



About the Lesson

In this activity, students will verify the conversion formula from degrees Celsius to degrees Fahrenheit. Data collection for the activity gives very accurate results using TI technology.

Vocabulary

- conversion formula
- line of best fit, line of prediction
- independent variable
- dependent variable
- percent error

Teacher Preparation and Notes

- This activity can be done in a variety of ways depending on the equipment that is available.
- If no temperature sensors or EasyTemps are available, standard red alcohol-filled thermometers with dual scales can be used. Students would record 12 to 15 varied temperatures (Celsius and Fahrenheit pairs) and then enter the data into the Stat editor.
- To get a good range of temperatures, ice water and a source of hot water are suitable.

Activity Materials

- Compatible TI Technologies:
 - TI-84 Plus*
 - TI-84 Plus Silver Edition*
 -  TI-84 Plus C Silver Edition
 -  TI-84 Plus CE

* with the latest operating system (2.55MP) featuring MathPrint™ functionality.

- Vernier EasyData® App
- Vernier Easy Temps® Sensors
- Hot water and ice water



Tech Tips:

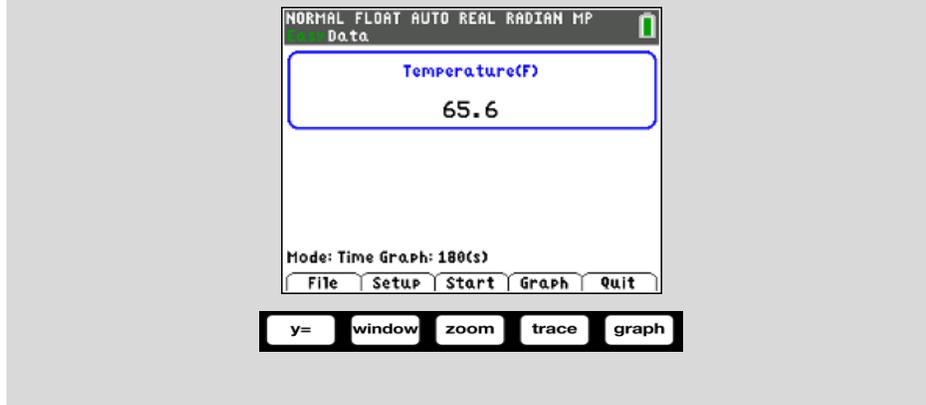
- This activity includes screen captures taken from the TI-84 Plus CE. It is also appropriate for use with the rest of the TI-84 Plus family. Slight variations to these directions may be required if using other calculator models.
- Watch for additional Tech Tips throughout the activity for the specific technology you are using.
- Access free tutorials at <http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials>
- Any required calculator files can be distributed to students via handheld-to-handheld transfer.

Lesson Files:

- Know_F&C_Student.pdf
- Know_F&C_Student.doc

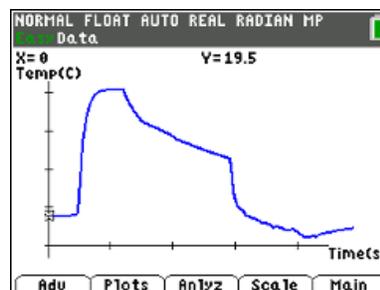


Tech Tip: While using the Vernier EasyData® App, the tabs at the bottom of the screen indicate menus that are accessed by pressing the key directly below it. A frequent example is shown

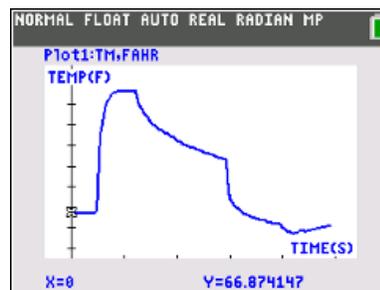


Collecting the Data

1. Starting the data collection at room temperature gives a graph that may be useful for a discussion about rate of change.



2. The directions in the student activity have the students starting the probes in the hot water then moving to the ice water. If your hot water is not very hot, then this order would be helpful to catch the hot water before it cools off too much. In the examples shown, the maximum temperature was 99.3°C and the coldest temperature was 6°C. Boiling water was used for the maximum, and the minimum was obtained by holding the tips of the two EasyTemps close to an ice cube while in the ice water.



3. When the students have a graph, they need to quit the EasyData app. The data will be in L1 and L2. Direct students to insert a new list by using the arrow keys to highlight the header of L3 as shown. Press **[2nd][ins]** and **[enter]**. Then lock the alpha mode, by pressing **[2nd][alpha]** and type the names of the lists CELS or FAHR depending on what data the calculator collected.

L1	L2	L3	L4	L5	0
0	19.5	-----	-----	-----	
1	19.5				
2	19.562				
3	19.562				
4	19.562				
5	19.625				
6	19.625				
7	19.687				
8	19.687				
9	19.687				
10	19.687				

L3=



To copy L2 into CELS, with the header of the list CELS highlighted, type **[2nd] [L2]** and press **[enter]**. See the screens below:

NORMAL FLOAT AUTO REAL RADIAN MP					NORMAL FLOAT AUTO REAL RADIAN MP					NORMAL FLOAT AUTO REAL RADIAN MP					NORMAL FLOAT AUTO REAL RADIAN MP							
L1	L2	L3	L4	↵	L1	L2	CELS	L3	L4	↵	L1	L2	CELS	L3	L4	↵	L1	L2	FAHR	L3	L4	↵
0	19.5				0	19.5	19.5				0	66.874	66.874				0	66.874	66.874			
1	19.5				1	19.5					1	66.874	66.874				1	66.874	66.874			
2	19.562				2	19.562	19.562				2	66.987	66.987				2	66.987	66.987			
3	19.562				3	19.562	19.562				3	66.987	66.987				3	66.987	66.987			
4	19.562				4	19.562	19.562				4	66.987	66.987				4	66.987	66.987			
5	19.625				5	19.625	19.625				5	67.099	67.099				5	67.099	67.099			
6	19.625				6	19.625	19.625				6	67.099	67.099				6	67.099	67.099			
7	19.687				7	19.687	19.687				7	67.099	67.099				7	67.099	67.099			
8	19.687				8	19.687	19.687				8	67.212	67.212				8	67.212	67.212			
9	19.687				9	19.687	19.687				9	67.212	67.212				9	67.212	67.212			
10	19.687				10	19.687	19.687				10	67.212	67.212				10	67.212	67.212			

Name=CELS CELS=L 2 CELS(1)= 19.49951573866 FAHR={66.87414683008,66.874

Calculator with CELS.

Calculator with FAHR.

As a result, half the calculators should have the CELS list and the other half the FAHR list. The next step is to link lists from calculator to calculator so that every calculator has the named lists, CELS, and FAHR. Use the unit-to-unit link cable to connect a calculator with the Fahrenheit data with a calculator with the Celsius data. The left screenshot below shows what the sending calculator must do; the right side shows what the receiving calculator screen should look like. If an "Error in Xmit" occurs, press enter and try again after making sure the cables are connected properly.

Sending Calculator:

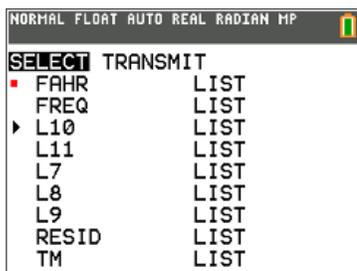


Receiving Calculator:



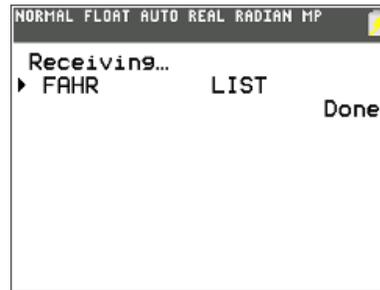
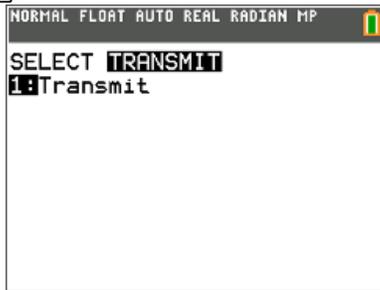
Note: Make sure the desired lists are selected by moving away from the selected list to make sure a square is selecting the list.

Before the sending calculator can transmit, the receiving calculator must display the message, "Waiting. . ."





Press `enter`.



4. When the list is sent to the next calculator, it must be inserted into the Stat Editor window to be able to see it. Highlight the header of the first empty list, press `2nd``[ins]` and `enter`. This inserts a new column. Press `2nd``[list]` and select the name of the list you need. Press `enter`. Both CELS and FAHR should be seen in the Stat Editor.

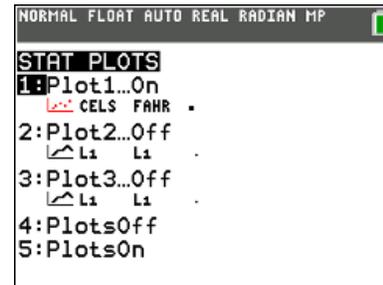
L1	L2	FAHR	L3	L4	4
0	66.874	66.874	-----	-----	
1	66.874	66.874			
2	66.987	66.987			
3	66.987	66.987			
4	66.987	66.987			
5	67.099	67.099			
6	67.099	67.099			
7	67.099	67.099			
8	67.212	67.212			
9	67.212	67.212			
10	67.212	67.212			

L3=

L1	L2	FAHR	CELS	L3	5
0	66.874	66.874	19.5	-----	
1	66.874	66.874	19.5		
2	66.987	66.987	19.562		
3	66.987	66.987	19.562		
4	66.987	66.987	19.562		
5	67.099	67.099	19.625		
6	67.099	67.099	19.625		
7	67.099	67.099	19.687		
8	67.212	67.212	19.687		
9	67.212	67.212	19.687		
10	67.212	67.212	19.687		

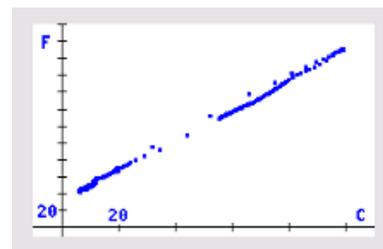
L3(1)=

5. The scatterplot can be set up as shown. CELS may be typed in as the Xlist and FAHR as the Ylist.



Looking at the Results

1. The relationship between Fahrenheit and Celsius is very strong, linear, and positive (as the degrees Celsius increase the degrees Fahrenheit increase).





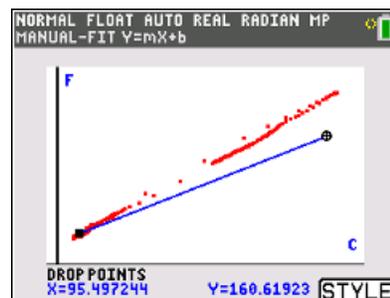
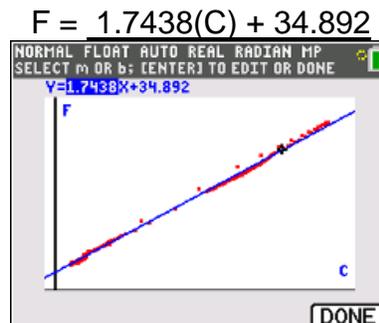
Tech Tip: If an error message occurs, frequently students may type in L1 instead of pressing $\text{2nd}[L1]$, they may not have the correct lists indicated, another plot may be on that has errors, or the lists do not have the same number of elements.

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NORMAL FLOAT AUTO REAL RADIAN MP
ERROR: INVALID DIMENSION
1:Quit

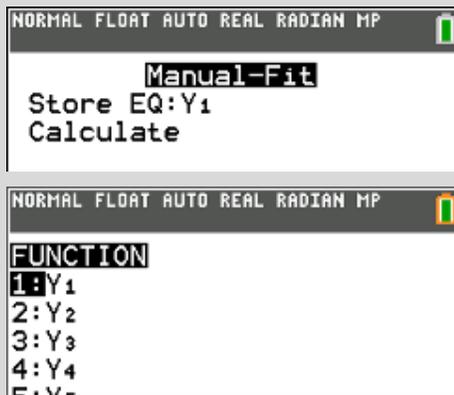
Check 1<dim(list)<999.
To set PlotsOff:
  2nd STAT PLOT; PlotsOff
Check 1<dim(matrix)<99.
Check inverse of square
  matrix only.
  
```

- To do a Manual Fit, press stat [CALC] and select [Manual-Fit $Y=mX+b$]. For the two drop points, choose a point in the lower (colder) part of the data and the other in the warmer part. When the line goes through the middle of the data, press enter . The equation of the line will be shown at the top. If you want to move the line, select the coefficient or the constant and press enter to type in a new value of m or the value of b. The results of the sample data are shown.





Tech Tip: According to your preference, you may store the regression equation in the Y= editor. Press $\boxed{\text{vars}}$, right arrow to the Y-VARS menu, select Function, and select the function slot Y1. Then if other regressions are done, they can be stored in a different function preserving the first one done.



3. Using the sample data,
 $F = 1.7438(47^{\circ}\text{C}) + 34.892 = 116.8506^{\circ}\text{F}$ (predicted value)

$F = 1.7438(-15^{\circ}\text{C}) + 34.892 = 8.735^{\circ}\text{F}$ (predicted value)

4. $F = \frac{9}{5}(47^{\circ}\text{C}) + 32 = \frac{583}{5} = 116.6^{\circ}\text{F}$ (accepted value), $F = \frac{9}{5}(-15^{\circ}\text{C}) + 32 = 5.0^{\circ}\text{F}$ (accepted value)

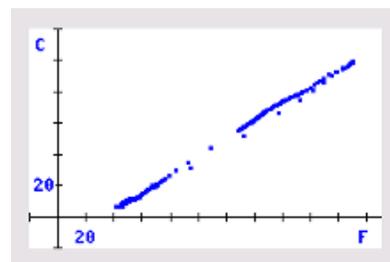
5. $\text{Percent Error} = \frac{116.851 - 116.6}{116.6} \times 100\% = 0.21\%$

$$\text{Percent Error} = \frac{8.735 - 5.0}{5.0} \times 100\% = 74.7\%$$

In the sample data, the top part of the manual line of best fit is more accurate than the bottom portion of the line. But since the temperatures are much less at the bottom, a small amount of error can be a large percent error.

Going Further

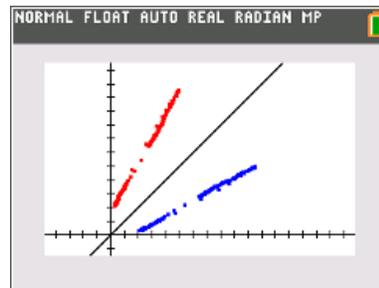
1. When the dependent and independent variables are switched, the relationship of F and C is still very strong, linear, and positive. The data is shifted closer to the horizontal axis.



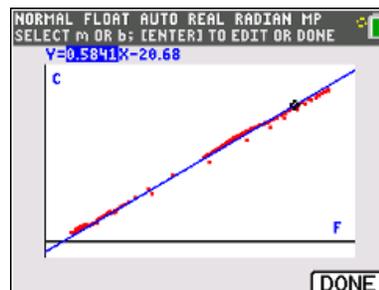


When both scatterplots are graphed along with the line $y=x$, you can help challenge your students to see that one graph is the reflection about the line $y=x$ of the other.

zoom [ZSquare] might be needed to see the transformation better.



2. A manual line of best fit for the sample data could be $C=0.5841(F)-20.68$.



3. To compare it with the line found in *Looking at the Results*—Question 2, solve the equation for F.

$$C = 0.5841(F) - 20.68$$

$$\frac{C + 20.68}{0.5841} = \frac{0.5841(F)}{0.5841}$$

$$1.7120(C) + 35.4049 = F$$

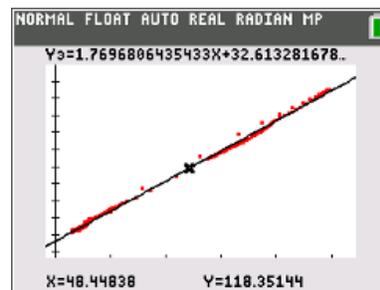
The equation in *Looking at the Results*—Question 2 was $F = 1.7438(C) + 34.892$. Considering experimental variability, the two equations are essentially the same.

4. To do a linear regression, press **[stat]**, right arrow to the CALC menu and select LinReg(ax+b). If preferred, you may use LinReg(a+bx) that will give the same results. Type in the names of the lists. For Store RegEQ, press **[vars]**, arrow to the Y-VARS menu and select Function. Select Y3. Read the following Tech Tip for the reason.

<p>NORMAL FLOAT AUTO REAL RADIAN MP</p> <p>EDIT ▢ CALC TESTS</p> <p>1:1-Var Stats</p> <p>2:2-Var Stats</p> <p>3:Med-Med</p> <p>4:LinReg(ax+b)</p> <p>5:QuadReg</p> <p>6:CubicReg</p> <p>7:QuartReg</p> <p>8:LinReg(a+bx)</p> <p>9:LnReg</p>	<p>NORMAL FLOAT AUTO REAL RADIAN MP</p> <p>▢ LinReg(ax+b)</p> <p>Xlist:CELS</p> <p>Ylist:FAHR</p> <p>FreqList:</p> <p>Store RegEQ:Y3</p> <p>Calculate</p>	<p>NORMAL FLOAT AUTO REAL RADIAN MP</p> <p>VARX Y-VARS COLOR</p> <p>1:Function...</p> <p>2:Parametric...</p> <p>3:Polar...</p> <p>4:On/Off...</p>	<p>NORMAL FLOAT AUTO REAL RADIAN MP</p> <p>FUNCTION</p> <p>1:Y1</p> <p>2:Y2</p> <p>3:Y3</p> <p>4:Y4</p> <p>5:Y5</p> <p>6:Y6</p> <p>7:Y7</p> <p>8:Y8</p> <p>9:Y9</p>
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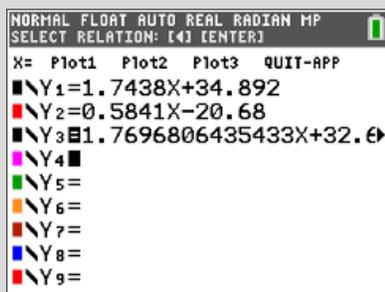


The linear regression results are displayed numerically. If you stored the regression equation, it will be shown visually in the graph.



The conversion formula: $F = \frac{9}{5}C + 32 = 1.8C + 32$ and the regression equation $F=1.77C+32.6$ are very similar, closer than the manual fit lines.

Tech Tip: The functions in the Y= editor can be turned off if you want to save the equation but do not want the equation graphed. Put the cursor on the = and press `enter`. In the example shown, the two manual fit equations in Y1 and Y2 have been turned off. Only Y3, the linear regression equation will be graphed.



5. $-40^{\circ}\text{F} = -40^{\circ}\text{C}$

$F = \frac{9}{5}C + 32$ and $C = \frac{5}{9}(F - 32)$ can be set equal to each other in one variable and solved.

$$\begin{aligned} \frac{5}{9}(x - 32) &= \frac{9}{5}x + 32 \\ \frac{5}{9}x - \frac{32(5)}{9} &= \frac{9}{5}x + 32 \\ \frac{-14 \cdot 32}{9} &= \frac{56}{45}x \\ -40 &= x \end{aligned}$$