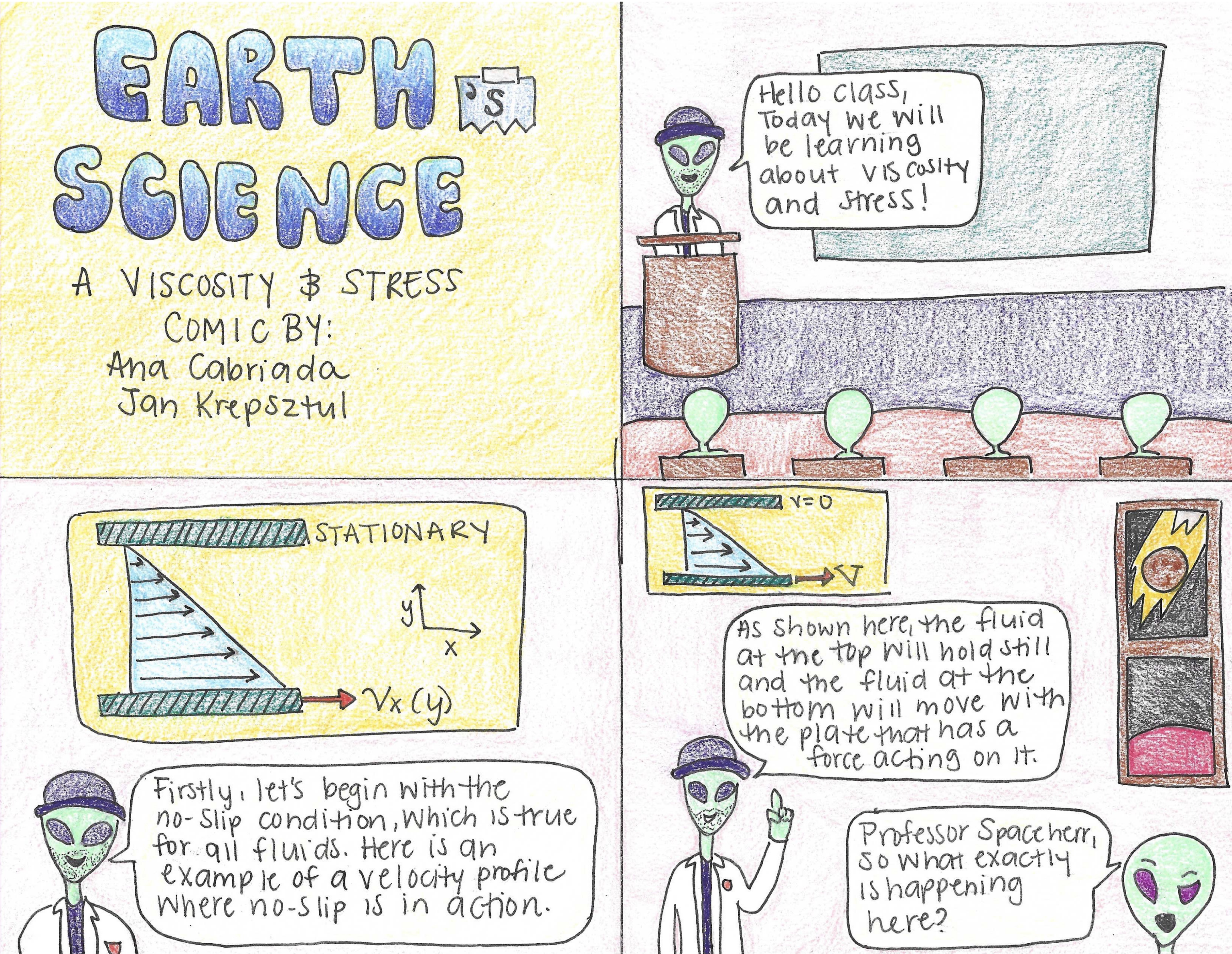
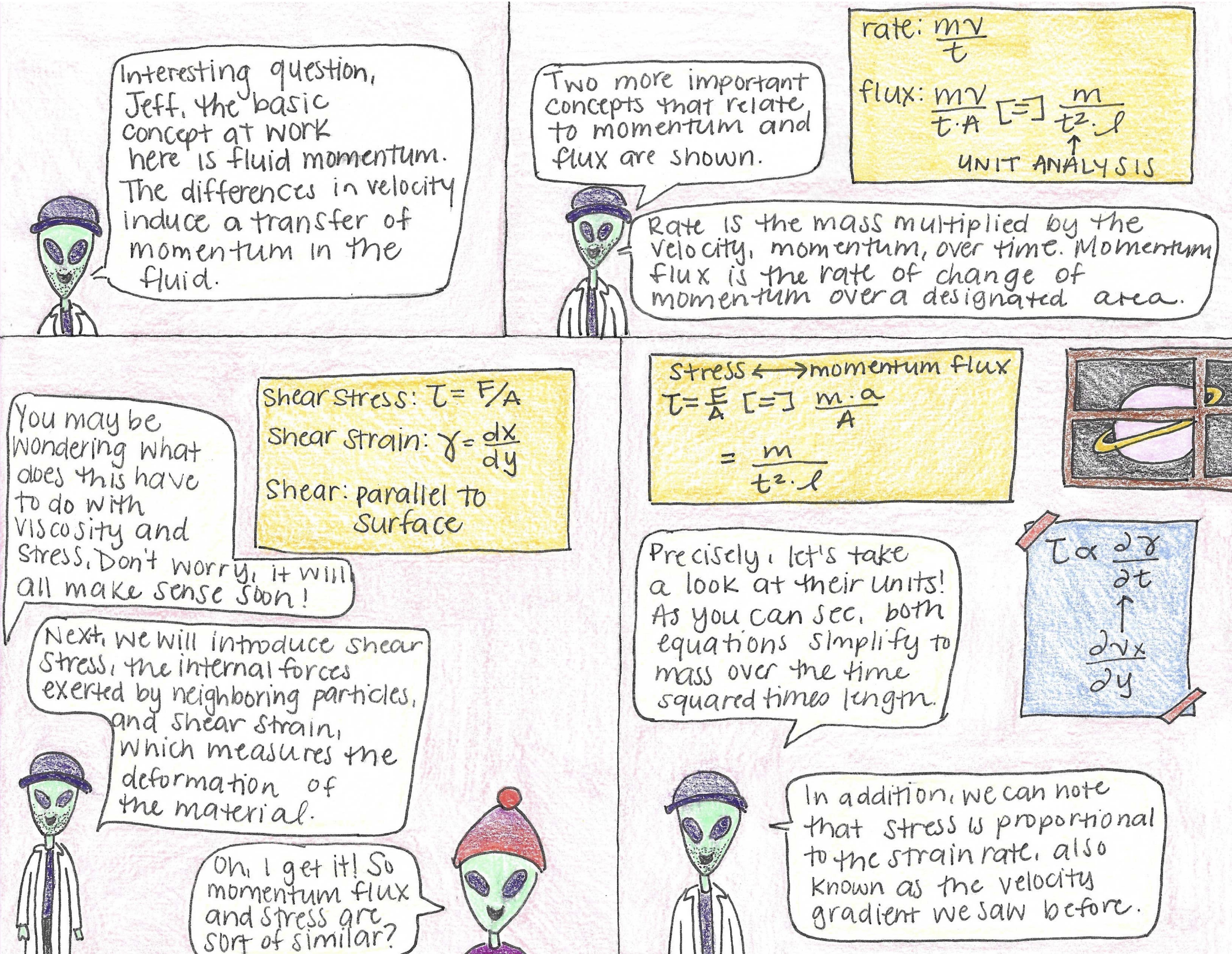
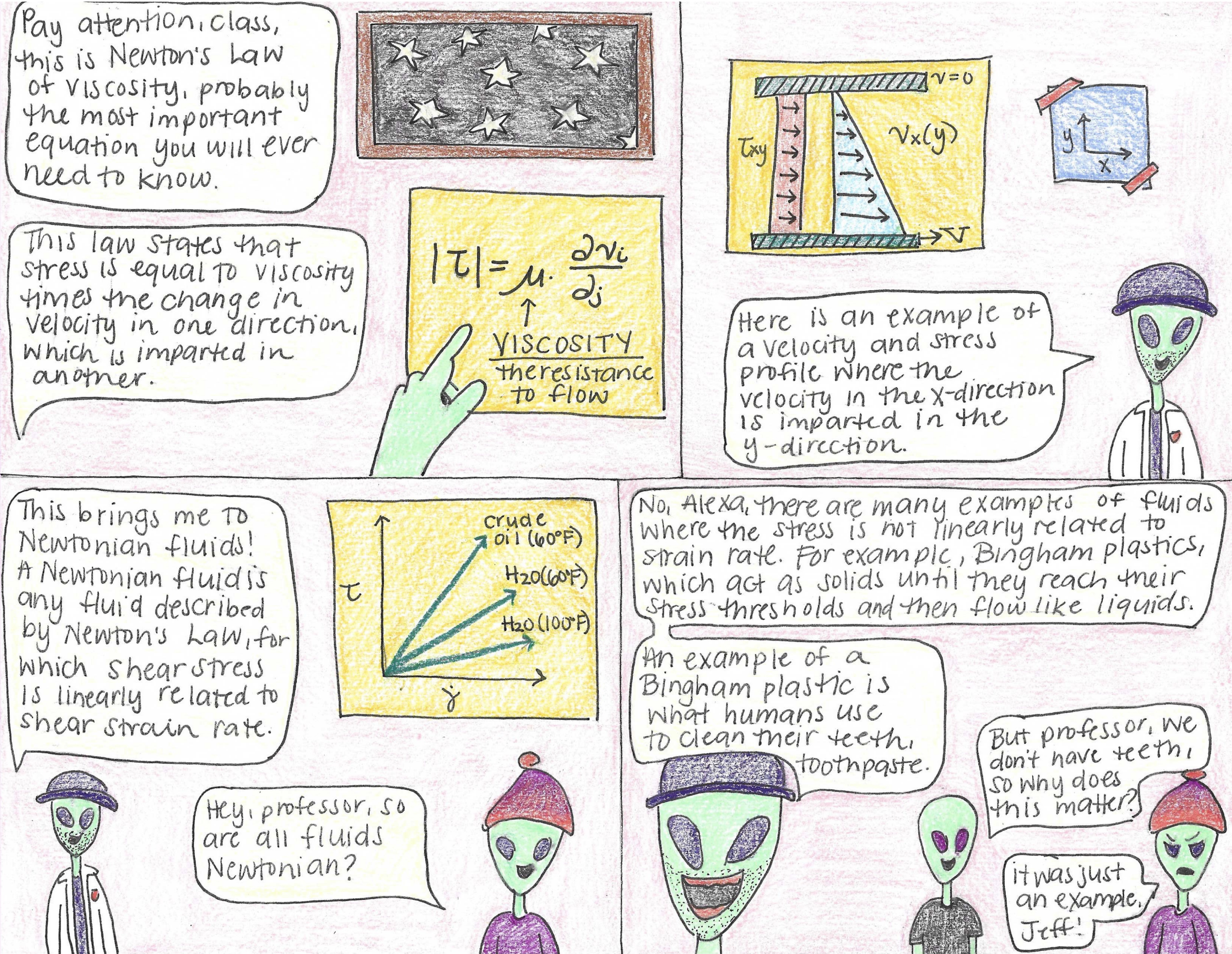

EARTH'S SCIENCE
A VISCOSITY & STRESS COMIC BY:
Ana Cabriada
Jan Krepsztul
Hello class, Today we will be learning about viscosity and stress!
STATIONARY
y
x
$v_x(y)$
Firstly, let's begin with the no-slip condition, which is true for all fluids. Here is an example of a velocity profile where no-slip is in action.
v=0
V
As shown here, the fluid at the top will hold still and the fluid at the bottom will move with the plate that has a force acting on it.
Professor Spaceherr, so what exactly is happening here?



Interesting question, Jeff. the basic concept at work here is fluid momentum. The differences in velocity induce a transfer of momentum in the fluid.
Two more important concepts that relate to momentum and flux are shown.
rate: mv/t
flux: mv/(t·A) [=] m/(t²·l)
UNIT ANALYSIS
Rate is the mass multiplied by the velocity, momentum, over time. Momentum flux is the rate of change of momentum over a designated area.
You may be wondering what does this have to do with viscosity and stress. Don't worry, it will all make sense soon!
Shear stress: τ = F/A
Shear strain: γ = dx/dy
Shear: parallel to surface
Next, we will introduce shear stress, the internal forces exerted by neighboring particles, and shear strain, which measures the deformation of the material.
Oh, I get it! So momentum flux and stress are sort of similar?
Stress ⟷ momentum flux
τ = F/A [=] m·a/A
= m/(t²·l)
Precisely, let's take a look at their units! As you can see, both equations simplify to mass over the time squared times length.
τ ∝ ∂γ/∂t
∂vx/∂y
In addition, we can note that stress is proportional to the strain rate, also known as the velocity gradient we saw before.



Pay attention, class, this is Newton's Law of Viscosity, probably the most important equation you will ever need to know.
This law states that stress is equal to viscosity times the change in velocity in one direction, which is imparted in another.
$|\tau| = \mu \cdot \frac{\partial v_i}{\partial_j}$
VISCOSITY
the resistance to flow
$v=0$
τ_{xy}
$v_x(y)$
V
y
x
Here is an example of a velocity and stress profile where the velocity in the x-direction is imparted in the y-direction.
This brings me to Newtonian fluids! A Newtonian fluid is any fluid described by Newton's Law, for which shear stress is linearly related to shear strain rate.
crude oil (60°F)
H_2O (60°F)
H_2O (100°F)
τ
$\dot{\gamma}$
Hey, professor, so are all fluids Newtonian?
No, Alexa, there are many examples of fluids where the stress is not linearly related to strain rate. For example, Bingham plastics, which act as solids until they reach their stress thresholds and then flow like liquids.
An example of a Bingham plastic is what humans use to clean their teeth, toothpaste.
But professor, we don't have teeth, so why does this matter?
It was just an example, Jeff!


Moving on...
There are also shear thinning fluids. For these fluids, as the strain rate increases, the viscosity will decrease. Another thing we don't have on this planet, Jeff, is quicksand, which just happens to be an example of a shear thinning fluid.
Finally, there is also shear thickening fluids. For these fluids, as the strain rate increases, the viscosity will also increase. A perfect example of a shear thickening fluid is corn starch, our main food source!
Wow, professor is making me hungry right about now!
Bingham plastic
shear thinning
Newtonian
shear thickening
τyx
γ̇yx
To end off class, I want to show you guys a graph of the stress over the strain rate for Newtonian fluids, Bingham plastics, shear thinning, and shear thickening fluids.
Okay class, you're dismissed now. Next week we will have a lesson about how to take control of human minds.
BREAK!
Awesome!
Cool!