in both Cartesian and polar coordinates: addition, subtraction, dot product, cross product, angle between two vectors, and direct conversion of a vector between rectangular and polar coordinate systems. Chain operations are allowed. The mode may be changed between polar and rectangular at any point during program execution without adversely affecting intermediate results.

COMPLEX—Provides for the most common complex number arithmetic operations: addition, subtraction, multiplication, division, calculation of magnitude, conjugation, base- e logarithms, e to complex powers, sines, cosines, arc sines, and arc cosines. Chain operations are allowed.

ADVMATH—Provides 24 common trig functions in degree or radian measure. It also provides logarithms to any base and an exponentiation function which can raise negative numbers to positive or integral negative powers.

SIMEQ—Solves systems of up to nine linear simultaneous equations for all unknowns. It can also be used to complete a Gaussian reduction of matrices from 2×2 to 9×9 .

PCALC—Provides common polynomial functions and calculus solutions for polynomials to the ninth order. Included are: evaluation of the polynomial at any point, calculation of an exact derivative at any point, calculation of an exact integral between any two points, and Newtonian root search.

TRIANG—Will solve for the three common unknown triangles (side-side-side, side-angle-side, angle-side-angle) and also can solve from three Cartesian coordinates. TRIANG solves for all sides and angles in any angular unit (degrees, radians, or grads), calculates area, and tests for equilateral, right, isosceles, obtuse, and scalene properties.

Appendix B—Making a Backup

A Backup is a tape copy of a program and is an extremely effective method of insuring that an accident or equipment fault will not result in the loss of software. Your first action as owner of the Engineering Math II Package should be to make working copies of the original cassette(s) and then put the originals away in a safe place.

Although it may be possible to make direct copies using two cassette recorders or on cassette duplicating equipment, the most reliable method is to use the computer itself to make the Backups. Also, for frequently used programs, you may wish to put them on separate cassettes for easier loading. Here are step-by-step instructions for making a Backup:

1. Connect the Cassette Interface to the cassette recorder and install the computer in the Cassette Interface.
2. Place the cassette containing the program(s) to be copied in the recorder and either rewind the tape to the beginning or position the tape to a blank area just prior to the desired program. Place the recorder in the "Play" mode. It is recommended that the volume control setting be between 8 and

10 on your recorder. If your recorder has a tone control, set it at maximum treble.

3. Turn on the computer, make sure that it is either in the DEF mode or RUN mode and type in: `CLOAD" name "` (name refers to the name of the program to be copied). To make absolutely sure that the program has loaded correctly, use the loading verification procedure as described in the sixth instruction of this appendix.
4. When the program has been loaded into the computer and the cassette has stopped, remove the cassette and replace it with the cassette which is to receive the program copy. Either rewind the tape to the beginning or position it to the point where the copy is to start. You should leave about ten seconds of blank space if the copy is to follow another program on the same cassette. Place the recorder in the "Record" mode.
5. Make sure that the computer is in either the DEF or RUN mode and type in: `CSAVE" name "`. The recorder will save your program.
6. Now rewind the cassette to the blank space just prior to the program, put the recorder into the "Play" mode and type in: `CLOAD?" name "`.

This is the computer's verifying function. The recorder will start and compare the cassette copy with the program in the computer's memory. If the copy is good, the recorder will stop at the end of the program and the prompt sign (>) will reappear on the display. If an error occurred during the verification, the display will show an error message such as: 5.....

If the error message appears on the display, check the recorder volume setting and try the CLOAD? function once more. If you still get an error, the tape copy is probably damaged. Use the CSAVE function once more and verify the load. It is recommended that you use Radio Shack Supertape or TRS-80 certified cassettes for backing up your Pocket Computer programs.

7. Backup each program using Steps 1 through 6 above.
8. Put the original cassettes away in a safe place and use them only for making working copies.

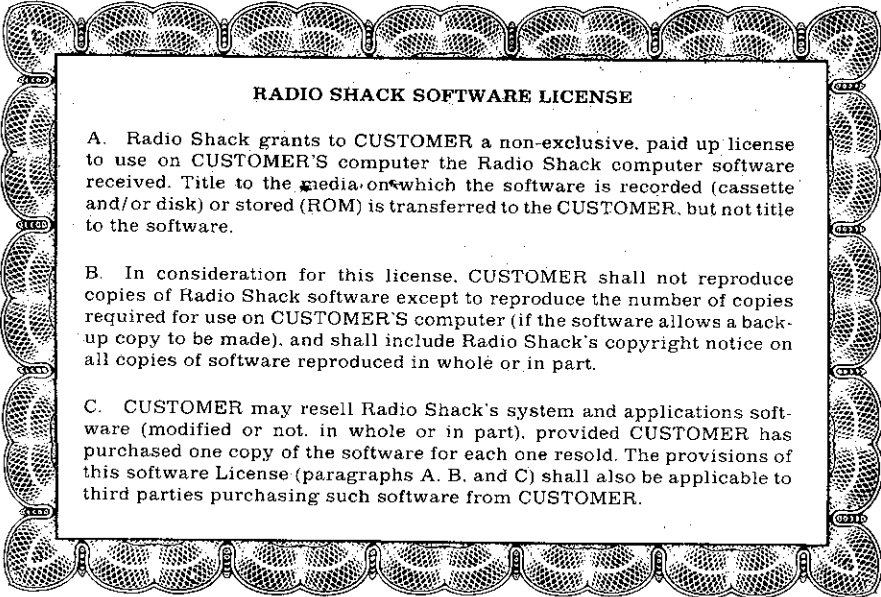
Appendix C—Maintenance

Maintenance of your Pocket Computer System is not difficult. Attention to the simplest points listed below should provide the best reliability and satisfaction:

1. Keep your program cassettes in their boxes when not in use. Do not expose cassettes to temperature extremes or magnetic fields. Never touch the exposed surface of the tape on the front edge of the cassette.
2. Clean and demagnetize the tape heads in the recorder at regular intervals. Follow the recommendations in the cassette recorder's manual.
3. The most reliable loading and saving is achieved by operating the cassette recorder on AC current, rather than batteries.
4. Use only fresh alkaline-type batteries in the recorder and Cassette Interface when operating your system away from AC current.
5. Always press the recorder's "Stop" key immediately after loading or saving a program. This will release the pressure on the rubber roller

which pulls the tape and prevent the roller from developing a permanent "flat" at the point of contact with the tape.

6. Always turn the computer "OFF" before installing it in or removing it from the Cassette Interface.
7. After removing the computer from the Cassette Interface, be sure to reinstall the protective plug to keep dirt out of the connector on the computer. Never touch the exposed parts on the Cassette Interface.



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NOTE: Good data processing procedure dictates that the user test the program, run and test sample sets of data, and run the system in parallel with the system previously in use for a period of time adequate to insure that results of operation of the computer or program are satisfactory.

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Addendum for Engineering Math II (26-3526)

Please note the following corrections to the manual:

1. On Page 2, in the list of functions available in program VECTOR, the characters "SHFT-" do NOT appear in the program's menu.
2. On page 5, in the list of functions available in program COMPLEX, the eighth line is titled "antilog." When this option is selected, the program will display "E^X." These are different names for the same operation.
3. On Page 9, in the example problem for the logarithm function in program ADVMath, the answer is incorrectly shown as 3. The correct answer to the sample problem is 2.

4 Line 79 From $A = \ln(B + \text{SQR}(BB-1))$
To $A = \ln(B + \text{SQR}(BB-1))$