GRAPHING WITH THE CALCULATOR

NOTE: The calculator we are using is a TI 83, or a TI 83 plus. The diagram below shows the symbols used for representing the calculator buttons.
**Limitation:** When using a calculator in College Algebra, we are only able to graph equations of the form: \( y = \text{Expression in } x \).

**EXAMPLE:** Our entire presentation will be focused on the graph of the equation: \( y = x^3 - 3x + 1 \).

**A. Button Functions**

With few exceptions, each button on the calculator keypad has two (or three) functions. The main function (which is also used for the button symbol) is printed on the button. The other functions are printed on the the keypad above the button in yellow (or green). These functions can be accessed by pressing the buttons 2nd and ALPHA. For example the ON button has two functions:

- the ON function, which turns the calculator on;
- the OFF function, activated with the sequence 2nd ON, which turns the calculator off.

**B. Basic Calculator Set-up**

By pressing MODE the basic calculator set-up window is displayed, as shown in Figure 1. Using the navigation buttons ▲, ▼, ◬, ◭, and ◮, various items may be highlighted. To select a highlighted item, press the ENTER key.

![Figure 1](#)

It is suggested to keep the settings exactly as those shown in Figure 1, with one possible exception: the Float specification. The highlighted number next to Float indicates the number of digits after the decimal point that are displayed. For example, if one uses the Float setting at 8, the result of \( \frac{52}{147} \) is: \( 0.35374150 \). If Float is set at 3, however, the same calculation will display \( 0.354 \). (Notice that this is rounded.) After the basic set-up is completed, press 2nd MODE (this activates the QUIT function) to return to the main screen.

1 Other types of equations that can be graphed on a calculator will be discussed in Trigonometry and Calculus.
C. Plots Off

A brand new calculator might have some of the plots turned on. Since this might prevent us from graphing equations correctly, the next step in setting up the calculator for graphing is turning all plots off. To do this, activate the STAT PLOT function by pressing 2nd Y=. This will open the plot set-up menu shown in Figure 2A. Note that, due to screen limitations, this menu is incomplete. This is indicated by the symbol ↓ on the last line.

Moving the cursor with ▼ to the 4th entry (shown in red) followed by ENTER, or simply pressing the 4 button, will return us to the main screen shown in Figure 2B. Finally, after pressing ENTER, the word Done will appear, indicating that all plots are off.

D. The Graphing Window

The GRAPH button will open the graphing window. On a brand new calculator, with no equation stored in memory, the graphing window appears as in Figure 3. By pressing the navigation buttons ▲ ▼ ◭ ◮ a cursor and its coordinates are displayed (shown in red in Figure 3).

The graphing window, shown exactly as in Figure 3, will be referred to as the Standard Graphing Window.
Of course, we cannot expect the graphing window to capture the entire coordinate plane. In fact, the graphing window only shows a rectangular region in the plane, as illustrated in Figure 4 (the region captured on the calculator is shown colored). This viewing region is completely characterized by two points:

- the lower-left corner \((x_{\text{min}}, y_{\text{min}})\);
- the upper-right corner \((x_{\text{max}}, y_{\text{max}})\).

With these facts in mind, we can set the Graphing Window as we please, simply by specifying the values for \(x_{\text{min}}, x_{\text{max}}, y_{\text{min}},\) and \(y_{\text{max}}\).

To set up the Graphing Window, we press the WINDOW button, which will bring up the Graphing Window Set-up Screen, shown in Figure 5A.

![Figure 5A](image)

The settings illustrated above are: \(x_{\text{min}} = -3, x_{\text{max}} = 10, y_{\text{min}} = -10,\) and \(x_{\text{min}} = 20\) (with the resulting Graphing Window shown in Figure 5B). Besides these four settings, the Graphing Window Set-up Screen has three more options:

- \(Xscl\) indicates the distance between two tickmarks on the \(x\)-axis;
- \(Yscl\) indicates the distance between two tickmarks on the \(y\)-axis;
- \(Xres\) indicates a resolution factor (we always keep it at 1).
**Tips:** With suitable settings, the Graphing Window will display the visible portions of the $x$- and $y$-axis. The $x$-axis is visible only when $y_{\text{min}}$ is negative and $y_{\text{max}}$ is positive. Likewise, the $y$-axis is visible only when $x_{\text{min}}$ is negative and $x_{\text{max}}$ is positive. In order to enter negative numbers in the Graphing Window Set-up Screen, we must use the $(−)$ button. To close the Graphing Window Set-up Screen, we either activate the QUIT function using 2nd MODE, or open a different window, such as GRAPH, or Y=.

One special setting – the *Standard Window* (shown in Figure 3) – is preset in the calculator memory. To set-up the Graphing Window with these preset parameters, we press the ZOOM button. This opens the ZOOM menu, as shown in Figure 6A. Moving the cursor with ▼ to the 6th entry (shown in red) followed by ENTER, or simply pressing the 6 button, will return us to the Graphing Window. The settings for the Standard Window, which can be viewed by pressing WINDOW, are shown in Figure 6B.

<table>
<thead>
<tr>
<th>ZOOM MEMORY</th>
<th>WINDOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: ZBox</td>
<td>Xmin=−10</td>
</tr>
<tr>
<td>2: Zoom In</td>
<td>Xmax=10</td>
</tr>
<tr>
<td>3: Zoom Out</td>
<td>Xscl=1</td>
</tr>
<tr>
<td>4: ZDecimal</td>
<td>Ymin=−10</td>
</tr>
<tr>
<td>5: ZSquare</td>
<td>Ymax=10</td>
</tr>
<tr>
<td>6: ZStandard</td>
<td>Yscl=1</td>
</tr>
<tr>
<td>7↓: ZTrig</td>
<td>Xres=1</td>
</tr>
</tbody>
</table>

*Figure 6A  Figure 6B*

REMARK: With very few exceptions, the Graphing Window shows a distorted image. This is due to the fact that the calculator screen has a fixed aspect ratio (width:height) which is approximatively 3:2. In “real life” (if we use graphing paper), the *Standard Window* will be a $20 \times 20$ square. On the calculator, however, any window is shown as a rectangle with a 3:2 aspect ratio. In order to simulate a “real-life” picture, one can use the **ZSquare** feature, available as the 5th option from the **ZOOM** menu. In fact any window setting, for which the width($= x_{\text{max}} − x_{\text{min}}$) and the height($= y_{\text{max}} − y_{\text{min}}$) obey the 3:2 ratio, will look very similar to a “real-life” one. The next two pictures show the graph of the circle equation

$$x^2 + y^2 = 25$$

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2 At this point the students are not assumed to know how to graph this, so they should trust the author.
both in the Graphing Window set with \textit{ZStandard} (Figure 7A) and in the Graphing Window set with \textit{Zsquare} (Figure 7B).

\begin{figure}[h]
\centering
\begin{tabular}{cc}
\includegraphics[width=0.4\textwidth]{figure7A} & \includegraphics[width=0.4\textwidth]{figure7B}
\end{tabular}
\caption{Figure 7A Figure 7B}
\end{figure}

\section*{E. Typing/Editing Equations}
To start typing or editing an equation, we press the \textbf{Y=} button, which will open up the Equation Window, as shown in Figure 8.

Besides the buttons used normally for arithmetic operations, the most useful one is the \textbf{XT} button, which allows us to enter the \(x\)-variable.

In our example, we want to type

\[ y = x^3 - 3x + 1, \]

so we move the cursor (using \textbf{▼} or \textbf{▲}) to the first line (the one that starts with \texttt{\textbackslash Y1 =}), and we type the expression using the sequence:

\begin{center}
\begin{tabular}{cccc}
\textbf{XT} & \textbf{\^} & 3 & \textbf{\textbackslash Y}
\end{tabular}
\end{center}

(The displayed equation shown in Figure 8 in red.)

\textbf{Tips:} One can type up to seven equations. A highlighted item on the first line (\texttt{\textbackslash Plot1 Plot3 Plot3}) indicates which plots are turned on. If some plots are on, you need to turn them off.
F. Working with the Graph

At this point it is assumed that the equation \( y = x^3 - 3x + 1 \) was typed (and this is the only equation!), as described in Section E. Upon pressing the \( \text{GRAPH} \) button the Graphing Window is displayed as in Figure 9A (without the red symbols):

![Figure 9A](image1)

\( X = 1.064 \quad Y = 0.645 \)

One important operation we want to perform is either \( \text{Zoom In} \) or \( \text{Zoom Out} \). If we press \( \text{ZOOM} \) and we choose one of these two options (2 or 3) from the ZOOM menu, we will be returned back to the Graphing Window (unchanged). At this point we can move the cursor, using \( \triangle \uparrow \downarrow \triangleright \triangleright \) and it will become visible (shown in red in Figure 9A). After positioning the cursor at a desired position, if we press \( \text{ENTER} \), a new Graphing Window will be displayed (like the one shown in Figure 9B, produced by \( \text{Zoom In} \)), with the cursor placed in the center.

![Figure 9B](image2)

\( X = 1.064 \quad Y = 0.645 \)

As noticed before, the buttons \( \triangle \uparrow \downarrow \triangleright \triangleright \) will move the cursor \textit{freely} in the Graphing Window. Occasionally, we want to move the cursor on the graph. We can accomplish this by using the \( \text{TRACE} \) button. This will put the calculator in \( \text{TRACE} \) mode, in which the navigation buttons \( \triangleright \triangleright \) will move the cursor on the graph:

![Figure 10](image3)

\( Y1 = x^3 - 3x + 1 \)

\( X = 1.436 \quad Y = -0.346 \)

To exit the \( \text{TRACE} \) mode, we simply press \( \text{GRAPH} \).
G. Finding $x$-intercepts

In this section we will focus on locating the $x$-intercepts of the graph of the equation

$$y = x^3 - 3x + 1.$$ 

If we were to do this “by hand,” we know that we have to set $y = 0$ in the equation, and solve for $x$. In our case this would mean to solve the equation

$$x^3 - 3x + 1 = 0,$$

which is a very difficult one.

Using the calculator, we notice that the graph displayed in the Standard Window (Figure 9A) reveals three $x$-intercepts.

Tip: When looking for certain points on the graph, it is recommended that we use Zoom In function, to get a close-up look at the graph near the point we are interested in.

Suppose, for instance, we want to locate the rightmost $x$-intercept. From the Standard Window we Zoom In (use same procedure as in Section F), thus producing the graph shown in Figure 11. Note that the screen captures two $x$-intercepts (shown in red). To locate the $x$-intercepts, we use the sequence 2nd TRACE to bring up the CALCULATE menu, shown in Figure 12.

![Figure 11](image1.png)  ![Figure 12](image2.png)

We now select the second item (zero) by pressing 2, which will return us to the Graphing Window, this time in TRACE mode. Furthermore (see Figure 13A below), the question “Left Bound?” appears in the lower left corner. Assuming now that we want to locate the rightmost $x$-intercept, we move the cursor using close to the $x$-intercept, but on the left side of it. Once we moved the cursor to such a position (as shown in Figure 13A), we
press \textbf{ENTER}. This will bring up a new screen (shown in Figure 13B), similar to the preceding one, with the left bound marked as $\triangleright$, but this time the question “Right Bound?” appears in the lower left corner.

\begin{figure}[h]
\centering
\includegraphics[width=0.4\textwidth]{figure13a.png}
\caption{Figure 13A}
\end{figure}

As before we move the cursor using $\triangleright$ close to the x-intercept, but on the right side of it. Once we moved the cursor to such a position (as shown in Figure 13B), we press \textbf{ENTER}. This will bring up a new screen (shown in Figure 13C), similar to the preceding one, with both the left and right bounds marked as $\triangleright \leftarrow$, but this time the question “Guess?” appears in the lower left corner. At this point we simply press \textbf{ENTER}, and the calculator will display its finding, as shown in Figure 13D.

\begin{figure}[h]
\centering
\includegraphics[width=0.4\textwidth]{figure13c.png}
\caption{Figure 13C}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.4\textwidth]{figure13d.png}
\caption{Figure 13D}
\end{figure}

One should repeat the same procedure to find the other two x-intercepts. (For the reader’s reference, these are: .347 and -1.879.)

\textbf{A Word of Caution:} The information from the Graphing Window concerning the \textit{number of x-intercepts}, should not be trusted. (After all, some x-intercepts may exist outside the viewing window.) It is the additional knowledge about certain graphs that will help us estimate the number of x-intercepts correctly.