



PHYS 229 - Ryan Kaufmann/Experiment 3/Cooling Lab

SIGNED by Ryan Kaufmann Apr 10, 2018 @02:40 PM PDT

Ryan Kaufmann Apr 09, 2018 @08:37 PM PDT

Cooling 1 - Comparison to Convection

Ryan Kaufmann Apr 09, 2018 @05:42 PM PDT

In the first section of this lab, we took data from the cooling of the rods. After placing the rods in boiling water and rising the temperature of each up to approximately 90 degrees Celsius, we placed the rods on a stand and let them cool down to 30 degrees Celsius. A thermometer was inserted in the top of each rod into a pre-cut hole to measure the temperature as it cooled. Measurements of the temperature of the rod were taken every 2 minutes, but were extended to 5 minutes when the rod wasn't cooling fast enough, or rather when the change in temperature was less than 1 degree. This continued until the rod reached 30 degrees Celsius. We got the following data sets:

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```
#Time  Temp  TempError  TempError
0 90 90 0.1
2 79 80 0.1
4 75 76 0.1
6 70 71 0.1
8 66 67 0.1
10 60 61 0.1
12 55 56 0.1
14 50 51 0.1
16 45 46 0.1
18 40 41 0.1
20 35 36 0.1
22 30 31 0.1
24 25 26 0.1
26 20 21 0.1
28 15 16 0.1
30 10 11 0.1
32 5 6 0.1
34 0 1 0.1
36 0 1 0.1
38 0 1 0.1
40 0 1 0.1
42 0 1 0.1
44 0 1 0.1
46 0 1 0.1
48 0 1 0.1
50 0 1 0.1
```

DataSet1.txt(364 Bytes)

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```
#Time #Smooth #LogPeriod #Height #Uncertainty
0 70 80.5 80 0.1
2 70 79 0.1
4 72 79 74 0.1
6 68 64 69 0.1
8 64 69 64 0.1
10 61 56 58 0.1
12 58 52 56 0.1
14 55 49.5 53 0.1
16 52 46.5 50.5 0.1
18 49.5 44 48 0.1
20 47 41.5 45.5 0.1
22 46 48 45.5 0.1
24 44 39 41 0.1
26 42 36 40 0.1
28 40 34 38 0.1
30 38.5 33 36.5 0.1
32 37 31.5 35 0.1
34 36 28.5 34 0.1
36 35 29.5 32 0.1
38 32.5 28.5 31.5 0.1
40 30 26 30.5 0.1
42 31.7 27.7 29.9 0.1
44 28 27.5 28.4 0.1
46 30 27.3 29.9 0.1
```

DataSet2.txt(519 Bytes)

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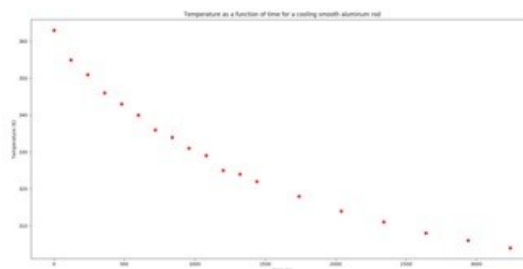
```
#Time #Smooth #LogPeriod #Height #Uncertainty
0 61.0 70.5 80.1 0.1
2 77.0 71.0 75.3 0.1
4 72.0 67.0 71.3 0.1
6 70.7 62.0 67.1 0.1
8 67.4 55.0 62.0 0.1
10 64.3 54.7 59.2 0.1
12 61.4 51.1 55.0 0.1
14 59.0 49.2 52.9 0.1
16 56.0 45.7 50.3 0.1
18 52.0 42.0 47.0 0.1
20 51.5 40.9 45.0 0.1
22 48.9 39.7 40.9 0.1
24 42.9 33.2 36.9 0.1
26 36.9 29.2 31.9 0.1
28 32.2 25.8 27.0 0.1
30 29.4 24.0 25.3 0.1
```

DataSet3.txt(407 Bytes)

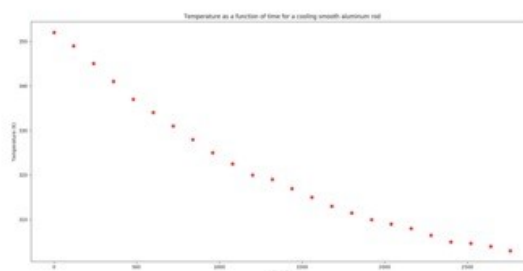
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When can then plot each of the data sets separately and compare them all, eventually with the convection equation we derived in the prelab. For the smooth rods, we get the following data plots:

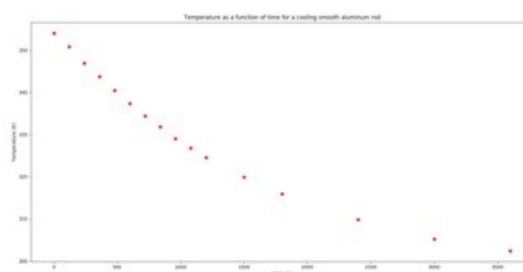
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**SmoothSet1.png(32 KB)**

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**SmoothSet2.png(31.6 KB)**

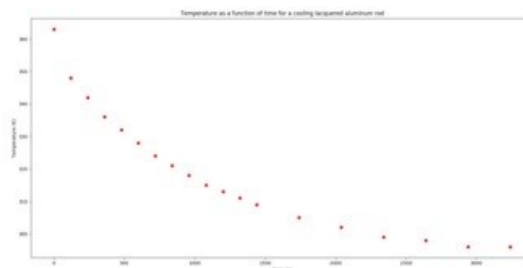
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**SmoothSet3.png(31.4 KB)**

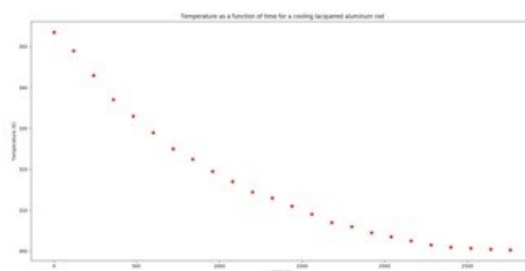
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And equally for the lacquered rods:

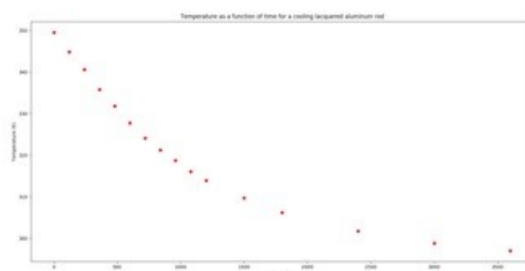
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**LacqueredSet1.png(33.3 KB)**

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**LacqueredSet2.png(33 KB)**

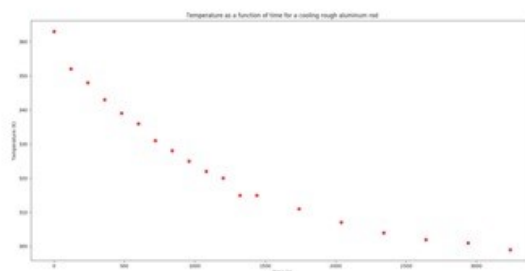
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**LacqueredSet3.png(32.2 KB)**

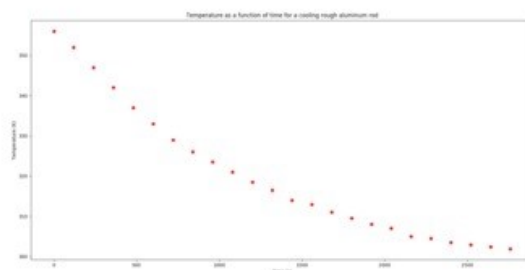
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And rough rods:

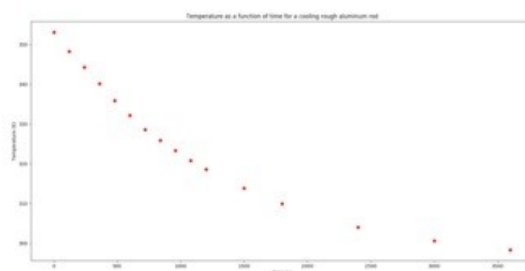
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**RoughSet1.png(32.4 KB)**

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**RoughSet2.png(32.3 KB)**

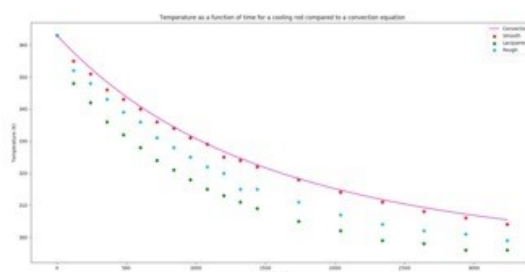
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**RoughSet3.png(31.2 KB)**

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We can also see them compared to the convective heat loss equation. Comparing all three of these data sets to the convection equation (setting the maximum at 90 degrees Celsius) we derived gives us the following graphs:

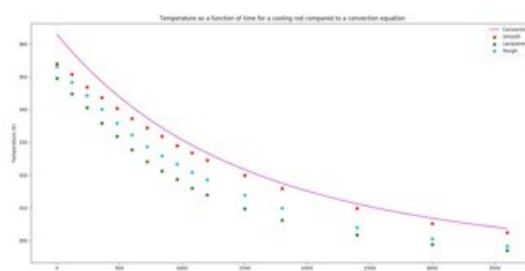
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**AllSet1.png(68.2 KB)**

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**AllSet2.png(71.8 KB)**

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**AllSet3.png(68.1 KB)**

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We can see that there is some comparable form between the convection curves and the curve in the data sets, but this curve cannot be adjusted for anything except for the starting temperature. Instead, let us look at the radiation equation using numerical integration.

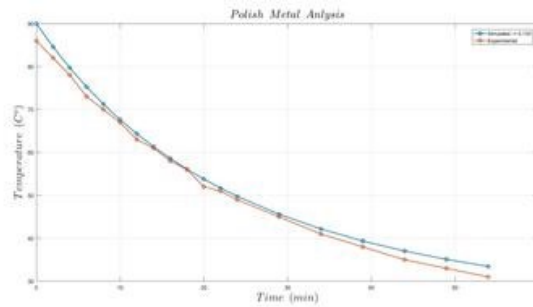
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Cooling Process 2 - Radiation Equation

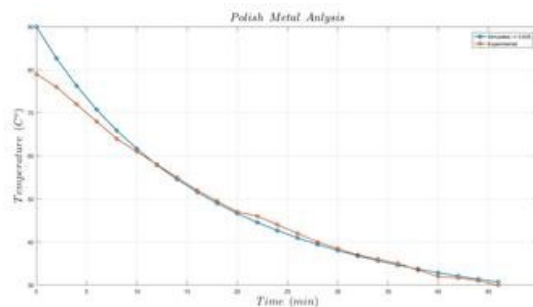
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We can see that the convection equation doesn't quite work out, so we can also try to add radiation into the equation. When we do so we get more interesting results. Since the equation for radiation requires one more variable which we cannot measure directly, we can adjust our equation such that we find this variable. We are looking at the emissivity of the rod. The emissivity of the rod depends on various properties such as the roughness of the surface or the coating on the rod. We can use matlab codes to set up differential equations and numerically solve them until we get reasonable values for emissivity. We get the following graphs for the smooth rod:

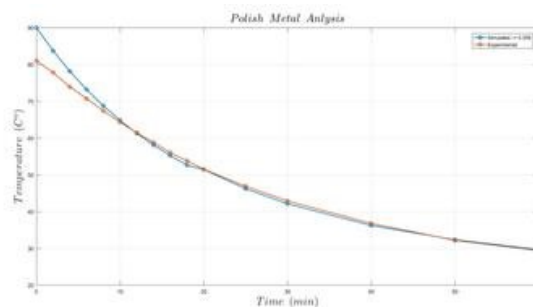
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**SmoothSet1Radiation.jpg(81.2 KB)**

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**SmoothSet2Radiation.jpg(84.5 KB)**

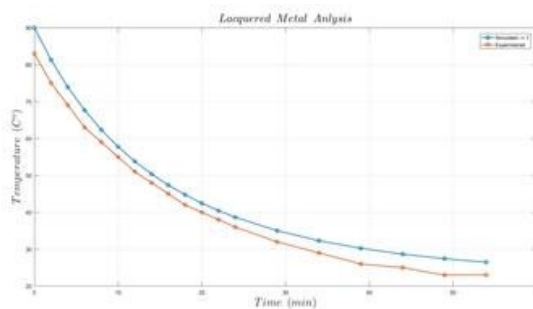
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**SmoothSet3Radiation.jpg(80.1 KB)**

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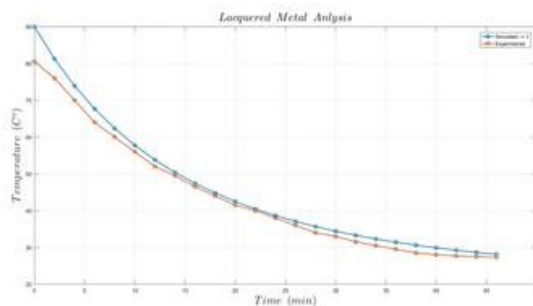
and the lacquered:

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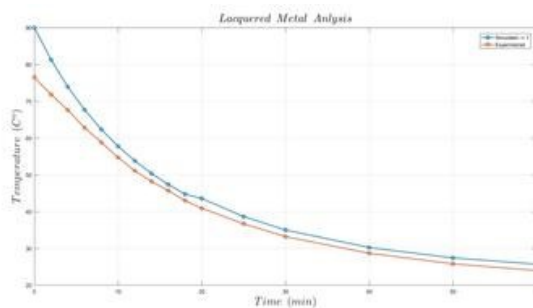
LacqueredSet1Radiation.jpg(84.5 KB)

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LacqueredSet2Radiation.jpg(87.9 KB)

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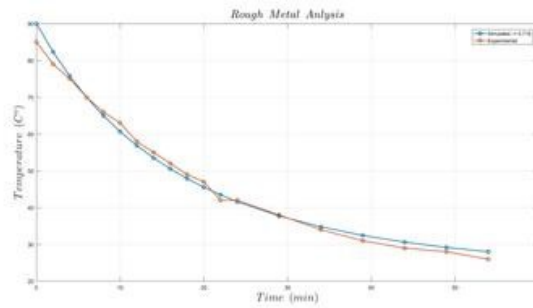


LacqueredSet3Radiation.jpg(84.2 KB)

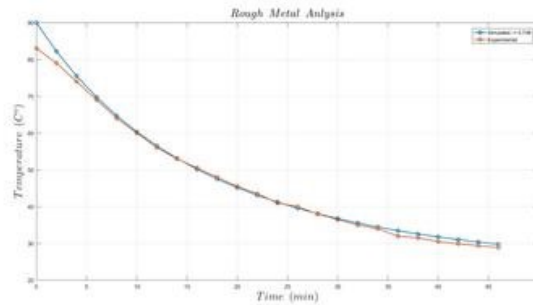
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and rough rods:

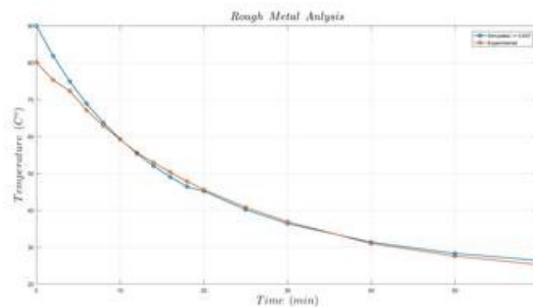
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**RoughSet1Radiation.jpg(81.6 KB)**

Ryan Kaufmann Apr 10, 2018 @02:23 PM PDT

**RoughSet2Radiation.jpg(84.5 KB)**

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**RoughSet3Radiation.jpg(80.5 KB)**

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All of these data sets give slightly different values for emissivity which we can average to find the closest approximate value of emissivity. Between all three sets, the order of the highest to lowest emissivity is maintained so that we have a general idea of this order. From the fitting, we get the following values of emissivity:

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$$\epsilon_{s1} = 0.1330$$

$$\epsilon_{s2} = 0.6250$$

$$\epsilon_{s3} = 0.3550$$

$$\epsilon_{l1} = 1$$

$$\epsilon_{l2} = 1$$

$$\epsilon_{l3} = 1$$

$$\epsilon_{r1} = 0.7150$$

$$\epsilon_{r2} = 0.7480$$

$$\epsilon_{r3} = 0.8470$$

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We can then average these values to see the approximate emissivity of each of the type of rods. We notice a particularly large spread in the emissivity of the smooth rod which we believe is simply a property of the smooth rod and the other conditions of the room. We get the following averages:

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$$\epsilon_s = 0.3710$$

$$\epsilon_l = 1$$

$$\epsilon_r = 0.7700$$

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As we can see from the graphs as well, the fitted functions generally hold the shape of the data points as well compared to the convection equations, suggesting that the convection along with the radiation equation is the most accurate of the two methods for analyze the cooling of the rods, although it may require numerical solutions.

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Cooling Process 3 - Conclusion

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This lab delved deep into using methods of differential equations to analyze physical properties of objects, namely a cooling rod. We see from the data that when we take into account the radiation of the object, we get a much better fit for the data than simply looking at the convection equation. While in this case only two types of cooling were considered, we can conclude that one is better than the other from our graphs. Although this answer isn't completely sure, as it doesn't take into account any residuals or chi-squares but simply the shape of the graph, which in some cases is not the best comparison, such as the lacquered rod. However, it does give some evidence that one method is better at analyzing than the other. Furthermore, we could make approximation about physical quantities of the object, such as emissivity. In this case, while it is not a fantastic method of measuring such a quantity, it gives us ballpark estimates of each of the rod, but more importantly the order from highest emissivity to lowest emissivity. Finally this lab shows, that while the physics or mathematics of a particular phenomenon might not be known, by recreating the process we can make some approximation as to how certain things can be order or an approximation of the values that are needed to make equations work.