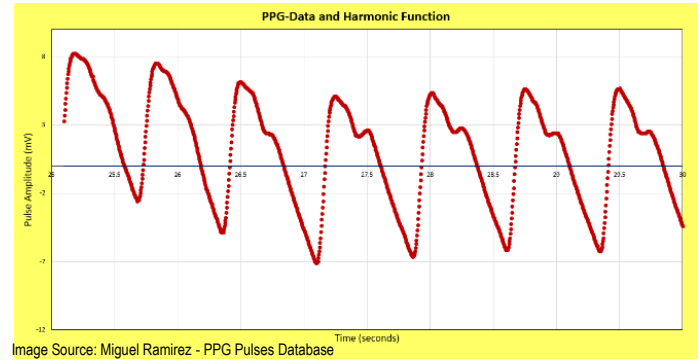


Student Activity Guide



The purpose of this activity is to find a mathematical function that fits your photoplethysmogram (PPG). You will obtain your personal PPG using digital pulse oximeters. The graph of the pulse obtained with the pulse oximeters will be inserted in a Graphical User Interface (GUI) developed in Excel. In this GUI, you will fit your PPG graph in a harmonic function obtained by adding several trigonometric functions, specifically sine functions with different amplitudes and frequencies. Once you obtain the best fitting harmonic function—reading some values on this function—you will obtain your own personalized cardiovascular information such as pulse interval, cardiac period, and systolic and diastolic phases. Students with a background in calculus will be able to find additional information as arterial stiffness and vascular age.

By the end of this activity you will:

After this activity, students should be able to:

- Understand how a photoplethysmogram (PPG) analyzes and outputs information.
- Use a digital pulse oximeter.
- Identify important cardiovascular information contained in a PPG graph.
- Learn that a superposition of basic trigonometric functions like sines and cosines can be used to describe a more complex periodic function.

Activity Guidelines

1. Choose a partner to work with.
2. Each group will need the next materials:
 - CONTEC CMS 50D+ Digital Pulse Oximeter with USB cable
 - computer with Windows OS with the Snipping Tool extension installed
 - Excel and pulse oximeter software interface installed in computer
 - Excel GUI for PPG pulse analysis spreadsheet
 - laser printer, PowerPoint or Google Slides for poster or presentation creation
3. With the digital pulse oximeter connected to the computer and the software interface detecting the pulse oximeter signal, **every student** can obtain their PPG. Capture your PPG, which is displayed in the pulse oximeter software interface, with the Snipping Tool. Save this file.
4. Open the Excel GUI. Save a copy with your name. In worksheet *PPG-Graph*, insert the saved file from above as background of the graphing region.
5. By modifying the values in the cells at the left of the graph, try to fit the blue line to match your PPG. You have to set the values for the first two harmonics, H.1 and H.2. Including more harmonics may improve the match.

6. Once you obtain the best function that approximates your PPG, write your function in the box at the bottom of the worksheet. Use the equation editor to type your function.
7. Go to worksheet *Cardiovascular Analysis*. On the graph, locate the values for the information displayed on the image at the right by carefully placing the cursor on your function's graph. Annotate the values found in the boxes below.
8. Decide with your teacher how you are going to present your results, whether that be an in-class presentation, a poster session, or video presentation. For any of these options, you will have to create a poster as support. Use PowerPoint or Google Slides to create the poster. Each student should present their personal results.
9. **For students with a background in calculus:** In worksheet *Cardio-Calculus-Analysis*, analyze the second derivative of your function to obtain additional information from your PPG. Use the graphs at the right to identify the points on your graph. Write down those values. Perform the calculations in the listed formulas for arterial stiffness, vascular aging, and vascular age. Annotate the values in the corresponding boxes below the second derivative graph.

Poster-Presentation Content Checklist	Points	?	Evaluation
1. Title of the project, and student's names	5	?	_____
2. Description and purpose of the project	5	?	_____
3. Background of your activity	15	?	_____
4. Steps or process followed to find your function. Include PPG graph	20	?	_____
5. Obtained function(s) and its(their) graph(s)	20	?	_____
6. Summary of the cardiovascular information obtained	5	?	_____
7. Conclusions	5	?	_____
Total Points:			

Results Presentation Checklist	Points	?	Evaluation
8. Information clearly written and well organized	10	?	_____
9. Clear and concise explanation of the work done	10	?	_____
10. Creativity	5	?	_____
Total Points:			

Notes:



- This project is a major grade for this grading period
- Find videos for this activity background at <https://www.sophia.org/tutorials/heart-ecg-ppg>
- You will have to obtain your PPG pulse.
- The results presentation or submission dates will be set up during these work sessions.

Annex 1. Pulse Oximeter and Software Interface

Follow the next steps to obtain the graph of your photoplethysmogram (PPG).

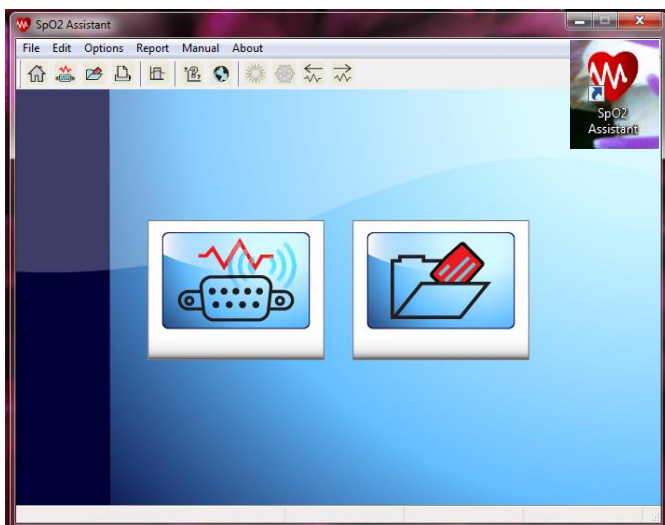
1. Connect the USB cable to the CMS 50D+ pulse oximeter into a USB port.



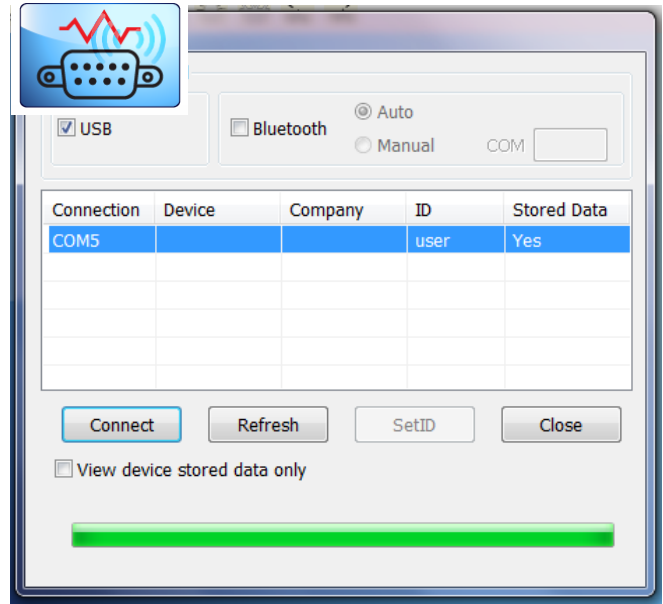
2. Insert a finger in the pulse oximeter. Turn on the device and wait until you obtain a reading. Configure the pulse oximeter to display the PPG by pressing the little white button.



3. Open the pulse oximeter interface SpO2 Assistant.



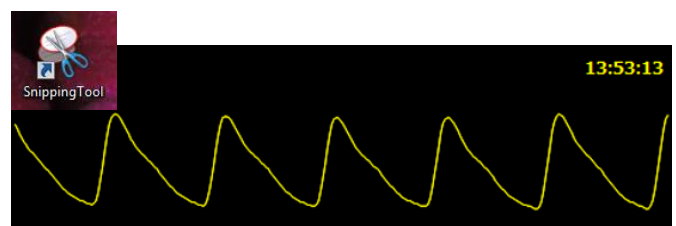
4. Click the connection button. On the *Devices* window select the port the pulse oximeter is connected to, and click the "Connect" button.



5. Let the SpO2 assistant window display a full and stable pulse. On the main menu click Edit -> Freeze Wave.



6. Open Snipping Tool, capture the frozen pulse, and save



Annex 2. Pulse Analysis using the Excel Graphic User Interface (GUI)

Follow the next instructions to analyze your PPG.

1. Look for the file PPG-GUI.xls. You should open the GUI on the worksheet PPG-Graph.

PPG-Data and Harmonic Function

Primary Frequency
 $w = 11$ /sec

Vertical Shift
 $h = 170$ mV

Harmonics' Parameters

H.1 Amplitud & Phase shift
 $A_1 = 25$ mV
 $c_1 = 0$

H.2 Amplitud & Phase shift
 $A_2 = 0$ mV
 $c_2 = 0$

H.3 Amplitud & Phase shift
 $A_3 = 0$ mV
 $c_3 = 0$

H.4 Amplitud & Phase shift
 $A_4 = 0$ mV
 $c_4 = 0$

H.5 Amplitud & Phase shift
 $A_5 = 0$ mV
 $c_5 = 0$

Pulse Amplitude (mV)

Time (seconds)

$$F(t) = h + A_1 \sin(2\pi wt + c_1) + A_2 \sin(4\pi wt + c_2) + A_3 \sin(6\pi wt + c_3) + A_4 \sin(8\pi wt + c_4) + A_5 \sin(10\pi wt + c_5)$$

The Trigonometric Function in My Heart

$F(t) =$ (type your function here)

Student: {Your Name here} Date: {Date here}

2. Important: Save a copy of this GUI. Use your name as the new file's name.
3. Insert your PPG pulse as background of the graphing region. To do this, follow the next steps.

PPG-Data and Harmonic Function

(a). Click on the graph region
 (b). Press mouse right button
 (c). On the displayed menu select Format Plot Area...

Format Plot Area

PLOT AREA OPTIONS



(d). On the Format Plot Area expand FILL

(e). Click on *Picture or Texture Fill* button

(f). Click on button Yes

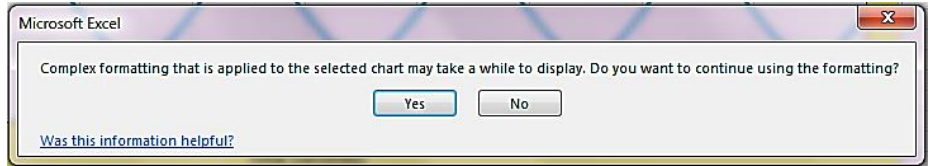
FILL

- No fill
- Solid fill
- Gradient fill
- Picture or texture fill
- Pattern fill
- Automatic

Color Color

Transparency 0%

BORDER



Format Plot Area

PLOT AREA OPTIONS



(g). On the expanded menu

Insert picture from,
click the *File...* button

FILL

- No fill
- Solid fill
- Gradient fill
- Picture or texture fill
- Pattern fill
- Automatic

Insert picture from

File... Clipboard Online...

Texture Texture

Transparency 0%

Tile picture as texture

Offset X 0 pt

Offset Y 0 pt

Scale X 100%

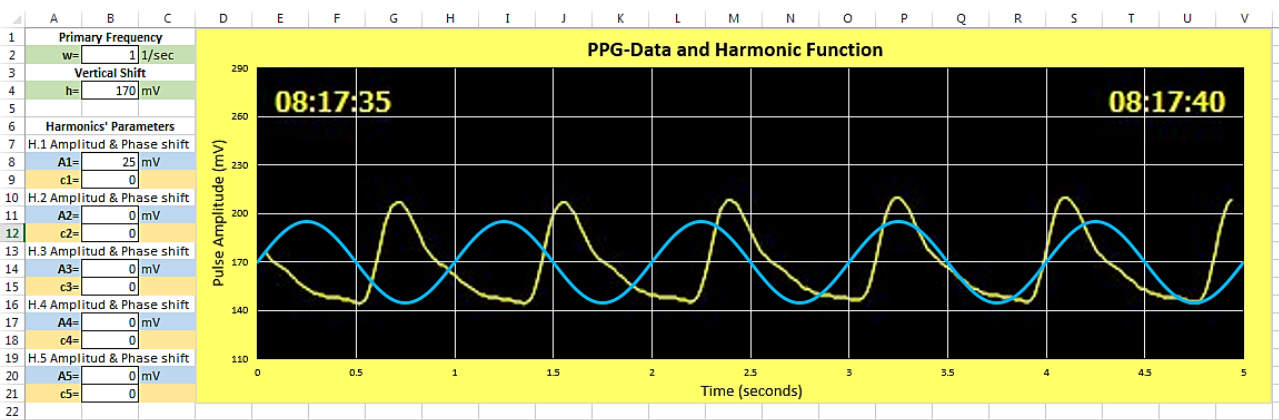
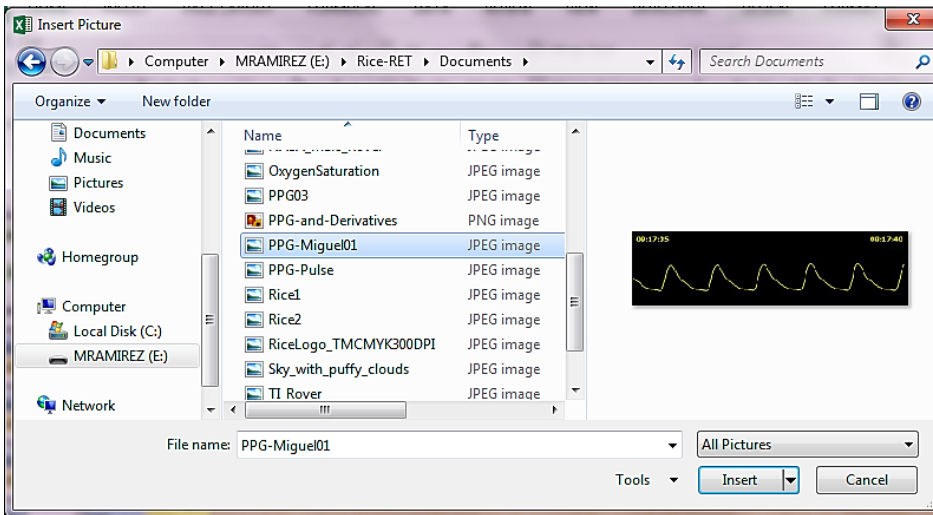
Scale Y 100%

Alignment Top left

Mirror type None

Rotate with shape

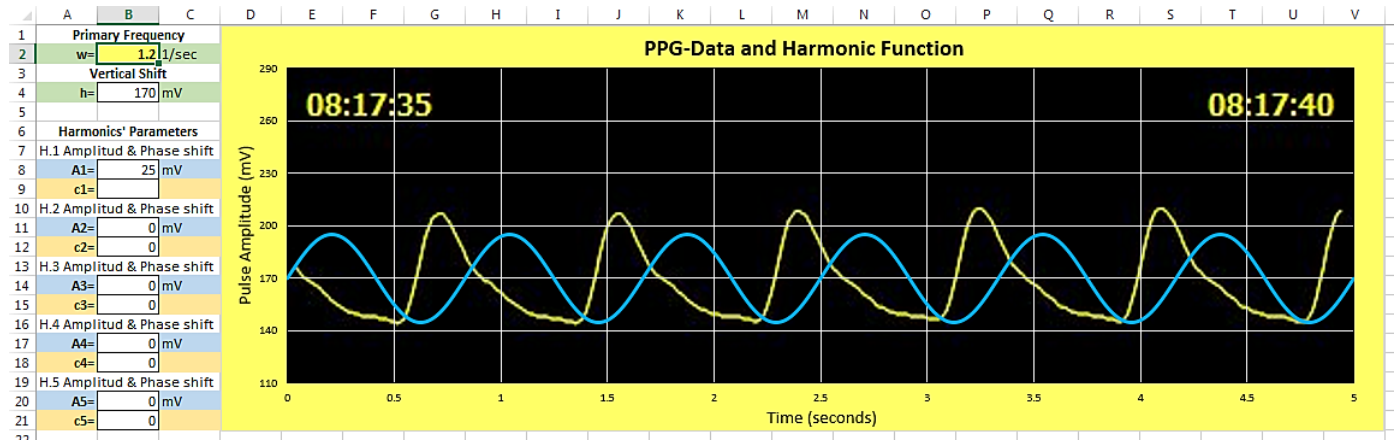
(h). In the open *Insert Picture* window select your saved PPG file and press Insert



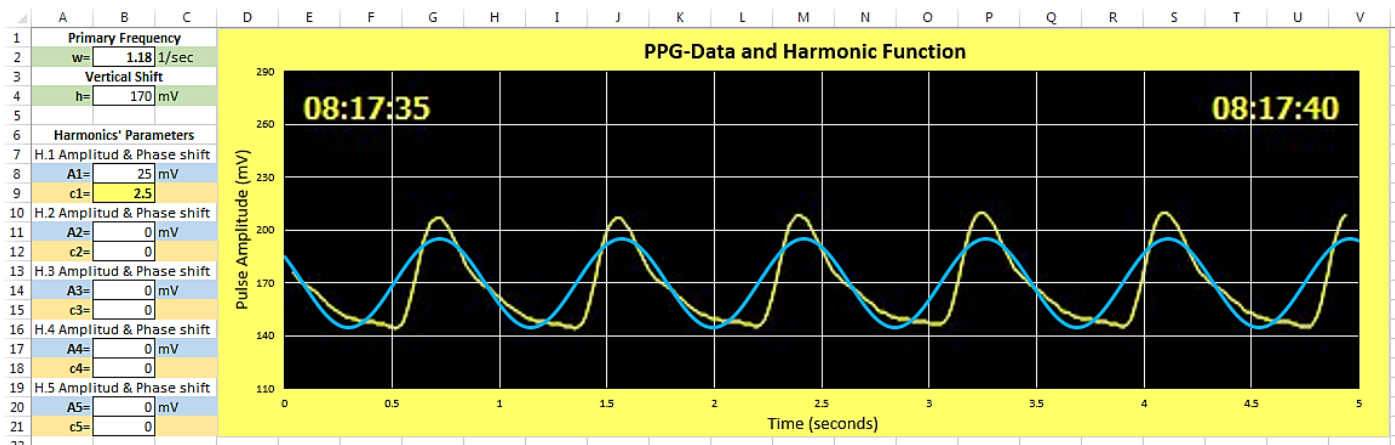
The graphing window is ready for you...

(4). To overlap the best possible both lines consider the next tips.

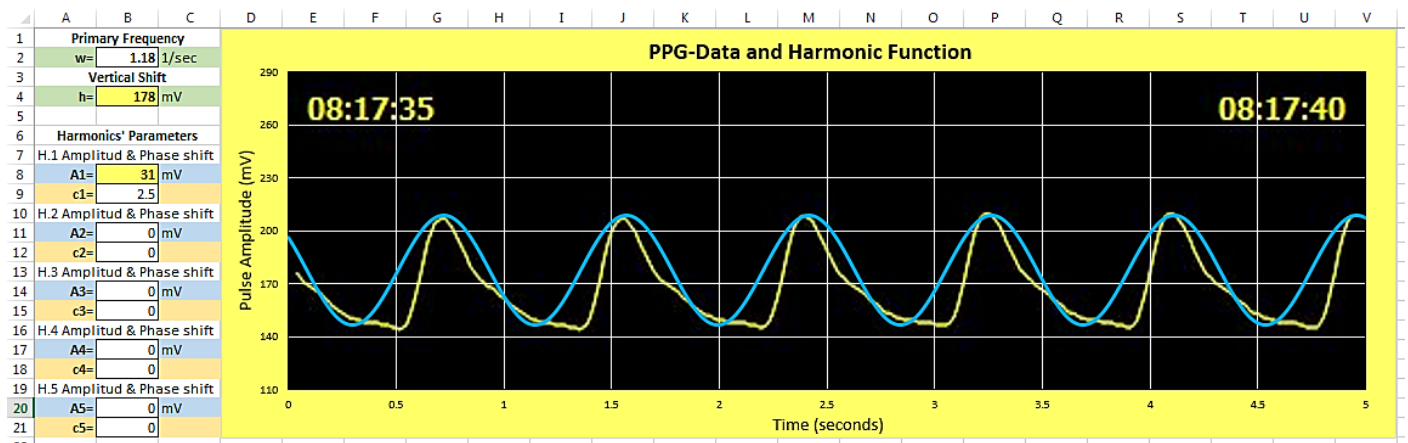
(a). First modify the frequency ω . Find the value that makes the distance between maximums the same for both lines



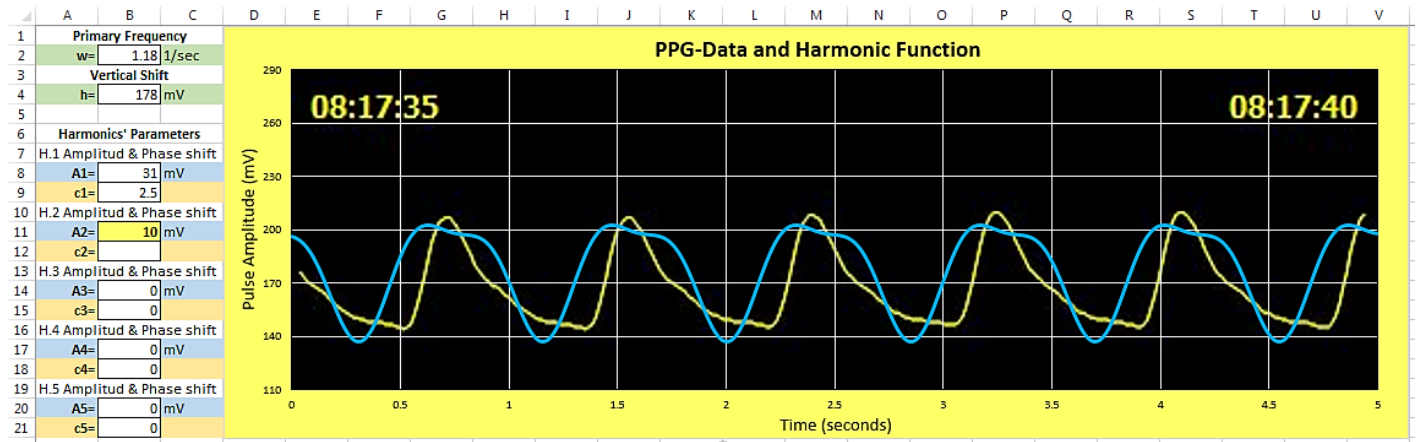
(b). Next modify shift c_1 of first harmonic H.1. Find the value that makes the maximums of both lines more or less match



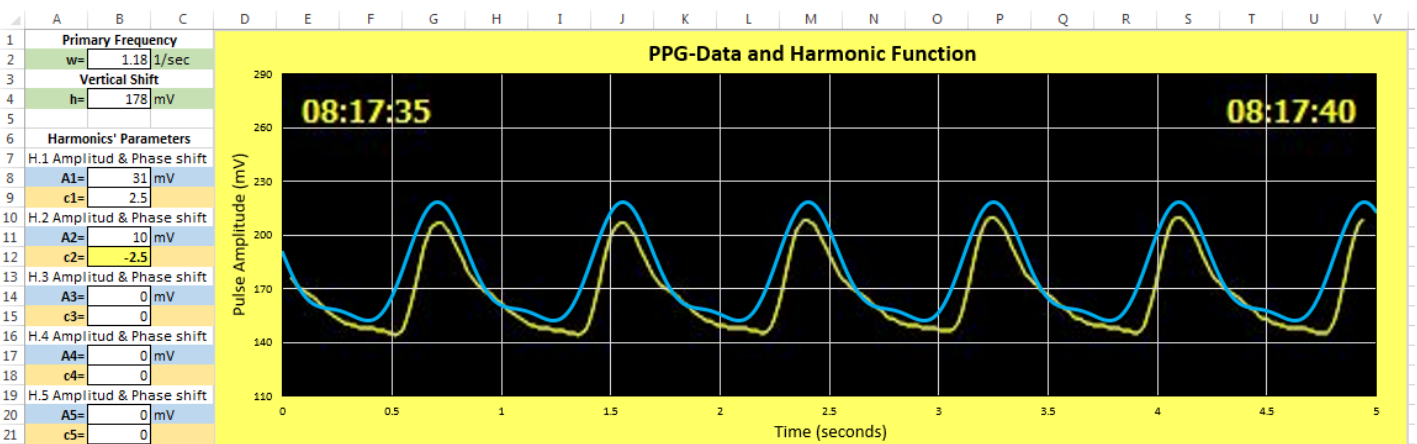
(c). Modify the values ω and c_1 until you get the best match possible. Modify the value of the amplitude A_1 for the first harmonic H.1, until the heights of both pulses match. It is possible that you have also to modify a little the value of the vertical shift h .



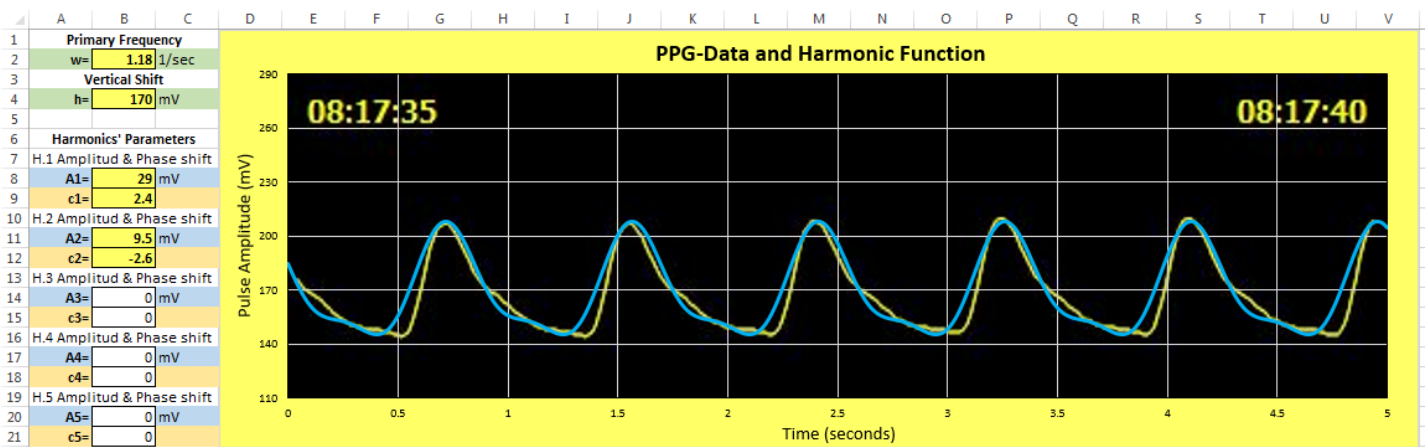
(d). Give a value to the amplitude A2 of the second harmonic H.2. Try values less than half of A1.



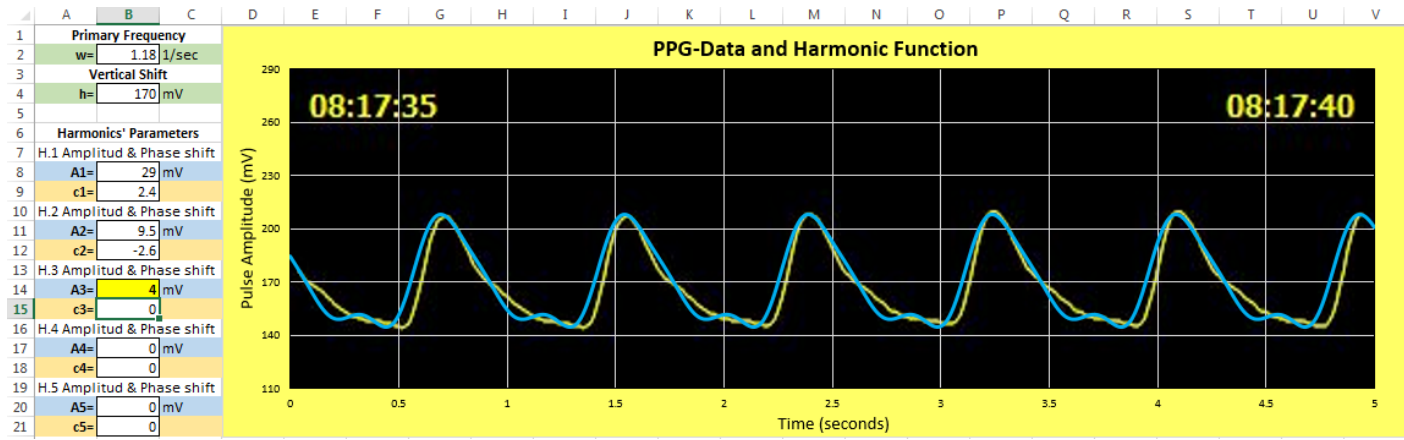
(e). Try now values for the shift phase c2 for harmonic H.2. Try positives and negatives until get the best match.



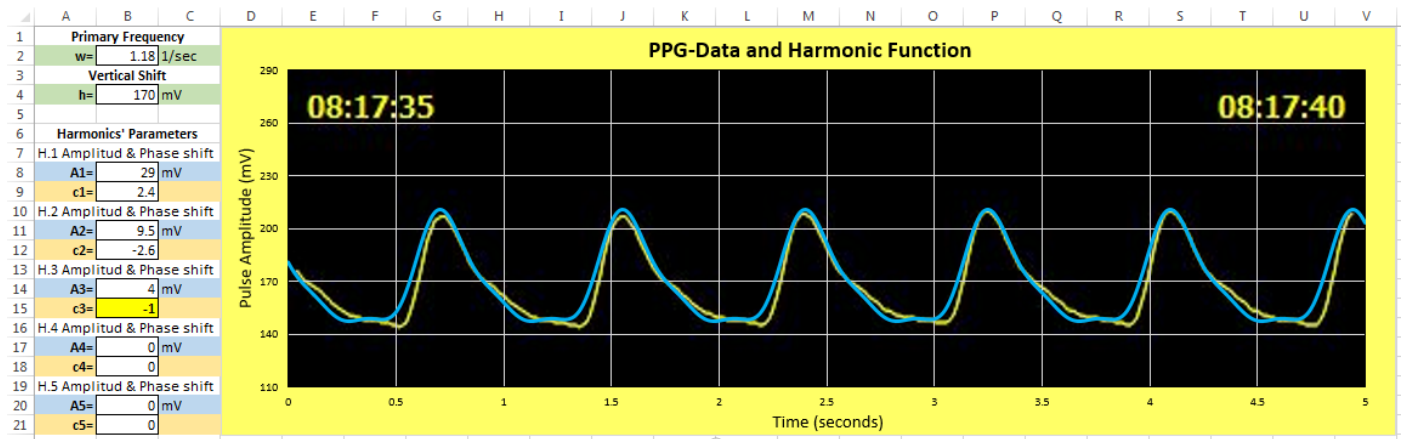
(f). It is important to modify a little these six parameters in order to achieve the best fit of these two curves. This is a guess and check, modify and see process that requires some patience. Keep a written record of the values producing a good fit. (Don't forget to save your file frequently!)



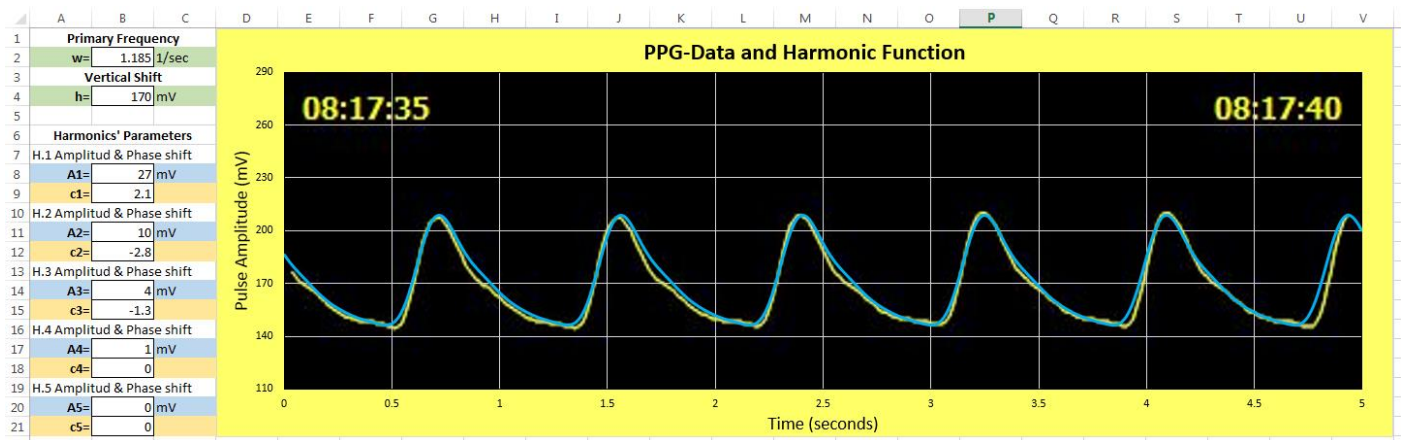
(g). A better match between these curves can be achieved using more harmonics. Proceed in the same way as above. Give a value to the amplitude A3 of the third harmonic H.3, less than half the value of A.2.



(h). Give a value to the shift phase c_3 of harmonic H.3. Try again positive and negative values until you get the best fit.



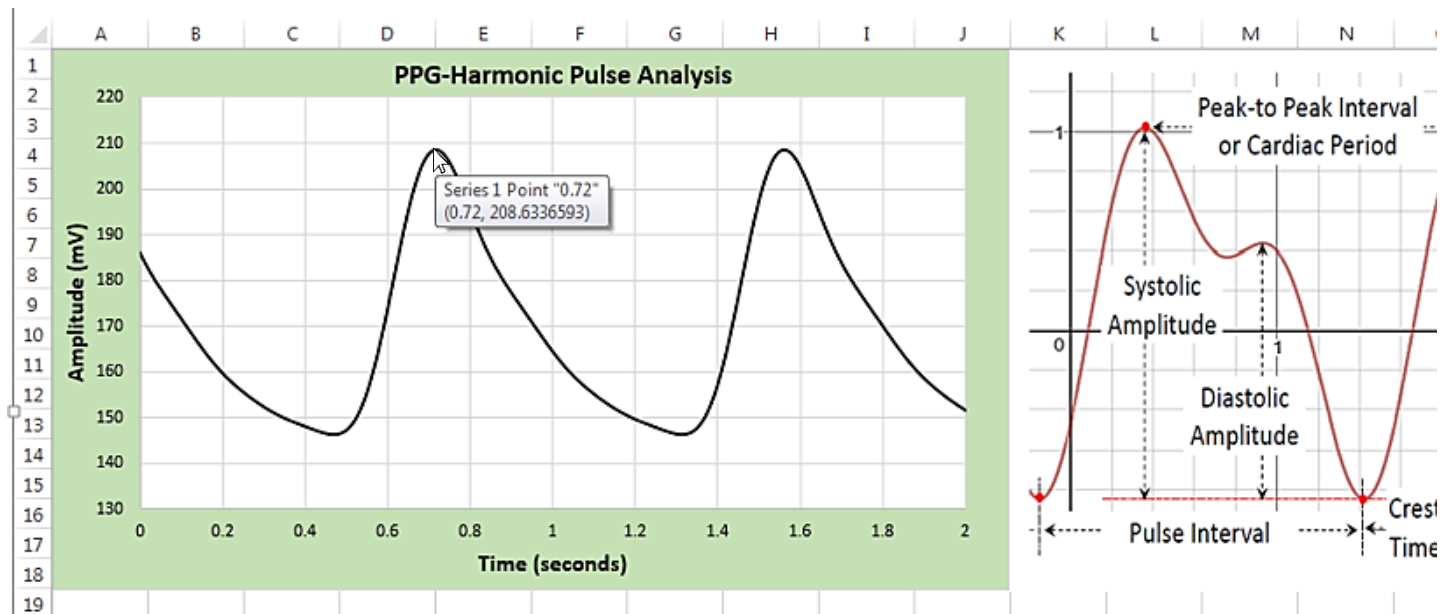
(i). Modify the eight parameters used until now, looking for the best possible fit. This will require more time and patience but you can find a good match. Repeat the above process for an additional harmonic. You can add up to five harmonics in this GUI. Here is a match with four harmonics.



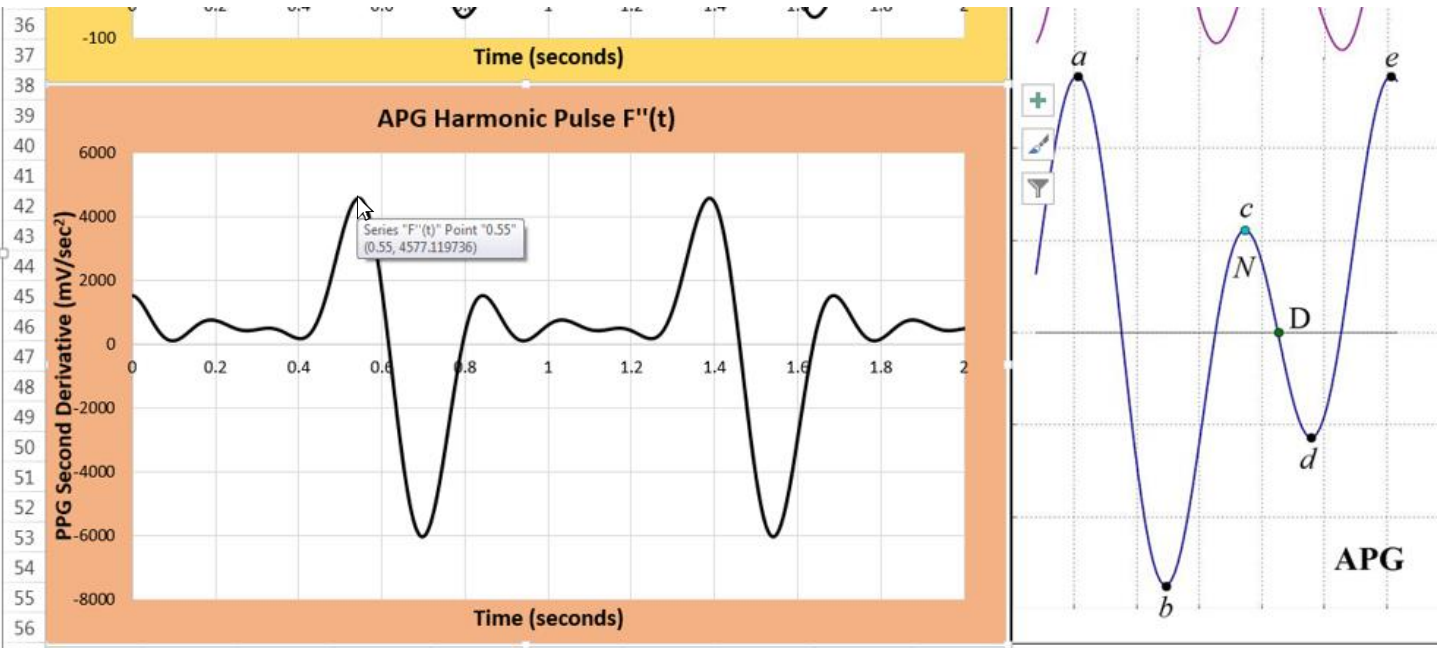
Be patient and good luck!

Annex 3. Reading Values on the Graphs.

Read the values for the obtained function on the graph in worksheet *Cardiovascular Analysis*. This is an easy task that only requires a firm hand on the computer's mouse. After selecting the graph, you have only to carefully place the mouse pointer on the graph line and the software will display the corresponding coordinates for that point.



Students with a background in calculus will use the same procedure to find the coordinates of points on curves in worksheet *Cardio Calculus-Analysis*.



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“For years your teachers kept telling you to settle down and sit still. You can stop now.”