MAE 3724 Systems Analysis
Fall 2019

Laboratory Experiment 8
Step Response of a Thermal System

Final Report for Lab 8 (Each individual needs to submit a Final Report)

SHOW ALL YOUR WORK ON THIS AND THE FOLLOWING PAGES. Scan these pages and the requested plots and upload them into the Brightspace Dropbox for Lab 8.

1. *[0 pts]* Record the initial and steady state temperatures from each case when you do the experiments.

$T_{1\_initial}$ = 21.05 °C T_{1_final} = 76.8 °C

$T_{2\_initial}$ = 76.8 °C T_{2_final} = 18.0 °C

$T_{3\_initial}$ = 77.5 °C T_{3_final} = 4.5 °C

2. *[0 pts]* There is a lot of noise in the thermocouples used in this experiment. In order to eliminate some of the noise, you are going to average the data to smooth it out.

To do this, create a new column in Excel to calculate the "Averaged Temperature". Use Excel's " =AVERAGE() " function to average the 4 data points before and after with the current data point to determine the "Averaged Temperature" at that point. See the picture below for clarification.

E	F	G
Hot-Water Plunge (Case 1)		
Time (s)	Temp (C)	Avg. Temp (C)
1.88	22.28	
1.9	22.07	
1.92	22.28	
1.94	22.28	
1.96	22.49	=AVERAGE(F3:F11)
1.98	21.87	22.21
2	22.28	22.19
2.02	21.87	22.21
2.04	21.66	22.40
2.06	23.11	22.40
2.08	21.87	22.65
2.1	22.49	22.77

Adjust the time, so that the start of the response occurs at $t = 0\ sec$.

Average the data for each of the 3 cases and plot them. (Do NOT print them yet. You will later plot each case's averaged data and its model (based on its measured time constant) at the end of your report in Part 6).

3. *[3 pts]* Determine the time constant for each step response, using the 63% method.

$\tau_1 =$ 0.72 sec $\quad \tau_2 =$ 7.14 sec $\quad \tau_3 =$ 1.68 sec

4. *[2 pts]* How do the time constants for convection through water compare? (τ_1 and τ_3) **Explain why.**

$\tau_3 > \tau_1$

5. *[2 pts]* How do the time constants between convection through water and convection through air compare? **Explain why.** (τ_1 and τ_2)

$\tau_1 < \tau_2$

6. *[3 pts]* Eqn. (4) is the model of the thermocouple. Solve Eqn (4) for each of the three Cases using the experimentally determined time constants.

All three systems have a forcing function $f(t) = T_b$ $\therefore$

The Solution to $\tau \dot{T} + T = T_b$ is $T(t) = T(0)e^{-t/\tau} + T_b(1 - e^{-t/\tau})$.

case 1: $T(t) = 21.05\, e^{-t/0.72} + 76.8(1 - e^{-t/0.72})$

case 2: $T(t) = 76.8\, e^{-t/7.14} + 18.0(1 - e^{-t/7.14})$

case 3: $T(t) = 77.5\, e^{-t/1.68} + 4.5(1 - e^{-t/1.68})$

7. *[6 pts]* Plot each model on the same graph with the corresponding experimental data.

<u>Print and attach a copy of the graphs developed for each case (3 total) Each graph should contain the averaged data (Part 1) and its model based on the experimental time constant (Part 6).</u>

8. *[1 pt]* Comment on how the model for plunging into hot water from air (Case 1) compares to the corresponding experimental data. **<u>Explain any variation.</u>**

The model & experimental data align very closely. There are fluctiations in the data that can be caused by a change in h.

9. *[1 pt]* Comment on how the model for pulling out of hot water into air (Case 2) compares to the corresponding experimental data. **<u>Explain any variation.</u>**

The model & experimental data align very closely. The fluctuations are minimal and could be caused by convection currents in the air

10. *[1 pt]* Comment on how the model for plunging from hot into cold water (Case 3) compares to the corresponding experimental data. **<u>Explain any variation.</u>**

The experimental data lags behind the model but then even out to the same value. This could be caused by the sensor not being properly submerged.

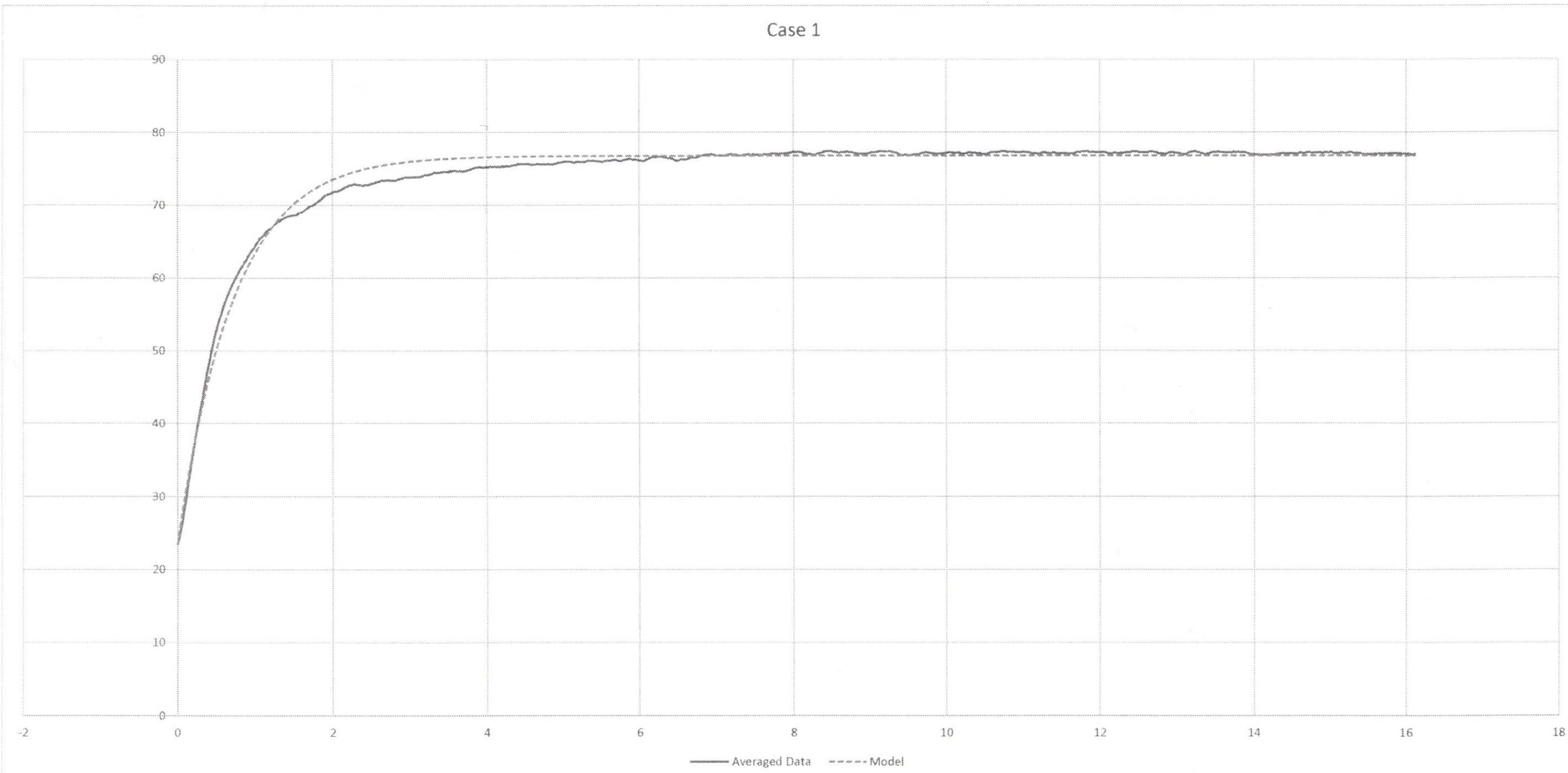
11. *[1 pt]* At the beginning you were asked to assume that the temperature of the water in the beaker and in the cup do not change during the period from insertion and withdrawal of the thermocouple. Is this a good assumption? Under what conditions would it NOT be a good assumption?

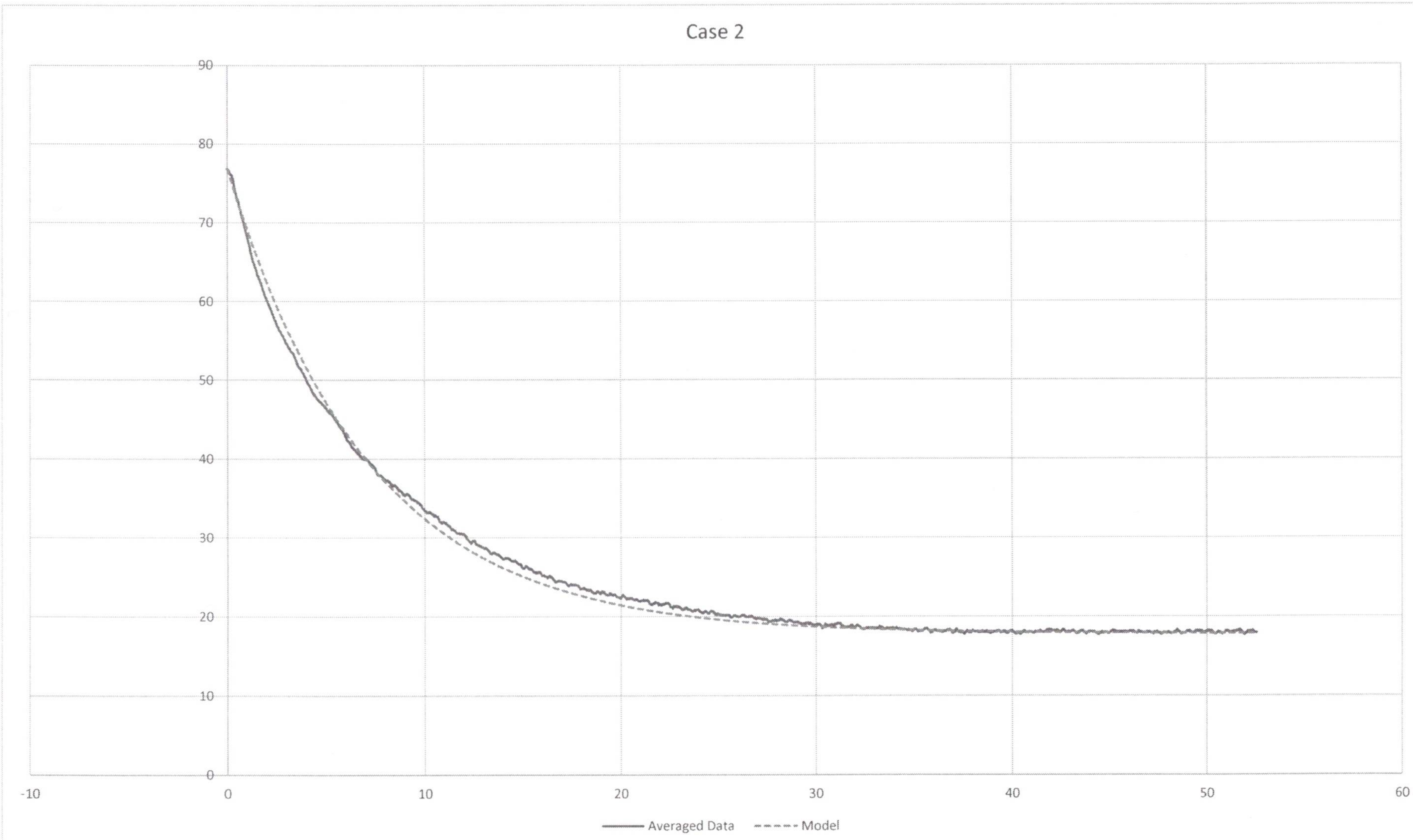
Yes it is, but it would not be if the thermal mass of the water is low.

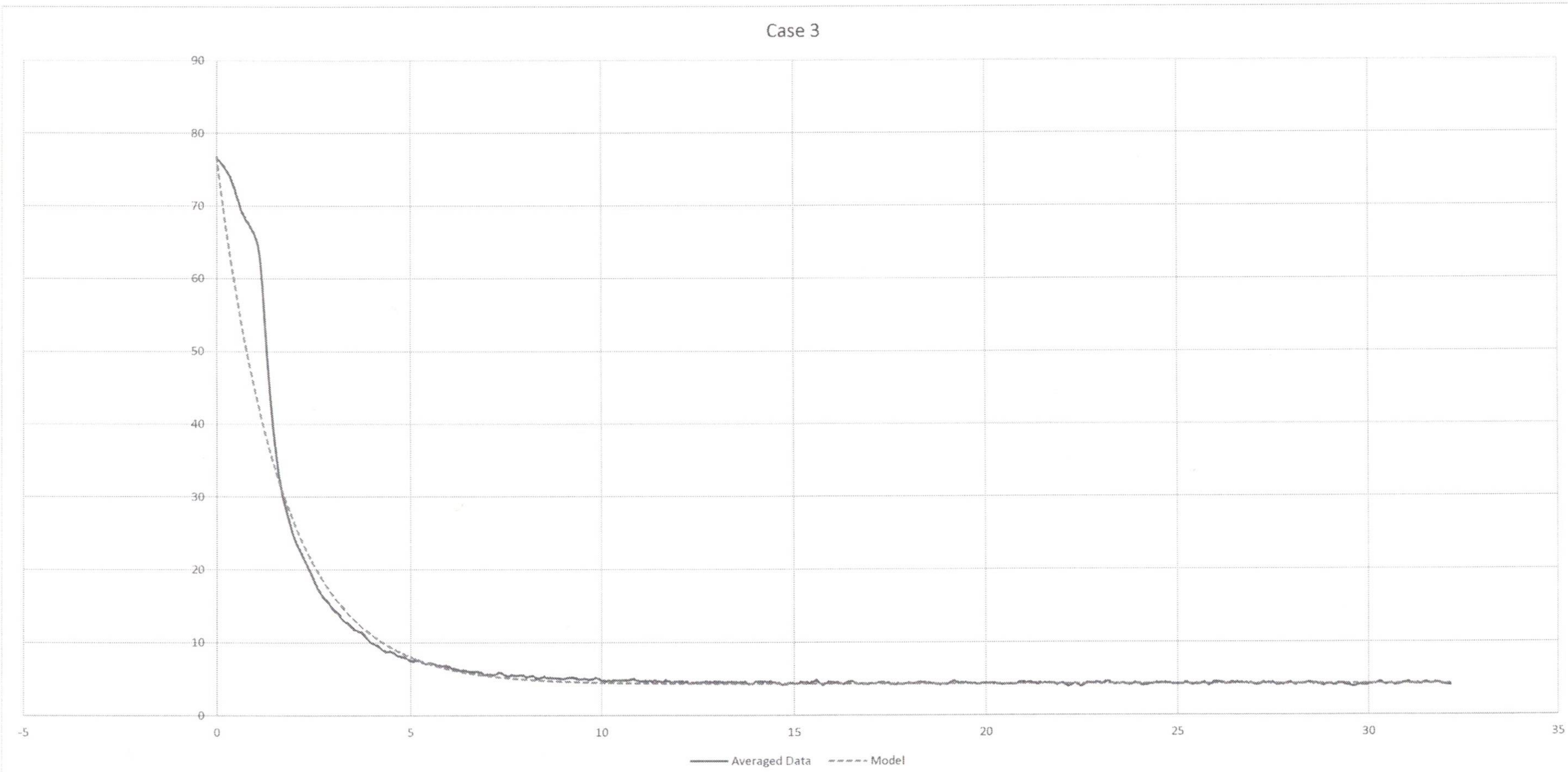
<u>Final Evaluation (Answers do not affect the grade)</u>

1. What did you learn from this experiment?

2. What could be done to make the experiment more beneficial?


Case 1
90
80
70
60
50
40
30
20
10
0
-2
0
2
4
6
8
10
12
14
16
18
Averaged Data
Model


Case 2
90
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
Averaged Data
Model


Case 3
90
80
70
60
50
40
30
20
10
0
-5
0
5
10
15
20
25
30
35
Averaged Data
Model