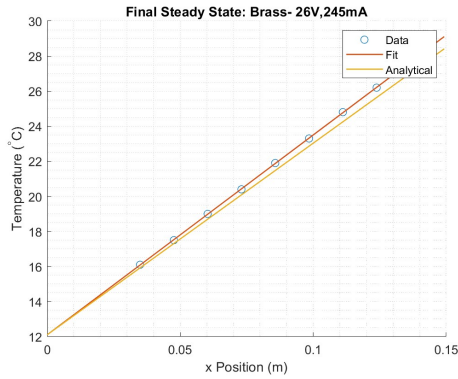


Lab 2 Part 1
February 2025

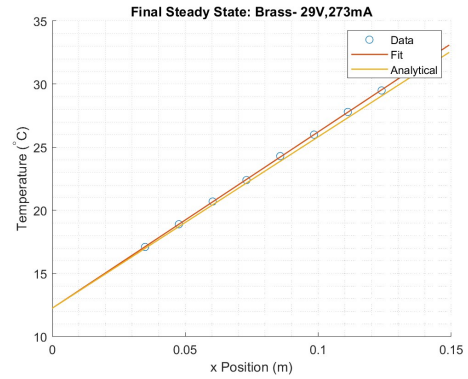
Skylar Harris
Lauren Lajoie
Andrew Patella
Yaseen Mustapha

1 Task 1

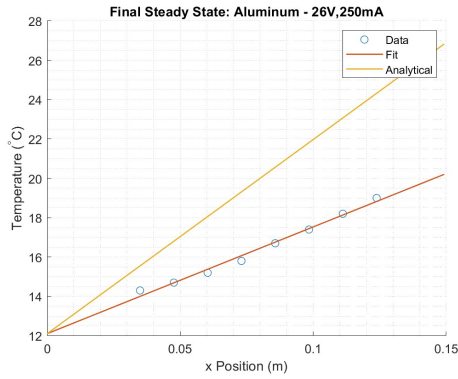
Material	T_0 [°C]	H_{exp} [$\frac{°C}{m}$]	H_{an} [$\frac{°C}{m}$]
Steel 21V,192mA	11	277.0	491.2
Brass 26V,245mA	12	114.0	109.3
Brass 29V,273mA	12	139.8	135.9
Aluminum 26V,250mA	12	54.3	98.6
Aluminum 28V,269mA	12	66.8	114.3



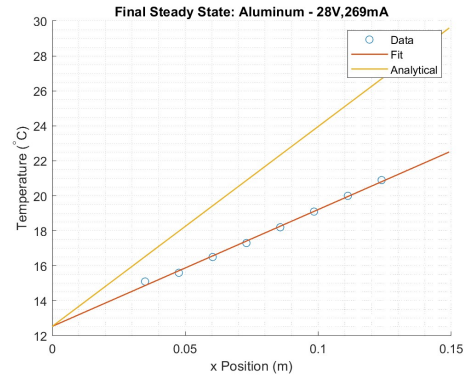
(a) Brass at 26V



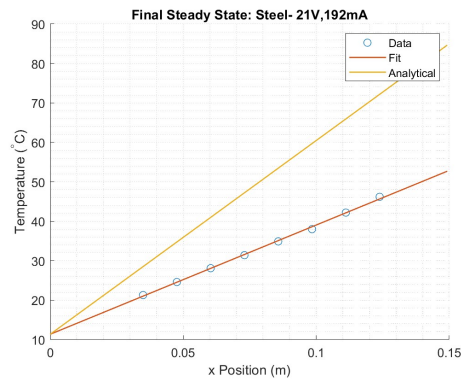
(b) Brass at 29V



(c) Aluminum at 26V



(d) Aluminum at 28V



(e) Steel

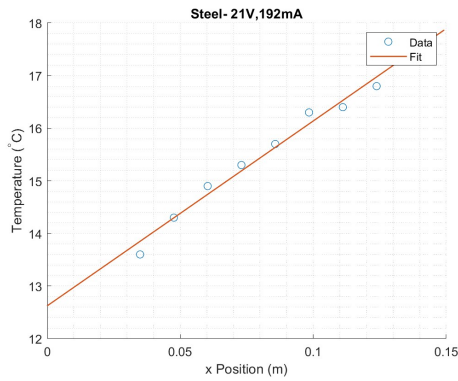
Figure 1: Steady State Temperature Vs. Position for Different Materials At Different Voltages and Currents

1.1 Discussion

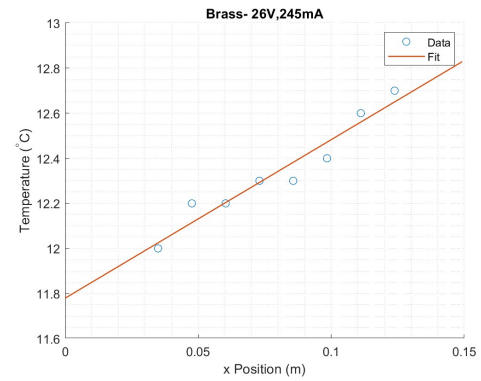
From the provided plots we are able to see that brass had the smallest error between analytical versus experimental steady-state slopes. Steel had the largest error between analytical and experimental and aluminum was in between the other two materials. The difference in error between materials is partly due to thermal conductivity. Steel has the lowest thermal conductivity, so while the inside is heated, the outside does not reach the same temperature. However, our analytical model assumes a 1-D bar with uniform temperature distribution. This results in the experimental data measuring lower temperatures than the analytical model, resulting in smaller steady-state slopes. This explains why the analytical steady-state slopes for steel and aluminum are greater than their experimental counterparts. For brass, the steady-state slopes are very similar, which is due to its higher thermal conductivity. However, there is a discrepancy in our results for brass and aluminum. Generally, higher thermal conductivity, like aluminum, should result in a smaller error between analytical and experimental steady-state slopes, but this was not the case. This discrepancy comes from the interaction between the aluminum and the insulation on the thermocouple, making the temperature measurements for aluminum less accurate.

2 Task 2

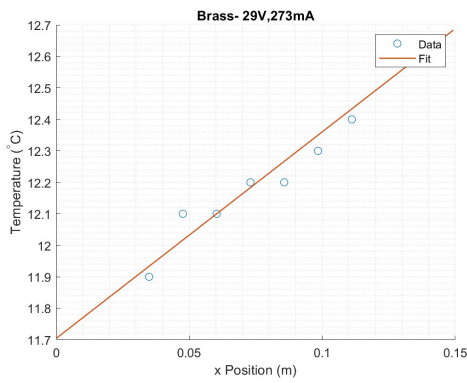
Material	$M_{exp} \left[\frac{^{\circ}\text{C}}{\text{m}} \right]$
Steel 21V,192mA	35.2
Brass 26V,245mA	7.0
Brass 29V,273mA	6.6
Aluminum 26V,250mA	-3.4
Aluminum 28V,269mA	0.3



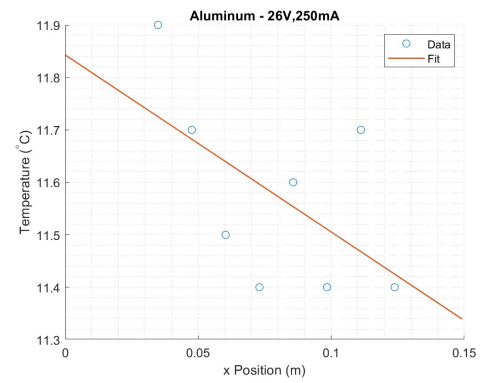
(a) Steel



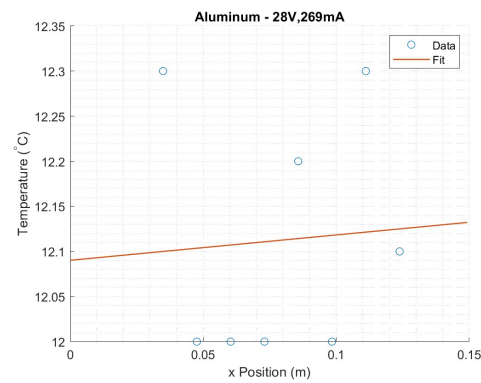
(b) Brass at 26V



(c) Brass at 29V



(d) Aluminum at 26V



(e) Aluminum at 28V

Figure 2: Temperature Vs. Position at T_0 for Different Materials at Different Voltages and Currents

2.1 Discussion

If the initial temperature in the entire rod was constant for each respective data set, we would expect to see the slope, M_{exp} , to be zero as there would be no variation in temperature with changes in position. The assumption that the initial temperature of the entire rod was constant for each data set is valid. The slope, M_{exp} , is the variation in the initial temperature of the rod with respect to the length of the rod. For aluminum and brass, we see slopes with magnitudes of 0 to 7 $^{\circ}C/m$. If we take into account the accuracy of the thermocouples to be within 2 $^{\circ}C$, the slopes are relatively close to zero. We can then conclude that the temperature was constant throughout the bar for aluminum and brass. The slope for steel was higher than that of brass and aluminum at 35 $^{\circ}C/m$. As deduced in Task 1, we believe this larger discrepancy is not solely due to the accuracy of the thermocouples but also due to steel having the lowest thermal conductivity. This would cause a larger amount of time for the entire bar to reach a constant temperature throughout. So while the brass and aluminum might have reached the same initial temperature throughout the bar, the steel might not have reached a constant temperature.

3 Appendix

3.1 Code

```
1 close all; clear; clc;
2
3 %Storing Data
4 al1 = readmatrix("Aluminum_26V_250mA.txt");
5 al2 = readmatrix("Aluminum_28V_269mA.txt");
6 br1 = readmatrix("Brass_26V_245mA.txt");
7 br2 = readmatrix("Brass_29V_273mA.txt");
8 st1 = readmatrix("Steel_21V_192mA.txt");
9
10 %% Properties:
11 % Thermocouple locations
12 dx = 0.0127; %m
13 x0 = 0.034925;
14 xpos = x0:dx:x0 + 0.1016 - dx;
15
16 % Conductivity
17 k_al = 130;
18 k_br = 115;
19 k_st = 16.2;
20
21 % Cross sectional area
22 A = pi*(0.0127)^2;
23
24 % Heat transfer
25 Q_al1 = 26*0.25;
26 Q_al2 = 28*0.269;
27 Q_br1 = 26*0.245;
28 Q_br2 = 29*0.273;
29 Q_st1 = 21*0.192;
30
31 % Steady State slope (analytical)
32 H_al1 = Q_al1/(k_al*A);
33 H_al2 = Q_al2/(k_al*A);
34 H_br1 = Q_br1/(k_br*A);
35 H_br2 = Q_br2/(k_br*A);
36 H_st1 = Q_st1/(k_st*A);
37
38 %% Experimental Data
39 % breaking data into channels
40 % cell row is which thermocouple
41 %preallocation
42 al1_c = cell(8,1);
43 al2_c = cell(8,1);
44 br1_c = cell(8,1);
45 br2_c = cell(8,1);
46 st1_c = cell(8,1);
47 al1_ss_start = zeros(8,1);
48 al2_ss_start = zeros(8,1);
49 br1_ss_start = zeros(8,1);
50 br2_ss_start = zeros(8,1);
51 st1_ss_start = zeros(8,1);
52 al1_ss_end = zeros(8,1);
53 al2_ss_end = zeros(8,1);
54 br1_ss_end = zeros(8,1);
```

```

55 br2_ss_end = zeros(8,1);
56 st1_ss_end = zeros(8,1);
57 al1_t = al1(:,1);
58 al2_t = al2(:,1);
59 br1_t = br1(:,1);
60 br2_t = br2(:,1);
61 st1_t = st1(:,1);
62
63 for i = 1:8
64     % Storing experimental data
65     al1_c{i} = al1(:,i+1);
66     al2_c{i} = al2(:,i+1);
67     br1_c{i} = br1(:,i+1);
68     br2_c{i} = br2(:,i+1);
69     st1_c{i} = st1(:,i+1);
70
71     % Creating initial steady state vector
72     al1_ss_start(i) = al1_c{i}(1);
73     al2_ss_start(i) = al2_c{i}(1);
74     br1_ss_start(i) = br1_c{i}(1);
75     br2_ss_start(i) = br2_c{i}(1);
76     st1_ss_start(i) = st1_c{i}(1);
77
78     % Creating Final Steady State vector
79     al1_ss_end(i) = al1_c{i}(end);
80     al2_ss_end(i) = al2_c{i}(end);
81     br1_ss_end(i) = br1_c{i}(end);
82     br2_ss_end(i) = br2_c{i}(end);
83     st1_ss_end(i) = st1_c{i}(end);
84 end
85
86 %% Plotting the Data
87 figure()
88 hold on
89 for i = 1:8
90     plot(al1_t, al1_c{i})
91 end
92 grid minor
93 xlabel("Time (s)")
94 ylabel('Temperature_1(^{\circ}C)')
95 legend('Channel_1', 'Channel_2', 'Channel_3', 'Channel_4', 'Channel_5', 'Channel_6', 'Channel_7',
96         'Channel_8', 'Location', 'northwest')
97 title("Aluminum - 26V, 250mA")
98
99 figure()
100 hold on
101 for i = 1:8
102     plot(al2_t, al2_c{i})
103 end
104 grid minor
105 xlabel("Time (s)")
106 ylabel('Temperature_2(^{\circ}C)')
107 legend('Channel_1', 'Channel_2', 'Channel_3', 'Channel_4', 'Channel_5', 'Channel_6', 'Channel_7',
108         'Channel_8', 'Location', 'northwest')
109 title("Aluminum - 28V, 269mA")
110
111 figure()
112 hold on

```

```

111 for i = 1:8
112     plot(br1_t,br1_c{i})
113 end
114 grid minor
115 xlabel("Time (s)")
116 ylabel('Temperature_␣(^␣\circ␣C)')
117 legend('Channel_1','Channel_2','Channel_3','Channel_4','Channel_5','Channel_6','Channel_7',
118     'Channel_8','Location','northwest')
119 title("Brass - 26V,245mA")
120
121 figure()
122 hold on
123 for i = 1:8
124     plot(br2_t,br2_c{i})
125 end
126 grid minor
127 xlabel("Time (s)")
128 ylabel('Temperature_␣(^␣\circ␣C)')
129 legend('Channel_1','Channel_2','Channel_3','Channel_4','Channel_5','Channel_6','Channel_7',
130     'Channel_8','Location','northwest')
131 title("Aluminum - 29V,273mA")
132
133 figure()
134 hold on
135 for i = 1:8
136     plot(st1_t,st1_c{i})
137 end
138 grid minor
139 xlabel("Time (s)")
140 ylabel('Temperature_␣(^␣\circ␣C)')
141 legend('Channel_1','Channel_2','Channel_3','Channel_4','Channel_5','Channel_6','Channel_7',
142     'Channel_8','Location','northwest')
143 title("Steel - 21V,192mA")
144
145 %% Creating Linear Fits of Steady States
146
147 % Generating Fits
148 x_query = linspace(0,0.0254+xpos(end),10);
149
150 % Start steady state
151 p1s = polyfit(xpos,al1_ss_start,1);
152 al1_fits = polyval(p1s,x_query);
153 p2s = polyfit(xpos,al2_ss_start,1);
154 al2_fits = polyval(p2s,x_query);
155 p3s = polyfit(xpos,br1_ss_start,1);
156 br1_fits = polyval(p3s,x_query);
157 p4s = polyfit(xpos,br2_ss_start,1);
158 br2_fits = polyval(p4s,x_query);
159 p5s = polyfit(xpos,st1_ss_start,1);
160 st1_fits = polyval(p5s,x_query);
161
162 % End Steady State
163 % 1st Aluminum sample
164 p1e = polyfit(xpos,al1_ss_end,1);
165 al1_fite = polyval(p1e,x_query);
166 al1_T0 = p1e(2);

```



```

166 % Second AL sample
167 p2e = polyfit(xpos,al2_ss_end,1);
168 al2_fite = polyval(p2e,x_query);
169 al2_T0 = p2e(2);
170
171 % 1st Brass sample
172 p3e = polyfit(xpos,br1_ss_end,1);
173 br1_fite = polyval(p3e,x_query);
174 br1_T0 = p3e(2);
175
176 % 2nd Brass Sample
177 p4e = polyfit(xpos,br2_ss_end,1);
178 br2_fite = polyval(p4e,x_query);
179 br2_T0 = p4e(2);
180
181 % Steel Sample
182 p5e = polyfit(xpos,st1_ss_end,1);
183 st1_fite = polyval(p5e,x_query);
184 st1_T0 = p5e(2);
185
186
187 %% Plots of start steady state
188 figure()
189 hold on
190 scatter(xpos,al1_ss_start)
191 plot(x_query,al1_fits,'LineWidth',1)
192 legend("Data","Fit")
193 grid minor
194 xlabel("x Position (m)")
195 ylabel("Temperature (^{\circ}C)")
196 title("Initial Steady State: Aluminum - 26V,250mA")
197
198 figure()
199 hold on
200 scatter(xpos,al2_ss_start)
201 plot(x_query,al2_fits,'LineWidth',1)
202 legend("Data","Fit")
203 grid minor
204 xlabel("x Position (m)")
205 ylabel("Temperature (^{\circ}C)")
206 title("Initial Steady State: Aluminum - 28V,269mA")
207
208 figure()
209 hold on
210 scatter(xpos,br1_ss_start)
211 plot(x_query,br1_fits,'LineWidth',1)
212 legend("Data","Fit")
213 grid minor
214 xlabel("x Position (m)")
215 ylabel("Temperature (^{\circ}C)")
216 title("Initial Steady State: Brass- 26V,245mA")
217
218 figure()
219 hold on
220 scatter(xpos,br2_ss_start)
221 plot(x_query,br2_fits,'LineWidth',1)
222 legend("Data","Fit")
223 grid minor

```

```

224 xlabel("x Position (m)")
225 ylabel("Temperature (^{\circ}C)")
226 title("Initial Steady State: Brass- 29V,273mA")
227
228
229 figure()
230 hold on
231 scatter(xpos,st1_ss_start)
232 plot(x_query,st1_fits,'LineWidth',1)
233 legend("Data","Fit")
234 grid minor
235 xlabel("x Position (m)")
236 ylabel("Temperature (^{\circ}C)")
237 title("Initial Steady State: Steel- 21V,192mA")
238
239
240 %% Plots of end steady state
241
242 % Calculating analytical solution
243 al1e_an = al1_T0 + H_al1.*x_query;
244 al2e_an = al2_T0 + H_al2.*x_query;
245 br1e_an = br1_T0 + H_br1.*x_query;
246 br2e_an = br2_T0 + H_br2.*x_query;
247 st1e_an = st1_T0 + H_st1.*x_query;
248
249
250 figure()
251 hold on
252 scatter(xpos,al1_ss_end)
253 plot(x_query,al1_fite,'LineWidth',1)
254 plot(x_query,al1e_an,'LineWidth',1)
255 legend("Data","Fit","Analytical")
256 grid minor
257 xlabel("x Position (m)")
258 ylabel("Temperature (^{\circ}C)")
259 title("Final Steady State: Aluminum - 26V,250mA")
260
261 figure()
262 hold on
263 scatter(xpos,al2_ss_end)
264 plot(x_query,al2_fite,'LineWidth',1)
265 plot(x_query,al2e_an,'LineWidth',1)
266 legend("Data","Fit","Analytical")
267 grid minor
268 xlabel("x Position (m)")
269 ylabel("Temperature (^{\circ}C)")
270 title("Final Steady State: Aluminum - 28V,269mA")
271
272 figure()
273 hold on
274 scatter(xpos,br1_ss_end)
275 plot(x_query,br1_fite,'LineWidth',1)
276 plot(x_query,br1e_an,'LineWidth',1)
277 legend("Data","Fit","Analytical")
278 grid minor
279 xlabel("x Position (m)")
280 ylabel("Temperature (^{\circ}C)")
281 title("Final Steady State: Brass- 26V,245mA")

```

```

282 figure()
283 hold on
284 scatter(xpos,br2_ss_end)
285 plot(x_query,br2_fite,'LineWidth',1)
286 plot(x_query,br2e_an,'LineWidth',1)
287 legend("Data","Fit","Analytical")
288 grid minor
289 xlabel("x Position (m)")
290 ylabel("Temperature (^{\circ}C)")
291 title("Final Steady State: Brass- 29V,273mA")
292
293
294
295 figure()
296 hold on
297 scatter(xpos,st1_ss_end)
298 plot(x_query,st1_fite,'LineWidth',1)
299 plot(x_query,st1e_an,'LineWidth',1)
300 legend("Data","Fit","Analytical")
301 grid minor
302 xlabel("x Position (m)")
303 ylabel("Temperature (^{\circ}C)")
304 title("Final Steady State: Steel- 21V,192mA")

```