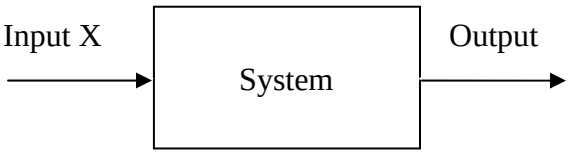
Engin 103 February 18, 2010 back to e-syllabus	Topics: CW 3 (Cont.) CW4 Logbook questions

Introduction to Project 1

Systems

A system is a physical object that produces a measurable output (Y) for every measurable input (X).



Y'= f(X)

Examples of a system could be a catapult (X=initial height of a weight; Y=range for a clay ball), a pendulum (X=period; Y=length needed to produce that period), or a car on an inclined ramp (X=ramp angle; Y=distance traveled in 2s). When random factors affecting the system are controlled (task of the engineering design team), it can be described with an equation or model, that is, using this model it is possible to predict the output given an input.

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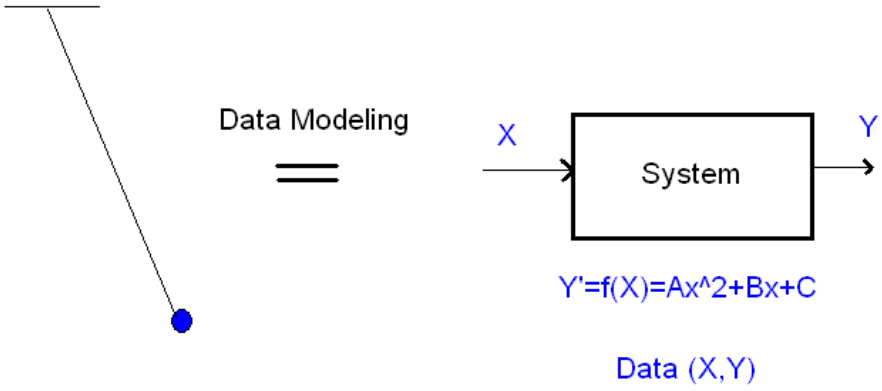
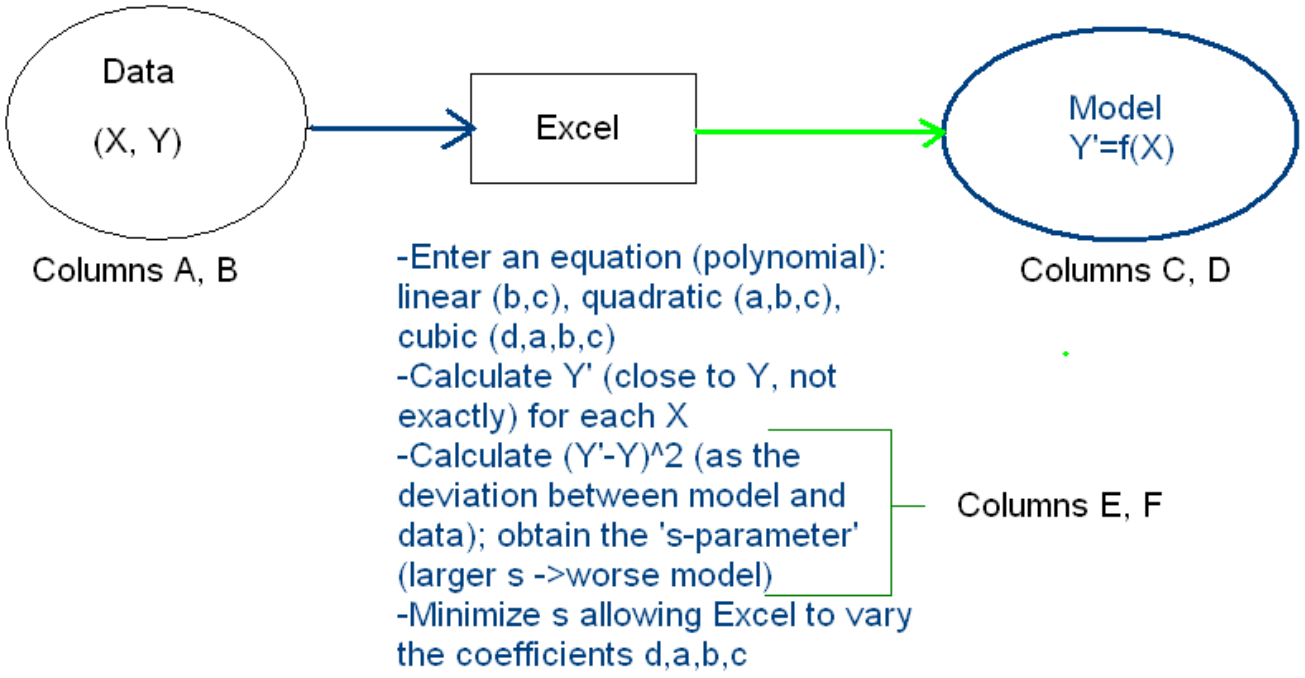
Data Modeling





Project 1 requires the use of data modeling with Excel (© Microsoft), this is learned by doing CW3-CW5, a polynomial or exponential curve-fitting or data modeling. **What is data modeling?** When an input X is applied to a system, an output Y is produced. A mathematical model of the system can be obtained by relating Y to X: e.g. Y'=f(X). We have used a Y' to indicate that it is not be possible in general to obtain an equation that relates all measured Y values to all measured X values but approximate Y' values to all measured X values.
To simplify the introduction, we discuss just simple polynomial models, e.g.

$Y'=aX^2+bX+c$
$Y'=\quad bX+c$
$Y'=dX^3+aX^2+bX+c$
$Y'=\exp(-b1*X)/(b2+b3*X)$

How to obtain a model? Perform CW3 by following 7 steps shown in class and repeated below. The process consists of using Solver (get it under Tools/Add-ins if needed) to minimize a "standard deviation" parameter s by allowing the polynomial coefficients to vary. After using Solver, the final values for a, b, c determine our quadratic model that describes the pendulum. In this CW3, to save time, we will be using only 4 pairs of data, however this is not sufficient to obtain a good model in practice: **For your Project 1, please use at least 10 pairs of data.**

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CW3

Open Excel and type your first and last name in cell A1, today's date in cell D1

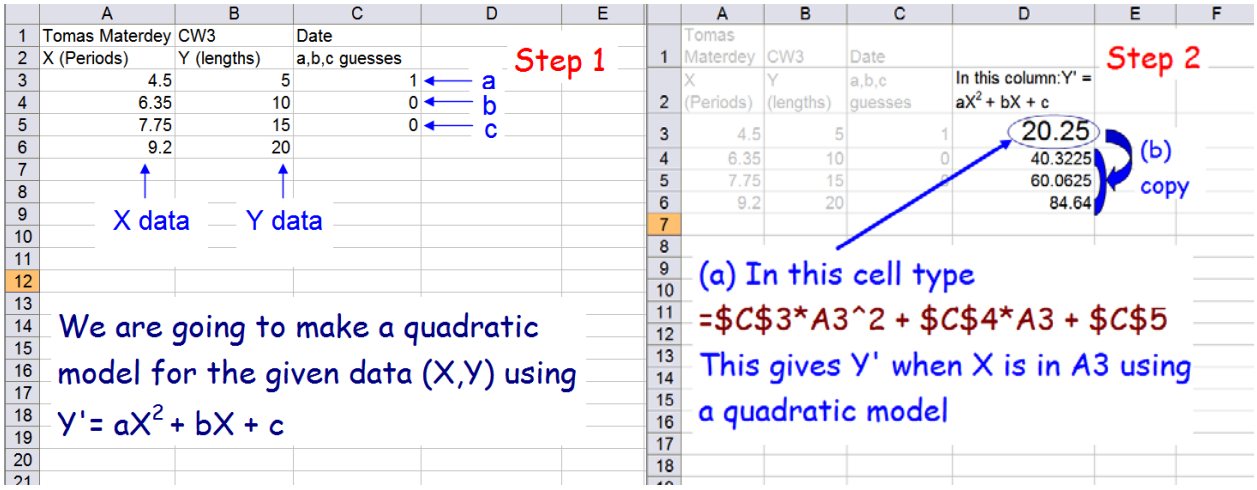
Quadratic curve fitting with Excel:

Use Excel Solver (under Tools) to produce coefficients a,b,c for your quadratic model ($y'=a*x^2+b*x+c$) by minimizing the 'standard deviation' s for the following set of data ($s \equiv \frac{\sum_{i=1}^{n}(y_i' - y_i)^2}{n}$, this is not a conventional standard deviation, and so it is not given by the 'stdev' function in Excel, but it is what we need to model our data; n is the number of data; y' indicates values predicted by our model; y indicates measured values given as data). Use '=' to start the formula for y' in cell D3; click on the corresponding cells to enter the coefficients and variables into the formula (if a is in cell C3, then click on C3, if the first x is in A3, then click on A3, etc.); remember to add a '$' before and after the letter of the cell containing the coefficients (since we don't want these to change for the second, third, and fourth x's); produce similar results for cells D4-D6 by 'copy D2 and paste' into those; produce the squared difference formula between y' and y using another '=' in E3; etc. Produce the average of E3-E6 by writing in E7 '=average(E3..E6)' and hit enter. Click on E7 and pull out 'Solver' under 'Tools'; select 'minimum' and in the 'by changing' box click and drag on the cells containing your guesses for the coefficients. Note that after running 'Solver', the 'standard deviation' or 'how far is our model from the data' is reduced to be a small number (0.1 or less, the smaller the better model you've built for those data). Watch the movies clip 'curve-fitting with Excel' as you follow these instructions.

Periods x (s)	***Lengths y (m)***
4.5	**5**
6.35	**10**
7.75	**15**
9.2	**20**

By alphabetical order of the last names, the first two students in each team will submit file cw3_XX_a.html and folder cw3_XX_a_files, the next two students will submit file cw3_XX_b.html and folder cw3_XX_a_files, to the *files* folder in the server. These files need to be uploaded to the server on the due date to receive credit.

Follow these 7 steps to perform CW3:



	A	B	C	D	E
1	Tomas Materdey	CW3	Date		
2	X (Periods)	Y (lengths)	a,b,c guesses	In this column: $Y' = aX^2 + bX + c$	In this column: $(Y'-Y)^2$
3	4.5	5	1	20.25	232.56
4	6.35	10	0	40.3225	919.45401
5	7.75	15	0	60.0625	2030.6289
6	9.2	20		84.64	4178.3296

Step 3

(a) In this cell type =(D3-B3)^2
This gives the deviation between the model value Y' and the data Y in row 3

(b) copy

	A	B	C	D	E	F
1	Tomas Materdey	CW3	Date			
2	X (Periods)	Y (lengths)	a,b,c guesses	In this column: $Y' = aX^2 + bX + c$	In this column: $(Y'-Y)^2$	In this cell: parameter s, the Std. Dev.
3	4.5	5	1	20.25	232.5625	1840.24375
4	6.35	10	0	40.3225	919.45401	
5	7.75	15	0	60.0625	2030.629	
6	9.2	20		84.64	4178.33	

Step 4

In this cell type =average(E3:E6)
This gives the parameter s, an indicator of how far your model Y' is from the data Y. For a given set of data, smaller s implies better model.

Step 5

(a) In A9 type 2
(b) In A10 type =A9+0.2
(c) Copy to A11-A47, until you get 9.6
(d) In B9 type =$C$3*A9^2 + $C$4*A9 +$C$5
(e) Copy to B11-B47

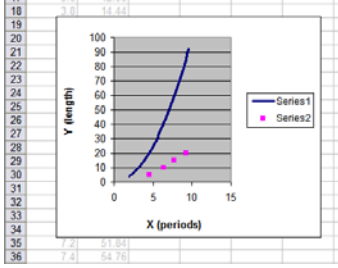
(c) copy

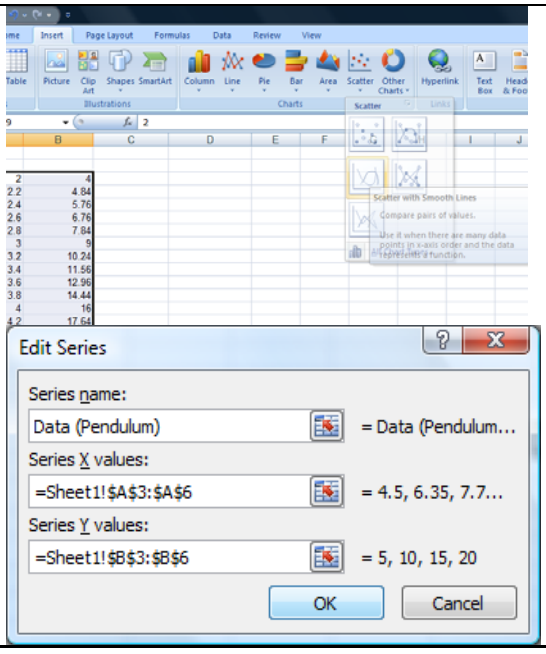
(e) copy

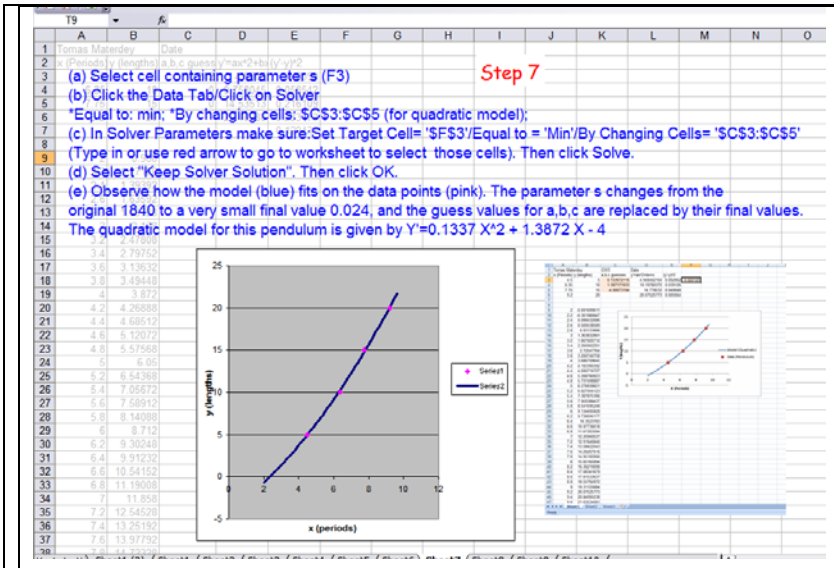
9	2	4
10	2.2	4.84
11	2.4	5.76
12	2.6	6.76
13	2.8	7.84
14	3	9
15	3.2	10.24
16	3.4	11.56
17	3.6	12.96
18	3.8	14.44
19	4	16
20	4.2	17.64
21	4.4	19.36
22	4.6	21.16

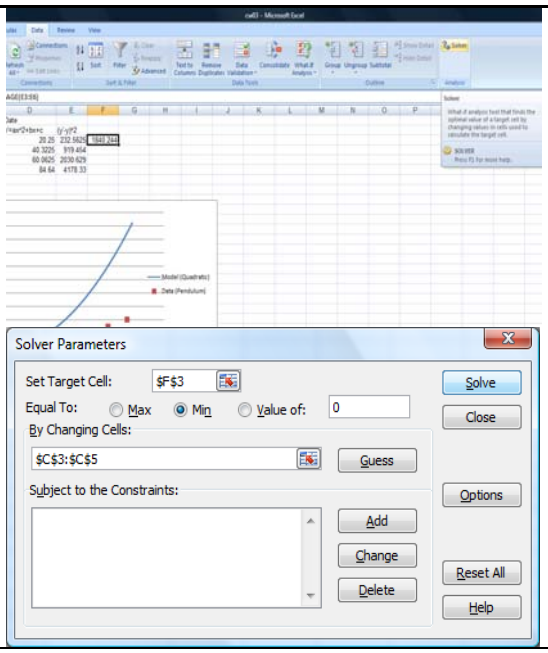
Step 6

(a) Select A9 through B47
(b) Click on the Insert tab/Scatter/Scatter with Smooth Lines
(c) Right click on plot/Select Data/Click on Add (in Select Data Source)
(d) In Edit Series, type 'Data (Pendulum)' under Series Name
(e) Under Series X Values, click on red arrow to go to the worksheet, select A3 through A6, click on red arrow
(f) Under Series Y Values, click on red arrow to go to the worksheet, select B3 through B6, click on red arrow
(g) Click OK, in Select Data Source click on Series1, then click Edit.
(h) In Edit Series, type 'Model (Quadratic)' under Series Name. Click OK. Click OK again in Select Data Source
(i) Right click on red curve, click on Change Series Chart Type. Select XY Scatter with markers only. Click OK.
(j) Click on the Layout tab/Axis Titles/Primary Horizontal Axis Title/Title Below Axis. Type in 'X (periods)'
(k) Click on Axis Titles/Primary Vertical Axis Title/Rotated Title. Type in 'Y (lengths)'









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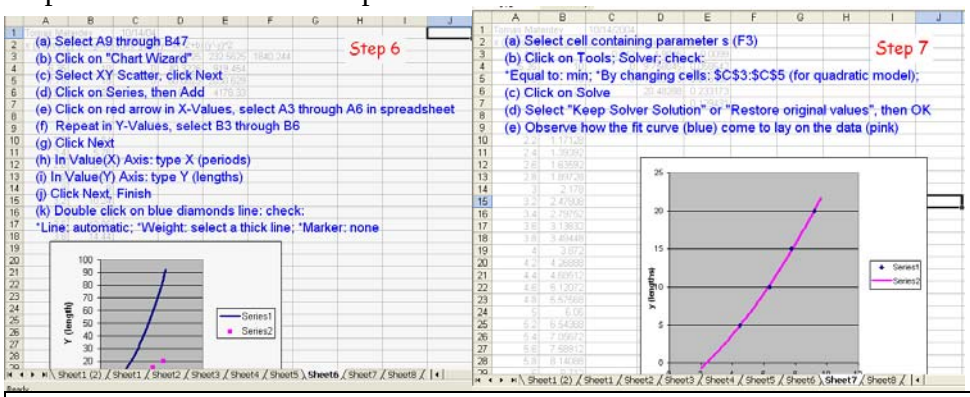
CW3 (cont.)

Steps 6 and 7 in CW3 were performed.



FAQ:

1) What are the series?

Each series consists of two sets of numbers, one for X and one for Y. The X values will be represented along the horizontal axis, the Y values along the vertical axis, so each pair (x,y) is a dot on the graph.

2) Why do we need two series?

We use the data series to show the data points, and the calculated series to show the curve or mathematical model for the data.

3) How can I add a series to a graph?

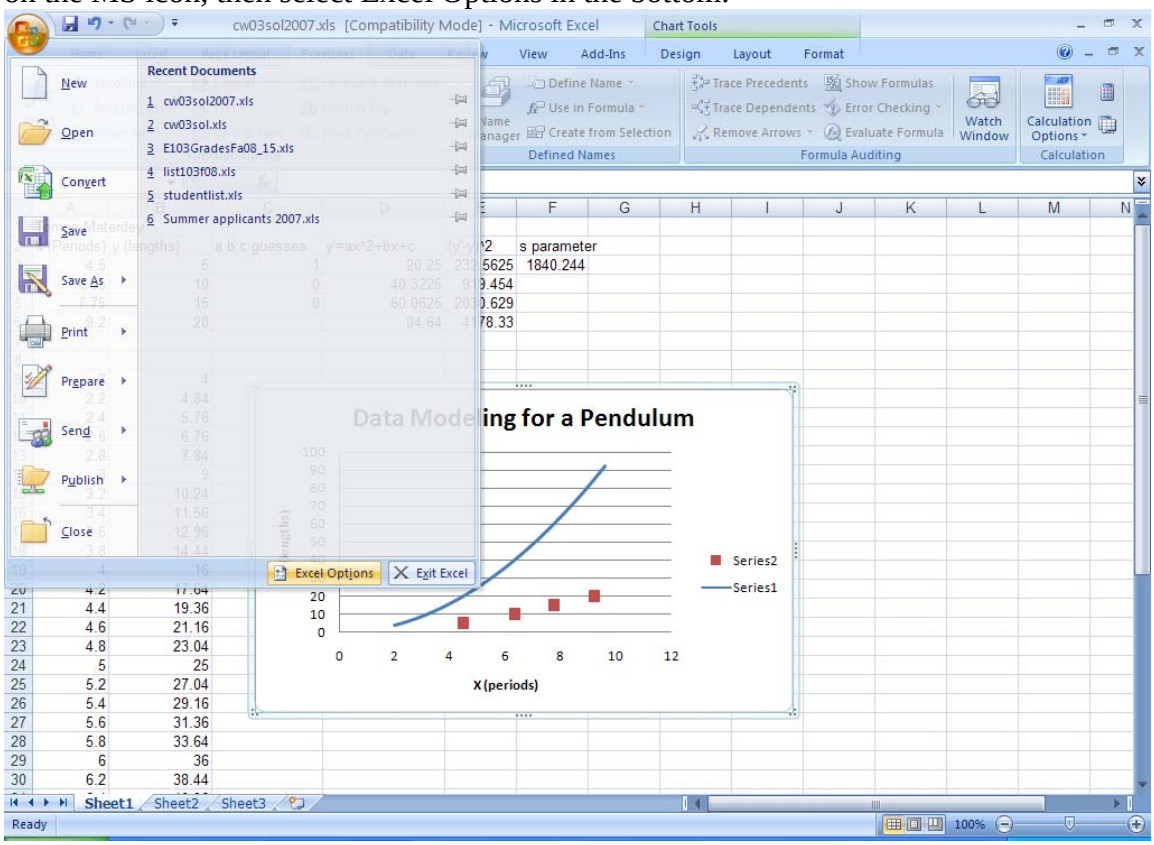
Right click on the graph, click Select Data, then click Add, then enter 'Series X

values' and 'Series Y values'.

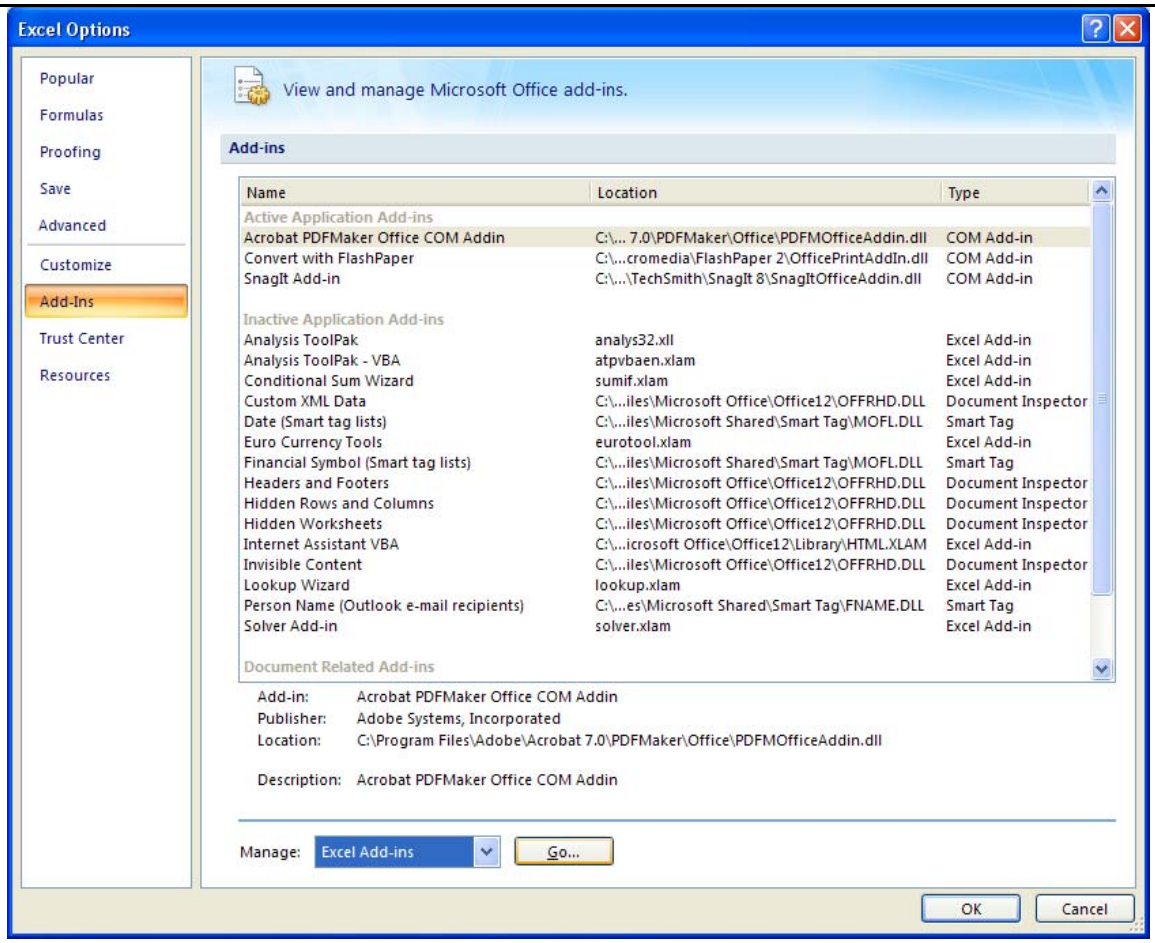
5) How can I change the dots for the calculated series into a line?

Right click on the dots, then select Change Series Chart Type. Then select Line.

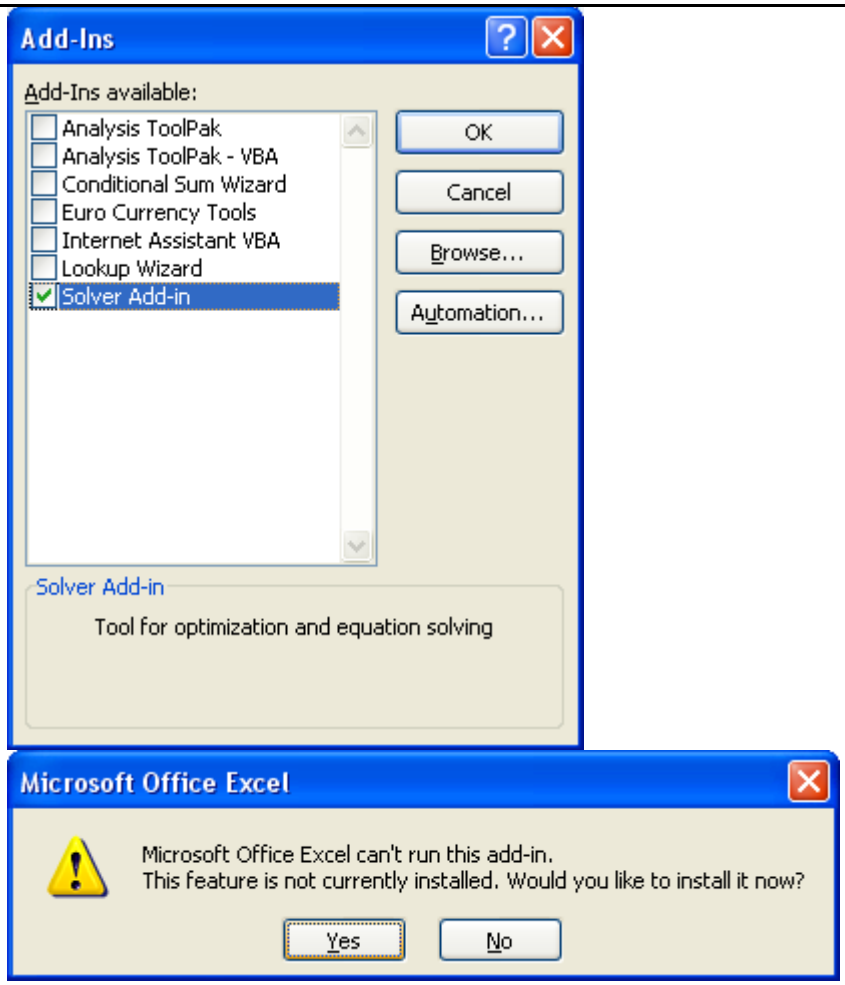
6) Where is Solver? If this is your first time using Solver, it may not be installed yet so click on the MS icon, then select Excel Options in the bottom:



Then click on Add-ins on the left, and next to Manage, select Excel Add-ins, then click Go (see below)

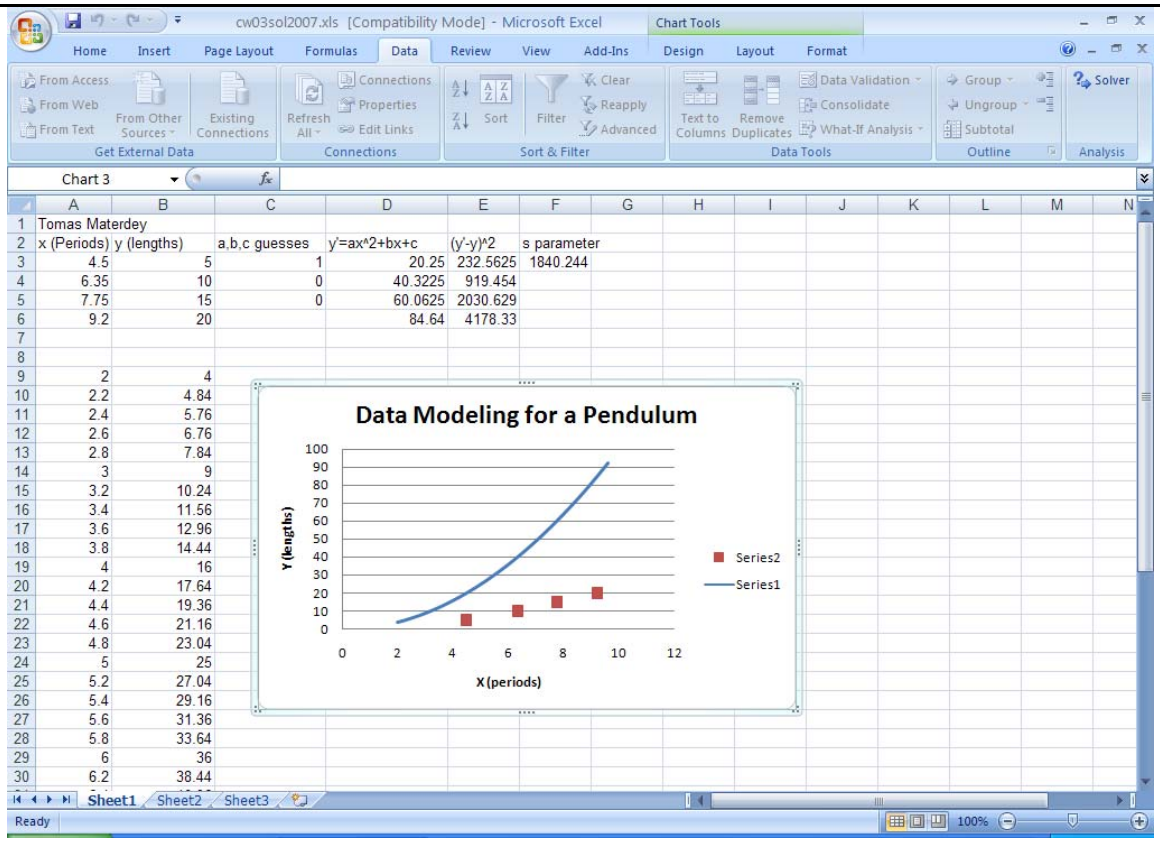


Make sure Solver Add-in is checked in the next window. And click Yes to any error message



Excel will then install Solver, it takes a couple of minutes, be patience.

Then under the Data tab you will see Solver on the right (see below)



7) What do we use Solver for?

This is the heart of the data modeling process, we use Solver to obtain the model for the measured data. **How to obtain a model?** The process consists of using Solver (get it under Tools/Add-ins if needed) to minimize a "standard deviation" parameter s by allowing the polynomial coefficients a, b, c to vary.

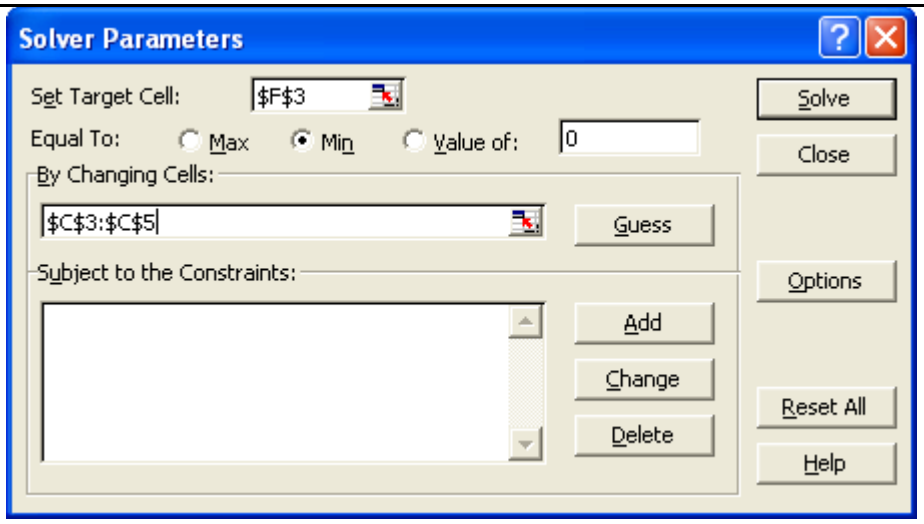
$Y' = aX^2 + bX + c$

Starting with your guesses, Solver varies a, b, c until the s parameter, contained in cell $F$3 and which is the average of the deviations $(Y-Y')^2$, is minimum. When this is achieved, the final values for a, b, c determine our polynomial (quadratic) model for the measured data.

In this CW3, to save time, we used only 4 pairs of data, however this is not sufficient to obtain a good model in practice, **for your Project 1, please use at least 10 pairs of data.**

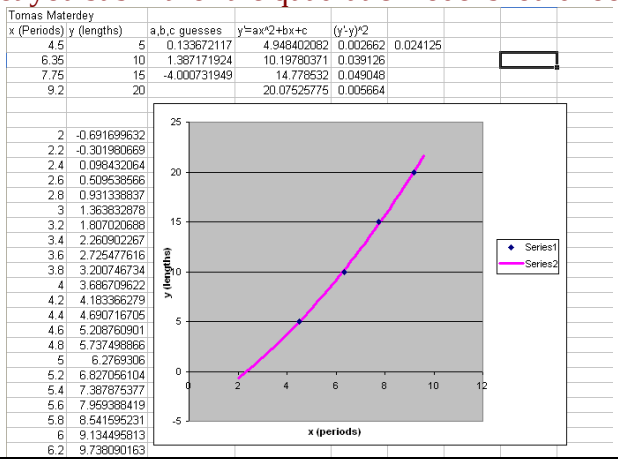
8) Why my data points are far from the curve after using Solver?

Make sure you select the Minimize option and not the Maximize option. See below.



8) What should I submit for CW3?

The Spreadsheet you submit for the quadratic model should look like this



Tomas Materdey					
x (Periods)	y (lengths)	a,b,c guesses	y=ax^2+bx+c	(y'-y)^2	
4.5	5	0.133672117	4.948402082	0.002662	0.024125
6.35	10	1.387171924	10.19780371	0.039126	
7.75	15	-4.000731949	14.778532	0.049048	
9.2	20		20.07525775	0.005664	

2	-0.691699632
2.2	-0.301980669
2.4	0.098432064
2.6	0.509538566
2.8	0.931338837
3	1.363832878
3.2	1.807020688
3.4	2.260902267
3.6	2.725477616
3.8	3.200746734
4	3.686709622
4.2	4.183366279
4.4	4.690716705
4.6	5.208760901
4.8	5.737498866
5	6.2769306
5.2	6.827056104
5.4	7.387875377
5.6	7.959388419
5.8	8.541595231
6	9.134495813
6.2	9.738090163

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CW4

(a) Save CW3 into a new file, then in Sheet #1 modify it to produce a linear and a cubic model for the same data set, insert snapshots of these worksheets into **Table 1** in a MS Word file. Make a table like the one below for the "s" values for the linear, quadratic, and cubic models, along with the coefficients obtained for each model. Indicate which is the best model (linear, quadratic, or cubic) for our set of data, and explain why.

Model	Coefficients	S parameter
Linear 	A= B= C= D=	

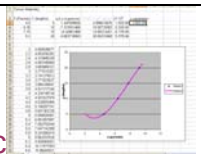
Quadratic 	A= B= C= D=	
Cubic 	A= B= C= D=	

Table 1: All terms in polynomial models using same data set as in CW3

(b) Download this data set, repeat the table above for this new data set: (i) In Sheet#2 using all terms in each polynomial model. Insert spreadsheet snapshots, polynomial coefficients, and parameter s into **Table 2** in your MS Word file (ii) In Sheet #3 using only the highest order term in each polynomial model. Insert spreadsheet snapshots, polynomial coefficients, and parameter s into **Table 3** in your MS Word file. Can you conclude what is the dominant relationship (linear, quadratic, or cubic) between the periods and the lengths of a pendulum?

(c)

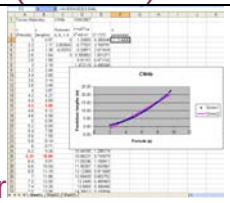
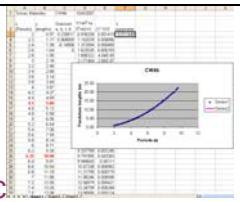
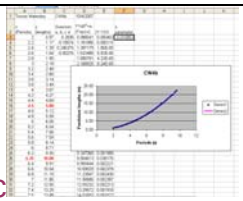
Model (all terms)	Coefficients	S parameter
Linear 	A= B= C= D=	
Quadratic 	A= B= C= D=	
Cubic 	A= B= C= D=	

Table 2: All terms in polynomials models using new data set

Model (only leading terms)	Coefficients	S parameter

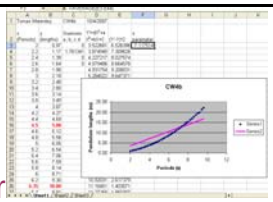
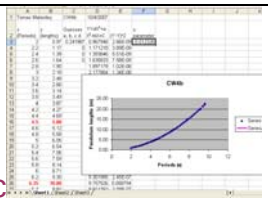
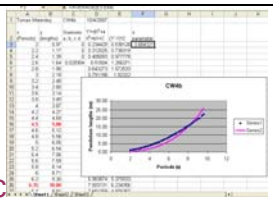
Linear 	A= B= C= D=	
Quadratic 	A= B= C= D=	
Cubic 	A= B= C= D=	

Table 3: Only highest order term in polynomial models using new data set

In each team, students working together at a computer numbered between 1 and 10 will submit file cw4_XX_a.html and folder cw4_XX_a_files, students working at a computer numbered between 11 and 20 will submit file cw4_XX_b.html and folder cw4_XX_b_files, to the *files* folder in the server. Replace XX by 01 if team 1, etc. Include your names within the files.

Q&A

1) What is the purpose of CW4?

The purpose is to modify the Excel Spreadsheet we created for CW3 to apply a cubic and linear model to the same set of data. After assembling a table with the s parameters and coefficients for the three models, we will be able to determine the best model for a given set of data. This is something you should do for part II of Project 1.

2) How many coefficients are there in these different models?

Cubic polynomial:
$Y'=f(X)= D*X^3 + A*X^2 + B*X + C$ (has 4 coefficients: D, A, B, C)

Quadratic polynomial:
$Y'=f(X)= A*X^2 + B*X + C$ (has 3 coefficients: A, B, C)

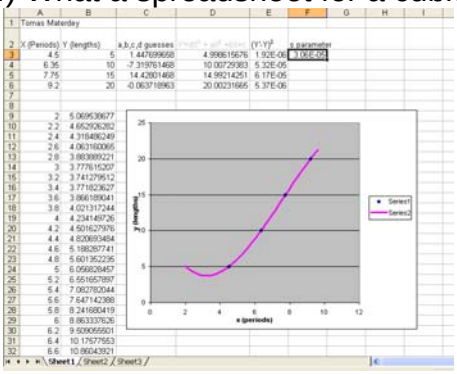
Linear polynomial:
$Y'=f(X)= B*X + C$ (has 2 coefficients: B, C)

3) How can I get a snapshot of the worksheet?

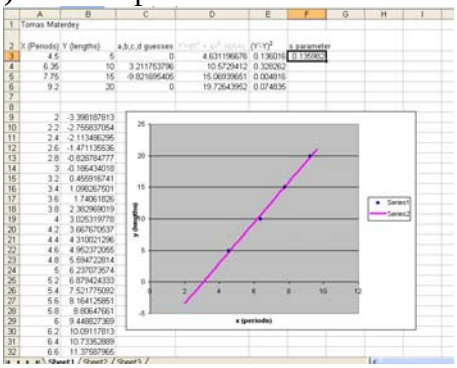
Copy a snapshot of the Excel screen by doing ALT+PRINT SCREEN, then

PASTE into a WORD file

4) What a spreadsheet for a cubic model would look like?



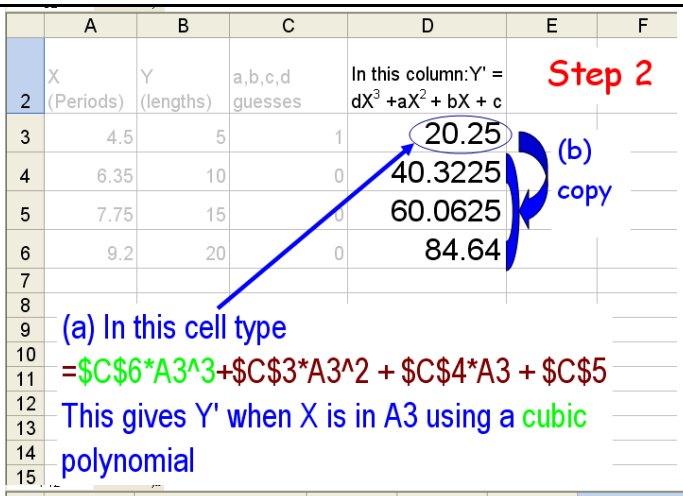
5) What a spreadsheet for a linear model would look like?

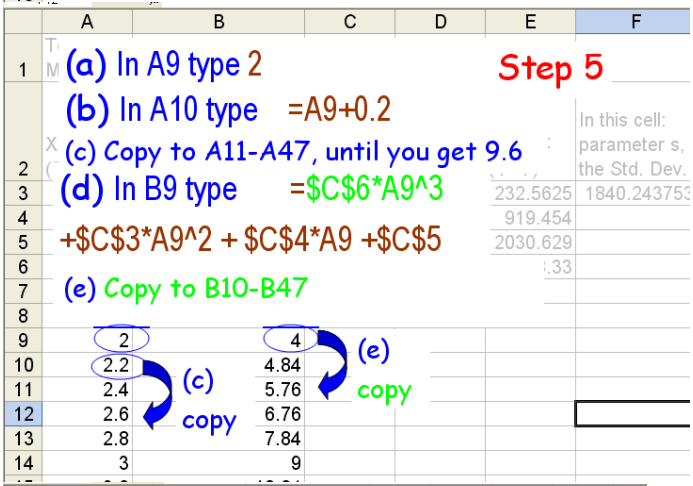


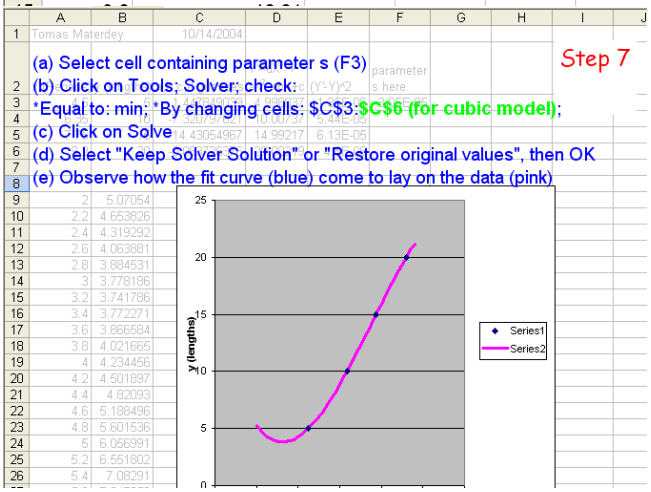
6) What changes should I make to the CW3 spreadsheet to produce a cubic model?

Here are the changes (in green) to make to the spreadsheet for CW4a)

	A	B	C	D	E
1	Your name		10/19/2004		
2	X (Periods)	Y (lengths)	a,b,c, d guesses	Step 1	
3	4.5	5	1	← a	
4	6.35	10	0	← b	
5	7.75	15	0	← c	
6	9.2	20	0	← extra cubic parameter 'd'	
7					
8					
9	↑ X data	↑ Y data			
10					
11					
12					
13					
14	We are trying to relate X to Y				
15					
16	using $Y' = dX^3 + aX^2 + bX + c$				
17					







6) **How to get a QUADRATIC model using the spreadsheet made for a CUBIC model?**

7) **How to get a Linear model using the spreadsheet made for a CUBIC model?**

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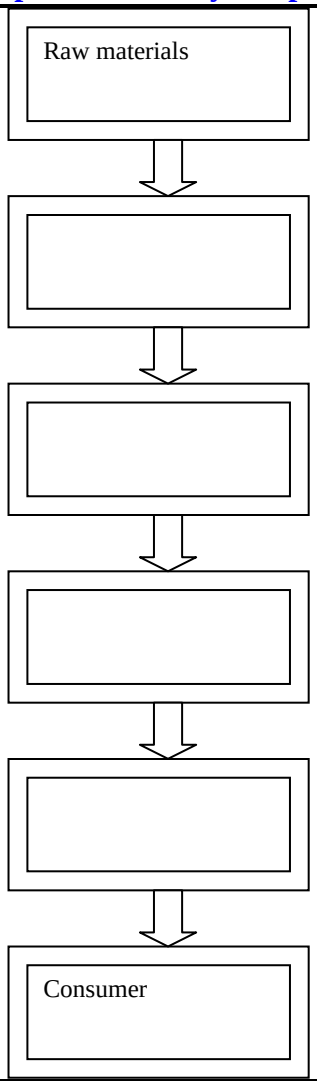
LOGBOOK: example of a logbook page

-Use a quadrille notebook; number all pages; date all entries
-Write your notes for all activities, thoughts, problems and solutions, and learning conclusions related to Engin 103. You should write down progress, outcomes, and conclusions on projects and teamwork; conclusions from class work (including LabVIEW) and homework.
-In addition you should answer in the logbook all questions listed in these notes in blue, as shown below:

13) Create a flow chart to show the supply chain of an automobile from the raw materials to the end consumer. The chain should include at least 6 steps: 1) Raw materials 2)_____ 3)_____ 4)_____ 5)_____ 6) Consumer. In each step, indicate what type of engineers from the table below would be involved. In a few words explain what they do specifically. Can you include all ten fields in the supply chain?



Engineering fields	Abbreviations
Aeronautical and Aerospace Engineering	AAE
Biomedical Engineering	BME
Chemical Engineering	ChE
Civil Engineering	CiE
Computer Engineering	CE
Electrical Engineering	EE
Geological/Geophysical Engineering	GGP
Industrial and Manufacturing Engineering	IME
Material Science Engineering	MSE
Mechanical Engineering	ME

14) Sketch the Engineering Design Cycle in your logbook, explain specific actions to be taken by you and your team for Project 1 as related to the different steps in the cycle. Be as specific and as detailed as

possible.

15) Explain in your own words, steps 1-4 on how to prepare an Excel spreadsheet to obtain the model/equation describing a system. In other words, explain what to do in columns A to E in the spreadsheet. Be as detailed as possible.

16) Explain why when implementing the quadratic model in cell D3: =$C$3*A3^2+$C$4*A3+$C$5 we used a $ before and after the C, but not for A

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