Part IV: Texas Instruments TI-92 Graphics Calculator

IV.1 Systems of Linear Equations

IV.1.1 Basics: Press the ON key to begin using your TI-92 calculator. If you need to adjust the display contrast, first press ◆, then press − (the minus key) to lighten or + (the plus key) to darken. To lighten or darken the screen more, press ◆ then + or − again. When you have finished with the calculator, turn it off to conserve battery power by pressing 2nd and then OFF.

Check the TI-92's settings by pressing MODE. If necessary, use the arrow key to move the blinking cursor to a setting you want to change. You can use F1 to go to page 1 or F2 to go to page 2 of the MODE menu. To change a setting, use ▼ to get to the setting that you want to change, then press ▶ to see the options available. Use the ▲ or ▼ to highlight the setting that you want and press ENTER to select the setting. To start, select the options shown in Figures IV.1 and IV.2: function graphs, main folder, floating decimals with 10 digits displayed, radian measure, normal exponential format, real numbers, rectangular vectors, pretty print, full screen display, home screen showing, and approximate calculation. Note that some of the lines of the MODE menu are not readable. These lines pertain to options that are not set above. For now, leave the MODE options by pressing ◆ HOME or 2nd QUIT. Some of the current settings are shown on the status line of the Home screen.

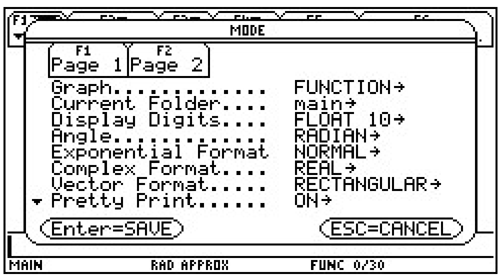

Figure IV.1: MODE menu, page 1

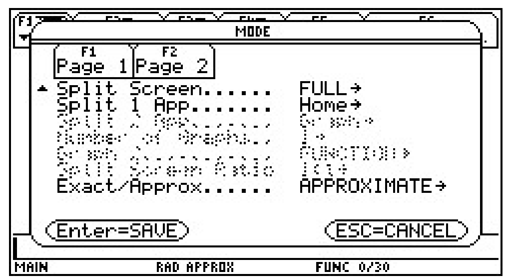

Figure IV.2: MODE menu, page 2

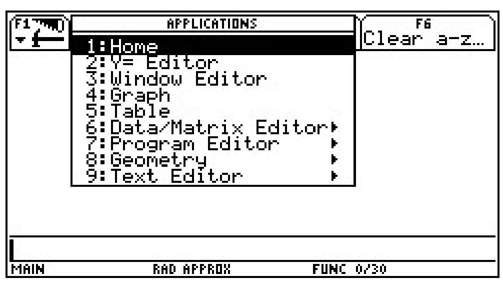

Figure IV.3: APPS menu

Technology Tip: There are many ways to get the most commonly used screens on your TI-92. One method is by using APPS menu (see Figure IV.3) which is accessed by pressing the blue APPS key. To return to the Home screen press 2nd QUIT, ◆ HOME, or ENTER.

IV.1.2 Key Functions: Most keys on the TI-92 offer access to more than one function, just as the keys on a computer keyboard can produce more than one letter ("g" and "G") or even quite different characters ("5" and "%"). The primary function of a key is indicated on the key itself, and you access that function by a simple press on the key.

To access the *second* function indicated to the *left* above a key, first press 2nd (2nd appears on the status line) and *then* press the key. For example, to calculate $\sqrt{25}$, press 2nd $\sqrt{\ }$ 25) ENTER.

Technology Tip: A simple press of a letter key will produce a lowercase letter while pressing ⇧ and the key will produce an uppercase letter.

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IV.1.3 Algebraic Expressions and Memory: Your calculator can evaluate expressions such as $\frac{N(N+1)}{2}$ *after* you have entered a value for *N*. Suppose you want *N* = 200. Press 200 STO ► ⬆ N ENTER to store the value 200 in memory location *N*. Whenever you use *N* in an expression, the calculator will substitute the value 200 until you make a change by storing another number in *N*. Next enter the expression $\frac{N(N+1)}{2}$ by typing ⬆ N x (⬆ N + 1) ÷ 2 ENTER. For $N = 200$, you will find that $\frac{N(N+1)}{2} = 20100$.

Technology Tip: The contents of any memory location may be revealed by typing just its letter name and then ENTER. Simply press ⬆ N ENTER to see the current value of the variable *N*. And the TI-92 retains memorized values even when it is turned off, so long as its batteries are good.

Technology Tip: Because variable names may be more than one character in length, multiplication between variables must always be *expressed*. So for the product *ab*, you *must* enter a x b with the multiplication key. With a *numerical* coefficient, however, the multiplication does *not* need to be expressed; hence for *4ab* you may enter 4 a x b.

IV.1.4 The MATH Menu: Operators and functions associated with a scientific calculator are available either immediately from the keys of the TI-92, by 2nd keys, or by ◆ keys. You have direct key access to common arithmetic operations (2nd $\sqrt{\ }$, 2nd x^{-1}, ^), trigonometric functions (SIN, COS, TAN) and their inverses (2nd SIN^{-1}, 2nd COS^{-1}, 2nd TAN^{-1}), exponential and logarithmic functions (LN, 2nd e^x), and a famous constant (2nd π).

Note that the TI-92 distinguishes between *subtraction* and the *negative* sign. If you wish to enter a negative number, it is necessary to use the (-) key. For example, you would evaluate $-5 - (4 \cdot -3)$ by pressing (-) 5 – (4 x (-) 3) ENTER to get 7.

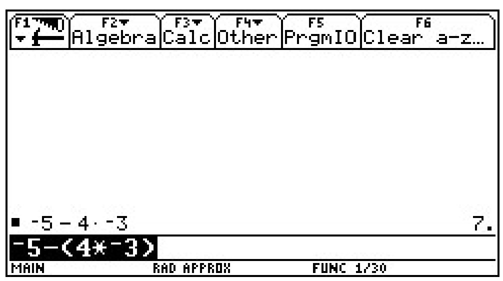

Figure IV.4: *Subtraction* and the *Negative* sign

A significant difference between the TI-92 and many scientific calculators is that the TI-92 requires the argument of a function after the function, as you would see a formula written in your textbook. For example, on the TI-92 you calculate $\sqrt{16}$ by pressing the keys 2nd $\sqrt{\ }$ 16) in that order.

Here are keystrokes for basic mathematical operations. Try them for practice on your TI-92.

Expressions	*Keystrokes*	*Display*
$\sqrt{3^2+4^2}$	2nd $\sqrt{\ }$ 3 ^ 2 + 4 ^ 2) ENTER	5.
$2\frac{1}{3}$	2 + 3 ^ (-) 1 ENTER or 2 + (1 ÷ 3) ENTER	2.333333333
ln 200	LN 200) ENTER	5.298317367
$2.34 \cdot 10^5$	2.34 x 10 ^ 5 ENTER	234000.

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Technology Tip: Note that if you had set the calculation to either AUTO or EXACT (the last line of page 2 of the MODE menu), the TI-92 would display $\frac{7}{3}$ for $2\frac{1}{3}$ and $2\ln(5) + \ln(2)$ for ln 200. Thus, you can use either fractions and exact numbers or decimal approximations. The AUTO mode will give exact rational results whenever all of the numbers entered are rational, and decimal approximations for other results.

Additional mathematical operations and functions are available from the MATH menu. Press 2nd MATH to see the various sub-menus. Press 1 *[Number]* or just ENTER to see the options available under the Number sub-menu. You will learn in your mathematics textbook how to apply many of them. As an example, calculate the remainder of 437 when divided by 49 by pressing 2nd MATH 1 *[Number]* then *either* a *[remain (] or* ▼ ▼ ▼ ▼ ▼ ▼ ▼ ▼ ▼ ENTER; finally press 437 , 49) ENTER to see 45. To leave the MATH menu (or any other menu) and take no other action, press 2nd QUIT or just ESC.

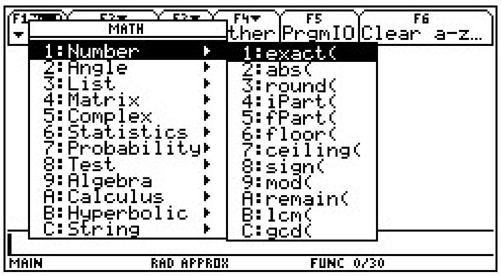

Figure IV.5: MATH Number menu

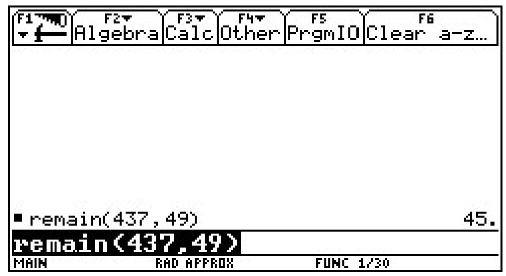

Figure IV.6: remain (function

Note that you can select a function or a sub-menu from the current menu by pressing either ▼ until the desired item is highlighted and then ENTER, or by pressing the number or letter corresponding to the function or sub-menu. It is easier to press alpha a than to press ▼ nine times to get the remain(function.

The *factorial* of a non-negative integer is the *product* of *all* the integers from 1 up to the given integer. The symbol for factorial is the exclamation point. So 4! (pronounced *four factorial*) is $1 \cdot 2 \cdot 3 \cdot 4 = 24$. You will learn more about applications of factorials in your textbook, but for now use the TI-92 to calculate 4! Press the keystrokes: 4 2nd MATH 7 *[Probability]* ENTER ENTER.

IV.1.5 Graphing Linear Functions: Once you have entered a function in the Y= screen of the TI-92, just press ◆ GRAPH to see its graph.

For example, here is how to graph $y = -x + 3$. Press the ◆ Y= key (above the W key) or APPS 2 *[Y= Editor]* to display the function editing screen (Figure IV.7). You may enter as many as ninety-nine different functions for the TI-92 to use at one time. If there is already a function y1 press ▲ or ▼ as many times as necessary to move the cursor to y1 and then press CLEAR to delete whatever was there. Then enter the expression $-x + 3$ by pressing (-) x + 3 ENTER. Now press ◆ GRAPH (above the R key).

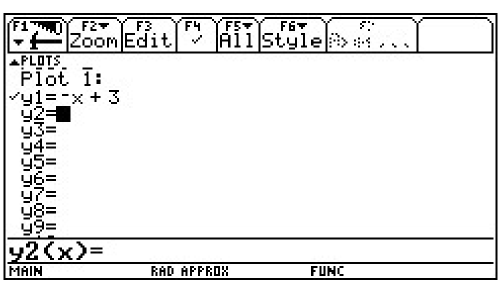

Figure IV.7: Y= screen

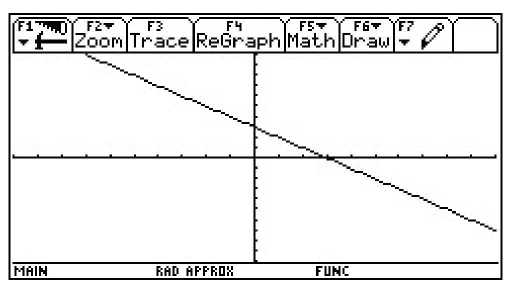

Figure IV.8: Graph of $y = -x + 3$

Technology Tip: While the TI-92 is calculating coordinates for a plot, it displays the word BUSY on the status line.

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The viewing rectangle in Figure IV.8 shows the part of the graph that extends horizontally from −10 to 10 and vertically from −10 to 10. Press ◆ WINDOW to see information about your viewing rectangle. Figure IV.9 shows the WINDOW screen that corresponds to the viewing rectangle in Figure IV.8. This is the *standard* viewing rectangle for the TI-92.

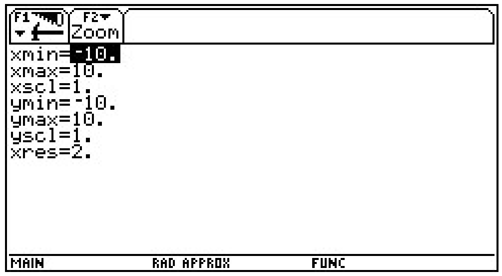

Figure IV.9: Standard WINDOW

The variables Xmin and Xmax are the minimum and maximum *x*-values of the viewing rectangle: Ymin and Ymax are its minimum and maximum *y*-values.

Xscl and Yscl set the spacing between tick marks on the axes.

Xres sets the resolutions.

Use the arrow keys ▲ and ▼ to move up and down from one line to another in this list; pressing the ENTER key will move down the list. Press CLEAR to delete the current value and then enter a new value. Remember that a minimum *must* be less than the corresponding maximum or the TI-92 will issue an error message. Also, remember to use the (-) key, not − (which is subtraction), when you want to enter a negative value.

Technology Tip: To set the range quickly to standard values (see Figure IV.9), press ◆ WINDOW F2 *[Zoom]* 6 *[ZoomStd]*.

Technology Tip: If you would like to see a function in the Y = menu and its graph in a graph window, both at the same time, press MODE to open the MODE menu and press F2 to go to the second page. The cursor will be next to Split Screen. Select either TOP-BOTTOM or LEFT-RIGHT by pressing ▶ and 2 or 3, respectively. Now the 2 lines below the Split 1 APP line have become readable, since these options apply only when the calculator is in the split screen mode. The Split 1 APP will automatically be the screen you were on prior to pressing MODE. You can choose what you want the top or left-hand screen to show by moving down to the Split 1 APP line, pressing ▶ and the number of the application you want in that window. The Split 2 APP determines what is shown in the bottom or right-hand window. Press ENTER to confirm your choices and your TI-92's screen will now be divided either horizontally or vertically (as you choose). Figure IV.10 shows the graph and the Y = screen with the settings shown in Figure IV.11. The split screen is also useful when you need to do some calculations as you trace along a graph. In split screen mode, one side of the screen will be more heavily outlined. This is the active screen, i.e., the screen that you can currently modify. You can change which side is active by using 2nd ◫ (above the APPS key). For now, restore the TI-92 to Full screen.

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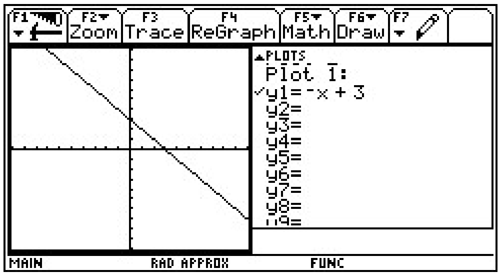

Figure IV.10: Split Screen

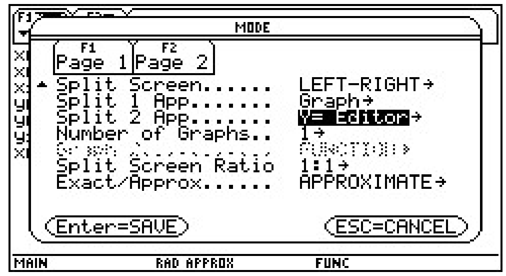

Figure IV.11: Settings for split screen

IV.1.6 Graphing Parametric Functions: The TI-92 plots parametric equations as easily as it plots functions. Up to ninety-nine pairs of parametric equations can be plotted. In the first page of the MODE menu (Figure IV.1) change the GRAPH setting to PARAMETRIC. Be sure, if the independent parameter is an angle measure, that the angle measure in the MODE menu has been set to whichever you need, RADIAN or DEGREE.

You can now enter the parametric functions. For example, here are the keystrokes needed to graph the parametric equations $x = \cos^3 t$ and $y = \sin^3 t$. First check that angle measure is in radians. Then press ◆ Y = COS T) ^ 3 ENTER SIN T) ^ 3 ENTER (Figure IV.12).

Press ◆ WINDOW to set the graphing window and to initialize the values of t. In the standard window, the values of t go from 0 to 2π in steps of $\frac{\pi}{24} \approx 0.1309$, with the view from –10 to 10 in both directions. In order to provide a better viewing rectangle press ENTER three times and set the rectangle to go from -2 to 2 horizontally and vertically (Figure IV.13). Now press ◆ GRAPH to draw the graph (Figure IV.14).

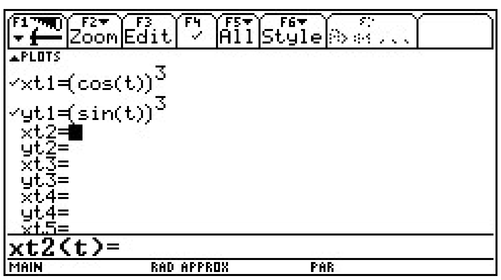

Figure IV.12: Parametric Y = menu

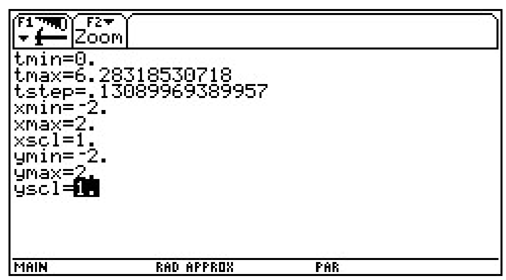

Figure IV.13: Parametric WINDOW menu

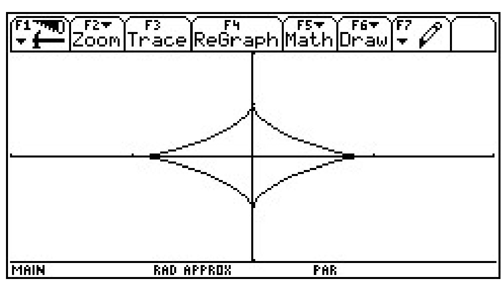

Figure IV.14: Parametric graph of $x = \cos^3 t$ and $y = \sin^3 t$

IV.1.7 Solving Linear Systems: The solutions to a system of equations correspond to the points of intersection of their graph. As an example, let's graph and solve the system $\begin{cases} 3x - y = 1 \\ 2x - y = 0 \end{cases}$.

First transform each equation by solving for y: $\begin{cases} y = 3x - 1 \\ y = 2x \end{cases}$. Then press ◆ Y = and enter $3x - 1$ for Y_1 and $2x$ for Y_2 (Figure IV.15).

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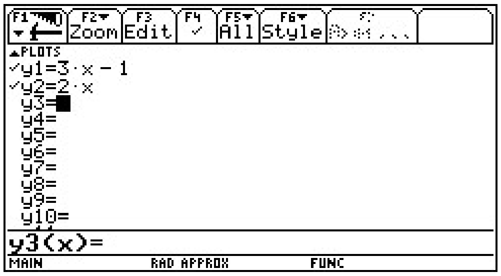

Figure IV.15: $3x - 1$ for Y_1 and $2x$ for Y_2

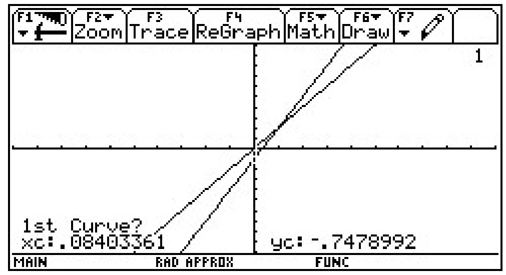

Figure IV.16: Setting up to locate the intersection

Find the coordinates of a point of intersection of the two graphs by pressing ◆ GRAPH F5 *[Math]* 5 *[Intersection]*. Trace with the cursor keys ◀ or ▶ first along one graph near an intersection (Figure IV.16) and press ENTER; then trace with the cursor along the other graph and press ENTER. Move the cursor just left of the point of intersection (Figure IV.17) and press ENTER again. Finally, move the cursor just right of the point of intersection and press ENTER again. Coordinates of the intersection will be displayed at the bottom of the window (Figure IV.18).

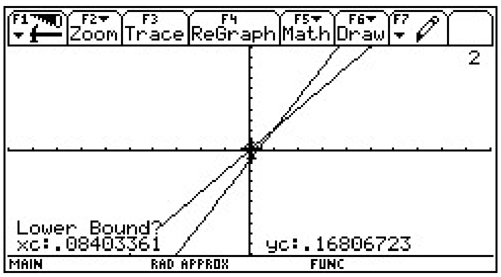

Figure IV.17: Setting up to locate the intersection

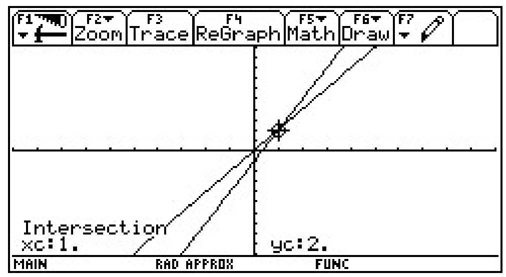

Figure IV.18: Point of intersection

The TI-92 also has a solve(function that you can use to solve a linear system. The technique is based on the fact that any solution of the system $\begin{cases} y = 3x - 1 \\ y = 2x \end{cases}$ is a *root* of the equation $3x - 1 = 2x$. From the home screen press F2 1*[solve (]* or (2nd MATH 9 *[Algebra]* 1 *[Solve (]*) 3x – 1 = 2x , x) then press ENTER for the x-coordinate of the point of intersection (Figure IV.19). Then to calculate its y-coordinate, save this value as x (press 1 STO▶ x ENTER) and evaluate either $3x - 1$ or $2x$.

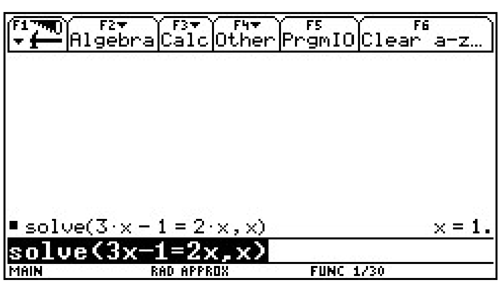

Figure IV.19: Solve (function

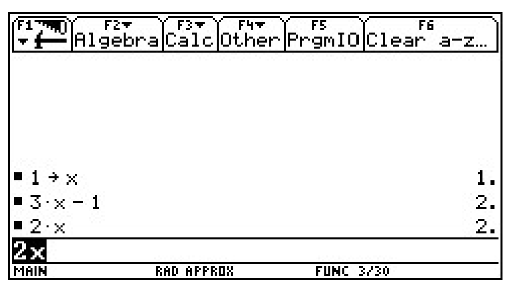

Figure IV.20: Calculate the y-coordinate

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IV.2 Matrices

IV.2.1 Making a Matrix: The TI-92 can work with as many different matrices as the memory will hold. Here's how to create the 3×4 matrix $\begin{bmatrix} 1 & -2 & 3 & 9 \\ -1 & 3 & 0 & -4 \\ 2 & -5 & 5 & 17 \end{bmatrix}$ in your calculator.

From the Home screen, press APPS 6 *[Data/Matrix Editor]* 3 *[New]*. Set the Type to Matrix, the Variable to a (this is the 'name' of the matrix), the Row Dimension to 3 and the Col Dimension to 4 (Figure IV.21). Press ENTER to accept these values.

Figure IV.21: Data/Matrix menu

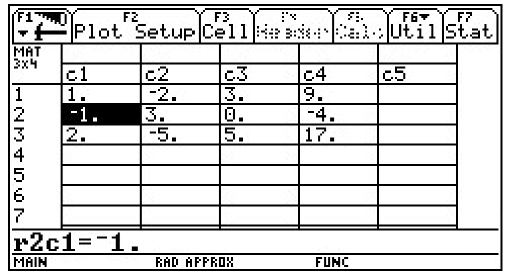

Figure IV.22: Editing a matrix

The display will show the matrix by showing a grid with zeros in the rows and columns specified in the definition of the matrix.

Use the cursor pad or ENTER repeatedly to move the cursor to a matrix element you want to change. If you press ENTER, you will move right across a row and then back to the first column of the next row. The lower left of the screen shows the cursor's current location within the matrix. The element in the second row and first column in Figure IV.22 is highlighted, so the lower left of the window is r2c1 $= -1$, showing that element's current value. Enter all the elements of matrix a; pressing ENTER after inputting each value.

When you are finished, leave the editing screen by pressing 2nd QUIT or ◆ HOME to return to the home screen.

Technology Tip: The TI-92 enables you to create an identity matrix quickly. If you want to make the 3×3 identity matrix, for example, press 2nd MATH 4 *[Matrix]* 6 *[identity]* 3) ENTER (see Figure IV.23). If you want to save the 4×4 identity matrix as matrix b, press 2nd Math 4 *[Matrix]* 6 *[identity]* 4) STO▶ b ENTER.

Technology Tip: The TI-92 also enables you to create a matrix of any size and fill it with random single-digit integers -9 to 9. To create a 2×3 matrix filled with random integers, press 2nd MATH 4 *[Matrix]* a *[randMat(]* 2 , 3) ENTER (see Figure IV.24).

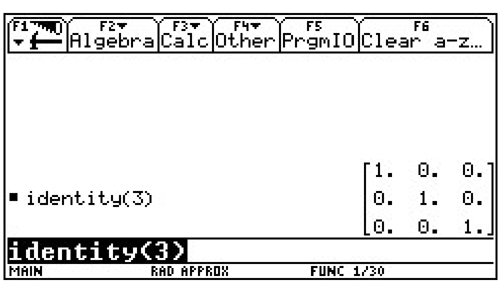

Figure IV.23: Identity matrix

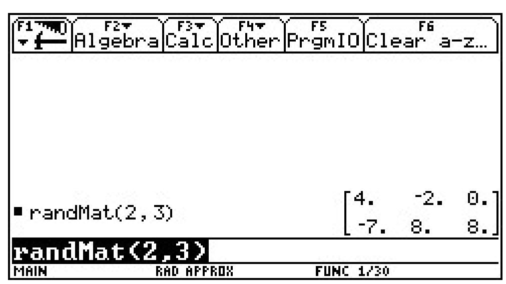

Figure IV.24: Random matrix

From the Home screen, you can perform many calculations with matrices. To see matrix a, press a ENTER.

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IV.2.2 Scalar Multiplication: Perform the scalar multiplication 2a pressing 2 a ENTER. The resulting matrix is displayed on the screen. To create matrix b as 2a press 2 a STO▶ b ENTER (Figure IV.26), or if you do this immediately after calculating 2a, press only STO▶ b ENTER. The calculator will display the matrix.

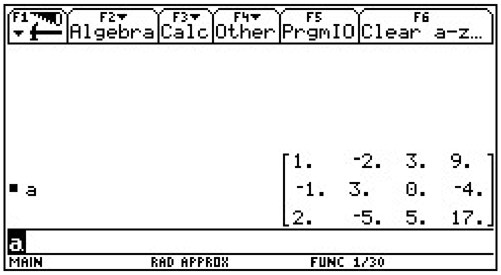

Figure IV.25: Matrix a

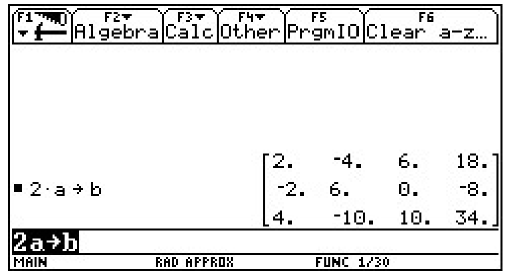

Figure IV.26: Matrix b

IV.2.3 Matrix Addition: To add two matrices, say a and b, create b (with the same dimensions as a) and then press a + b ENTER. Again, if you want to store the answer as a specific matrix, say m, then press STO▶ m. Subtraction is performed in a similar manner.

IV.2.4 Matrix Multiplication: Now create a matrix called c with dimensions of 2×3. Enter the matrix $\begin{bmatrix} 2 & 0 & 3 \\ 1 & -5 & -1 \end{bmatrix}$ as c. For matrix multiplication of c by a, press c × a ENTER. If you tried to multiply a by c, your TI-92 would notify you of an error because the dimensions of the two matrices do not permit multiplication in this way.

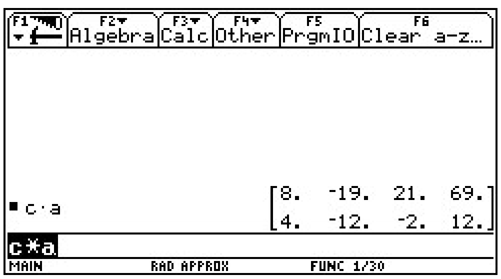

Figure IV.27: Matrix multiplication

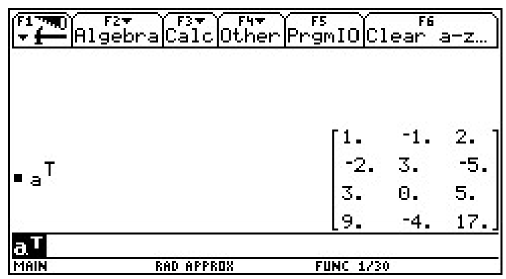

Figure IV.28: Transpose

IV.2.5 Transpose of a Matrix: The transpose of a matrix is another matrix with the rows and columns interchanged. The symbol for the transpose of a is a^T. To calculate a^T, press a 2nd MATH 4 *[Matrix]* 1 *[^{T}]* ENTER (see Figure IV.28).

IV.2.6 Row Operations: Here are the keystrokes necessary to perform elementary row operations on a matrix. Your textbook provides more careful explanation of the elementary row operations and their uses.

To interchange the second and third rows of the matrix a that was defined above, press 2nd MATH 4 *[Matrix]* d *[Row ops]* 1 *[rowSwap(]* a , 2 , 3) ENTER (see Figure IV.29). The format of this command is rowSwap(*matrix, row1, row2*).

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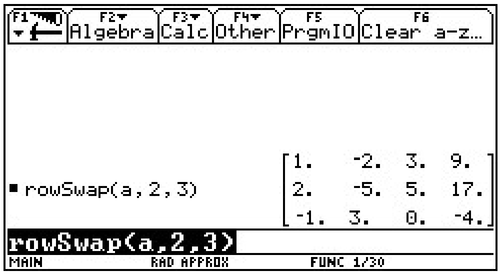

Figure IV.29: Swap rows 2 and 3

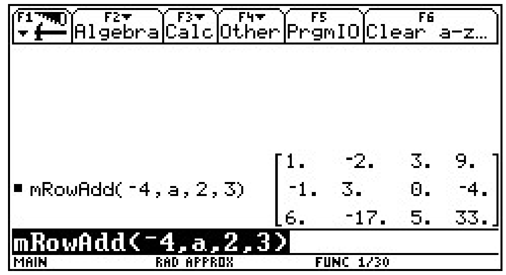

Figure IV.30: Add -4 times row 2 to row 3

To add row 2 and row 3 and *store* the results in row 3, press 2nd MATH 4 *[Matrix]* d *[Row ops]* 2 *[rowAdd(]* a , 2 , 3) ENTER. The format of this command is rowAdd(*matrix, row1, row2*).

To multiply row 2 by -4 and *store* the results in row 2, thereby replacing row 2 with new values, press 2nd MATH 4 *[Matrix]* d *[Row ops]* 3 *[mRow(]* (-) 4 , a , 2) ENTER. The format of this command is mRow(*expression, matrix1, index*).

To multiply row 2 by -4 and *add* the results to row 3, thereby replacing row 3 with new values, press 2nd MATH 4 *[Matrix]* d *[Row ops]* 4 *[mRowAdd(]* (-) 4 , a , 2 , 3) ENTER (see Figure IV.30). The format of this command is mRowAdd(*expression, matrix1, index1, index2*).

Note that your TI-92 does *not* store a matrix obtained as the result of any row operation. So when you need to perform several row operations in succession, it is a good idea to store the result of each one in a temporary place.

For example, use elementary row operations to solve this system of linear equations: $\begin{cases} x - 2y + 3z = 9 \\ -x + 3y = -4. \\ 2x - 5y + 5z = 17 \end{cases}$

First enter this *augmented matrix* as a in your TI-92: $\begin{bmatrix} 1 & -2 & 3 & 9 \\ -1 & 3 & 0 & -4 \\ 2 & -5 & 5 & 17 \end{bmatrix}$. Then return to the Home screen and store this matrix as e (press a STO► e ENTER), so you may keep the original in case you need to recall it.

Here are the row operations and their associated keystrokes. At each step, the result is stored in e and replaces the previous matrix e. The last two steps of the row operations are shown in Figure IV.31.

Row Operation	*Keystrokes*
add row 1 to row 2	2nd MATH 4 d 2 e , 1 , 2) STO► e ENTER
add –2 times row 1 to row 3	2nd MATH 4 d 4 (-) 2 , e , 1 , 3) STO► e ENTER
add row 2 to row 3	2nd MATH 4 d 2 e , 2 , 3) STO► e ENTER
multiply row 3 by $\frac{1}{2}$	2nd MATH 4 d 3 1 ÷ 2 , e , 3) STO► e ENTER

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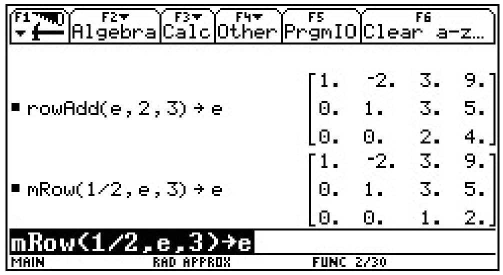

Figure IV.31: Row operations

Thus $z = 2$, so $y = -1$, and $x = 1$.

Technology Tip: The TI-92 can produce a row-echelon form and the reduced row-echelon form of a matrix. The row-echelon form of matrix a is obtained by pressing 2nd MATH 4 *[Matrix]* 3 *[ref(]* a) ENTER and the reduced row-echelon form is obtained by pressing 2nd MATH 4 *[Matrix]* 4 *[rref(]* a) ENTER. Note that the row-echelon form of a matrix is not unique, so your calculator may not get exactly the same matrix as you do by using row operations. However, the matrix that the TI-92 produces will result in the same solution to the system.

IV.2.7 Determinants and Inverses: Enter the 3×3 matrix as a: $\begin{bmatrix} 1 & -2 & 3 \\ -1 & 3 & 0 \\ 2 & -5 & 5 \end{bmatrix}$. Since this consists of the first three columns of the matrix a that was previously used, you can go to the matrix, move the cursor into the fourth column and press F6 *[Util]* 2 *[Delete]* 3 *[column]*. This will delete the column that the cursor is in. To calculate its determinate, $\left| \begin{bmatrix} 1 & -2 & 3 \\ -1 & 3 & 0 \\ 2 & -5 & 5 \end{bmatrix} \right|$, go to the Home screen and press 2nd MATH 4 *[Matrix]* 2 *[det(]* a) ENTER. You should find that the determinant is 2 as shown in Figure IV.32.

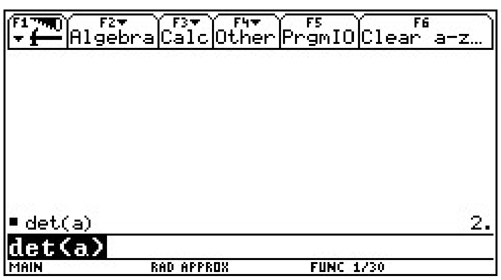

Figure IV.32: Determinant of a

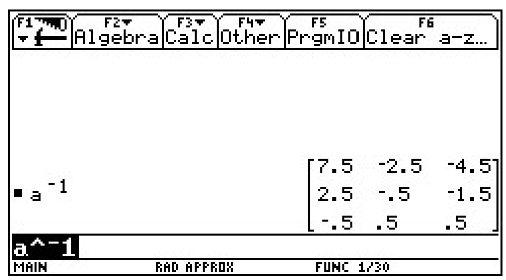

Figure IV.33: Inverse of a

Since the determinant of the matrix is not zero, it has an inverse matrix. Press a ^ (-) 1 ENTER to calculate the inverse. The result is shown in Figure IV.32.

Now let's solve a system of linear equations by matrix inversion. Once again, consider $\begin{cases} x - 2y + 3z = 9 \\ -x + 3y = -4 \\ 2x - 5y + 5z = 17 \end{cases}$. The coefficient matrix for this system is the matrix $\begin{bmatrix} 1 & -2 & 3 \\ -1 & 3 & 0 \\ 2 & -5 & 5 \end{bmatrix}$ which was entered as a matrix a in the previous example. Now enter the matrix $\begin{bmatrix} 9 \\ -4 \\ 17 \end{bmatrix}$ as b. Since b was used before, when we stored 2a as b, press APPS 6 *[Data/Matrix Editor]* 2 *[Open]* ▶ 2 *[Matrix]* ▼ ▼ ▶ and use ▼ to move

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the cursor to b, then press ENTER twice to go to the matrix previously saved as b, which can be edited. Return to the Home screen and press a ^ (-) 1 × b ENTER to get the answer as shown in Figure IV.34.

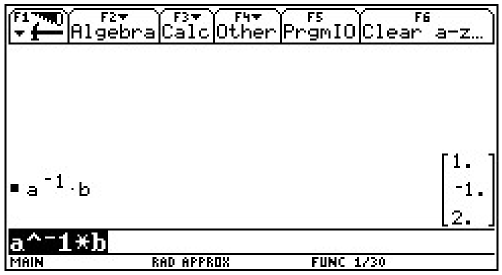

Figure IV.34: Solution matrix

The solution is still $x = 1$, $y = -1$, and $z = 2$.

IV.3 Additional Topics

IV.3.1 Length and Dot Product in R^n: Create a vector in the TI-92 with square brackets. For example, make the vector $V = (0, -2, 1, 4, -2)$ by pressing 2nd [0 , (-) 2 , 1 , 4 , (-) 2 2nd] STO► V ENTER.

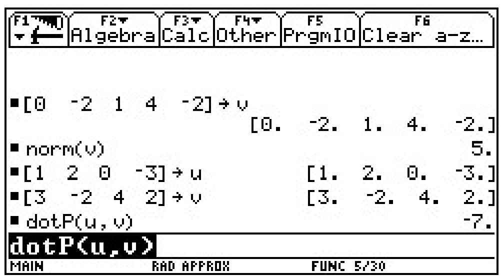

Figure IV.35: Vector norm and dot product

To calculate the length (norm) of the vector press 2nd MATH 4 *[Matrix]* b *[Norms]* 1 *[norm(]* v) ENTER (see Figure IV.35).

Now define the two vectors $U = (1, 2, 0, -3)$ and $V = (3, -2, 4, 2)$. Calculate the dot product $U \cdot V$ of the vectors by pressing 2nd MATH 4 *[Matrix]* F *[Vector ops]* 3 *[dotP (]* U , V) ENTER (see Figure IV.35).

IV.3.2 Cross Products: Evaluate the cross product of two vectors, $\mathbf{u} = \mathbf{i} - 2\mathbf{j} + \mathbf{k}$ and $\mathbf{v} = 3\mathbf{i} + \mathbf{j} - 2\mathbf{k}$, by pressing 2nd MATH 4 *[Matrix]* F *[Vector ops]* 2 *[crossP(]* 2nd [1 , (-) 2 , 1 2nd] , 2nd [3 , 1 , (-) 2 2nd]) ENTER. The cross product is $\mathbf{u} \times \mathbf{v} = 3\mathbf{i} + 5\mathbf{j} + 7\mathbf{k}$.

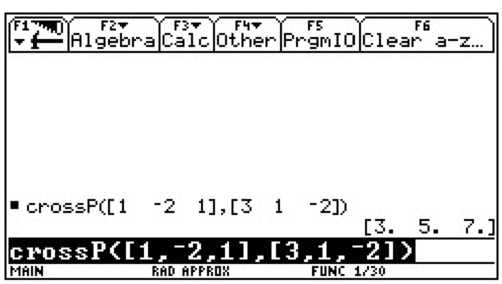

Figure IV.36: Vector cross products

IV.3.3 Complex Numbers: Press 2nd MATH 5 *[Complex]* to display the menu of special complex number operators (Figure IV.37).

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Expressions	*Keystrokes*	*Answer*
$(2 + 3i) + (5 - 7i)$	(2 + 3 2nd i) + (5 – 7 2nd i) ENTER	$7 - 4i$
$(2 + 3i)(5 - 7i)$	(2 + 3 2nd i) x (5 – 7 2nd i) ENTER	$31 + i$
$\frac{31 + i}{5 - 7i}$	(31 + 2nd i) ÷ (5 – 7 2nd i) ENTER	$2 + 3i$
$\lvert 5 - 12i \rvert$	2nd MATH 5 *[Complex]* 5 *[abs(]* 5 – 12 2nd i) ENTER	13
$\overline{5 - 12i}$	2nd MATH 5 *[Complex]* 1 *[conj(]* 5 – 12 2nd i) ENTER	$5 + 12i$

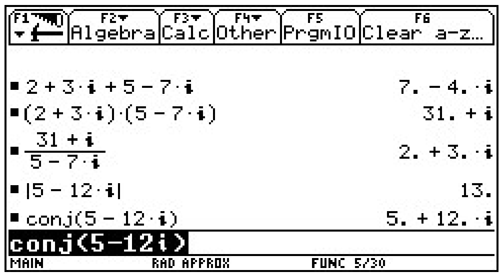

Figure IV.37: Complex number arithmetic

IV.3.4 Rectangular-Polar Conversion: The ANGLE sub-menu of the MATH menu provides a function for converting between rectangular and polar coordinate systems. These functions use the current angle measure setting, so it is a good idea to check the default angle measure before any conversion. For the following examples, the TI-92 is set to radian measure.

Given the rectangular coordinates $(x, y) = (4, -3)$, convert to polar coordinates (r, θ) in the Home screen by pressing 2nd MATH 2 *[ANGLE]* 5 *[R►Pr(]* 4 , (-) 3) ENTER to display the value of r. The value of θ is displayed after you press 2nd MATH 2 *[ANGLE]* 6 *[R►Pθ(]* 4 , (-) 3) ENTER. The polar coordinates are approximately $(5, -0.6435)$.

Suppose $(r, \theta) = (3, \pi)$. Convert to rectangular coordinates (x, y) by pressing 2nd MATH 2 *[ANGLE]* 3 *[P►Rx(]* 3 , 2nd π) ENTER. The x-coordinates displayed. Press 2nd MATH 2 *[ANGLE]* 4 *[P►Ry(]* 3 , 2nd π) ENTER to display the y-coordinate (Figure IV.38). The rectangular coordinates are $(-3, 0)$.

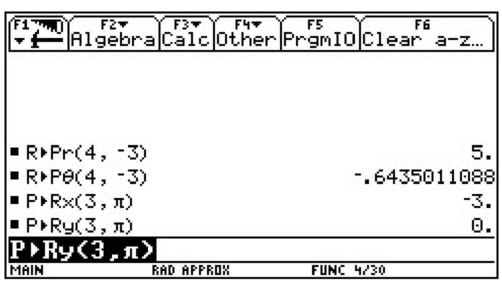

Figure IV.38: Converting between rectangular and polar coordinates

IV.4 Program: Visualizing Row Operations

IV.4.1 Entering the Program: The TI-92 is a programmable calculator that can store sequences of commands for later replay. Here's a useful program that demonstrates how elementary matrix row operations used in Gauss-Jordan elimination may be interpreted graphically.

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Press APPS 7 *[Program Editor]* to access the programming menu. The TI-92 has space for many programs, each called by a name you give it. Create a new program, so press APPS 7 *[Program Editor]* 3 *[New]*.

Set the Type to Program and the Folder to main (unless you have another folder in which you want to have the program). Enter a descriptive title for the program in the Variable line. Name this program Rowops and press ENTER twice to go to the program editor. The program name and the beginning and ending commands of the program are automatically displayed with the cursor on the first line after Prgm, the begin program command.

In the program, each line begins with a colon : supplied automatically by the calculator. Any command you could enter directly in the TI-92's Home screen can be entered as a line in a program. There are also special programming commands.

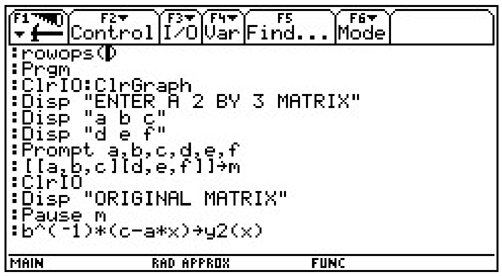

Figure IV.39: Part of program: ROWOPS

Input the program ROWOPS by pressing the keystrokes given in the following listing. You may interrupt program input at any stage by pressing 2nd QUIT. To return later for more editing, press APPS 7 *[Program Editor]* 2 *[Open]*, move the cursor down to Variable list, highlight the program's name, and press ENTER twice.

Program Line	*Keystrokes*
:rowops ()	
:Prgm	
:Clrio: ClrGraph	2nd CATALOG C *[arrow down to ClrIO]* ENTER 2nd : 2nd CATALOG C *[arrow down to ClrGraph]* ENTER ENTER
:Disp "ENTER A 2 BY 3 MATRIX"	F3 2 *[Disp]* 2nd " 2nd CAPS E N T E R A 2 B Y 3 M A T R I X 2nd " 2nd CAPS ENTER
:Disp "a b c"	F3 2 *[Disp]* 2nd "A B C 2nd " ENTER
:Disp "d e f"	F3 2 *[Disp]* 2nd " D E F 2nd " ENTER
:Prompt a, b, c, d, e, f	F3 5 *[Prompt]* A , B , C , D , E , F ENTER
:[[a, b, c][d, e, f]]→m	2nd [2nd [A , B , C 2nd] 2nd [D , E , F 2nd] 2nd] STO▶ M ENTER
:ClrIO	2nd CATALOG C *[arrow down to ClrIO]* ENTER ENTER
:Disp "ORIGINAL MATRIX"	F3 2 *[Disp]* 2nd " 2nd CAPS O R I G I N A L M A T R I X 2nd " 2nd CAPS ENTER
:Pause m	2nd CATALOG P *[arrow down to Pause]* ENTER M ENTER

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:b⁻¹ (c–a*x)→y_2 (x)	B ^ (-) 1 (C – A × X) STO▶ Y 2 (X) ENTER
:e⁻¹ (f–d*x)→y_1 (x)	E ^ (-) 1 (F – D × X) STO▶ Y 1 (X) ENTER
:ZoomStd: Pause: ClrIO	2nd CATALOG Z *[arrow down to ZoomStd]* ENTER 2nd : 2nd CATALOG P *[arrow down to Pause]* ENTER 2nd : 2nd CATALOG C *[arrow down to ClrIO]* ENTER ENTER
:Disp "OBTAIN LEADING"	F3 2 *[Disp]* 2nd " 2nd CAPS O B T A I N L E A D I N G 2nd " ENTER
:Disp "1 IN ROW 1"	F3 2 *[Disp]* 2nd " 1 I N R O W 1 2nd " 2nd CAPS ENTER
:mRow (a⁻¹, m, 1)→m	2nd MATH 4 *[Matrix]* D *[Row ops]* 3 *[mRow(]* A ^ (-) 1 , M , 1) STO▶ M ENTER
:Pause m: ClrDraw	2nd CATALOG P *[arrow down to Pause]* ENTER M 2nd : 2nd CATALOG C *[arrow down to ClrDraw]* ENTER ENTER
:(a/b) (c/a–x)→y_2(x)	(A ÷ B) (C ÷ A – X) STO▶ Y 2 (X) ENTER
:DispG: Pause: ClrIO	2nd CATALOG D *[arrow down to DispG]* ENTER 2nd : 2nd CATALOG P *[arrow down to Pause]* ENTER 2nd : 2nd CATALOG C *[arrow down to ClrIO]* ENTER ENTER
:Disp "OBTAIN 0 BELOW"	F3 2 *[Disp]* 2nd " 2nd CAPS O B T A I N 0 B E L O W 2nd " ENTER
:Disp "LEADING 1 IN"	F3 2 *[Disp]* 2nd " L E A D I N G 1 I N 2nd " ENTER
:Disp "COLUMN 1"	F3 2 *[Disp]* 2nd " C O L U M N 1 2nd " 2nd CAPS ENTER
:mRowAdd (–d, m, 1, 2)→m	2nd MATH 4 *[Matrix]* D *[Row ops]* 4 *[mRowAdd(]* (-) D , M , 1 , 2) STO▶ M ENTER
:Pause m: ClrDraw	2nd CATALOG P *[arrow down to Pause]* ENTER M 2nd : 2nd CATALOG C *[arrow down to ClrDraw]* ENTER ENTER
:(e–b*d/a)^–1 (f–d*c/a)→y1(x)	(E – B × D ÷ A) ^ (-) 1 (F – D × C ÷ A) STO▶ Y 1 (X) ENTER
:DispG: Pause: ClrIO	2nd CATALOG D *[arrow down to DispG]* ENTER 2nd : 2nd CATALOG P *[arrow down to Pause]* ENTER 2nd : 2nd CATALOG C *[arrow down to ClrIO]* ENTER ENTER
:m[2, 2] →g	M 2nd [2 , 2 2nd] STO▶ G ENTER
:If g ≠ 0 Then	F2 2 *[If…Then]* 1 *[If…Then…EndIf]* G 2nd MATH 8 *[Test]* 6 [≠] 0 *[arrow to the end of Then]* ENTER
:mRow (g^–1, m, 2)→m	2nd MATH 4 *[Matrix]* D 3 *[mRow(]* G ^ (-) 1 , M , 2) STO▶ M ENTER
:Disp "OBTAIN LEADING"	F3 2 *[Disp]* 2nd " 2nd CAPS O B T A I N L E A D I N G 2nd " ENTER
:Disp "1 IN ROW 2"	F3 2 *[Disp]* 2nd " 1 I N R O W 2 2nd " 2nd CAPS ENTER
:Pause m	2nd CATALOG P *[arrow down to Pause]* ENTER M ENTER

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:ClrDraw: DispGraph: Pause: ClrIO	
	2nd CATALOG C *[arrow down to ClrDraw]* ENTER 2nd : 2nd CATALOG D *[arrow down to DispG]* ENTER 2nd : 2nd CATALOG P *[arrow down to Pause]* ENTER 2nd : 2nd CATALOG C *[arrow down to ClrIO]* ENTER ENTER
:Disp "OBTAIN 0 ABOVE"	F3 2 *[Disp]* 2nd " 2nd CAPS O B T A I N 0 A B O V E 2nd " ENTER
:Disp "LEADING 1 IN"	F3 2 *[Disp]* 2nd " L E A D I N G 1 I N 2nd " ENTER
:Disp "COLUMN 2"	F3 2 *[Disp]* 2nd " C O L U M N 2 2nd " 2nd CAPS ENTER
:m[1, 2] →h	M 2nd [1 , 2 2nd] STO► H ENTER
:mRowAdd (–h, m, 2, 1)→m	
	2nd MATH 4 *[Matrix]* D *[Row ops]* 4 *[mRowAdd(]* (-) H , M , 2 , 1) STO► M ENTER
:Pause m: ClrDraw: FnOff 2	
	2nd CATALOG P *[arrow down to Pause]* ENTER M 2nd : 2nd CATALOG C *[arrow down to ClrDraw]* ENTER 2nd : 2nd CATALOG F *[arrow down to FnOff]* ENTER 2 ENTER
:m[1, 3] →j	M 2nd [1 , 3 2nd] STO► J ENTER
:LineVertical j	2nd CATALOG L *[arrow down to LineVert]* ENTER J ENTER
:DispG: Pause: ClrIO	2nd CATALOG D *[arrow down to DispG]* ENTER 2nd : 2nd CATALOG P *[arrow down to Pause]* ENTER 2nd : 2nd CATALOG C *[arrow down to ClrIO]* ENTER ENTER
:Disp "THE POINT OF"	F3 2 *[Disp]* 2nd " 2nd CAPS T H E P O I N T O F 2nd " ENTER
:Disp "INTERSECTION IS"	F3 2 *[Disp]* 2nd " I N T E R S E C T I O N I S 2nd " 2nd CAPS ENTER
:Disp "x = ", m[1, 3], "y = ", m[2, 3]	
	F3 2 *[Disp]* 2nd " X = 2nd " , M 2nd [1 , 3 2nd] , 2nd " Y = 2nd " , M 2nd [2 , 3 2nd] ENTER
:Stop	2nd CATALOG S *[arrow down to Stop]* ENTER ENTER
:EndIf	*[arrow to the end of EndIf]* ENTER
:If m[2, 3] = 0 Then	F2 2 *[If…Then]* 1 *[If…Then…EndIf]* M 2nd [2 , 3 2nd] = 0 *[arrow to the end of Then]* ENTER
:Disp "INFINITELY MANY"	F3 2 *[Disp]* 2nd " 2nd CAPS I N F I N I T E L Y M A N Y 2nd " ENTER
:Disp "SOLUTIONS"	F3 2 *[Disp]* 2nd " S O L U T I O N S 2nd " ENTER
:Stop	2nd CATALOG S *[arrow down to Stop]* ENTER ENTER
:Else	2nd CATALOG E *[arrow down to Else]* ENTER ENTER
:Disp "INCONSISTENT"	F3 2 *[Disp]* 2nd " I N C O N S I S T E N T 2nd " ENTER
:Disp "SYSTEM"	F3 2 *[Disp]* 2nd " S Y S T E M 2nd " 2nd CAPS ENTER

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`:Stop`	2nd CATALOG S *[arrow down to Stop]* ENTER ENTER
`:EndIf`	*[arrow to the end of EndIf]* ENTER
`:EndPrgm`	

When you have finished, press 2nd QUIT to leave the program editor.

You may remove a program from memory by pressing 2nd VAR-LINK. Then move the cursor to the program's name and press ← ENTER to delete the entire program.

IV.4.2 Running the Program: To execute the program you have entered, go to the Home screen and type the name of the program, including the parentheses and then press ENTER. If you have forgotten its name, press 2nd VAR-LINK to list all the variables that exist. The programs will have PRGM after the name. You can execute the program from this screen by highlighting the name and then pressing ENTER. The screen will return to the Home screen and you will have to enter the closing parentheses) and press ENTER to execute the program.

The program has been written to prompt you for values of the coefficients *a, b, c, d, e* and *f* in two linear equations, $ax + by = c$ and $dx + ey = f$. Input each value, then press ENTER to continue the program. This demonstration is most effective for equations that do not correspond to vertical or horizontal lines, and whose *y*-intercepts are between -10 and 10.

While the demonstration is running, note that each elementary row operation creates an equivalent system. The equivalence is reinforced graphically by the fact that while a row operation may change the *slope* of the lines, their *point of intersection* remains constant.

When the program comes to a pause, press ENTER to continue the program. If you need to interrupt the program during execution, press ON and then ENTER.

The instruction manual for your TI-92 gives detailed information about programming. Refer to it to learn more about programming and how to use other features of your calculator.

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