**Abstract:**

We examine the basic fundamentals of water in a bathtub and develop a mathematical model to simulate the temperature behavior of the system. Our model of the water is based primarily on two fundamental formulas of physics, the heat equation and the equation for rate of heat transfer. We also developed a model of the human body in the bathtub to account for its effect on the system’s temperature. From that simulation, we constructed a way to introduce and remove water from the system constantly and see how it would impact those results. Using this, we found several potential solutions that take into account reasonable temperature input and water conversion to most properly maintain the temperature of the bathtub.

**Basic Concept:**

We need some way to account for the way the water temperature in the bathtub will distribute over time. We do this through the use of the heat equation,

In the ideal scenario for this problem, this distribution over time would result in equal (or relatively equal) temperatures across the bathtub. The thermal capacity, thermal conductivity, and the density of the water are all dependent on the temperature of the water. These values are given by:

,respectively. The walls of the bathtub must also be accounted for. The relationship of the bathtub walls to the surrounding air temperature is given by the equation:

This yields the loss in temperature of the walls due to the outside surroundings and, in doing so, give us an eventual loss in bathtub water temperature.

The air also would result in heat loss for the water in the bathtub, assuming the temperature of the air is the less than that of the water. This can be modeled by the heat transfer rate equation:

This eventually yields a small temperature loss over time.

**The Model:**

**In Steps**

1. Model diffusion of water using heat equation amongst itself using sources
2. Model diffusion of water to bathtub walls
3. Model heat transfer rate from air to bathtub walls
4. Model air convection transfer to water
5. Model human effect on temperature of selected cells

The first step to actually modeling the problem is to model the bathtub itself. The bathtub was broken into various cells of equal length/width/height, and all assigned an initial temperature of 30 degrees Celsius. The walls of the bathtub were assumed to be cast iron, although the model can easily be altered in order to account for other materials. Thus, the formula for these cells was slightly different, based off the cast iron’s properties rather than that of water. So using formula (1), we were able to model the diffusivity of the water/bathtub walls.

The next step in the process was to

**Assumptions:**

That using a bubble bath additive while initially filling the bathtub would have little to no effect on our results. We believed that the fundamental properties would likely stay the same with the bubble bath additive, and thus did not change anything to reflect that.

The human is in a specific position at specific location.

That the bathtub is roughly rectangular and straight at the edges.

Our model for this problem is continuous, updated every .1 seconds, simulation discrete.

Assumed initial temperature of human was, and initial temperature of bathtub was. These can easily be changed.

Assumed motion of human was not a factor, which plays a factor with flow assumption.

Did not take into account flow of water

Bathtub is insulated.

Walls are ambient temperature

That no water is evaporating; the only water leaving the system is through the outflow drain.

Surrounding area is perfect sink

**Strengths**

Model accurately represents the water’s temperature over time with no introduction

Model handles impact of air on temperature

**Weaknesses**

Did not take into account of the flowing motion of the water

**Steps forward**

Decreasing cell size will always increase accuracy of model

Model flow of water and impact of flow on temperature.

Do more with bubble bath additive

Use full body model as found in material.