Animated heat transfer modeling for the average Joe – part #1

-This is an introduction to heat transfer modeling. Up until today I have not had much exposure to the subject except for the basic thermodynamics I had in my first and second trimesters of the 10th grade (high school physics).

-Back in the day while studying electrical engineering in Bucharest I had difficulties with a subject called "The microwave technology". The class was heavy with math, notations and hours of boring derivation to prove even something of small significance.

- With all of this in mind I will try to make the topic as easy and intuitive as possible. Try opening a book on heat or read the page in Wikipedia and you'll probably ruin your day. A 12 year old has the mental power and life experience to understand the base of the heat transfer concepts, or electromagnetic field, or fluid dynamics. That changes in college when our brain gets corrupted with too much vector calculus, Greek alphabet and our confidence in our own reason is forcibly shaken.

<excelunusual.com> by George Lungu

A rant: why sometimes standard teaching spoils your chances of learning?

- The answer is, it spoils motivation and it scares the shy and curious part of our brain who is responsible for creativity.
- I have seen the theory about heat transfer, or EM fields or fluid dynamics and combined with complicated notations and operators I think is perfect for preserving the knowledge or advancing it at high level but not for starting the learning process.

There is always a degree of understanding associated with literal derivation but usually deep understanding comes from thinking the process over and over (and over again), playing, enjoying, experimenting, and going to sleep thinking about it without notations/formulas/operators rather than from just reading/writing/teaching/patenting.

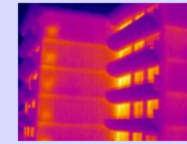
-Beginning the process of learning with letters and derivations I believe is a counterproductive proposition. It is unproductive because it gives you a surrogate of understanding. Secondly, starting with literal derivations kills genuine curiosity and interest (how many students are in the class only with their body – their mind is out). There is a third danger witch comes from the fact that the student, after passing the exam, has the illusion that he or she actually learned the matter.

- I also believe that the early steps in learning are more important than the later ones. Let's launch a rocket to Mars pointing slightly down and see what happens. But if the first few meters are pointed in the right direction the rocket will probably do well for the next 1 billion miles.

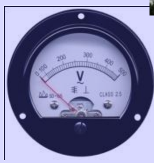
How about some analogies?

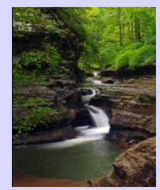
- Most people understand electricity when they finally start thinking about electricity-water analogy.
- The electricity-water analogy connects charge with amount of water, current intensity with water flow, voltage difference with pressure difference, current flow through a resistor with the impeded water flow through a narrow pipe, etc.
- The water-heat analogy will be connecting amount of water with heat, water flow with heat flow, water pressure with temperature, a barrel as a water collector with a body as a heat collector, water resistance or conductance due to pipe characteristics with heat resistance or conductance due to the thermal bonding characteristics.

Electricity: | **Water:** | **Heat:**

1. Electric charge  → 1. Water amount  → 1. Heat amount 

2. Electric current  → 2. Water flow  → 2. Heat flow 

3. Voltage  → 3. Pressure  → 3. Temperature 

4. Resistance  → 4. Water flow resistance  → 4. Heat resistance 

Basic storage principles

- I can briefly enunciate them but it's up to you to keep thinking about them for a while to see if they really make sense. I like to keep it light and casual without being too rigorous as I were to explain them to a 12 year old (IEEIKS = If Everything Else Is Kept the Same):

1. IEEIKS a body stores heat proportional to its mass.
2. IEEIKS a body stores heat in relation to the substance it is made from.
3. IEEIKS the net amount of heat a body exchanges with the environment in a certain time interval is proportional to the net temperature change the same body experiences during that time interval.

Let's see if the heat storage principles make sense

1. A young pretty Aleutian girl, who felt cold in her sleep during all her childhood, is getting married. Online she finds two options: a large man and a skinny man who himself suffered from the same problem in his own childhood. <u>Whom will she choose?</u>
- The problem is not rigorous since the human body is not just a reservoir of heat but a generator too. She is happy because for her the answer is simple, she will marry the bigger guy since he can store (and produce) more heat, unless she is the psycho type who likes to relate with her spouse in misery.

2. Some substances store heat better than others. Hydrogen and also water are known for storing the largest amount of heat per unit weight. Metals are poor at storage but good at conducting heat. This second principle has been proven experimentally so there is not much to think about.

3. The third principle is intuitive too, just try to take a large sip from a cup of water at room temperature (which is just 10 degrees cooler than the body) or from a cup of icy water (which is 37 degrees cooler). Before swallowing, try to measure how long it takes to roughly equalize the temperature of the water in your mouth with the temperature of the body.

Three storage principles in one formula:

$$\boxed{\Delta Q = c \cdot m \cdot \Delta T}$$

The previously mentioned principles are incorporated in the above formula. "ΔQ" is the stored heat variation [Joules], "m" is the mass of the object [Kg], "c" is called specific heat and it's a material specific property [J/Kg*K] and "ΔT" is the temperature variation [K]. I've seen this formula both in middle school and in high school. I've seen it in absolute form or in a differential form (like here). Numerical people can model the moon in the sky and they almost always prefer things differential.

$$\boxed{\Delta Q = c \cdot m \cdot \Delta T}$$

Often times for a given body, people like to bundle "m" and "c" together to form C=c*m the thermal capacitance [J/K] and in this case the formula becomes =>

$$\Delta Q = C \cdot \Delta T$$

$$C_{thermal} = \frac{\Delta Q}{\Delta T}$$

Isn't the previous formula for thermal capacity quite similar to the formula for the electrical capacity? You can verify the analogy two pages back.

$$C_{electric} = \frac{\Delta q}{\Delta V}$$

We can see even more similarities if we look a little farther to the standard formulas of thermal capacity and electric capacitance of a planar capacitor:

$$C_{thermal} = c \cdot m$$

$$C_{electric} = \varepsilon \cdot \frac{A}{d}$$

-Both specific heat and electric permittivity are material constants

- Mass, area and dielectric thickness depend on the body geometry

Conclusions:

In this part of the tutorial a few very basic heat concepts were introduced together with the heat storage as an analogy to electric charge storage on a capacitor. The next tutorial will deal with the concept of heat transfer or heat movement between a body and its environment.

to be continued…