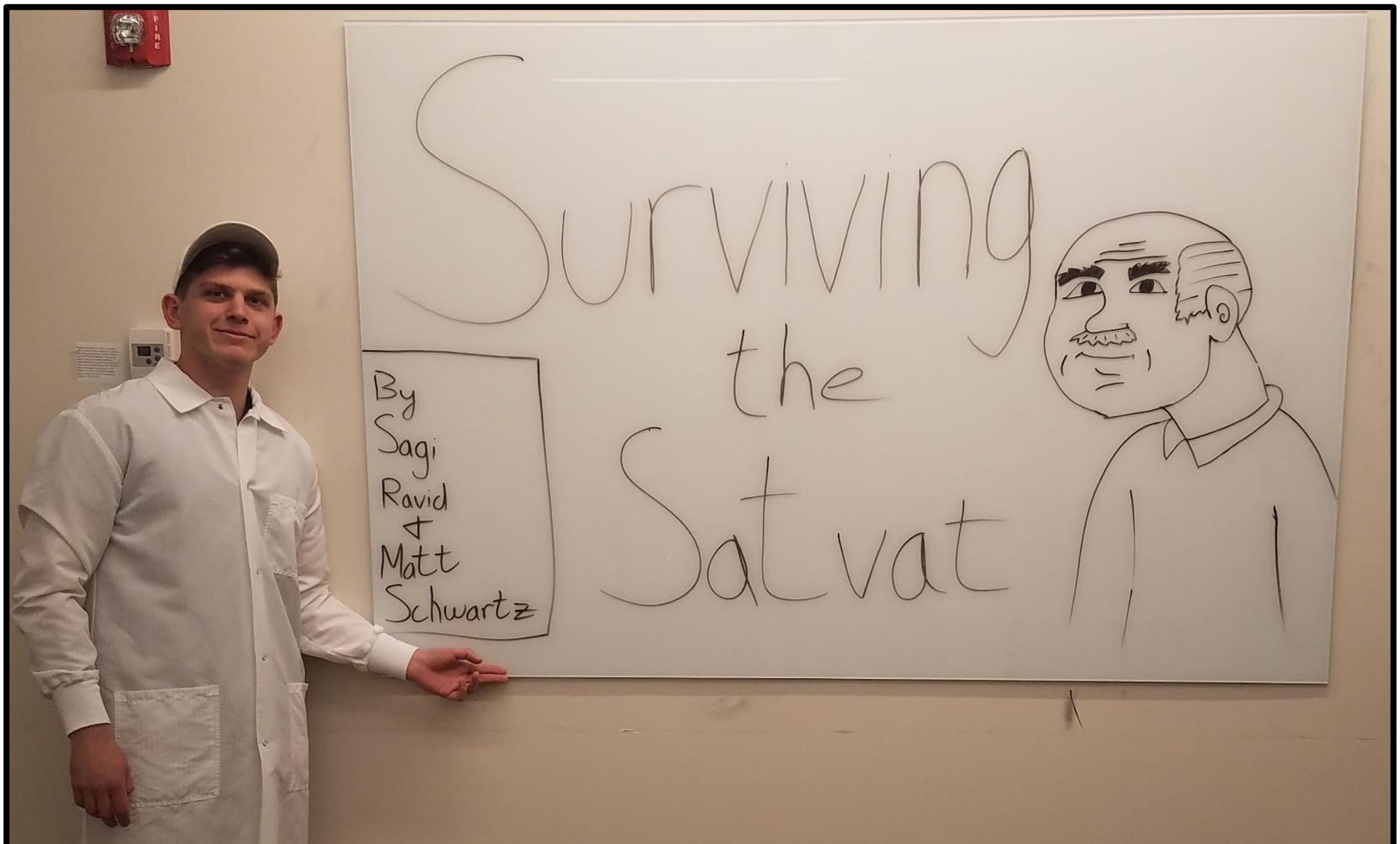
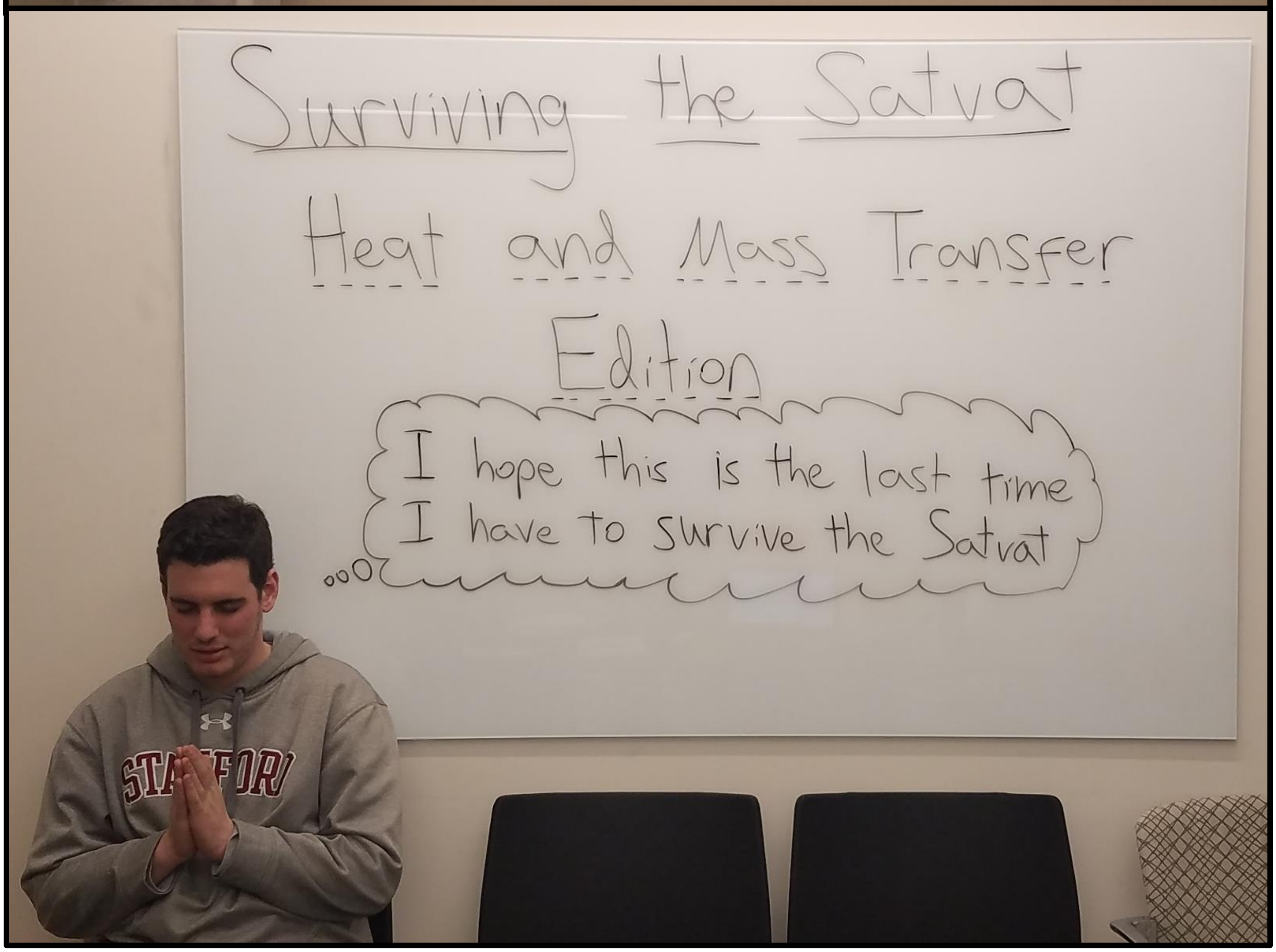
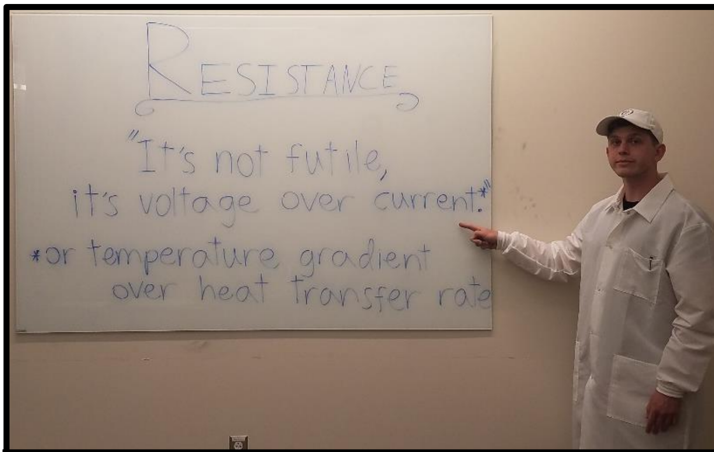
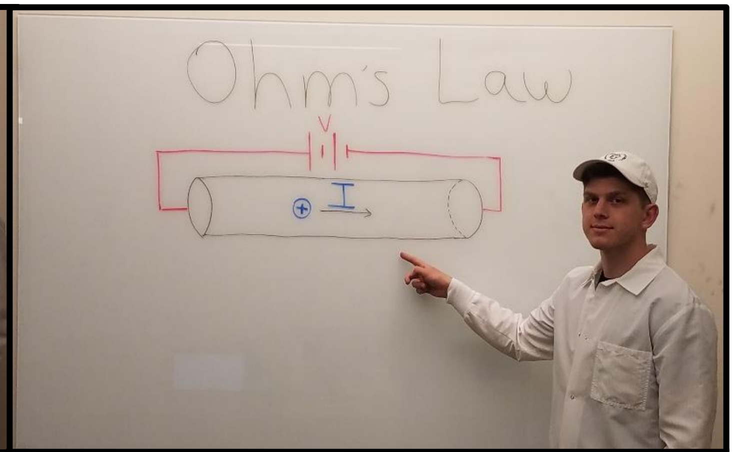

Surviving the Satvat
By Sagi Ravid & Matt Schwartz

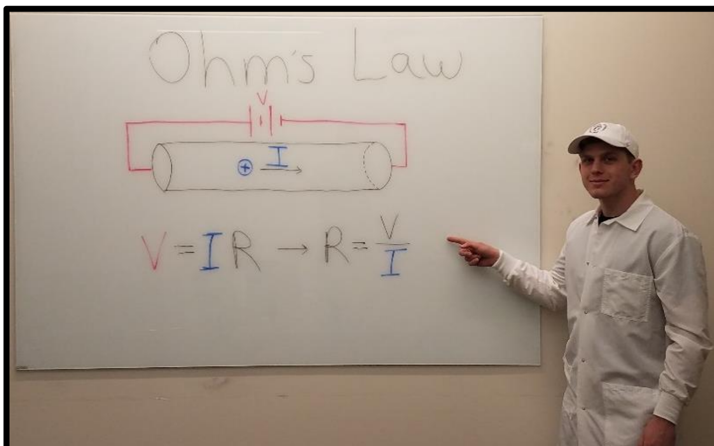

Surviving the Satvat
Heat and Mass Transfer Edition
I hope this is the last time I have to survive the Satvat



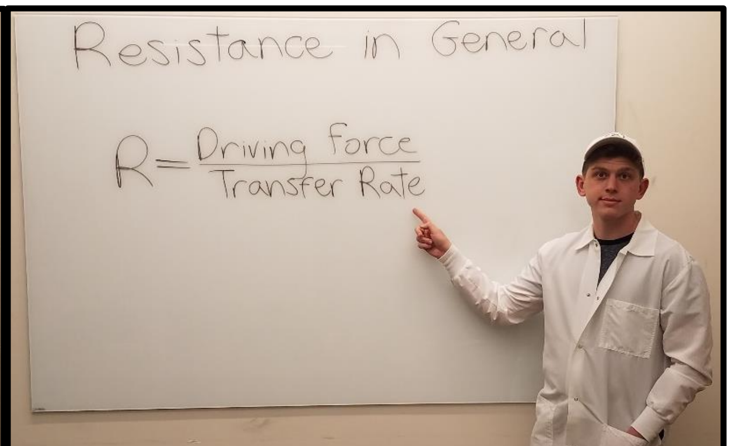
"Good morning class, today we will be learning about thermal resistance"



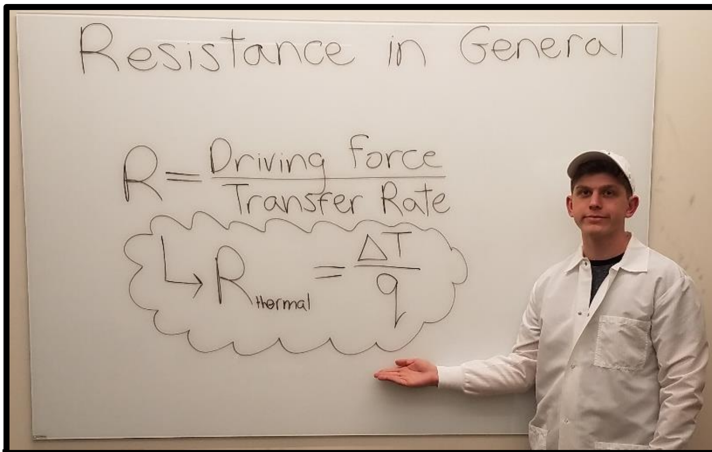
"Before we talk about thermal resistance, let's talk about a type of resistance we all know of, electrical resistance. Voltage (V) drives charge through a wire, and current (I) is the transfer rate."



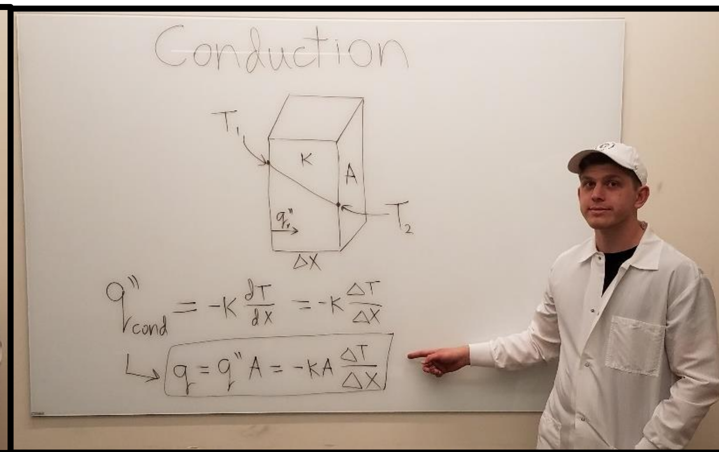
"Ohm's law states that $V = IR$ which can be rearranged to show that $R = \frac{V}{I}$. This demonstrates that electrical resistance is the ratio of electric potential over the charge transfer rate."



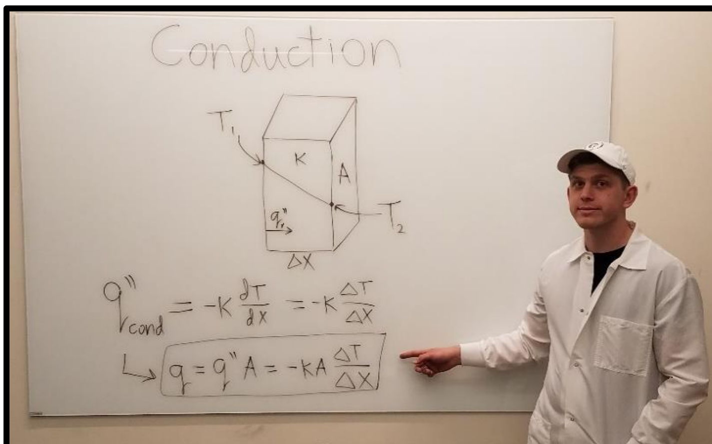
"From electrical resistance we can generalize resistance to be the ratio of the driving force over the transfer rate. This will give us the basis for our thermal resistance equation."



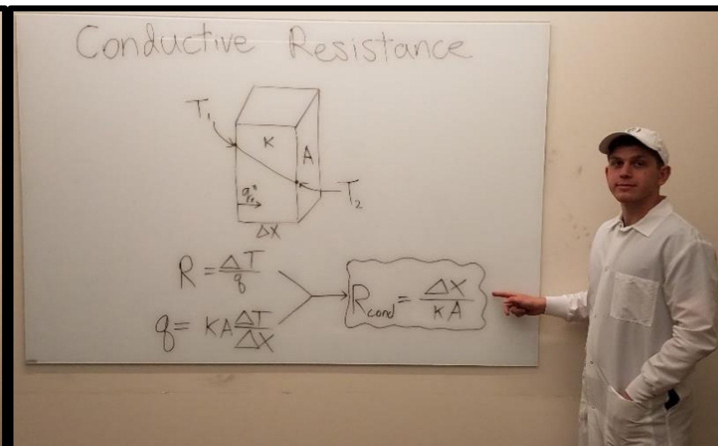
"Thus, our equation for thermal resistance is the ratio of temperature gradient over the heat transfer rate since a temperature difference cause heat to be transferred."



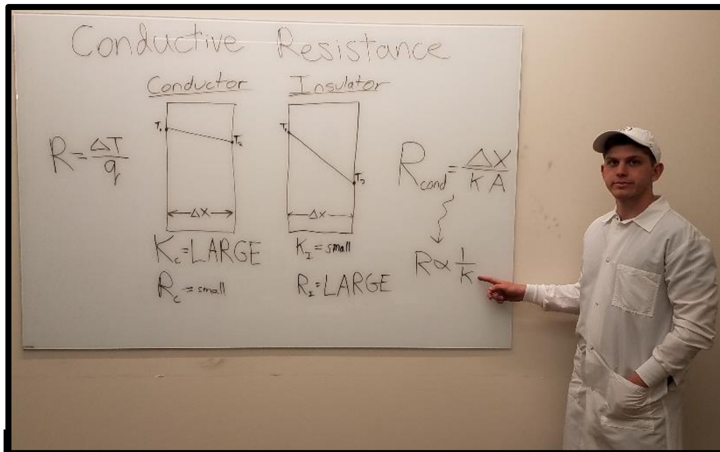
"Let's look at a single slab wall of a material with constant properties. According to Fourier's Law, $q''_{cond} = -k\frac{\partial T}{\partial x}$. Which can be simplified to $q''_{cond} = -k\frac{\Delta T}{\Delta x}$.

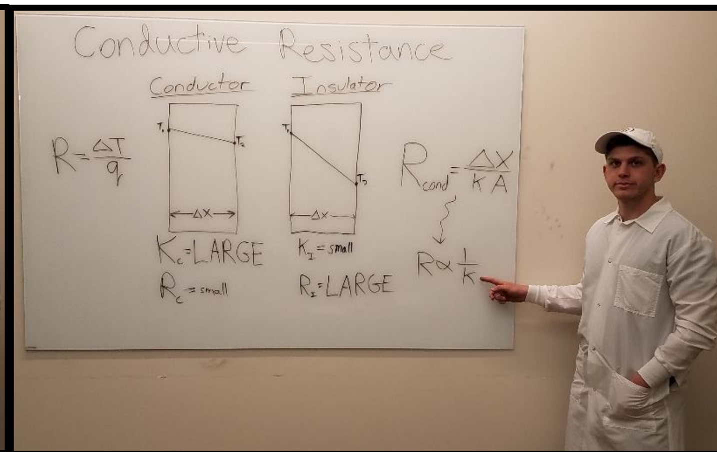


"And since we know that $q_{cond} = Aq''_{cond}$. We know that the heat rate is $q_{cond} = -kA\frac{\Delta T}{\Delta x}$."



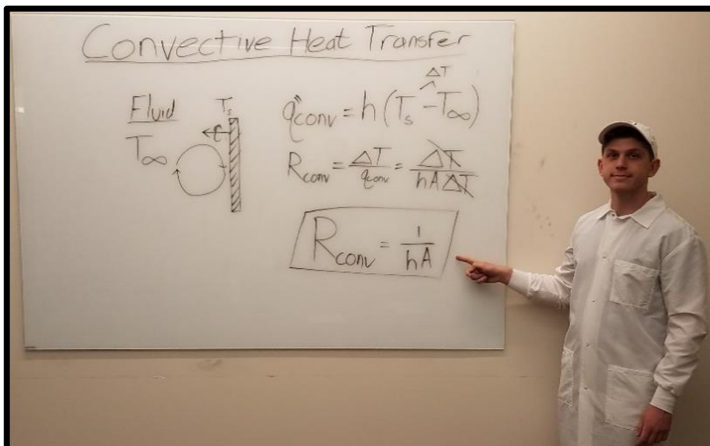
" Now that we have a relationship between resistance and heat rate, we can combine the equations to show that conductive thermal resistance for is $R_{cond} = \frac{\Delta x}{kA}$.

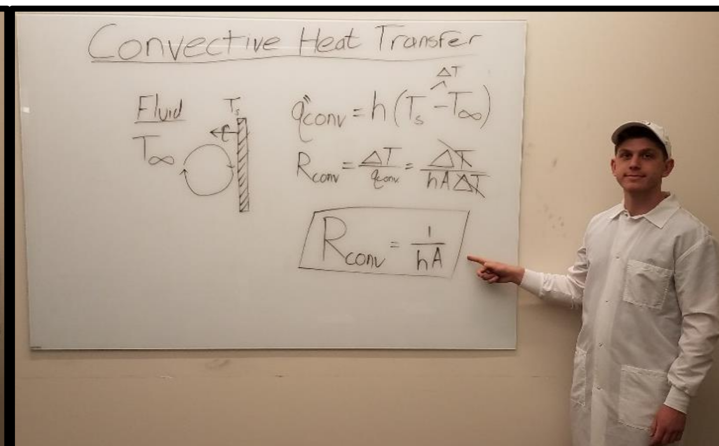




"As you can see from the conductive thermal resistance equation, the resistance depends on the material as materials vary in thermal conductivity (k)."

"Materials with a low thermal conductivity (k) are known as insulators, and materials with a high thermal conductivity (k) are known as conductors. Insulators have high resistance, while conductors have low resistance."

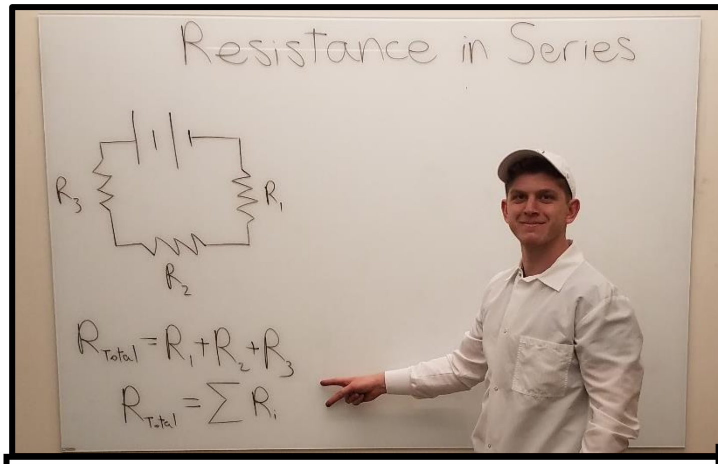


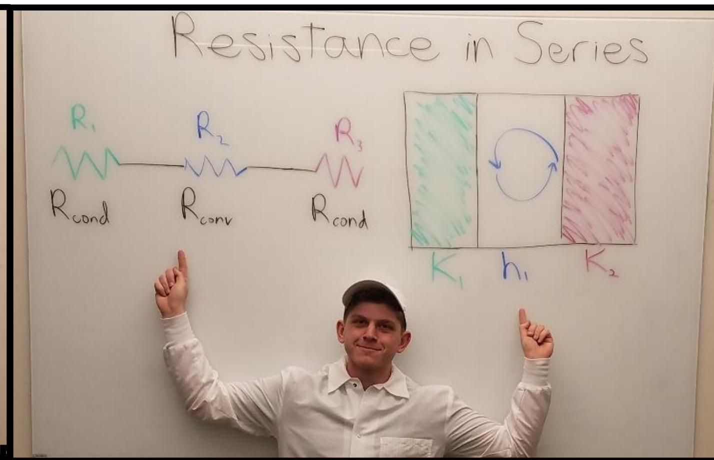


"Similar to how we derived conductive thermal resistance we derive convective thermal resistance. We know that

$q''_{conv} = h(T_s - T_\infty)$ and thus $q_{conv} = hA(T_s - T_\infty)$."

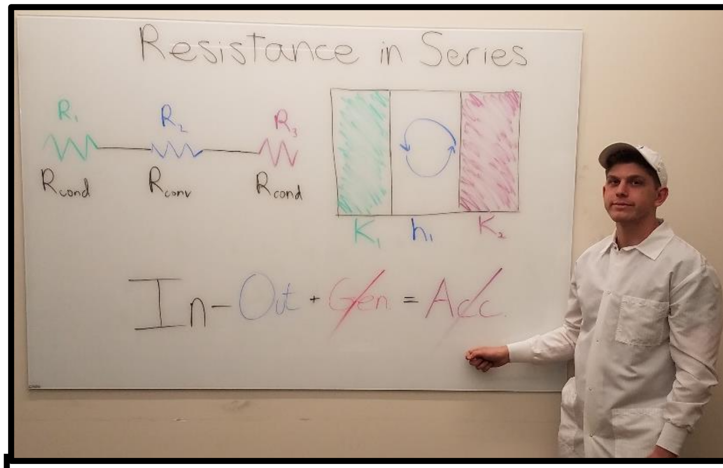
"We can then derive the convective resistance relationship to be $R_{conv} = \frac{1}{hA}$."

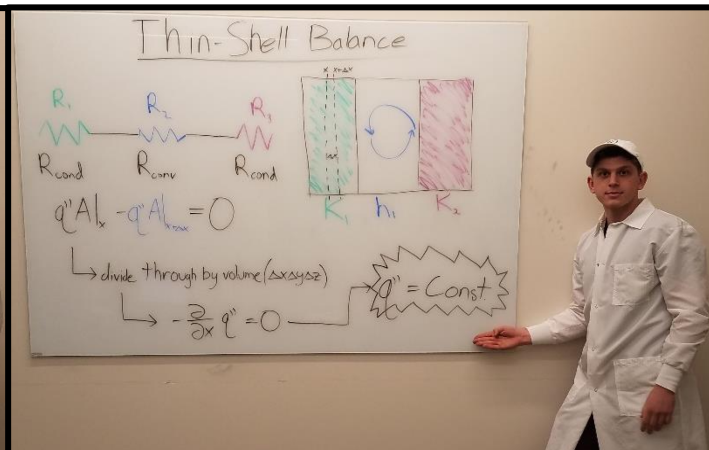




“In an electric circuit, the resistance of resistors in series can be combined to a total resistance. In heat transfer we can do the same thing, to get the overall resistance of the system.”

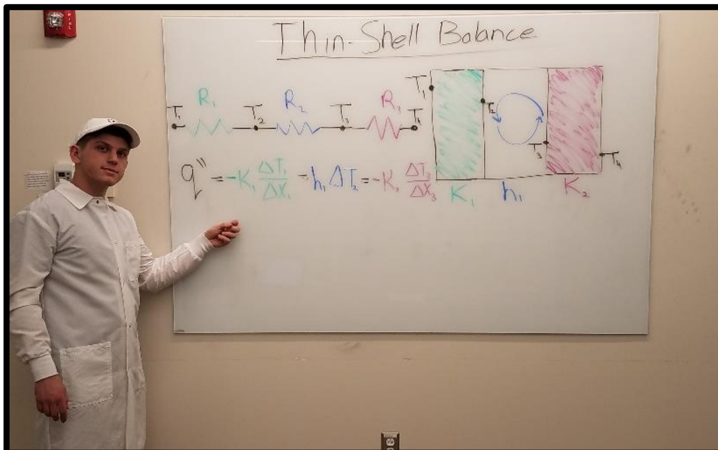
“Here we have a system that consists of two conductive materials, and one convective fluid between them. We will use the thermal circuit on the left to represent the system.”



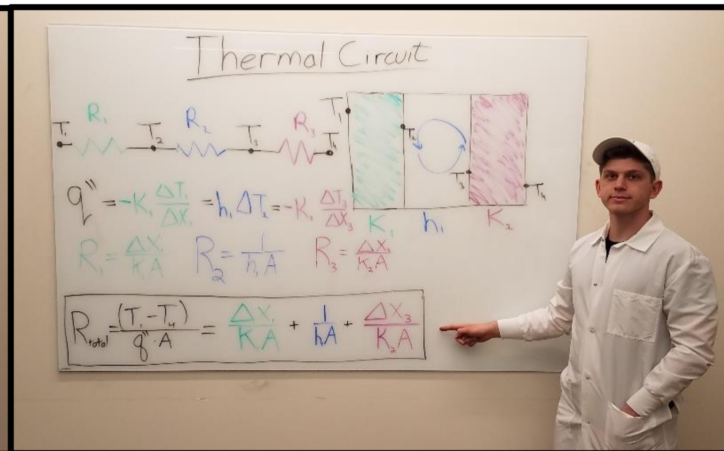


“Let’s assume the system is steady-state, has no generation, has constant properties, and heat is flowing in only one direction. This reduces our energy balance to $In - Out = 0$.”

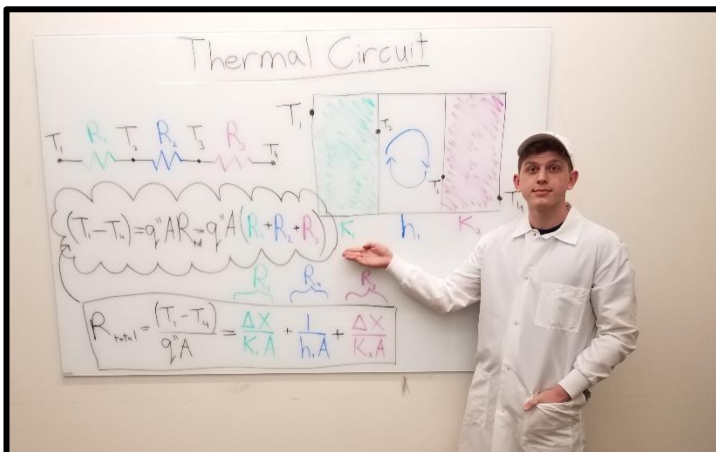
“We can then set up a thin-shell balance and solve to show that our heat flux is constant!”



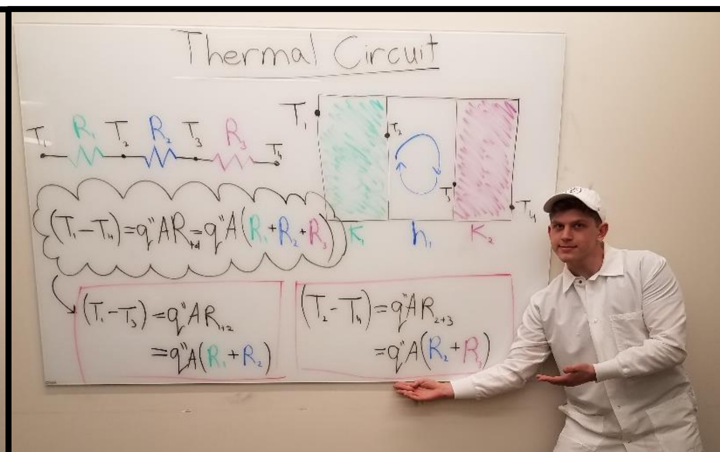
"With our flux constant, we can apply the right constitutive equation to each section of our system and see show how to determine the heat flux."



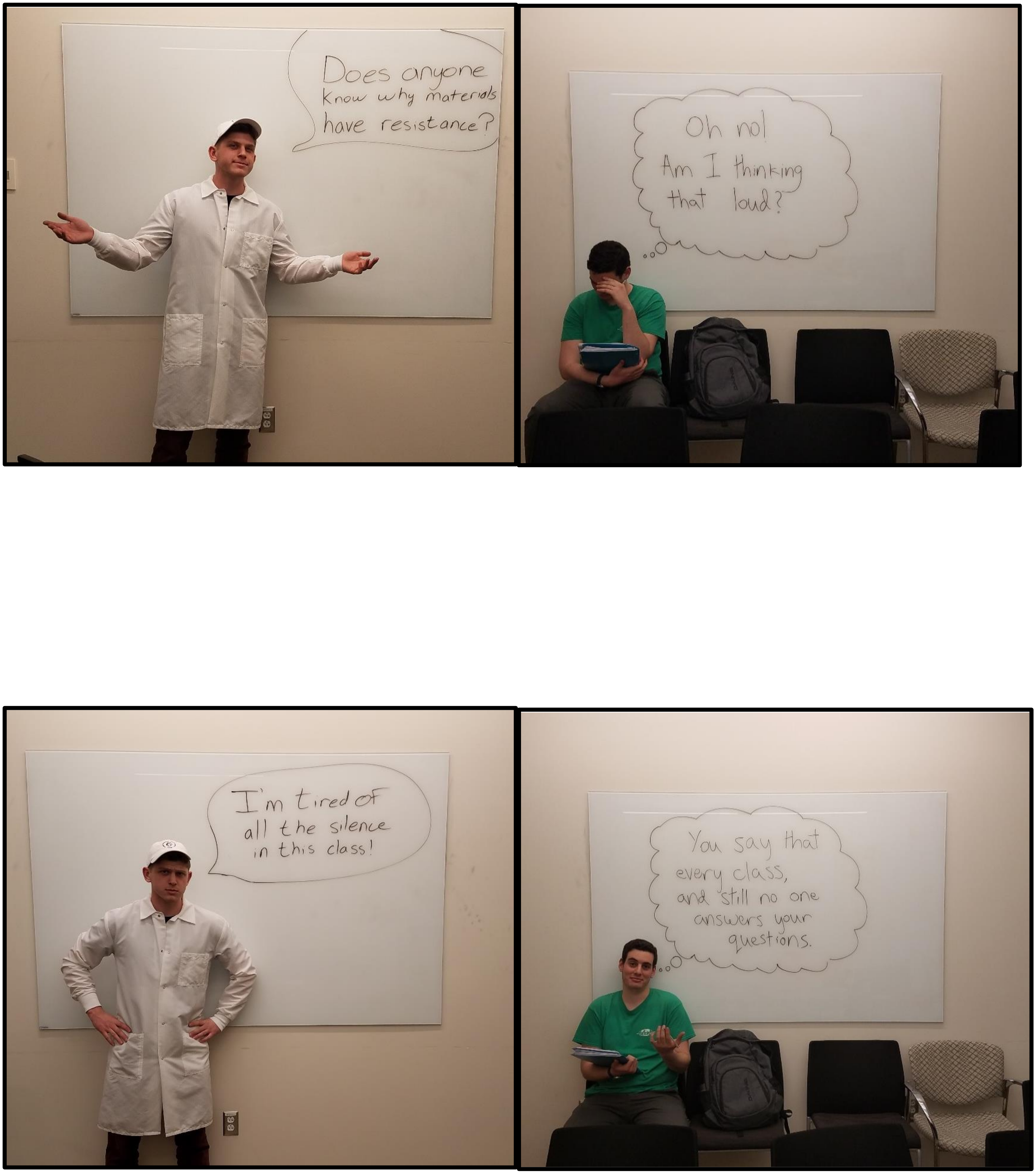
"We can then find the total resistance of our system in terms of our constant properties and set it equal to the ratio of the temperature difference across the system to the heat transfer rate through the system."

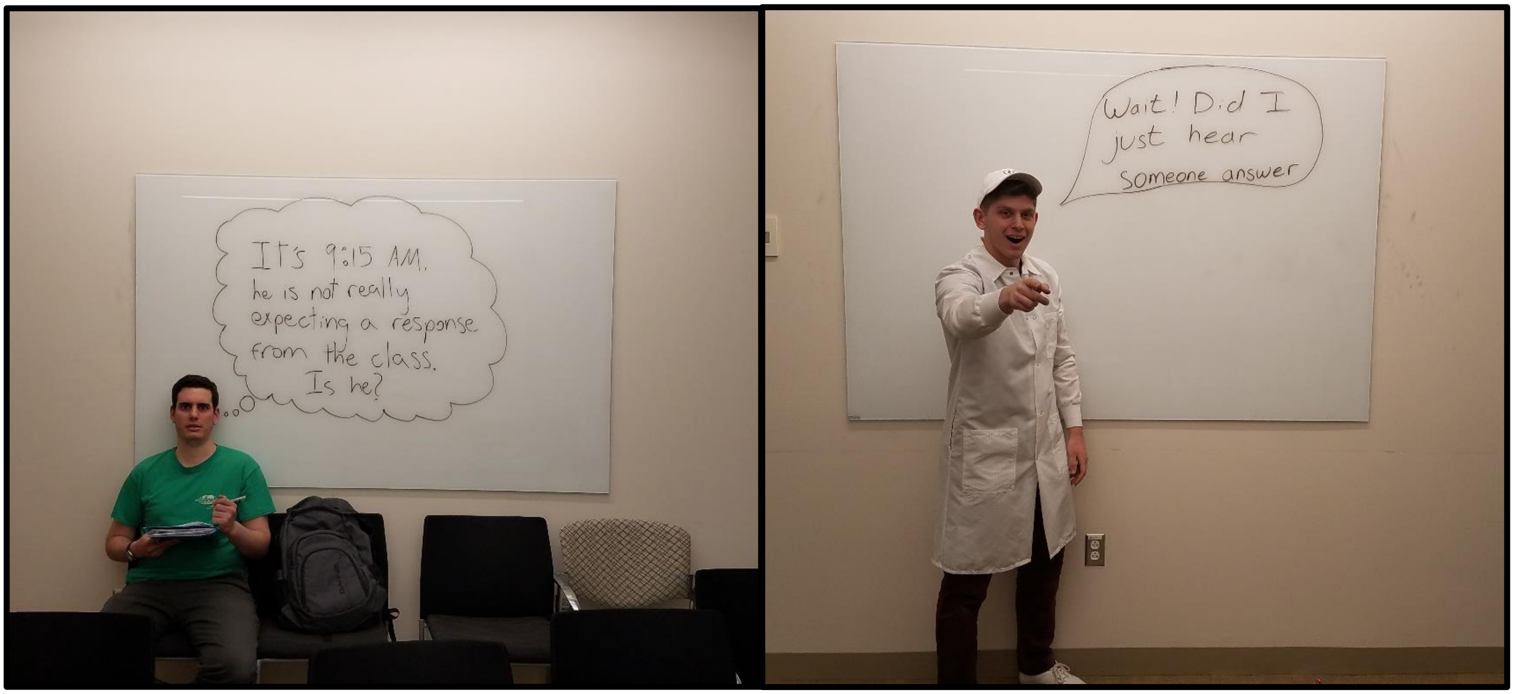


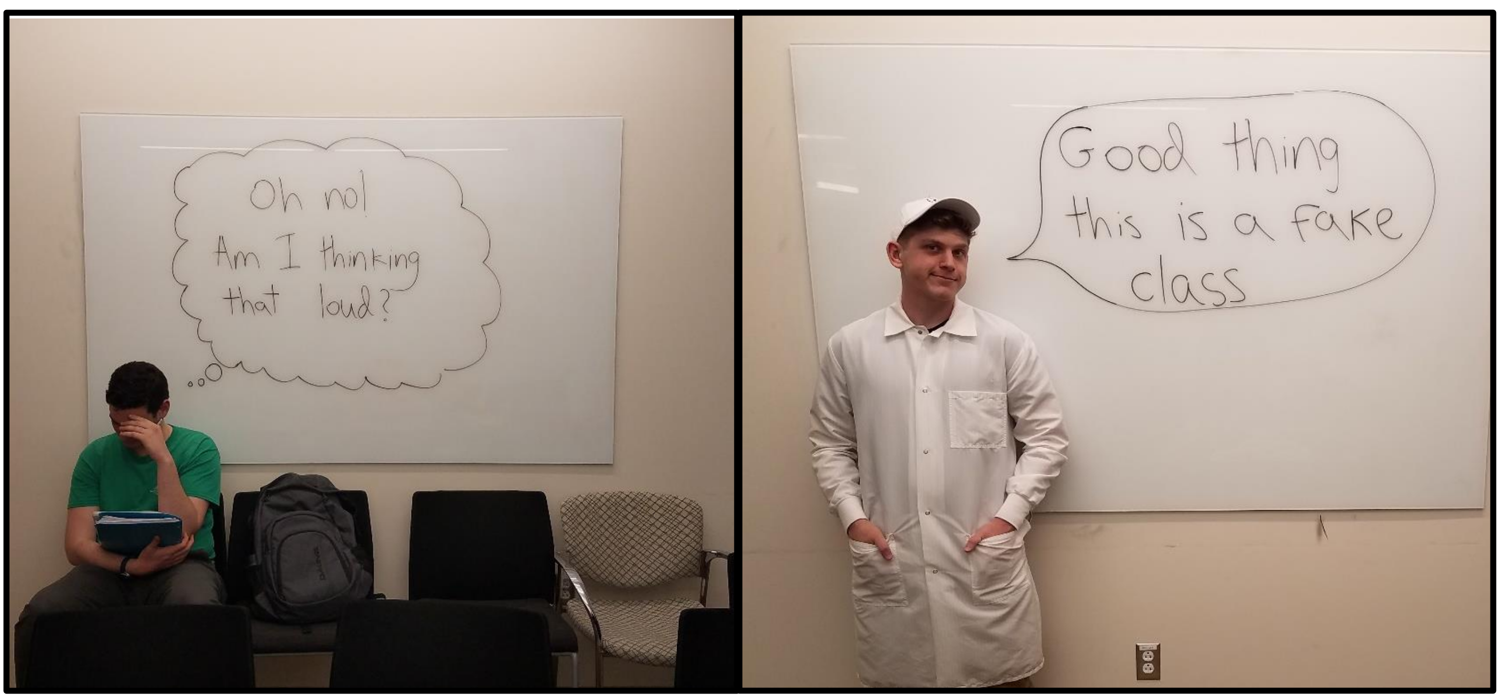
"By rearranging our total resistance equation, we can show that the temperature difference across the entire system is equal to the product of the the heat transfer and the total resistance."

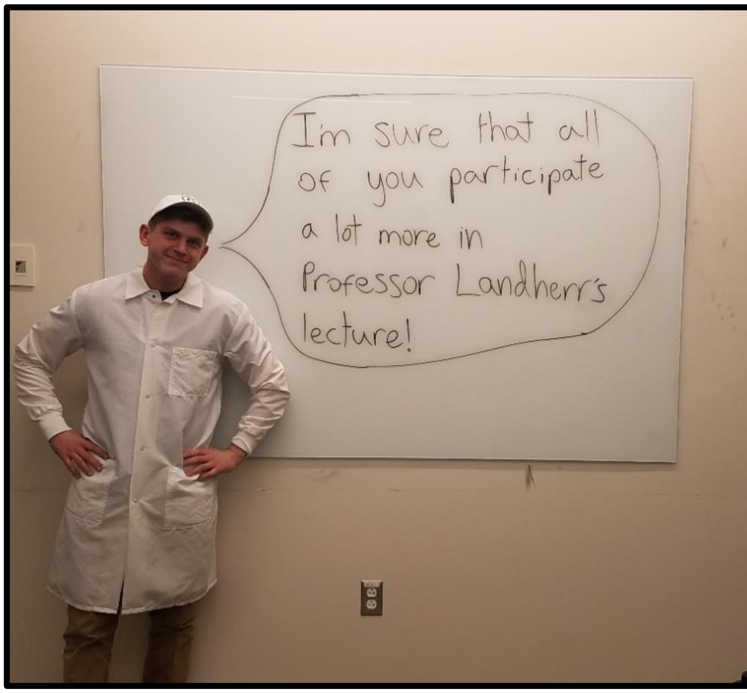


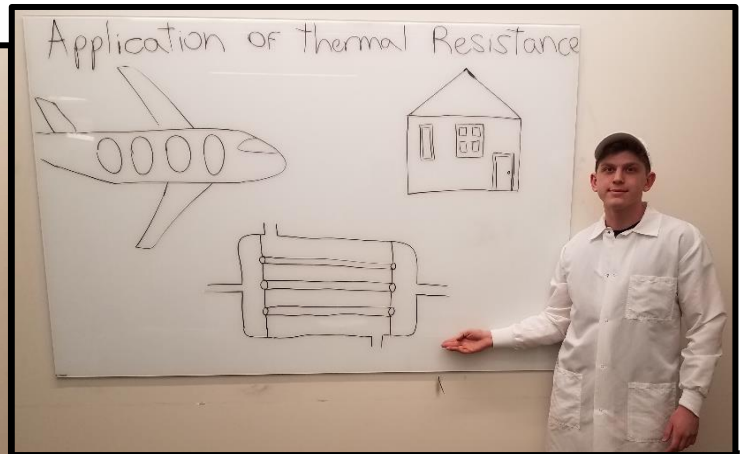
"We can then use the same idea to minimize our system and find the temperature difference across only 2 components. This can be even further simplified to only one component."


Does anyone know why materials have resistance?
Oh no! Am I thinking that loud?
I'm tired of all the silence in this class!
You say that every class, and still no one answers your questions.

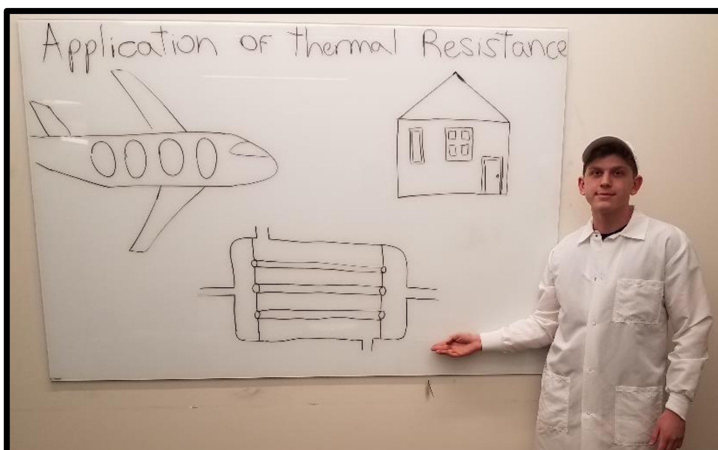

It's 9:15 AM. he is not really expecting a response from the class. Is he?
Wait! Did I just hear someone answer


Oh no! Am I thinking that loud?
Good thing this is a fake class

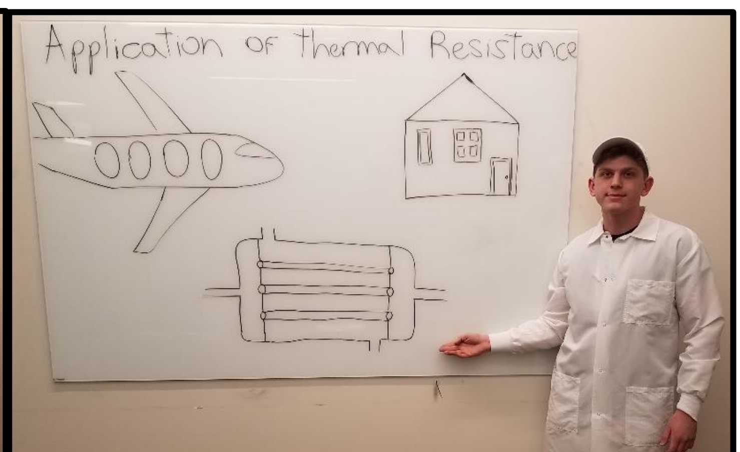




"Anyways, thermal resistance has a major application in the real world. Systems with high resistances are used to keep heat from travelling into or out of the surroundings."



"Airplanes have double-pane windows while walls in homes often have a layer of insulation. In both cases, the boundaries consist of a component with high thermal resistance, to keep the heat from the inside from escaping."



"On the other hand, the walls of heat exchangers are made from materials with low resistance. This is because heat exchangers need to promote the exchange of heat. Thus, for maximum heat transfer, walls have low resistances."