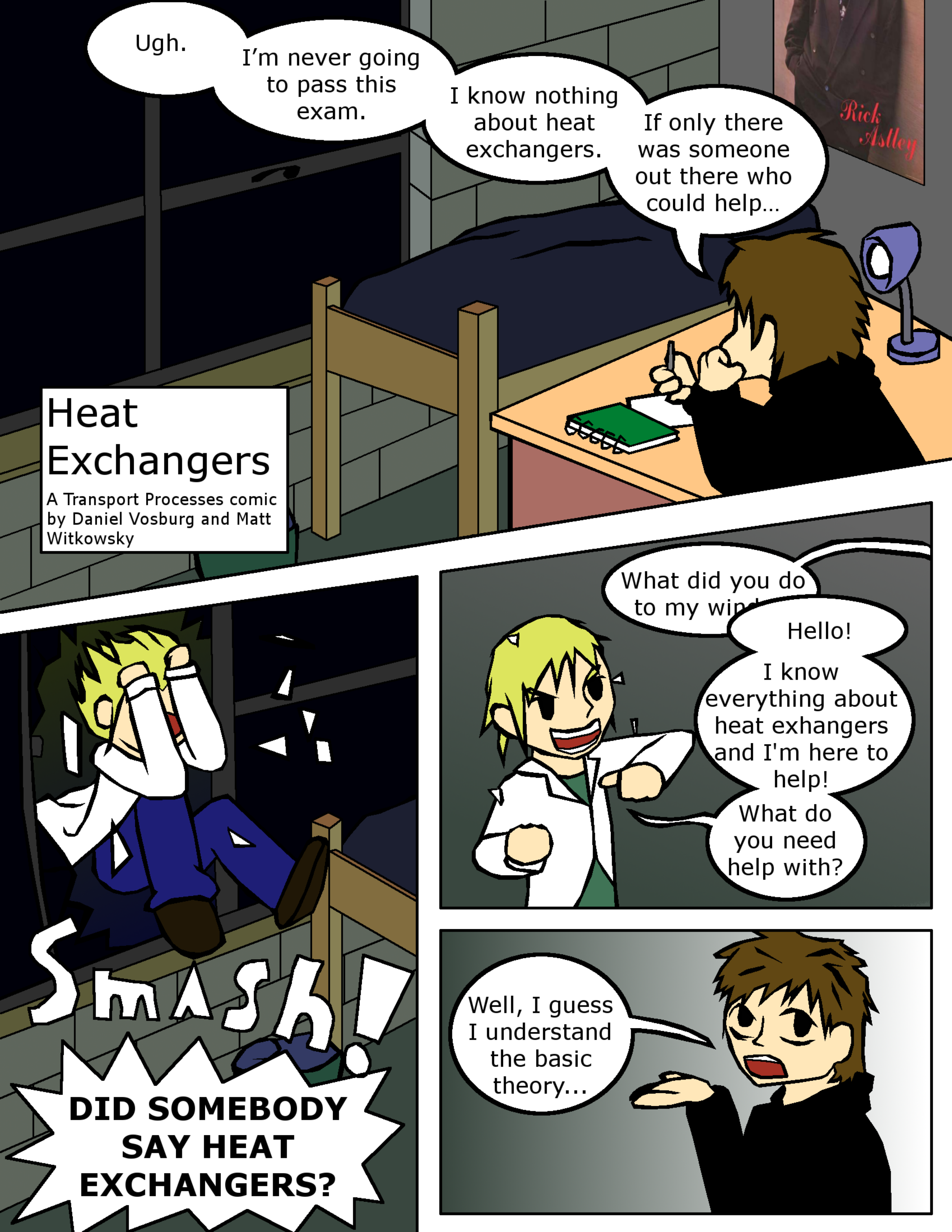
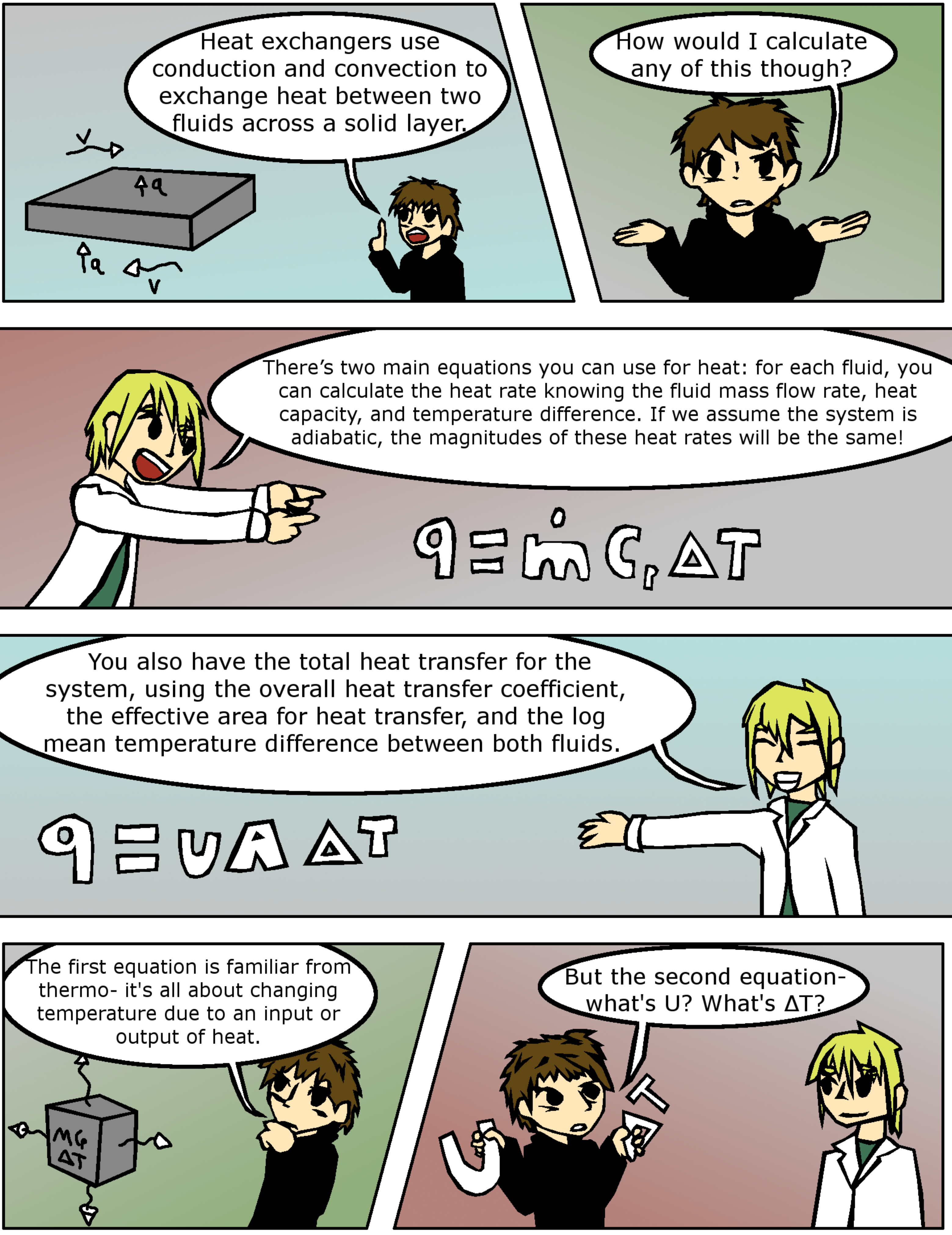
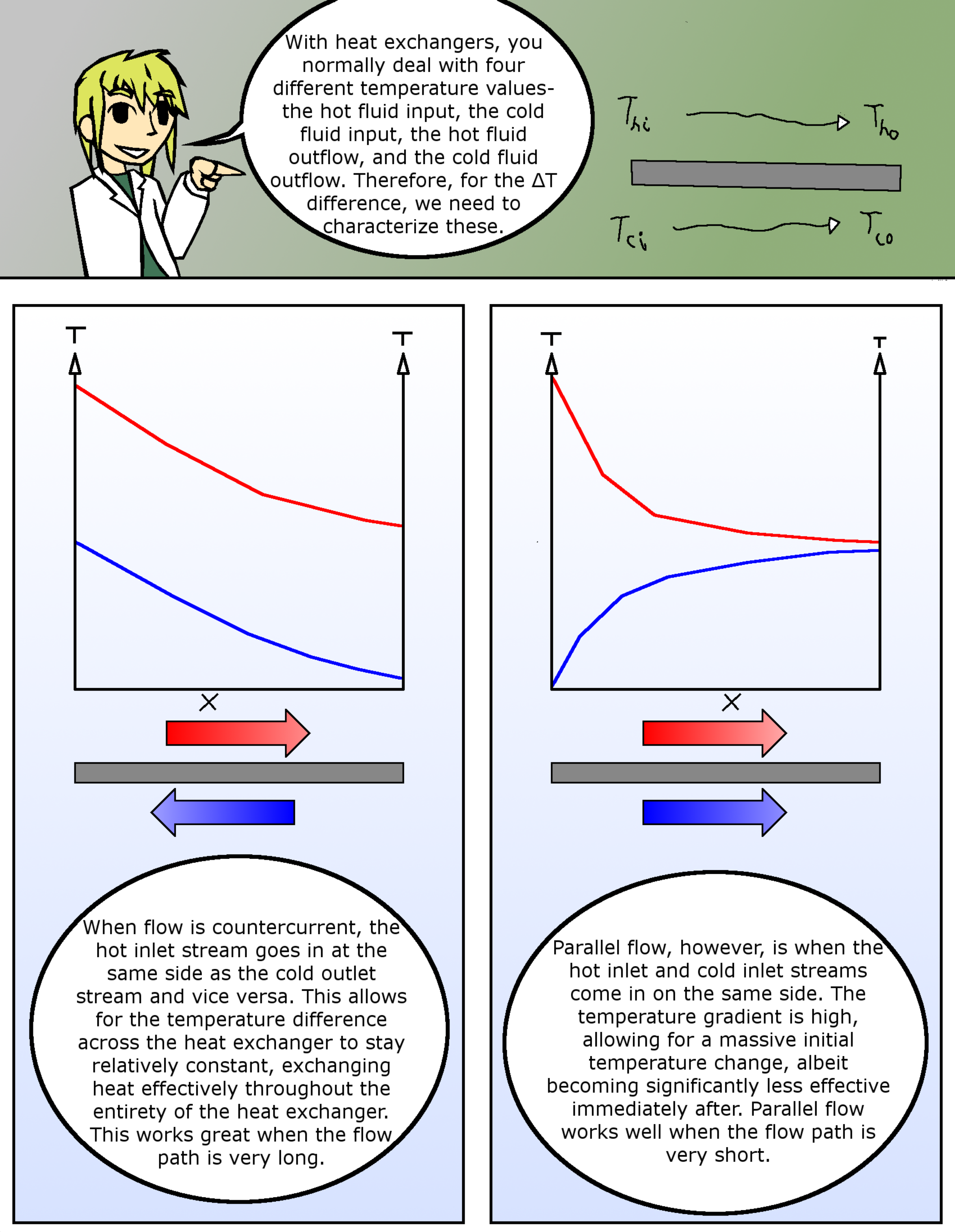
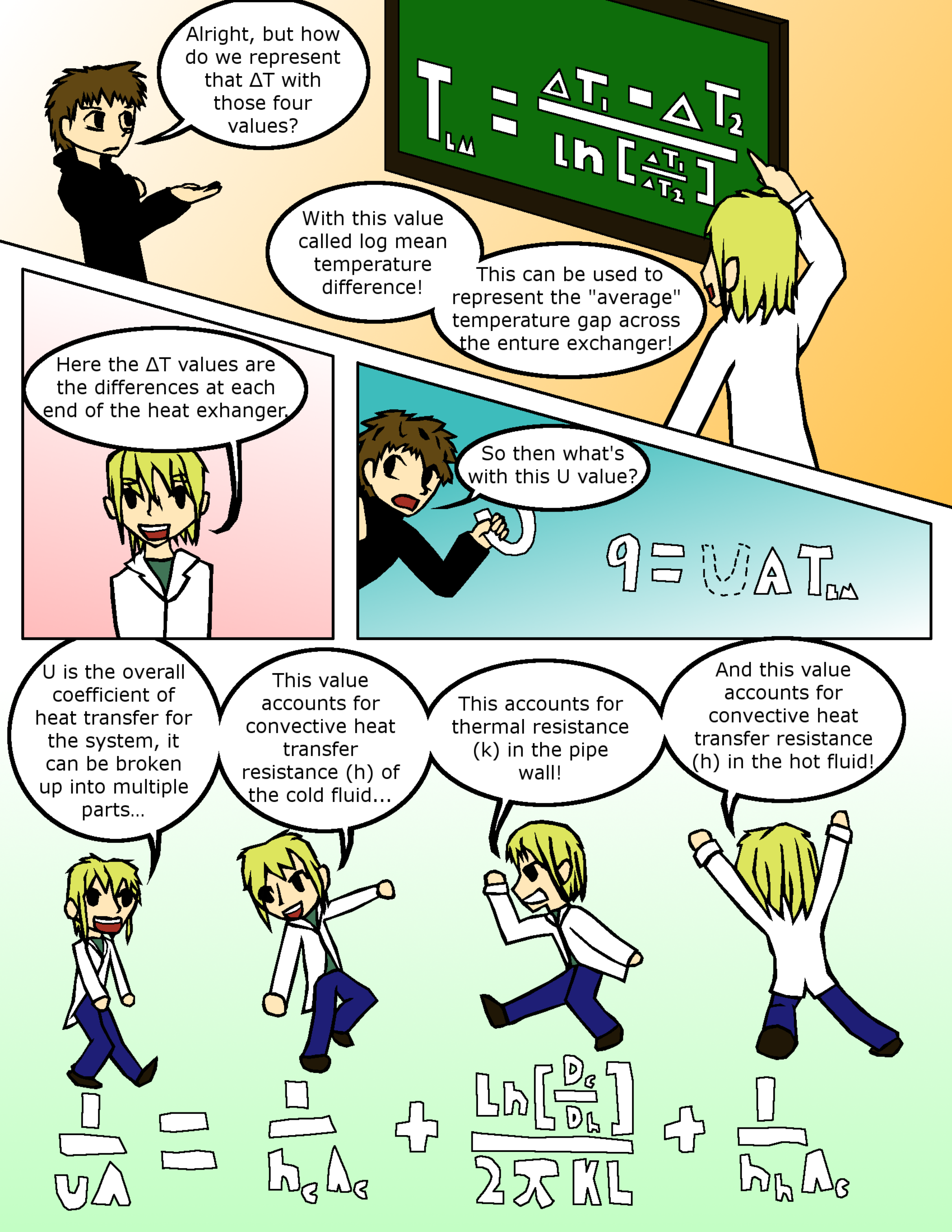

Ugh.
I'm never going to pass this exam.
I know nothing about heat exchangers.
If only there was someone out there who could help...
Rick Astley
Heat Exchangers
A Transport Processes comic by Daniel Vosburg and Matt Witkowsky
Smash!
DID SOMEBODY SAY HEAT EXCHANGERS?
What did you do to my win
Hello!
I know everything about heat exhangers and I'm here to help!
What do you need help with?
Well, I guess I understand the basic theory...

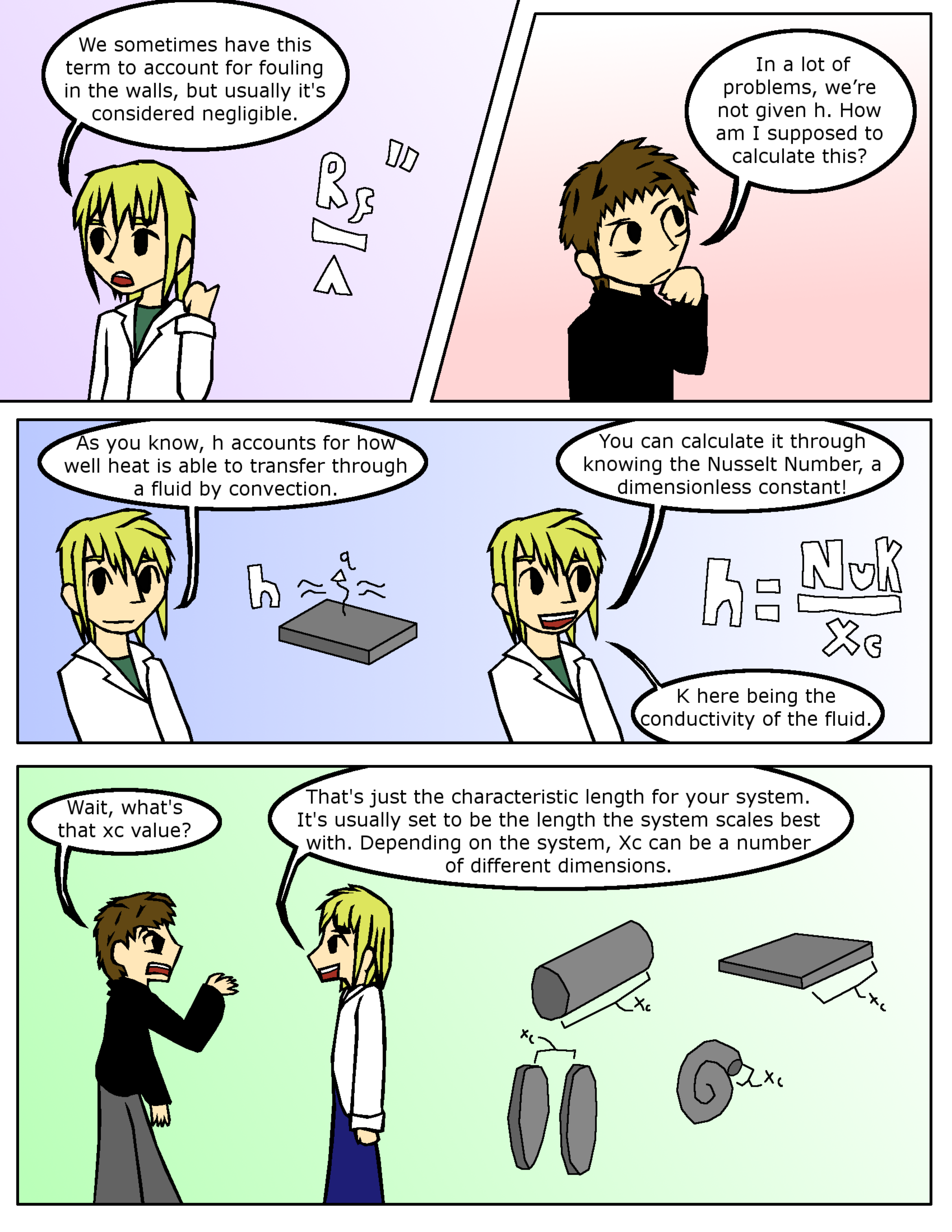

Heat exchangers use conduction and convection to exchange heat between two fluids across a solid layer.
v
q
q
v
How would I calculate any of this though?
There's two main equations you can use for heat: for each fluid, you can calculate the heat rate knowing the fluid mass flow rate, heat capacity, and temperature difference. If we assume the system is adiabatic, the magnitudes of these heat rates will be the same!
$q = \dot{m} C_p \Delta T$
You also have the total heat transfer for the system, using the overall heat transfer coefficient, the effective area for heat transfer, and the log mean temperature difference between both fluids.
$q = UA\Delta T$
The first equation is familiar from thermo- it's all about changing temperature due to an input or output of heat.
$mC_p \Delta T$
But the second equation- what's U? What's ΔT?
U
ΔT



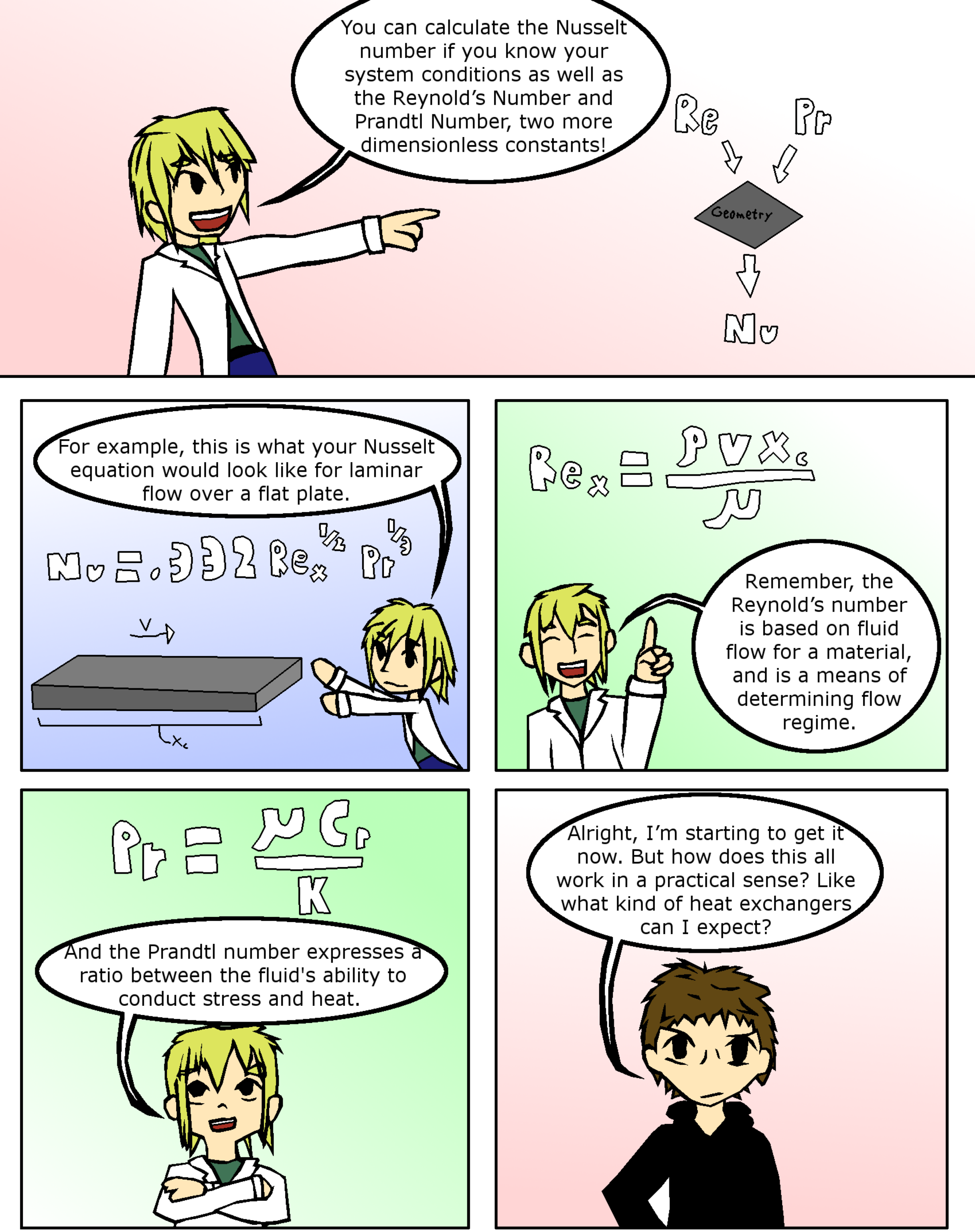
With heat exchangers, you normally deal with four different temperature values- the hot fluid input, the cold fluid input, the hot fluid outflow, and the cold fluid outflow. Therefore, for the ΔT difference, we need to characterize these.
T_{hi}
T_{ho}
T_{ci}
T_{co}
T
T
X
When flow is countercurrent, the hot inlet stream goes in at the same side as the cold outlet stream and vice versa. This allows for the temperature difference across the heat exchanger to stay relatively constant, exchanging heat effectively throughout the entirety of the heat exchanger. This works great when the flow path is very long.
T
T
X
Parallel flow, however, is when the hot inlet and cold inlet streams come in on the same side. The temperature gradient is high, allowing for a massive initial temperature change, albeit becoming significantly less effective immediately after. Parallel flow works well when the flow path is very short.

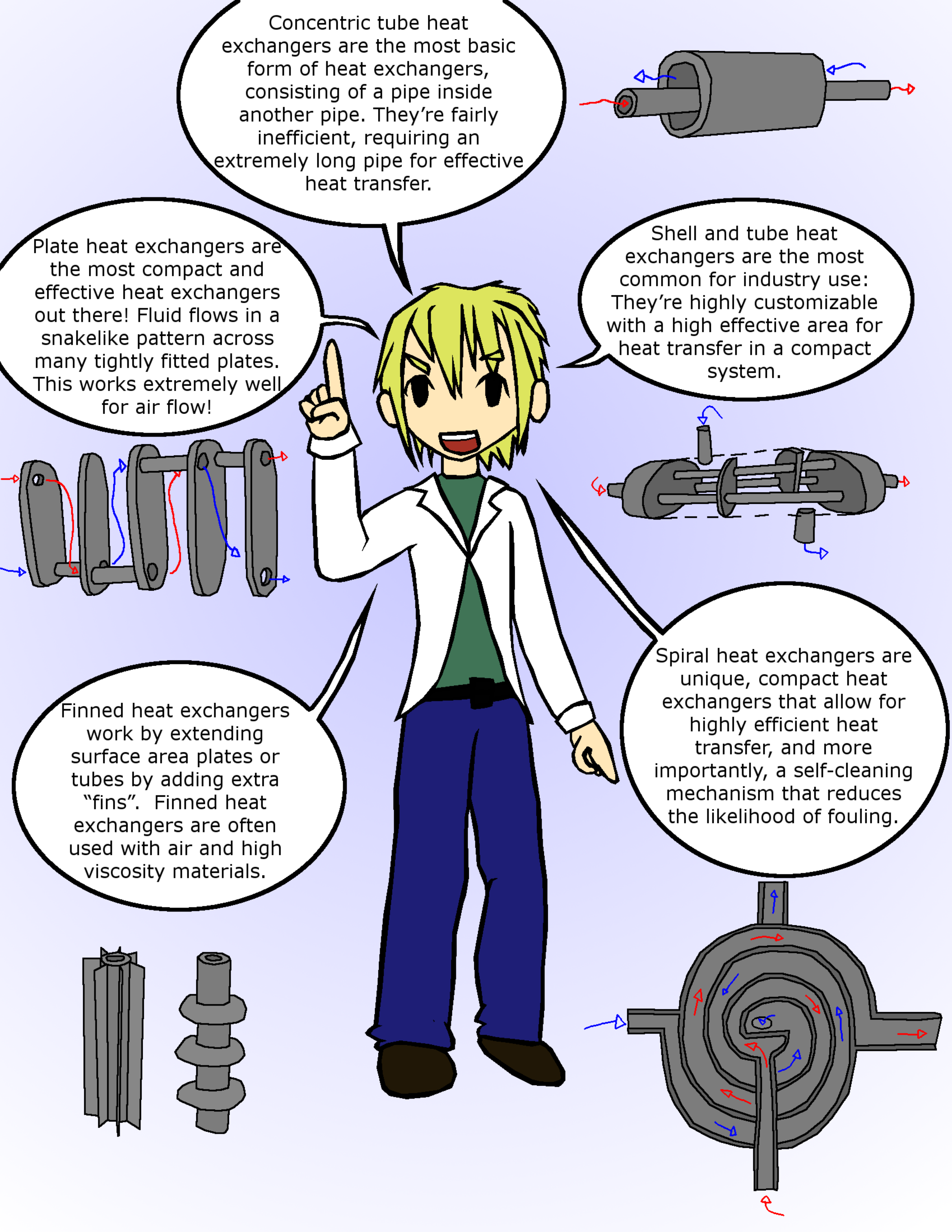


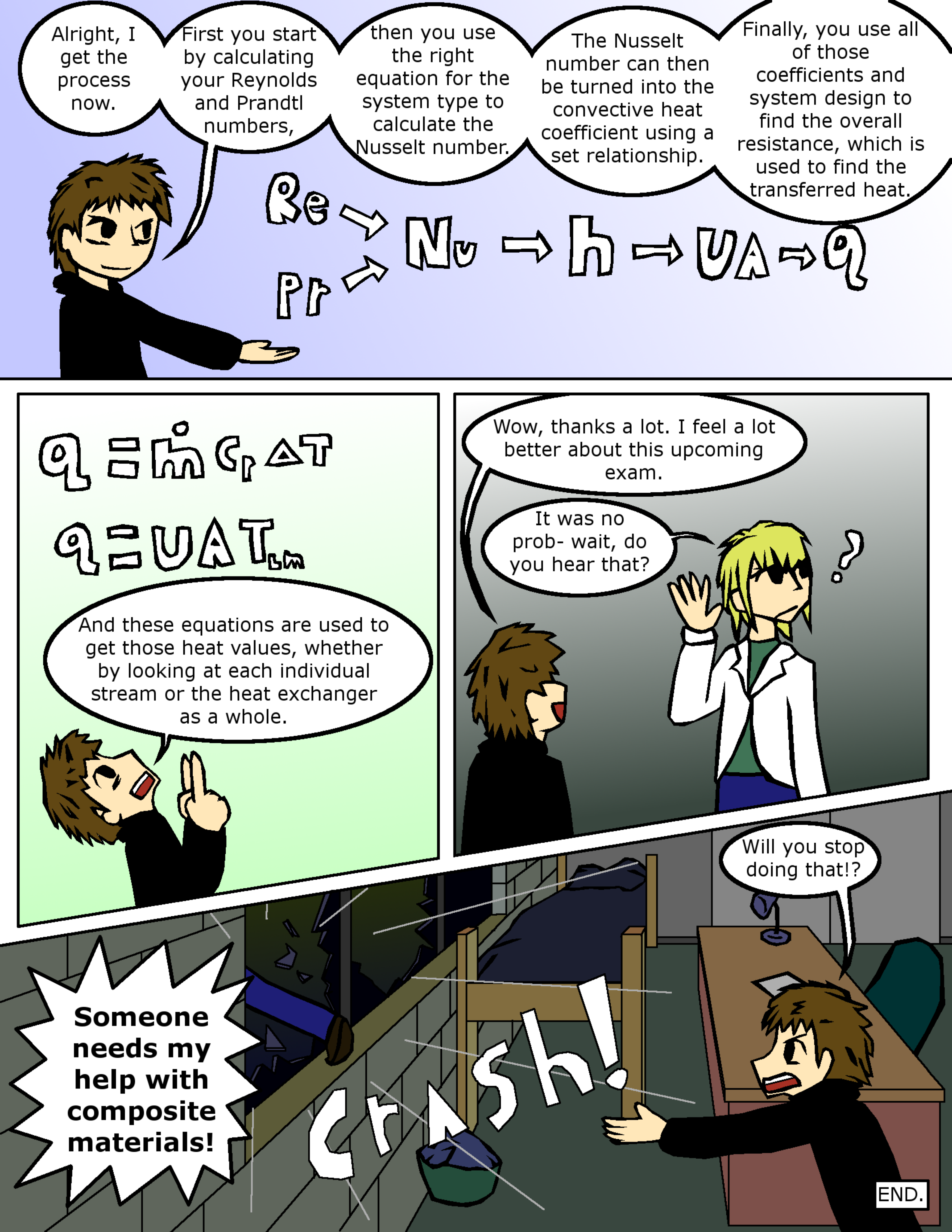
Alright, but how do we represent that ΔT with those four values?
$T_{LM} = \frac{\Delta T_1 - \Delta T_2}{\ln\left[\frac{\Delta T_1}{\Delta T_2}\right]}$
With this value called log mean temperature difference!
This can be used to represent the "average" temperature gap across the enture exchanger!
Here the ΔT values are the differences at each end of the heat exhanger.
So then what's with this U value?
$q = UAT_{LM}$
U is the overall coefficient of heat transfer for the system, it can be broken up into multiple parts...
This value accounts for convective heat transfer resistance (h) of the cold fluid...
This accounts for thermal resistance (k) in the pipe wall!
And this value accounts for convective heat transfer resistance (h) in the hot fluid!
$\frac{1}{UA} = \frac{1}{h_c A_c} + \frac{\ln\left[\frac{D_c}{D_h}\right]}{2\pi KL} + \frac{1}{h_h A_c}$



We sometimes have this term to account for fouling in the walls, but usually it's considered negligible.
"Rf / A"
In a lot of problems, we're not given h. How am I supposed to calculate this?
As you know, h accounts for how well heat is able to transfer through a fluid by convection.
h
q
You can calculate it through knowing the Nusselt Number, a dimensionless constant!
h = NuK / Xc
K here being the conductivity of the fluid.
Wait, what's that xc value?
That's just the characteristic length for your system. It's usually set to be the length the system scales best with. Depending on the system, Xc can be a number of different dimensions.
Xc
Xc
Xc
Xc


You can calculate the Nusselt number if you know your system conditions as well as the Reynold's Number and Prandtl Number, two more dimensionless constants!
Re
Pr
Geometry
Nu
For example, this is what your Nusselt equation would look like for laminar flow over a flat plate.
Nu = .332 Rex 1/2 Pr 1/3
V
xc
Rex = ρ v xc / μ
Remember, the Reynold's number is based on fluid flow for a material, and is a means of determining flow regime.
Pr = μ Cp / K
And the Prandtl number expresses a ratio between the fluid's ability to conduct stress and heat.
Alright, I'm starting to get it now. But how does this all work in a practical sense? Like what kind of heat exchangers can I expect?


Concentric tube heat exchangers are the most basic form of heat exchangers, consisting of a pipe inside another pipe. They're fairly inefficient, requiring an extremely long pipe for effective heat transfer.
Plate heat exchangers are the most compact and effective heat exchangers out there! Fluid flows in a snakelike pattern across many tightly fitted plates. This works extremely well for air flow!
Shell and tube heat exchangers are the most common for industry use: They're highly customizable with a high effective area for heat transfer in a compact system.
Finned heat exchangers work by extending surface area plates or tubes by adding extra "fins". Finned heat exchangers are often used with air and high viscosity materials.
Spiral heat exchangers are unique, compact heat exchangers that allow for highly efficient heat transfer, and more importantly, a self-cleaning mechanism that reduces the likelihood of fouling.



Alright, I get the process now.
First you start by calculating your Reynolds and Prandtl numbers,
then you use the right equation for the system type to calculate the Nusselt number.
The Nusselt number can then be turned into the convective heat coefficient using a set relationship.
Finally, you use all of those coefficients and system design to find the overall resistance, which is used to find the transferred heat.
Re
Pr
Nu
h
UA
q
q = ṁcpΔT
q = UAΔTlm
And these equations are used to get those heat values, whether by looking at each individual stream or the heat exchanger as a whole.
Wow, thanks a lot. I feel a lot better about this upcoming exam.
It was no prob- wait, do you hear that?
?
Will you stop doing that!?
Someone needs my help with composite materials!
Crash!
END.