**Density Heat Leak**

**Purpose**: In order to have an enjoyable and cost effective drinking experience, we need to determine which cup wall density keeps water at a desired temperature for the least dollar amount.

**Question:** Do plastic cups, produced on a 3D printer with the same design and size but different densities, vary in temperature retention?

**Hypothesis:** Over a time period of 10 minutes, a cup with a thicker wall (higher density) will maintain a liquid’s temperature closer to its initial temperature than a thinner walled (lower density) cup.

**Materials:**

**-**Da Vinci Jr 3D printer

- 3 cups printed with same volume (249.3 cm3) but different fill densities.

Red- 10% White-30% Blue- 50%

-Triple beam balance

-Graduated cylinder (100 ml)

- 3 Pasco wireless temperature probes

-Water (tap)

-Microwave to heat water

-Computer with Sparkvue to record data

-Container to heat 300 ml of water

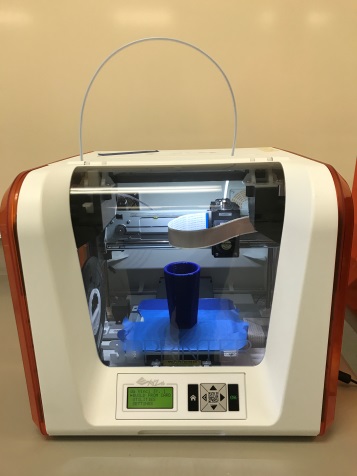
**Procedure**

1. All 3 cups were printed on the 3D printer. All were printed with identical dimensions but the fill densities and color. Then their masses were measured using a triple beam balance and all measurements were recorded in the table below.

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| **Cup** | **Fill Density** | **Mass (g)** | **Total Volume\* (mL)** | **Density (g/mL)** |
| **Blue** | **50%** | **69.2** | **249.3** | **0.278** |
| **White** | **30%** | **56.15** | **249.3** | **0.225** |
| **Red** | **10%** | **40.3** | **249.3** | **0.162** |

\*The external volume according to the printing program was 377.3 cm3 for each cup. Each cup’s internal volume was measured at 128 ml (cm3) using a graduated cylinder. The cups’ total volume = external volume – internal volume (377.3 – 128 = 249.3 ml/cm3).

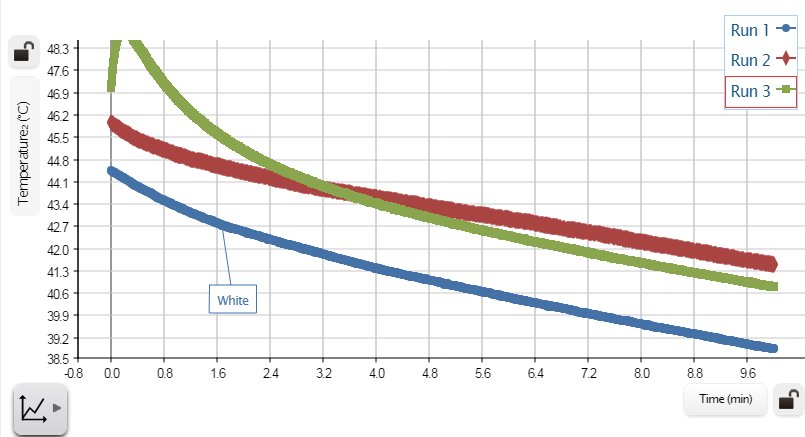
1. 300 ml water was heated using a microwave in a microwave safe container for 1 minute. 100 ml of heated water was poured in each cup.
2. A Pasco temperature probe and Sparkvue software were placed into each cup. The initial temperature was recorded and then monitored for 10 minutes. The temperature data was recorded in graphs (see results).
3. Repeat steps 2– 3 two more times.
4. Complete a cost benefit analysis to determine if the more dense cups are worth the extra materials and cost involved in producing them.

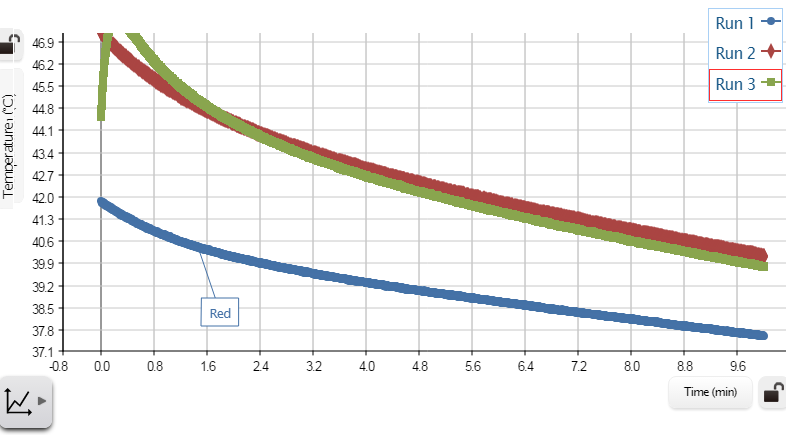
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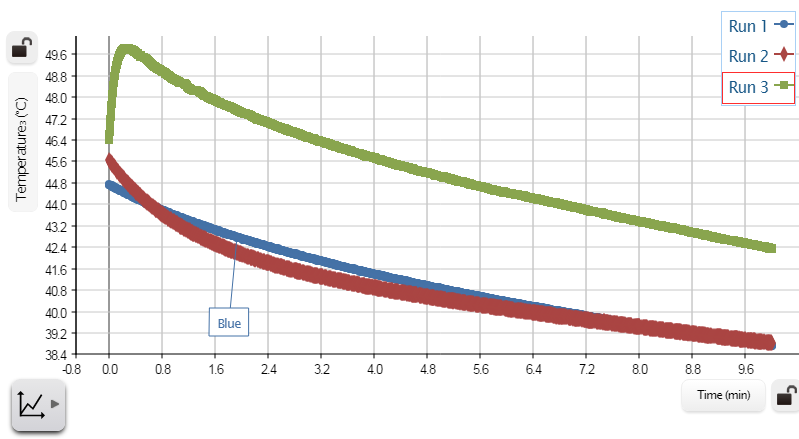
**Results**

The experiment was run 3 times, but in one of the experiments the results did not conform to the data in the other 2 runs. In this run, a probe may have been incorrectly designated for the cup it was in. Because there is no way to check which probe is which once data is being collected, the cause cannot be ascertained. Each probe in this run had an outlier which we decided to omit from our analysis. All 3 cups started at a temperature around 45-46 0C. The readings are as follows for the 2 data sets we used.

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**Conclusion**

After examining our data it seems the data does indicate the denser blue cup loses heat at a slower rate than the other 2 and the medium density white cup is slower than the least dense red cup. However it is our opinion that the temperature difference is not significant enough to warrant the use of the extra filament used in its production nor the time difference to produce the denser blue cup.