Lab 2 Part 1
Feburary 2025

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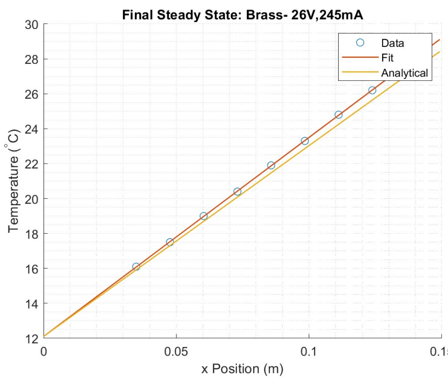
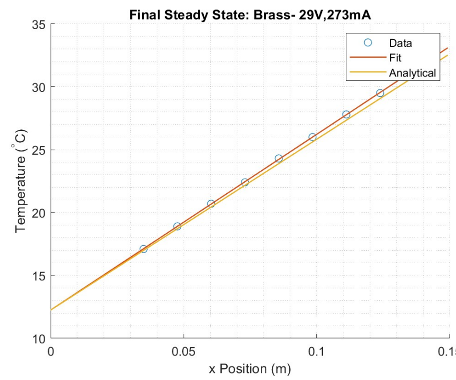
1 Task 1

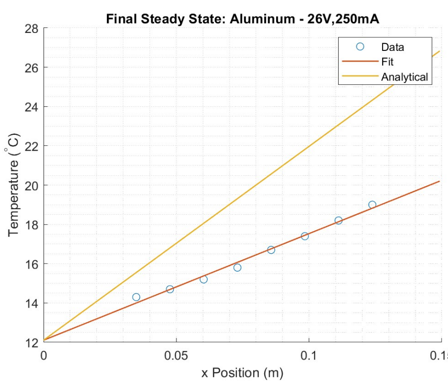
Material	T_0 [°C]	H_{exp} $[\frac{°C}{m}]$	H_{an} $[\frac{°C}{m}]$
Steel 21V,192mA	11	277.0	491.2
Brass 26V,245mA	12	114.0	109.3
Brass 29V,273mA	12	139.8	135.9
Aluminum 26V,250mA	12	54.3	98.6
Aluminum 28V,269mA	12	66.8	114.3



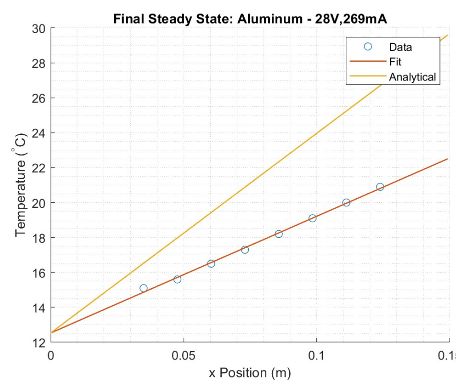
(a) Brass at 26V



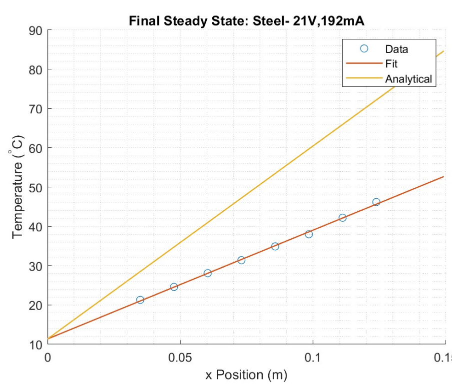
(b) Brass at 29V



(c) Aluminum at 26V



(d) Aluminum at 28V



(e) Steel

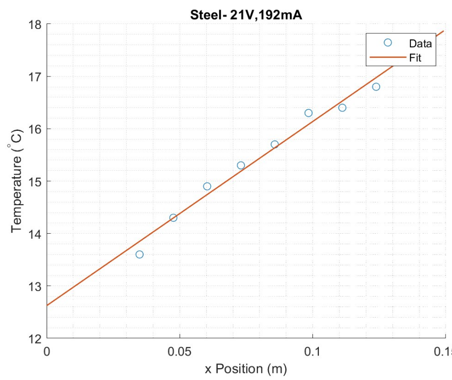
Figure 1: Steady State Temperature Vs. Position for Different Materials At Different Voltages and Currents

1.1 Discussion

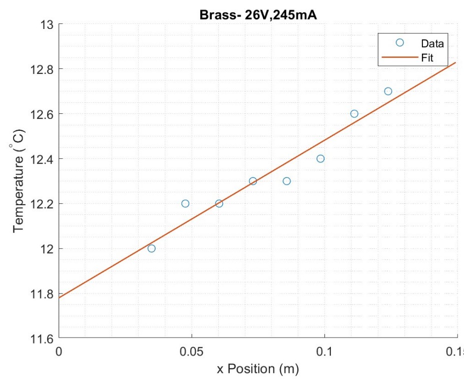
From the provided plots we are able to see that brass had the smallest error between analytical versus experimental steady-state slopes. Steel had the largest error between analytical and experimental and aluminum was in between the other two materials. The difference in error between materials is partly 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

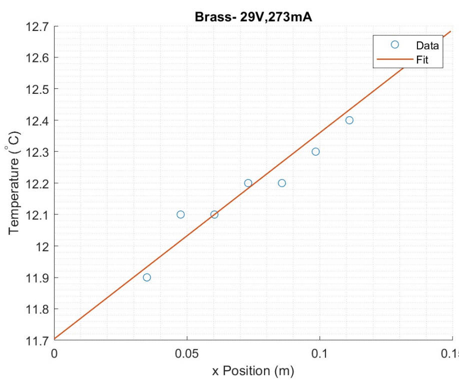
Material	M_{exp} $[\frac{^\circ C}{m}]$
Steel 21V,192mA	35.2
Brass 26V,245mA	7.0
Brass 29V,273mA	6.6
Aluminum 26V,250mA	-3.4
Aluminum 28V,269mA	0.3



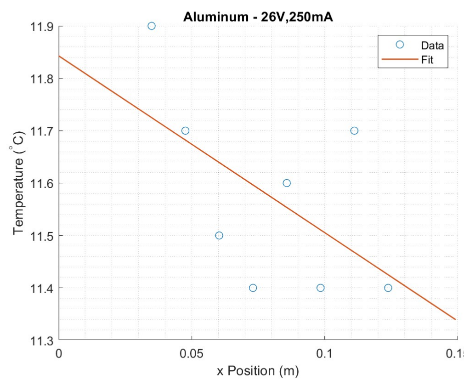
(a) Steel



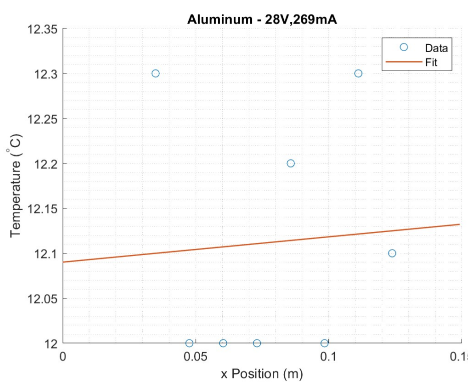
(b) Brass at 26V



(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 $°C/m$. If we take into account the accuracy of the thermocouples to be within $2°C$, 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 $°C/m$. 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

```
close all; clear; clc;

%Storing Data
al1 = readmatrix("Aluminum_26V_250mA.txt");
al2 = readmatrix("Aluminum_28V_269mA.txt");
br1 = readmatrix("Brass_26V_245mA.txt");
br2 = readmatrix("Brass_29V_273mA.txt");
st1 = readmatrix("Steel_21V_192mA.txt");

%% Properties:
% Thermocouple locations
dx = 0.0127; %m
x0 = 0.034925;
xpos = x0:dx:x0 + 0.1016 - dx;

% Conductivity
k_al = 130;
k_br = 115;
k_st = 16.2;

% Cross secitonal area
A = pi*(0.0127)^2;

% Heat transfer
Q_al1 = 26*0.25;
Q_al2 = 28*0.269;
Q_br1 = 26*0.245;
Q_br2 = 29*0.273;
Q_st1 = 21*0.192;

% Steady State slope (analytical)
H_al1 = Q_al1/(k_al*A);
H_al2 = Q_al2/(k_al*A);
H_br1 = Q_br1/(k_br*A);
H_br2 = Q_br2/(k_br*A);
H_st1 = Q_st1/(k_st*A);

%% Experimental Data
% breaking data into channels
% cell row is which thermocouple
%prealocation
al1_c = cell(8,1);
al2_c = cell(8,1);
br1_c = cell(8,1);
br2_c = cell(8,1);
st1_c = cell(8,1);
al1_ss_start = zeros(8,1);
al2_ss_start = zeros(8,1);
br1_ss_start = zeros(8,1);
br2_ss_start = zeros(8,1);
st1_ss_start = zeros(8,1);
al1_ss_end = zeros(8,1);
al2_ss_end = zeros(8,1);
br1_ss_end = zeros(8,1);
```

```
br2_ss_end = zeros(8,1);
st1_ss_end = zeros(8,1);
al1_t = al1(:,1);
al2_t = al2(:,1);
br1_t = br1(:,1);
br2_t = br2(:,1);
st1_t = st1(:,1);

for i = 1:8
    % Storing experimental data
    al1_c{i} = al1(:,i+1);
    al2_c{i} = al2(:,i+1);
    br1_c{i} = br1(:,i+1);
    br2_c{i} = br2(:,i+1);
    st1_c{i} = st1(:,i+1);

    % Creating initial steady state vector
    al1_ss_start(i) = al1_c{i}(1);
    al2_ss_start(i) = al2_c{i}(1);
    br1_ss_start(i) = br1_c{i}(1);
    br2_ss_start(i) = br2_c{i}(1);
    st1_ss_start(i) = st1_c{i}(1);

    % Creating Final Steady State vector
    al1_ss_end(i) = al1_c{i}(end);
    al2_ss_end(i) = al2_c{i}(end);
    br1_ss_end(i) = br1_c{i}(end);
    br2_ss_end(i) = br2_c{i}(end);
    st1_ss_end(i) = st1_c{i}(end);
end

%% Plotting the Data
figure()
hold on
for i = 1:8
    plot(al1_t,al1_c{i})
end
grid minor
xlabel("Time (s)")
ylabel('Temperature (^\circ C)')
legend('Channel 1','Channel 2','Channel 3','Channel 4','Channel 5','Channel 6','Channel 7'
    ,'Channel 8','Location','northwest')
title("Aluminum - 26V,250mA")

figure()
hold on
for i = 1:8
    plot(al2_t,al2_c{i})
end
grid minor
xlabel("Time (s)")
ylabel('Temperature (^\circ C)')
legend('Channel 1','Channel 2','Channel 3','Channel 4','Channel 5','Channel 6','Channel 7'
    ,'Channel 8','Location','northwest')
title("Aluminum - 28V,269mA")

figure()
hold on
```

```
for i = 1:8
    plot(br1_t,br1_c{i})
end
grid minor
xlabel("Time (s)")
ylabel('Temperature␣(^\circ␣C)')
legend('Channel␣1','Channel␣2','Channel␣3','Channel␣4','Channel␣5','Channel␣6','Channel␣7','Channel␣8','Location','northwest')
title("Brass - 26V,245mA")

figure()
hold on
for i = 1:8
    plot(br2_t,br2_c{i})
end
grid minor
xlabel("Time (s)")
ylabel('Temperature␣(^\circ␣C)')
legend('Channel␣1','Channel␣2','Channel␣3','Channel␣4','Channel␣5','Channel␣6','Channel␣7','Channel␣8','Location','northwest')
title("Aluminum - 29V,273mA")

figure()
hold on
for i = 1:8
    plot(st1_t,st1_c{i})
end
grid minor
xlabel("Time (s)")
ylabel('Temperature␣(^\circ␣C)')
legend('Channel␣1','Channel␣2','Channel␣3','Channel␣4','Channel␣5','Channel␣6','Channel␣7','Channel␣8','Location','northwest')
title("Steel - 21V,192mA")


%% Creating Linear Fits of Steady States

% Generating Fits
x_query = linspace(0,0.0254+xpos(end),10);

% Start steady state
p1s = polyfit(xpos,al1_ss_start,1);
al1_fits = polyval(p1s,x_query);
p2s = polyfit(xpos,al2_ss_start,1);
al2_fits = polyval(p2s,x_query);
p3s = polyfit(xpos,br1_ss_start,1);
br1_fits = polyval(p3s,x_query);
p4s = polyfit(xpos,br2_ss_start,1);
br2_fits = polyval(p4s,x_query);
p5s = polyfit(xpos,st1_ss_start,1);
st1_fits = polyval(p5s,x_query);

% End Steady State
% 1st Aluminum sample
p1e = polyfit(xpos,al1_ss_end,1);
al1_fite = polyval(p1e,x_query);
al1_T0 = p1e(2);

```

```
% Second AL sample
p2e = polyfit(xpos,al2_ss_end,1);
al2_fite = polyval(p2e,x_query);
al2_T0 = p2e(2);

% 1st Brass sample
p3e = polyfit(xpos,br1_ss_end,1);
br1_fite = polyval(p3e,x_query);
br1_T0 = p3e(2);

% 2nd Brass Sample
p4e = polyfit(xpos,br2_ss_end,1);
br2_fite = polyval(p4e,x_query);
br2_T0 = p4e(2);

% Steel Sample
p5e = polyfit(xpos,st1_ss_end,1);
st1_fite = polyval(p5e,x_query);
st1_T0 = p5e(2);


%% Plots of start steady state
figure()
hold on
scatter(xpos,al1_ss_start)
plot(x_query,al1_fits,'LineWidth',1)
legend("Data","Fit")
grid minor
xlabel("x Position (m)")
ylabel("Temperature (^\circC)")
title("Initial Steady State: Aluminum - 26V,250mA")

figure()
hold on
scatter(xpos,al2_ss_start)
plot(x_query,al2_fits,'LineWidth',1)
legend("Data","Fit")
grid minor
xlabel("x Position (m)")
ylabel("Temperature (^\circC)")
title("Initial Steady State: Aluminum - 28V,269mA")

figure()
hold on
scatter(xpos,br1_ss_start)
plot(x_query,br1_fits,'LineWidth',1)
legend("Data","Fit")
grid minor
xlabel("x Position (m)")
ylabel("Temperature (^\circC)")
title("Initial Steady State: Brass- 26V,245mA")

figure()
hold on
scatter(xpos,br2_ss_start)
plot(x_query,br2_fits,'LineWidth',1)
legend("Data","Fit")
grid minor
```

```
xlabel("x Position (m)")
ylabel("Temperature (^\circC)")
title("Initial Steady State: Brass- 29V,273mA")


figure()
hold on
scatter(xpos,st1_ss_start)
plot(x_query,st1_fits,'LineWidth',1)
legend("Data","Fit")
grid minor
xlabel("x Position (m)")
ylabel("Temperature (^\circC)")
title("Initial Steady State: Steel- 21V,192mA")


%% Plots of end steady state

% Calculating analytical solution
al1e_an = al1_T0 + H_al1.*x_query;
al2e_an = al2_T0 + H_al2.*x_query;
br1e_an = br1_T0 + H_br1.*x_query;
br2e_an = br2_T0 + H_br2.*x_query;
st1e_an = st1_T0 + H_st1.*x_query;


figure()
hold on
scatter(xpos,al1_ss_end)
plot(x_query,al1_fite,'LineWidth',1)
plot(x_query,al1e_an,'LineWidth',1)
legend("Data","Fit","Analytical")
grid minor
xlabel("x Position (m)")
ylabel("Temperature (^\circC)")
title("Final Steady State: Aluminum - 26V,250mA")

figure()
hold on
scatter(xpos,al2_ss_end)
plot(x_query,al2_fite,'LineWidth',1)
plot(x_query,al2e_an,'LineWidth',1)
legend("Data","Fit","Analytical")
grid minor
xlabel("x Position (m)")
ylabel("Temperature (^\circC)")
title("Final Steady State: Aluminum - 28V,269mA")

figure()
hold on
scatter(xpos,br1_ss_end)
plot(x_query,br1_fite,'LineWidth',1)
plot(x_query,br1e_an,'LineWidth',1)
legend("Data","Fit","Analytical")
grid minor
xlabel("x Position (m)")
ylabel("Temperature (^\circC)")
title("Final Steady State: Brass- 26V,245mA")
```

```

figure()
hold on
scatter(xpos,br2_ss_end)
plot(x_query,br2_fite,'LineWidth',1)
plot(x_query,br2e_an,'LineWidth',1)
legend("Data","Fit","Analytical")
grid minor
xlabel("x Position (m)")
ylabel("Temperature (^\circC)")
title("Final Steady State: Brass- 29V,273mA")


figure()
hold on
scatter(xpos,st1_ss_end)
plot(x_query,st1_fite,'LineWidth',1)
plot(x_query,st1e_an,'LineWidth',1)
legend("Data","Fit","Analytical")
grid minor
xlabel("x Position (m)")
ylabel("Temperature (^\circC)")
title("Final Steady State: Steel- 21V,192mA")
```