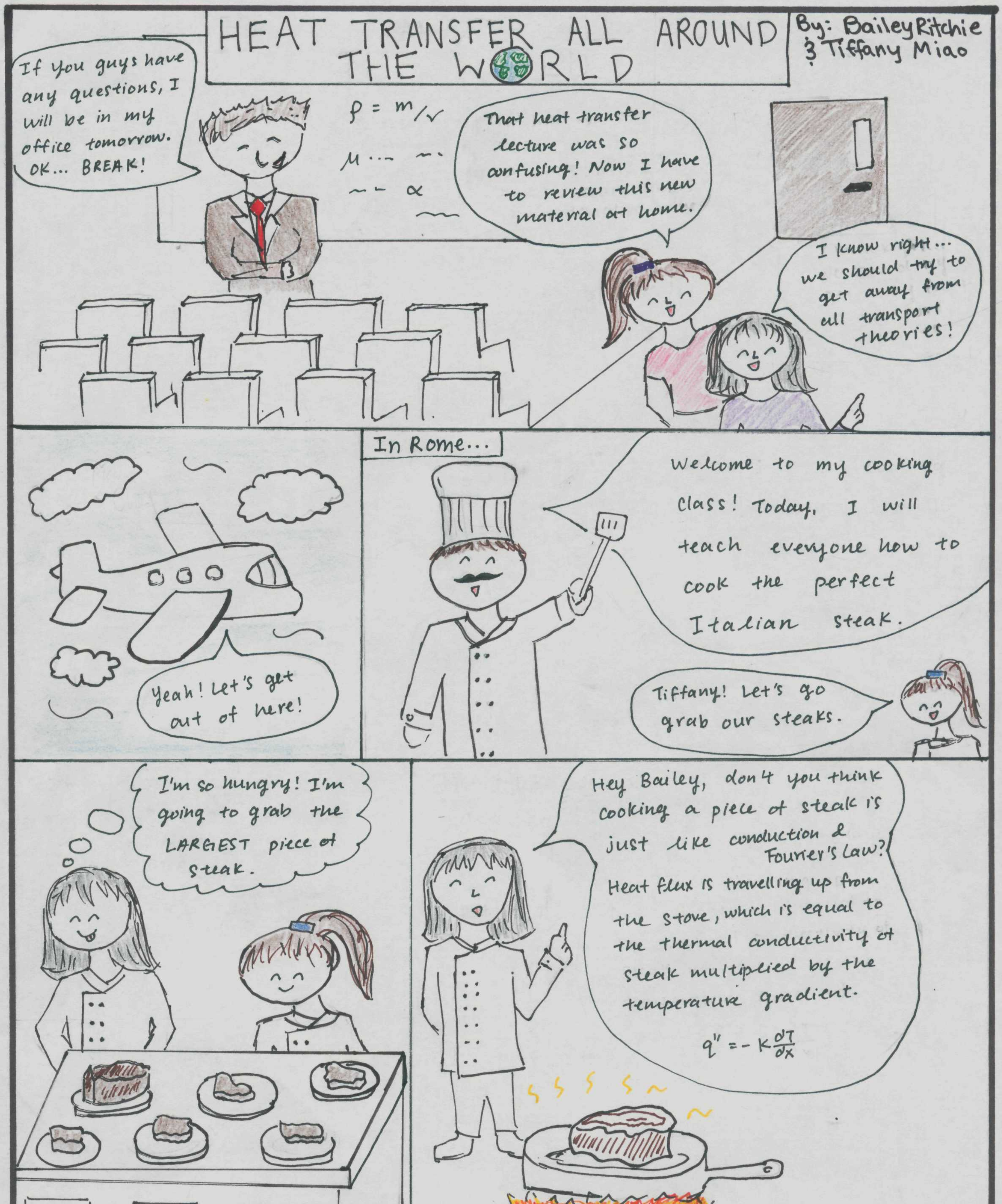
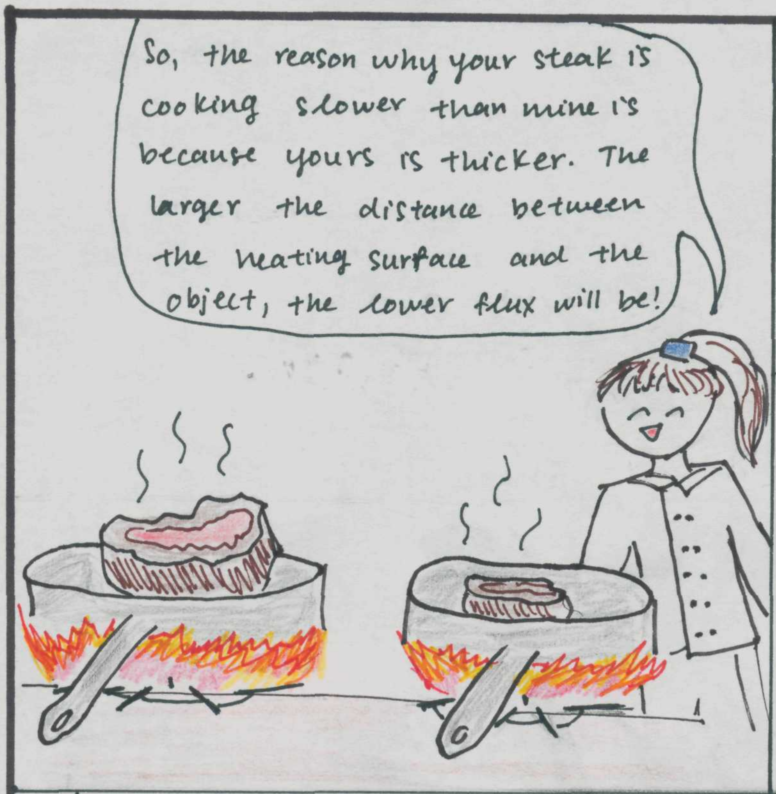
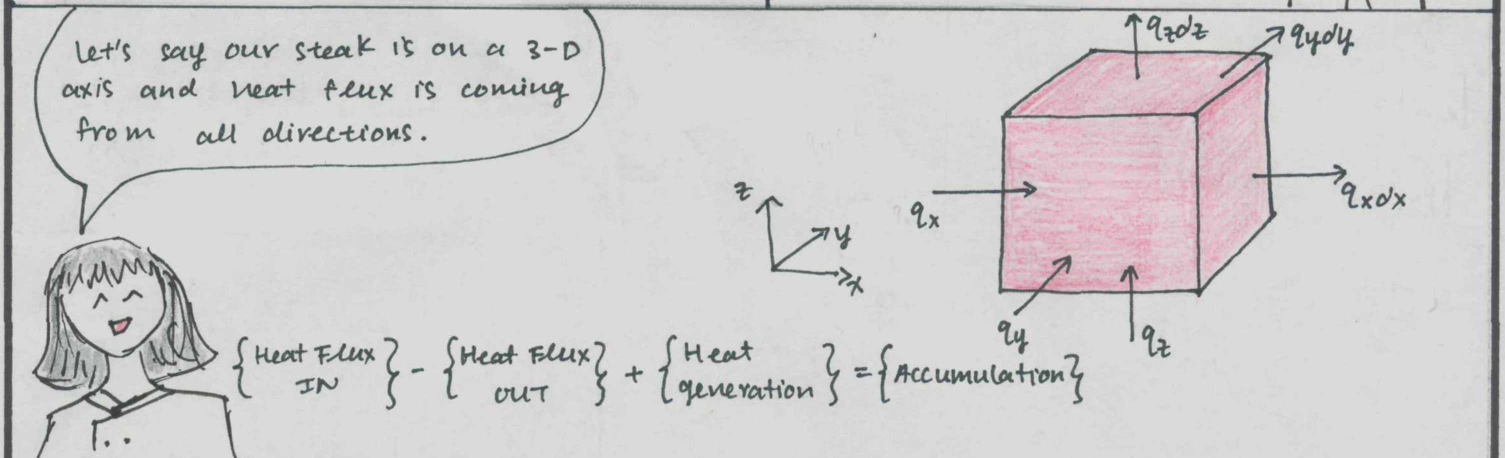

HEAT TRANSFER ALL AROUND THE WORLD
By: Bailey Ritchie & Tiffany Miao
If you guys have any questions, I will be in my office tomorrow. OK... BREAK!
ρ = m/v
That heat transfer lecture was so confusing! Now I have to review this new materral at home.
I know right... we should try to get away from all transport theories!
Yeah! Let's get out of here!
In Rome...
Welcome to my cooking class! Today, I will teach everyone how to cook the perfect Italian steak.
Tiffany! Let's go grab our steaks.
I'm so hungry! I'm going to grab the LARGEST piece of steak.
Hey Bailey, don't you think cooking a piece of steak is just like conduction & Fourier's Law? Heat flux is travelling up from the stove, which is equal to the thermal conductivity of steak multiplied by the temperature gradient.
q" = - k dT/dx
q"





$$\left[q''_x \Delta y \Delta z|_x - q_x \Delta y \Delta z|_{x+\Delta x}\right] + \left[q''_y \Delta x \Delta z|_y - q''_y \Delta x \Delta z|_{y+\Delta y}\right] + \left[q''_z \Delta x \Delta y|_z - q''_z \Delta x \Delta y|_{z+\Delta z}\right]$$

$$+\dot{q}_{gen} \Delta x \Delta y \Delta z = \rho C_p \frac{\partial T}{\partial t} \Delta x \Delta y \Delta z$$

This equation can be further simplified...

$$\underbrace{\frac{q''_x|_x - q''_x|_{x+\Delta x}}{\Delta x}}_{A} + \underbrace{\frac{q''_y|_y - q''_y|_{y+\Delta y}}{\Delta y}}_{B} + \underbrace{\frac{q''_z|_z + q''_z|_{z+\Delta z}}{\Delta z}}_{C} + \dot{q}_{gen} = \rho C_p \frac{\partial T}{\partial t}$$

1) Divide by volume

2) Take the limits of heat flux in each direction

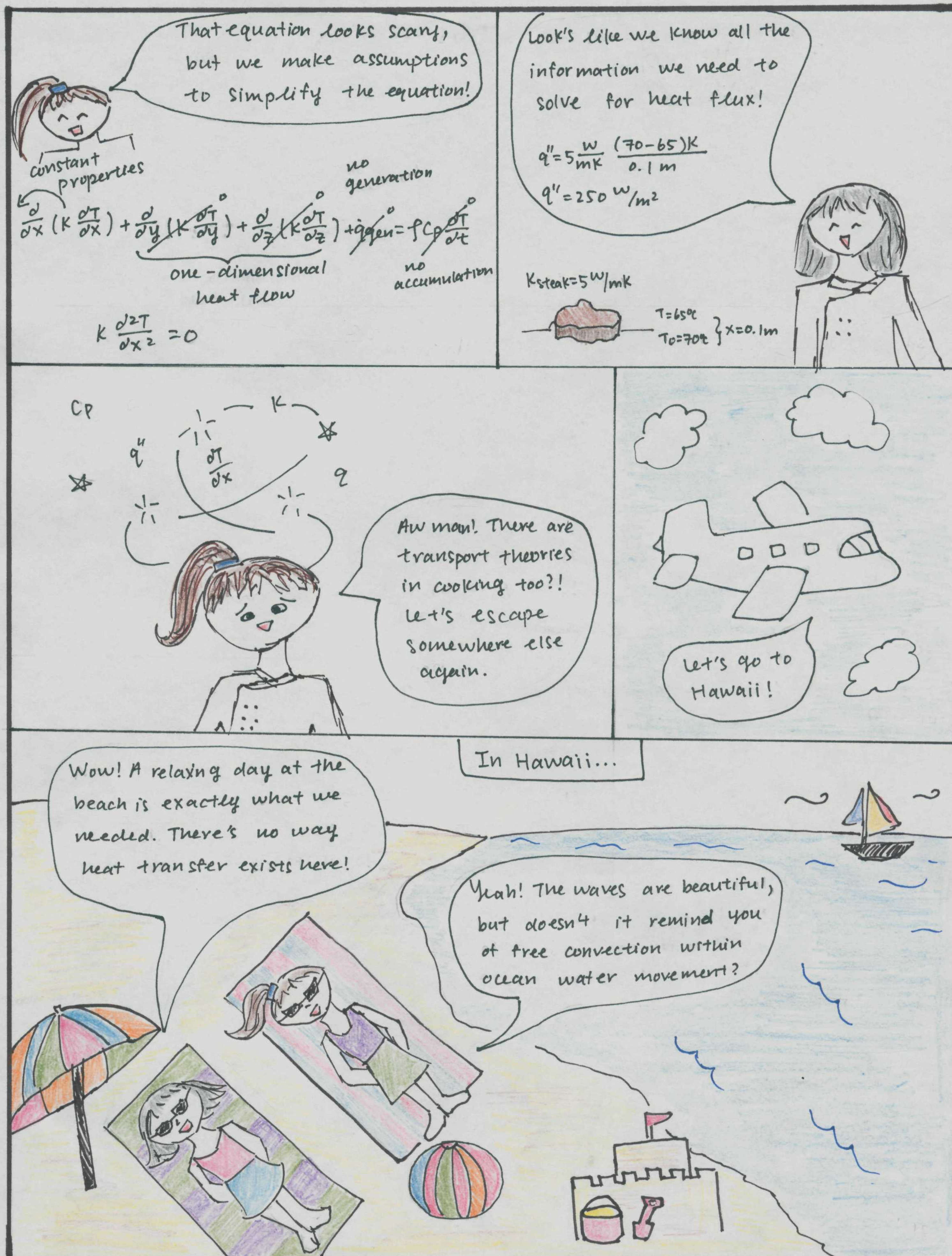
$$\lim_{\Delta x \to 0} A = -\frac{\partial q_x''}{\partial x} \qquad \lim_{\Delta y \to 0} B = -\frac{\partial q_y''}{\partial y} \qquad \lim_{\Delta z \to 0} C = \frac{-\partial q_z''}{\partial z}$$

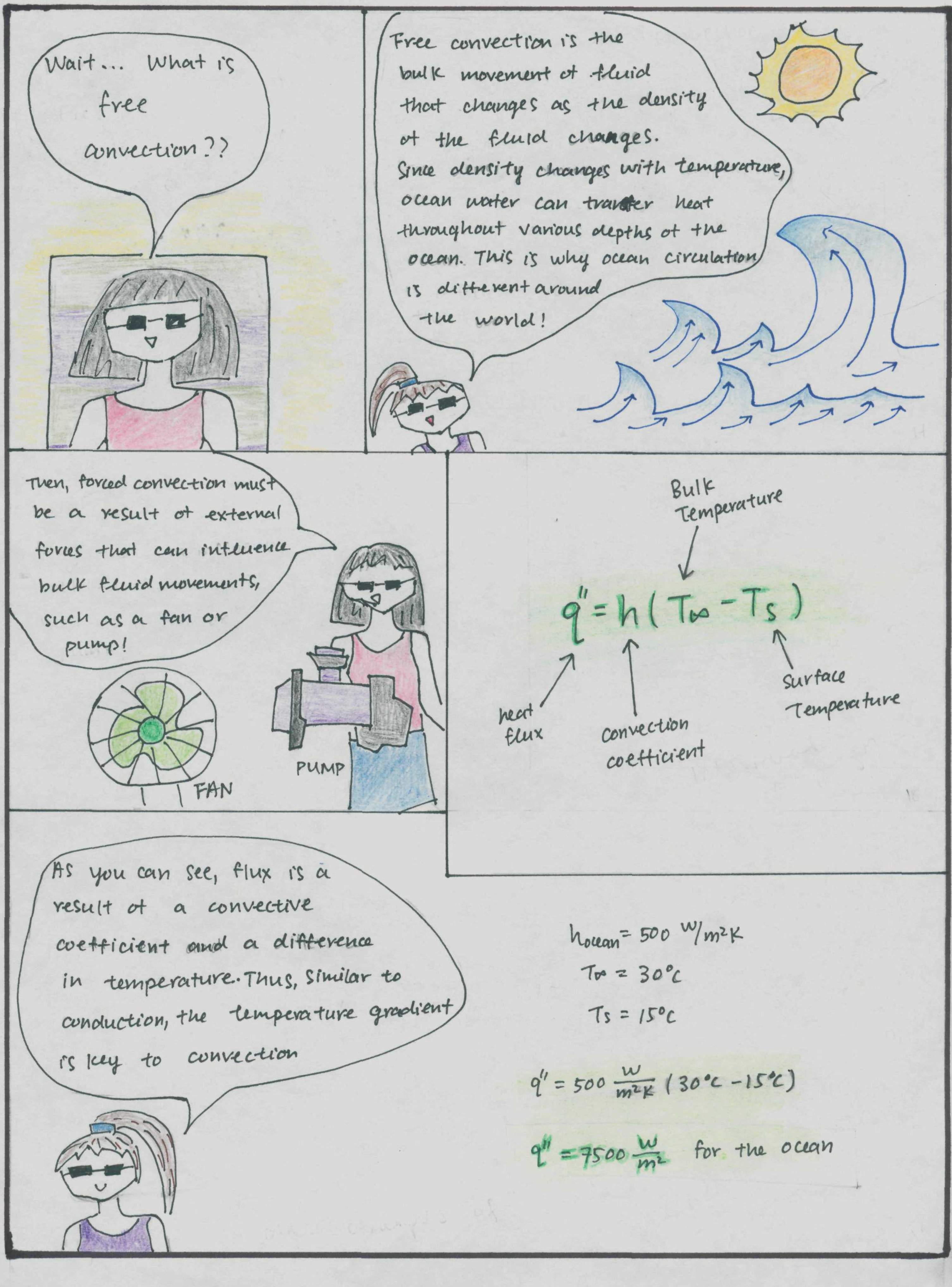
3) Combine the equations

$$-\frac{\partial q_x''}{\partial x} - \frac{\partial q_y''}{\partial y} - \frac{\partial q_z''}{\partial z} + \dot{q}_{gen} = \rho C_p \frac{\partial T}{\partial t}$$

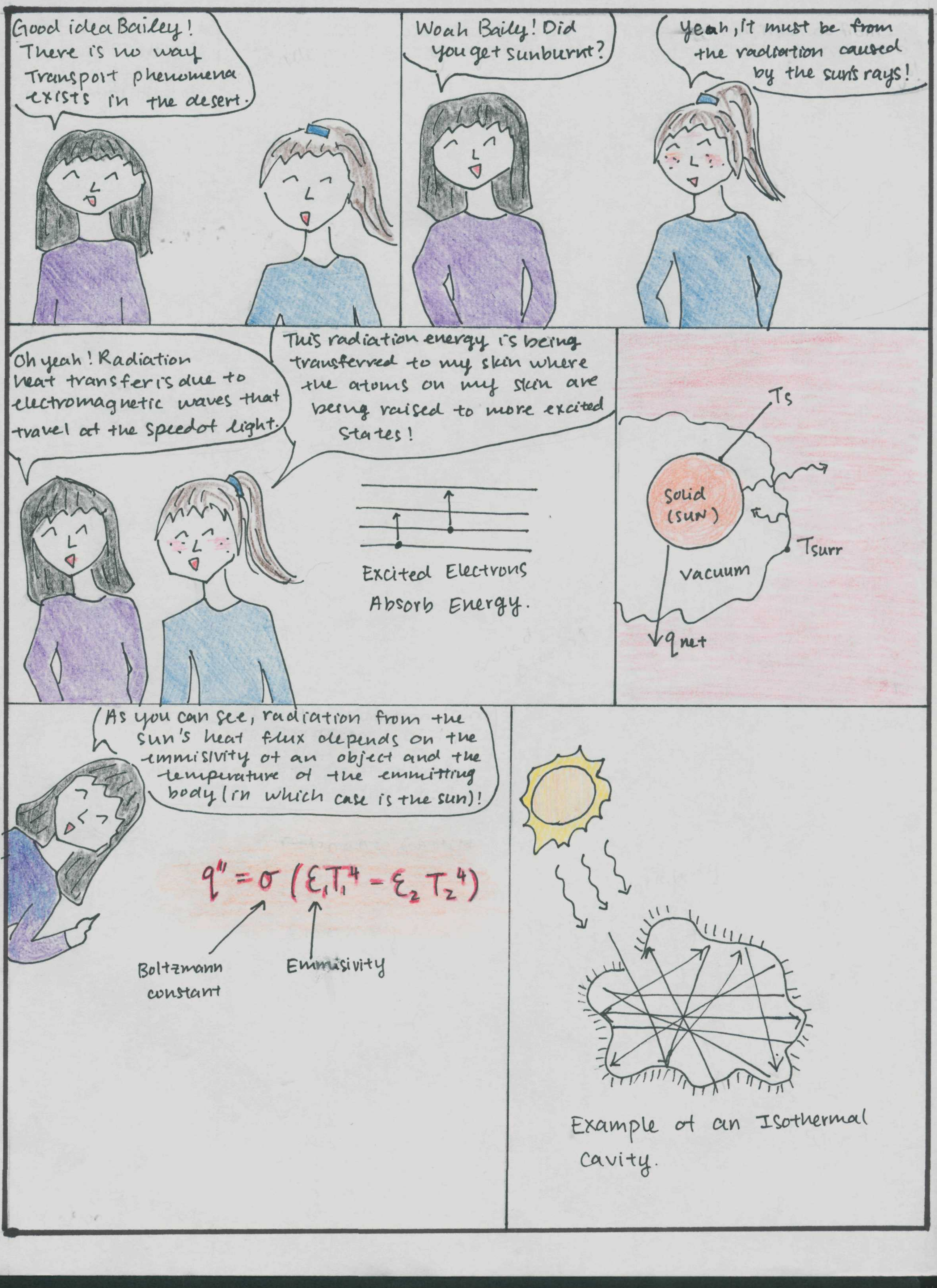
4) Substitute Fourier's Law!

$$\frac{\partial}{\partial x}\left(k \frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(k \frac{\partial T}{\partial y}\right) + \frac{\partial}{\partial z}\left(k \frac{\partial T}{\partial z}\right) + \dot{q}_{gen} = \rho C_p \frac{\partial T}{\partial t}$$


That equation looks scary, but we make assumptions to simplify the equation!
constant properties
no generation
$\frac{\partial}{\partial x}(k\frac{\partial T}{\partial x}) + \frac{\partial}{\partial y}(k\frac{\partial T}{\partial y}) + \frac{\partial}{\partial z}(k\frac{\partial T}{\partial z}) + \dot{q}_{gen} = \rho c_p \frac{\partial T}{\partial t}$
one-dimensional heat flow
no accumulation
$k\frac{\partial^2 T}{\partial x^2} = 0$
Look's like we know all the information we need to solve for heat flux!
$q'' = 5\frac{W}{mK}\frac{(70-65)K}{0.1\,m}$
$q'' = 250\,W/m^2$
$k_{steak} = 5\,W/mK$
$T = 65°C$
$T_0 = 70°C$
$x = 0.1m$
Cp
K
q''
$\frac{\partial T}{\partial x}$
q
Aw man! There are transport theories in cooking too?! Let's escape somewhere else again.
Let's go to Hawaii!
In Hawaii...
Wow! A relaxing day at the beach is exactly what we needed. There's no way heat transfer exists here!
Yeah! The waves are beautiful, but doesn't it remind you of free convection within ocean water movement?


Wait... What is free convection??
Free convection is the bulk movement of fluid that changes as the density of the fluid changes. Since density changes with temperature, ocean water can transfer heat throughout various depths of the ocean. This is why ocean circulation is different around the world!
Then, forced convection must be a result of external forces that can influence bulk fluid movements, such as a fan or pump!
FAN
PUMP
Bulk Temperature
$q'' = h(T_\infty - T_s)$
heat flux
convection coefficient
surface Temperature
As you can see, flux is a result of a convective coefficient and a difference in temperature. Thus, similar to conduction, the temperature gradient is key to convection
$h_{ocean} = 500\ W/m^2K$
$T_\infty = 30°C$
$T_s = 15°C$
$q'' = 500 \frac{W}{m^2K} (30°C - 15°C)$
$q'' = 7500 \frac{W}{m^2}$ for the ocean


You are right! Some materials have greater convection coefficients than others. For example, water has a higher h value and has more cooling/heating capabilities than air!
For example, convection also exists in boiling water over a stove and through weather patterns in the sky!
$\rho = \frac{m}{V}$
cool lowers
OR
hot rises
That's why I feel so much colder standing in the ocean than in air!
There is too much heat transfer in Hawaii. Let's go somewhere else!
CHEAP-O-AIR
Meanwhile in Egypt...


Good idea Bailey! There is no way Transport phenomena exists in the desert.
Woah Baily! Did you get sunburnt?
Yeah, it must be from the radiation caused by the sun's rays!
Oh yeah! Radiation heat transfer is due to electromagnetic waves that travel at the speed of light.
This radiation energy is being transferred to my skin where the atoms on my skin are being raised to more excited states!
Excited Electrons Absorb Energy.
Ts
Solid (SUN)
Tsurr
Vacuum
q net
As you can see, radiation from the sun's heat flux depends on the emmisivity of an object and the temperature of the emmitting body (in which case is the sun)!
q" = σ (ε1T1^4 - ε2 T2^4)
Boltzmann constant
Emmisivity
Example of an Isothermal Cavity.

The limit for radiation is defined through a concept called blackbody. This is a perfect radiatron surface that absorbeds all radiatron.
$q''_b = \sigma T^4$
flux from blackbody
However, this does NOT exist! Nonetheless, it can still be used to approximate ideal situations.
Additonally, there are two radiation processes: emmisron and absorption. Emmision occursas Photons are released or when a molecular/atomic system goes from a high to low energy state.
Examples of Emission particles include Alpha, Beta, and Gamma rays. These partides are given off as a material lowers it's energy state
α β Γ
So Absorption must be the addition of radiant energy, which causes the system to go from a low to high energy state.
Absorption can occur within metal roofs for example. The roofs trap energy from the suns rays and uses the energy to heal / insulate home.
heat


Giza
Wow, you can never really escape all the properties of heat transfer.
Yeah! I think it is best that we go back to Boston!
$q'' = -k\frac{dT}{dx}$
Fourier's Law
x
q''
conduction
convection
$q'' = h(T_\infty - T_s)$
radiaton
$q'' = \varepsilon\sigma T^4$
I never thought that heat transfer would be everywhere! It's ironic that I tried to get away from it, but ended up leaving so much about heat transfer!
Yeah! I learned that conduction can occur in cooking; convection can occur in the ocean water; and radiation can occur when the sun reflects onto any objects...
Our trip around the world helped me learn so much about heat transfer!
Transport II
I think I am ready to face reality now...