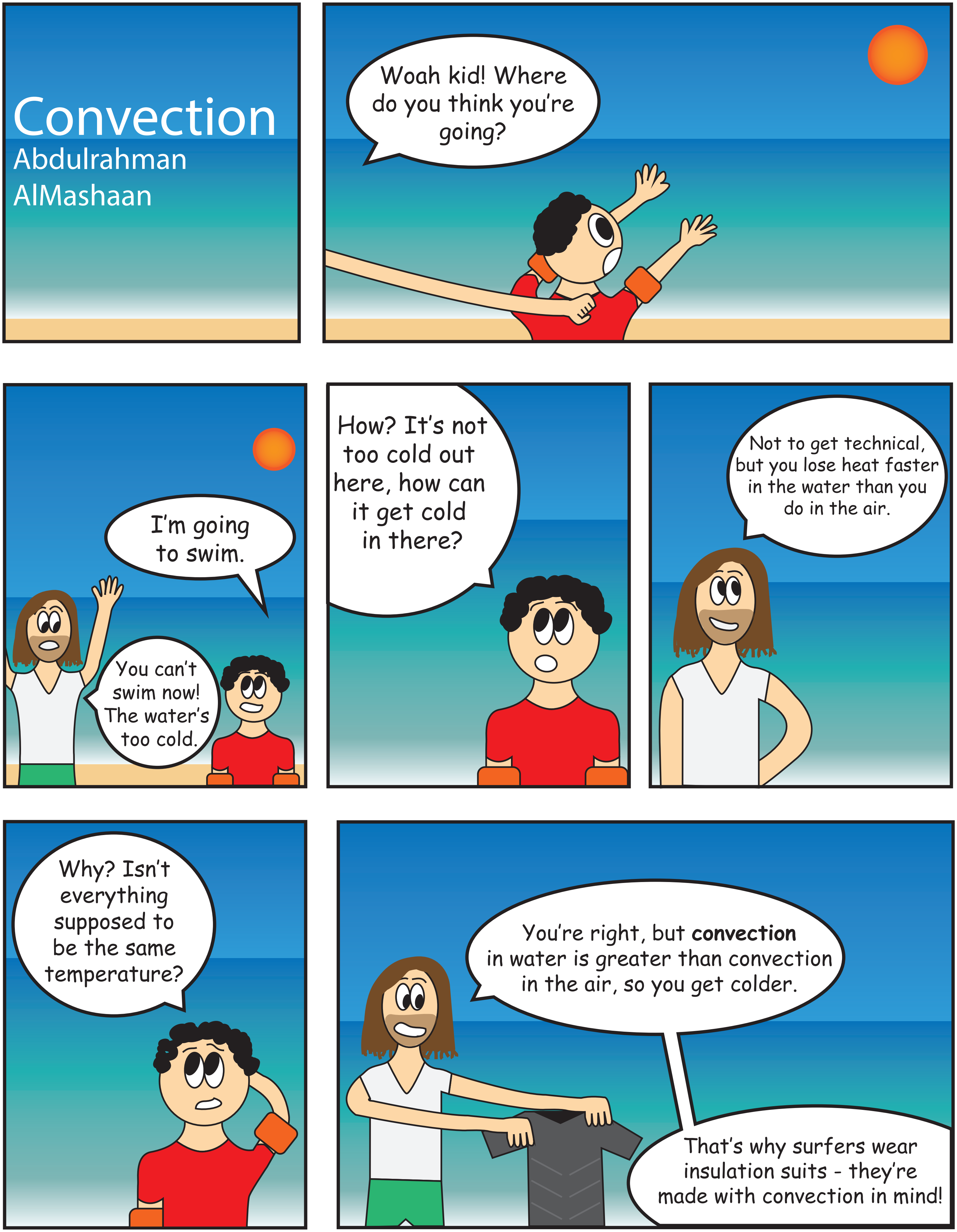
Convection
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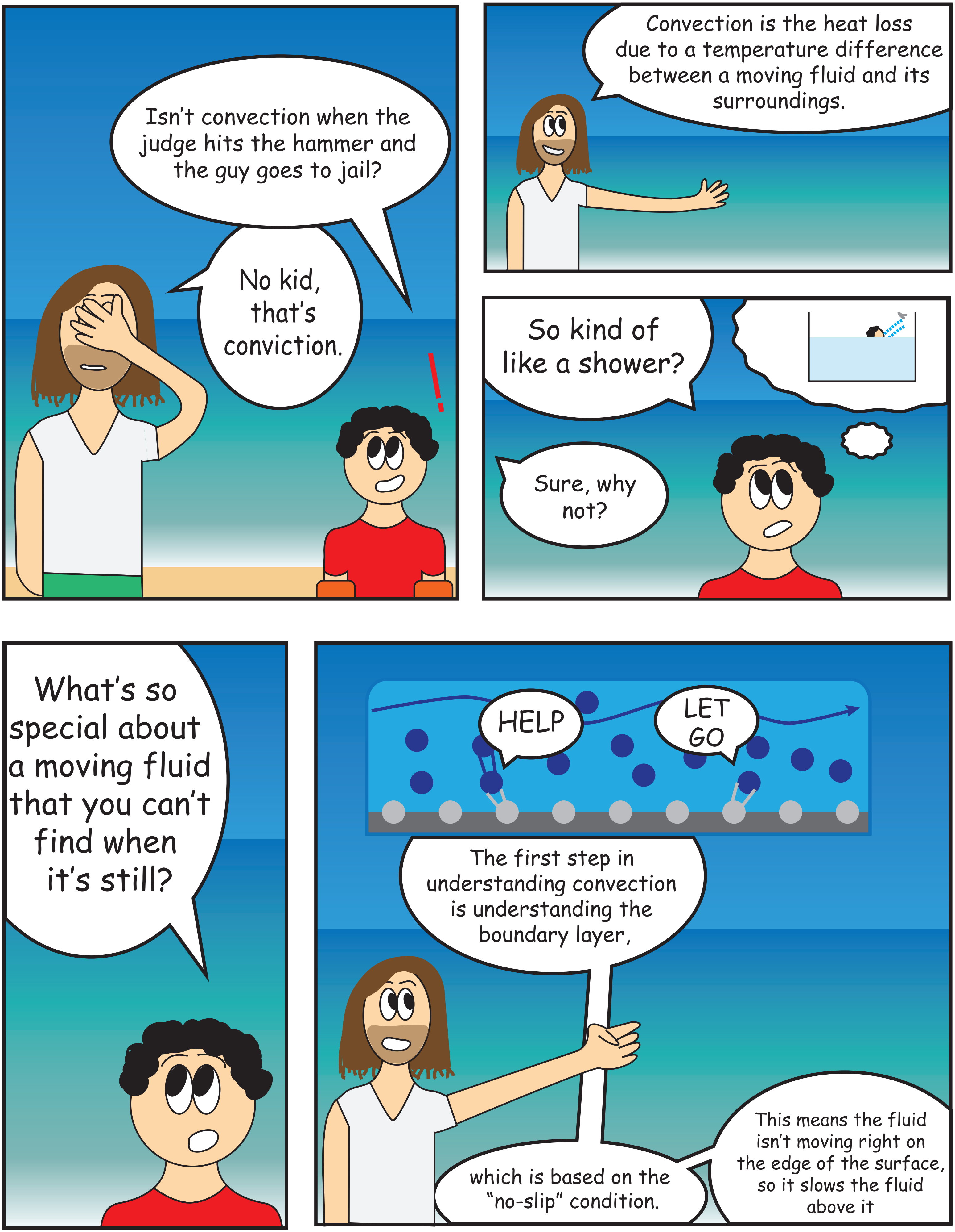
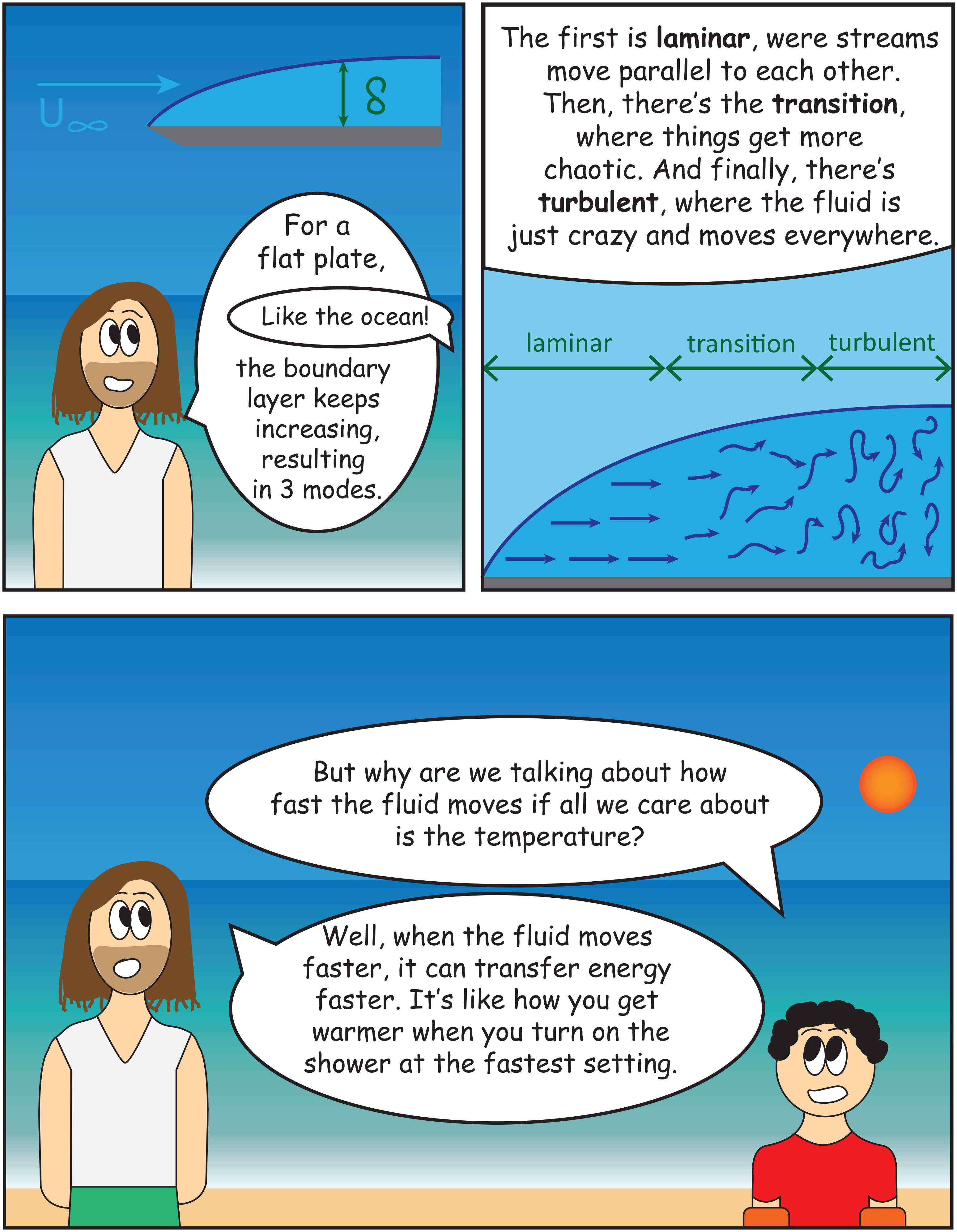
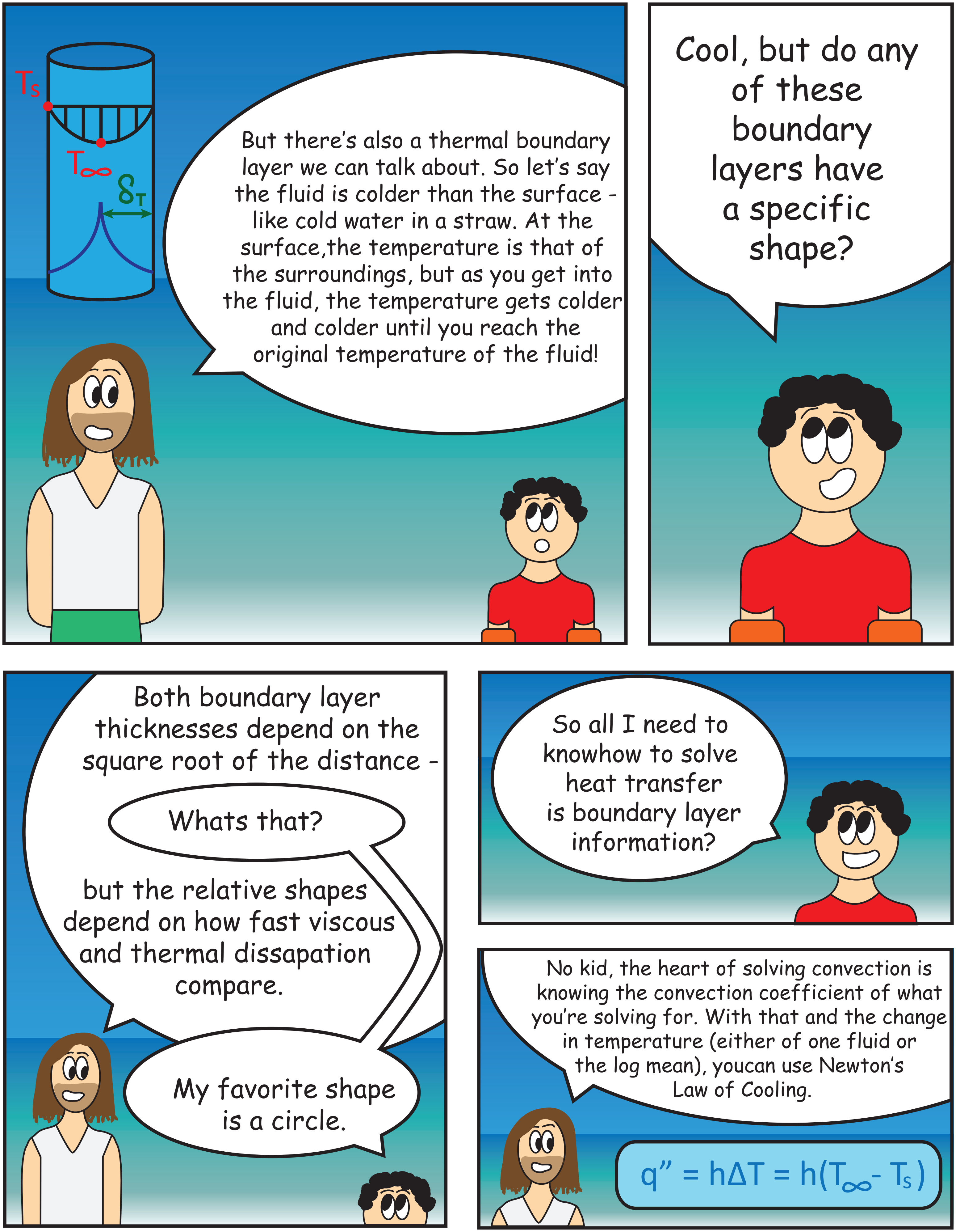
Woah kid! Where do you think you're going?
I'm going to swim.
You can't swim now! The water's too cold.
How? It's not too cold out here, how can it get cold in there?
Not to get technical, but you lose heat faster in the water than you do in the air.
Why? Isn't everything supposed to be the same temperature?
You're right, but **convection** in water is greater than convection in the air, so you get colder.
That's why surfers wear insulation suits - they're made with convection in mind!

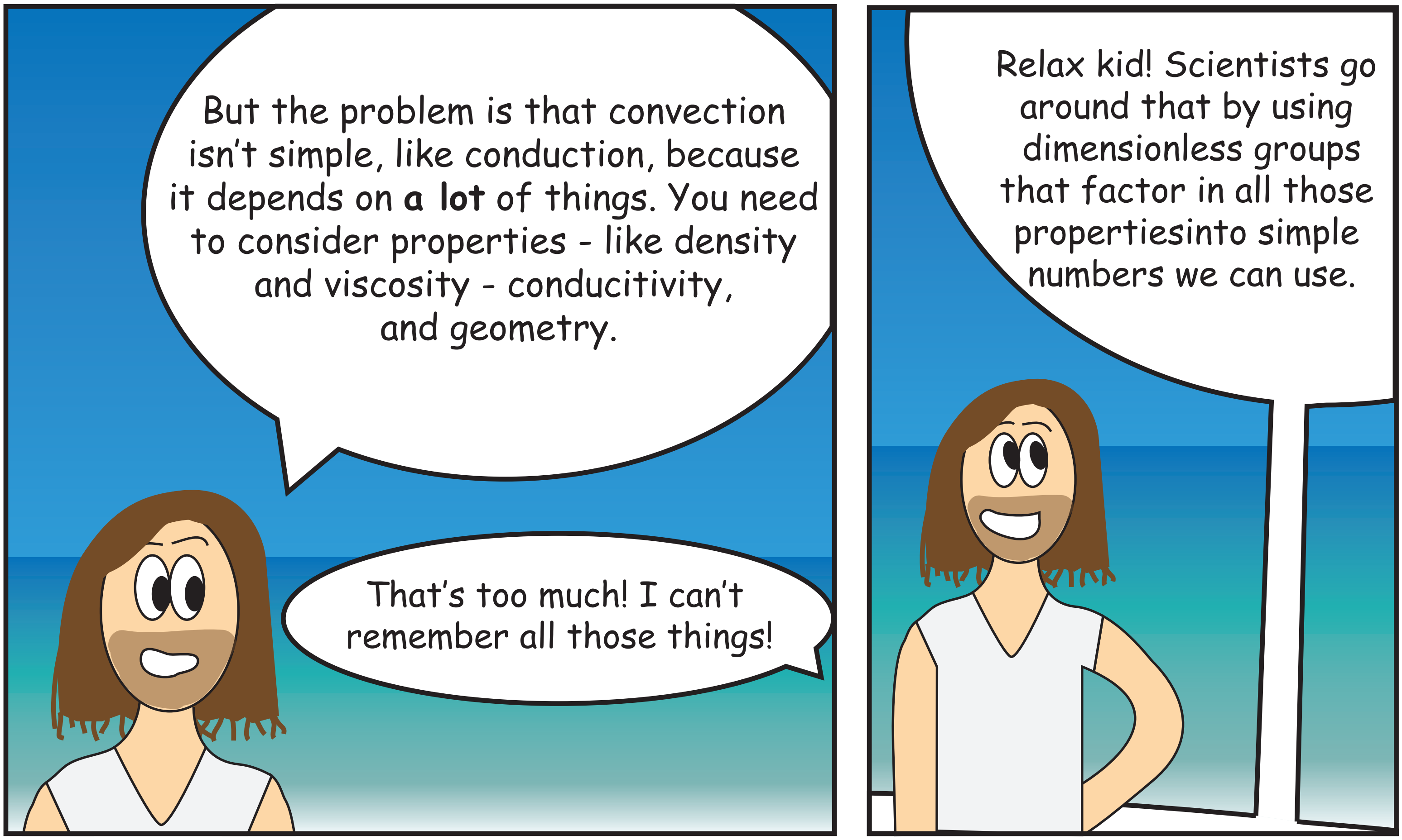

Isn't convection when the judge hits the hammer and the guy goes to jail?
No kid, that's conviction.
!
Convection is the heat loss due to a temperature difference between a moving fluid and its surroundings.
So kind of like a shower?
Sure, why not?
What's so special about a moving fluid that you can't find when it's still?
HELP
LET GO
The first step in understanding convection is understanding the boundary layer,
which is based on the "no-slip" condition.
This means the fluid isn't moving right on the edge of the surface, so it slows the fluid above it



U∞
δ
For a flat plate,
Like the ocean!
the boundary layer keeps increasing, resulting in 3 modes.
The first is **laminar**, were streams move parallel to each other. Then, there's the **transition**, where things get more chaotic. And finally, there's **turbulent**, where the fluid is just crazy and moves everywhere.
laminar
transition
turbulent
But why are we talking about how fast the fluid moves if all we care about is the temperature?
Well, when the fluid moves faster, it can transfer energy faster. It's like how you get warmer when you turn on the shower at the fastest setting.



T_s
T_∞
δ_T
But there's also a thermal boundary layer we can talk about. So let's say the fluid is colder than the surface - like cold water in a straw. At the surface,the temperature is that of the surroundings, but as you get into the fluid, the temperature gets colder and colder until you reach the original temperature of the fluid!
Cool, but do any of these boundary layers have a specific shape?
Both boundary layer thicknesses depend on the square root of the distance -
Whats that?
but the relative shapes depend on how fast viscous and thermal dissapation compare.
My favorite shape is a circle.
So all I need to knowhow to solve heat transfer is boundary layer information?
No kid, the heart of solving convection is knowing the convection coefficient of what you're solving for. With that and the change in temperature (either of one fluid or the log mean), youcan use Newton's Law of Cooling.
$q'' = h\Delta T = h(T_\infty - T_s)$



The first one is the Reynolds' Number.

$$Re = \frac{\rho v D}{\mu}$$

This number is a ratio of the fluid's inertia to viscosity forces, and we use it to quantify fluid flow. For example, if Re > 50,000 on a flat plate, we know that the flow is turbulent.

The second group is the Prandtl Number.

$$Pr = \frac{\nu}{\alpha} = \frac{c_p \mu}{k}$$

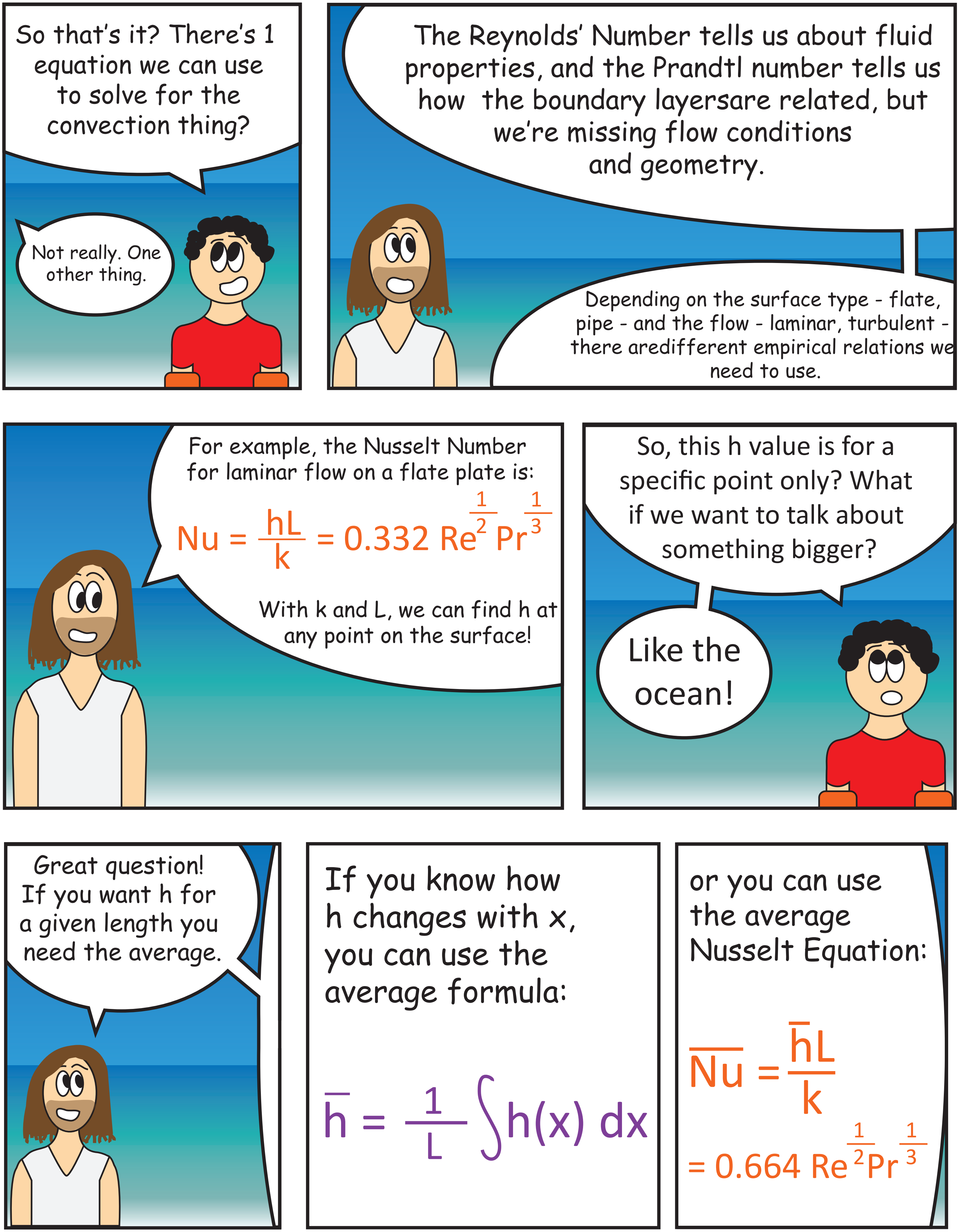
This number is a ratio of a fluid's momentum to thermal diffusivities. It tells us if momentum develops faster than temperature (this is true for Pr > 1, which is the case for most engineering fluids). It is also used for boundary layer sizes:

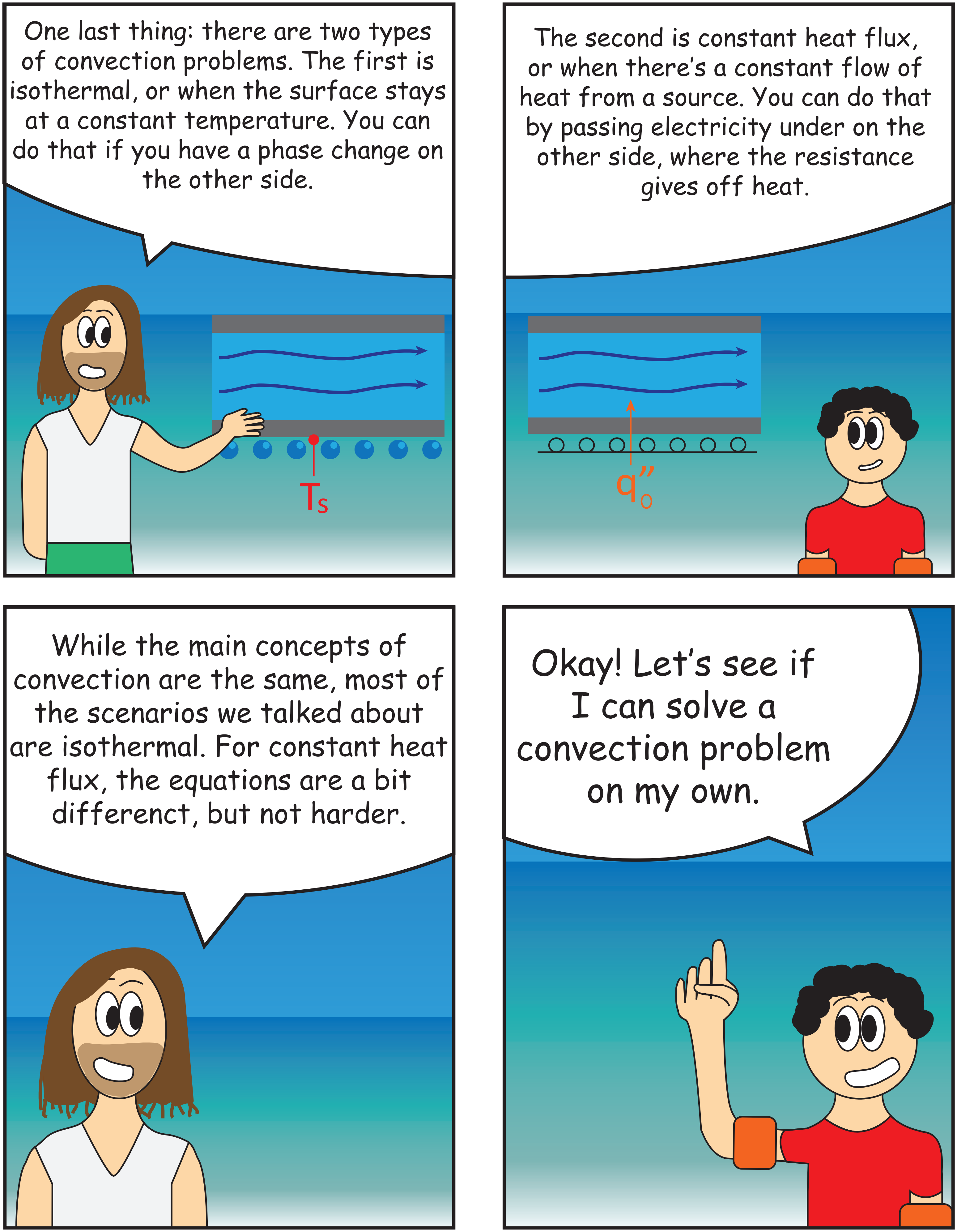
$$\frac{\delta}{\delta_T} = Pr^{\frac{1}{3}}$$

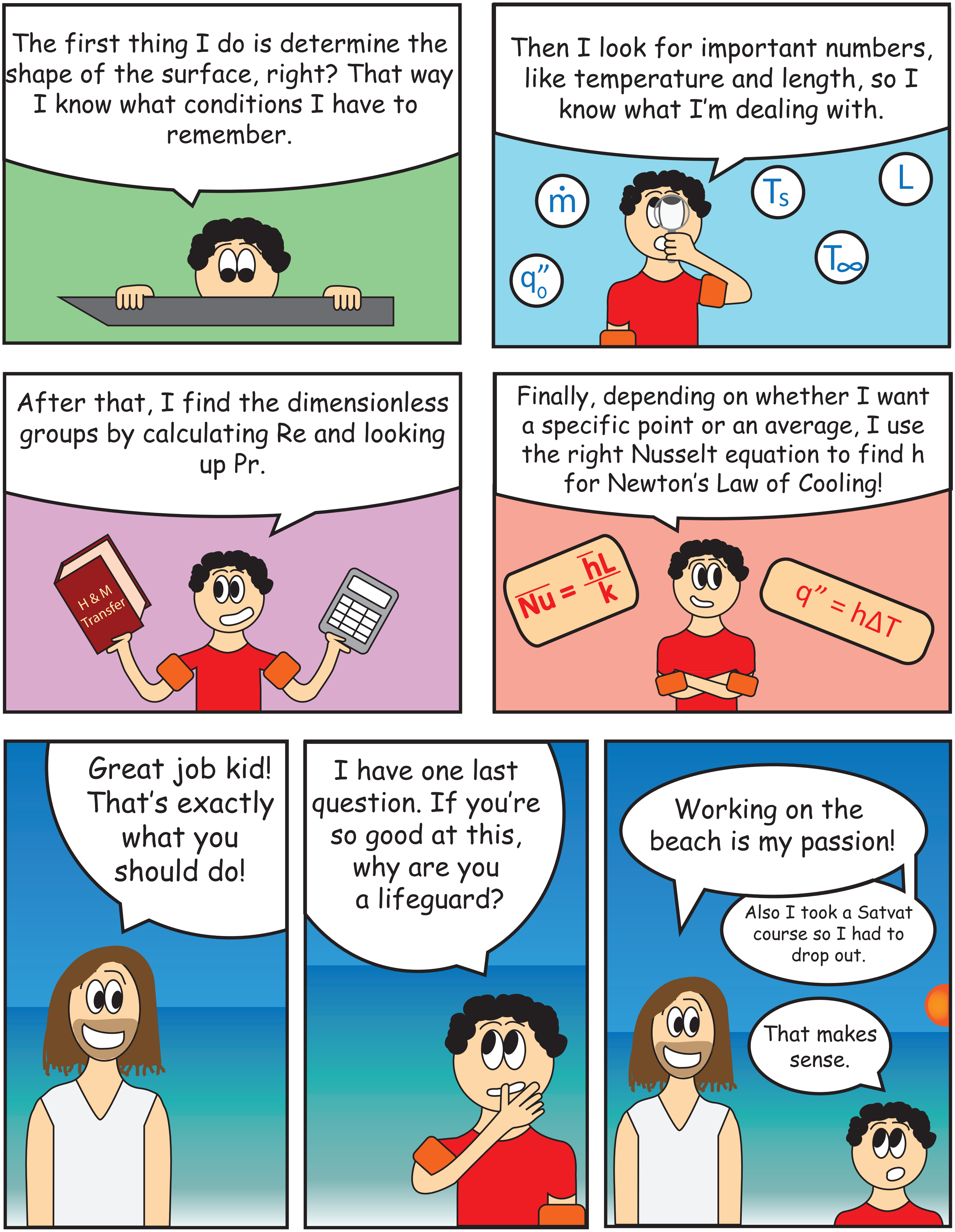
The last one is the Nusselt Number.

$$Nu = \frac{h D}{k}$$

The last number is a ratio of convection to conduction in a fluid. It's very important because we use it to calculate the convection coefficient (h). The Nusselt Number is a function of both Re and Pr.


So that's it? There's 1 equation we can use to solve for the convection thing?
Not really. One other thing.
The Reynolds' Number tells us about fluid properties, and the Prandtl number tells us how the boundary layersare related, but we're missing flow conditions and geometry.
Depending on the surface type - flate, pipe - and the flow - laminar, turbulent - there aredifferent empirical relations we need to use.
For example, the Nusselt Number for laminar flow on a flate plate is:
$Nu = \frac{hL}{k} = 0.332\ Re^{\frac{1}{2}}\ Pr^{\frac{1}{3}}$
With k and L, we can find h at any point on the surface!
So, this h value is for a specific point only? What if we want to talk about something bigger?
Like the ocean!
Great question! If you want h for a given length you need the average.
If you know how h changes with x, you can use the average formula:
$\bar{h} = \frac{1}{L} \int h(x)\, dx$
or you can use the average Nusselt Equation:
$\overline{Nu} = \frac{\bar{h}L}{k}$
$= 0.664\ Re^{\frac{1}{2}} Pr^{\frac{1}{3}}$


One last thing: there are two types of convection problems. The first is isothermal, or when the surface stays at a constant temperature. You can do that if you have a phase change on the other side.
Ts
The second is constant heat flux, or when there's a constant flow of heat from a source. You can do that by passing electricity under on the other side, where the resistance gives off heat.
q"o
While the main concepts of convection are the same, most of the scenarios we talked about are isothermal. For constant heat flux, the equations are a bit differenct, but not harder.
Okay! Let's see if I can solve a convection problem on my own.



The first thing I do is determine the shape of the surface, right? That way I know what conditions I have to remember.
Then I look for important numbers, like temperature and length, so I know what I'm dealing with.
$\dot{m}$
T_s
L
q''_0
T_∞
After that, I find the dimensionless groups by calculating Re and looking up Pr.
H & M Transfer
Finally, depending on whether I want a specific point or an average, I use the right Nusselt equation to find h for Newton's Law of Cooling!
$\overline{Nu} = \frac{\overline{h}L}{k}$
$q'' = h\Delta T$
Great job kid! That's exactly what you should do!
I have one last question. If you're so good at this, why are you a lifeguard?
Working on the beach is my passion!
Also I took a Satvat course so I had to drop out.
That makes sense.