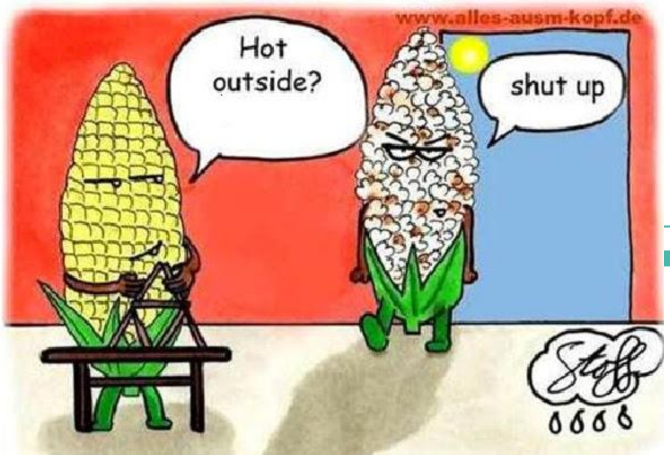
6.6 Thermal Energy, Temperature and Heat

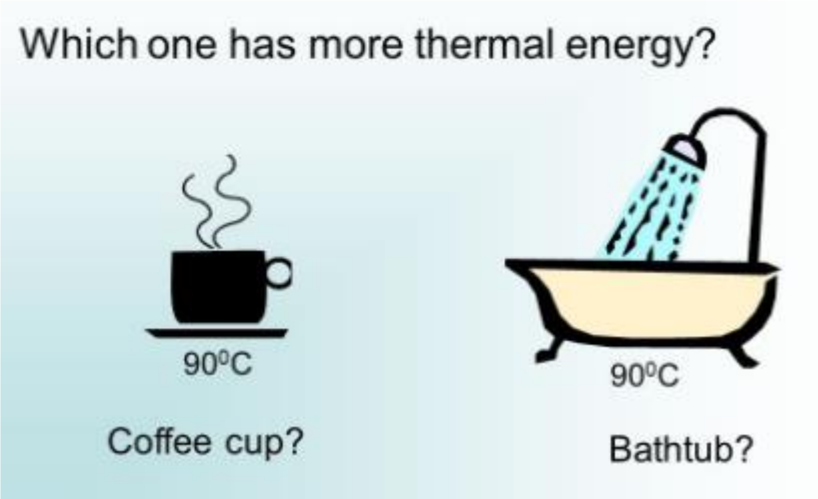


What's the difference?

Recall that **Thermal Energy, Temperature and Heat** are all related but mean slightly different things.

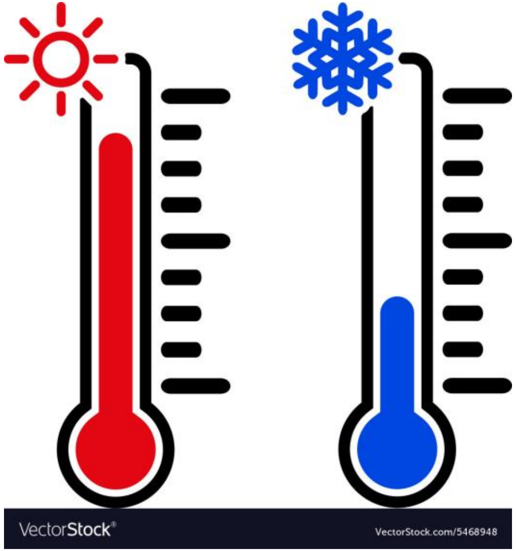
Thermal Energy

An energy *of the system* due to the motion of its atoms and molecules. It is the **total** kinetic energy of moving atoms.



Temperature

A variable that quantifies the 'hotness' or "coldness" of a system. It is the **average kinetic energy** of all the molecules in a substance, or the thermal energy per molecule.

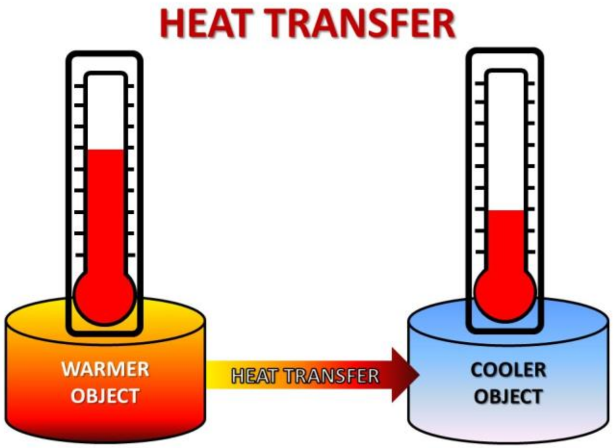


$$Temperature = \frac{E_{th}}{\#\ molecules}$$

Heat

The energy transfer between a system and the environment as a consequence of a temperature difference between them.

Heat is the amount of energy that moves between the system and the environment during a thermal interaction.



Which has the higher temperature?

Are the temperatures of the table top and the metal faucet the same?

____

Explain:

They are the same temperature. Metal is a better conductor of heat and it "sucks" (transfers) the thermal energy of out your hand faster when you touch it. This makes it feel colder.

Which has Higher Temp? Higher E_{TH}?

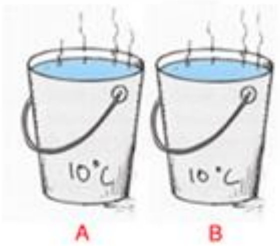
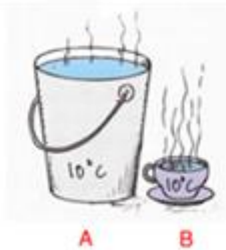
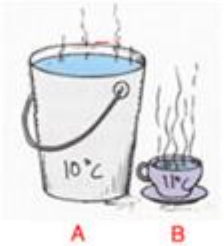
Candle

Cup of Hot Tea

The candle has the higher temperature. The cup of hot tea has more thermal energy. It has more molecules so it has more total kinetic energy.

Complete this in your notes

Consider This: How do the temperatures and thermal energy compare for each of the set ups below?

			
Temperature			
E_{th}			

Complete in your notes

Consider This: A sparkler is a safe toy for kids as the sparks don't burn the skin upon contact. In fact, they are quite cool to the touch. In actuality, each spark is 1600°C. Explain why a 1600°C spark doesn't burn your skin.

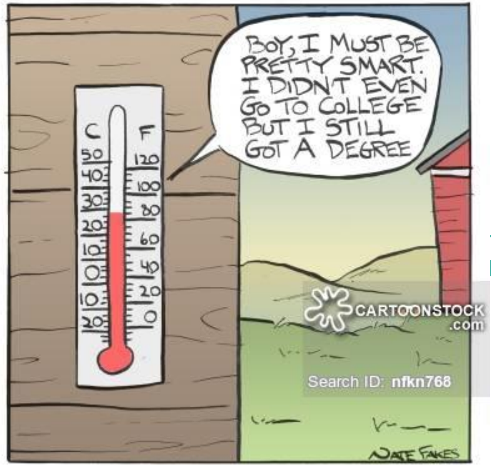
Even though it has an extremely high temperature, it does not burn your skin because the sparks have extremely low mass, therefore very low thermal energy. Without much energy, they don't have the capacity to do much damage to your skin

Complete in your notes

Consider This: An oven at 400°C is much cooler when compared with a sparkler, yet when you accidentally touch the side of the oven while getting your dinner out, it burns quite a bit. Explain why an oven at 400°C burns you significantly more than a sparkler at 1600°C.

Temperature is directly proportional to energy per molecule. How much energy depends on how many molecules. When you touch the oven, you're making contact with many, many molecules, and the flow of energy is a painful experience. Although the energy per molecule is much greater in the sparks of the firework, you make contact with only a relatively few molecules when a spark lands on you. The corresponding low energy transfer borders on your threshold of feeling.

6.7 Temperature Scales



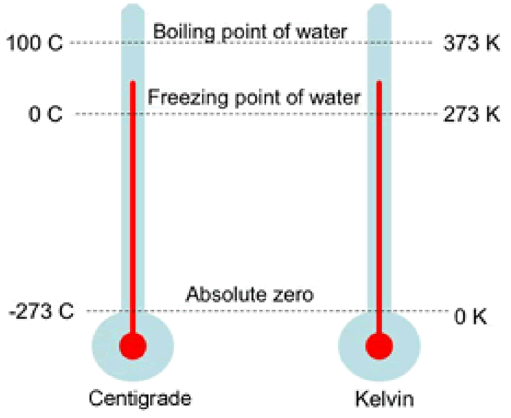
Temperature Scales

The Celsius scale defines 0 as the point at which water freezes, and 100 the point at which water boils.

The Kelvin scale defines 0 as absolute zero, the temperature at which the motion of particles stops (lowest temperature possible)

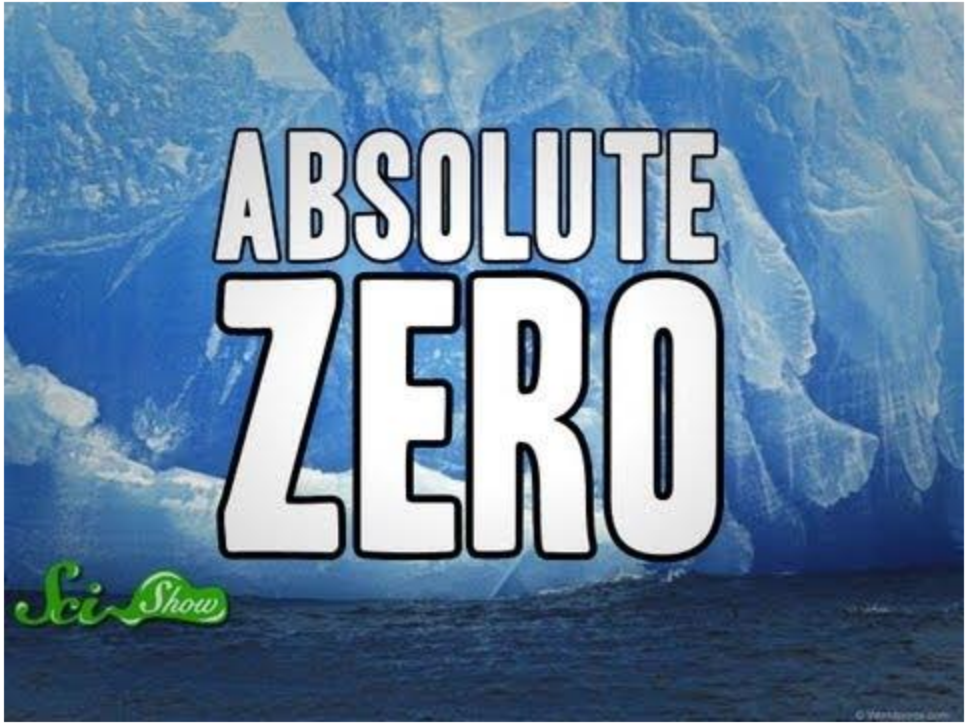
The size of one unit of degree Celsius is the exact same as one unit of degree Kelvin

Degrees in Kelvin = Degrees in Celsius + 273.1

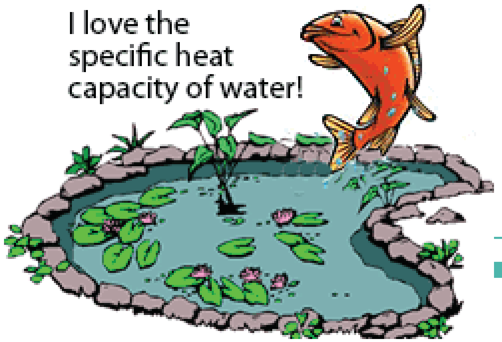


A comparison of the centigrade and Kelvin temperature scales. Note a change of 1 Kelvin is the same as a change of 1 degree centigrade. It is the zero-points differ that differ.

Watch

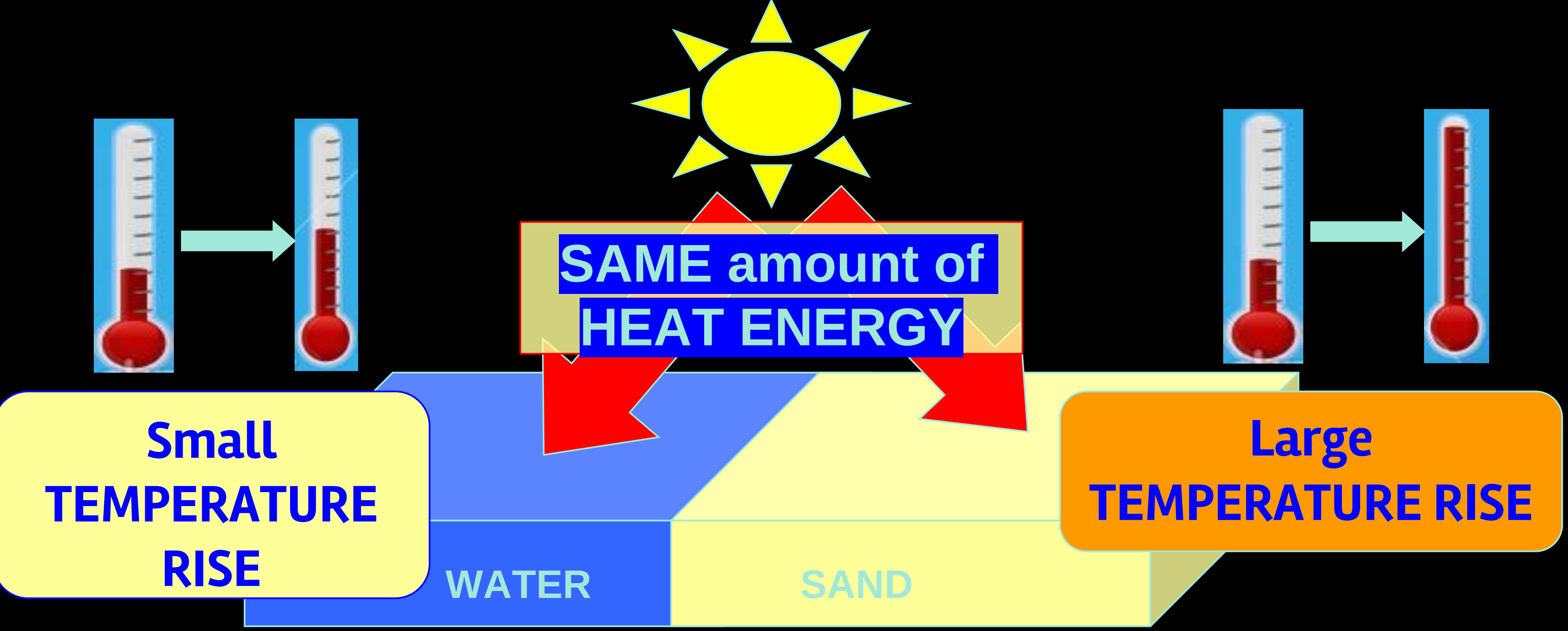


6.8 Specific Heat Capacity



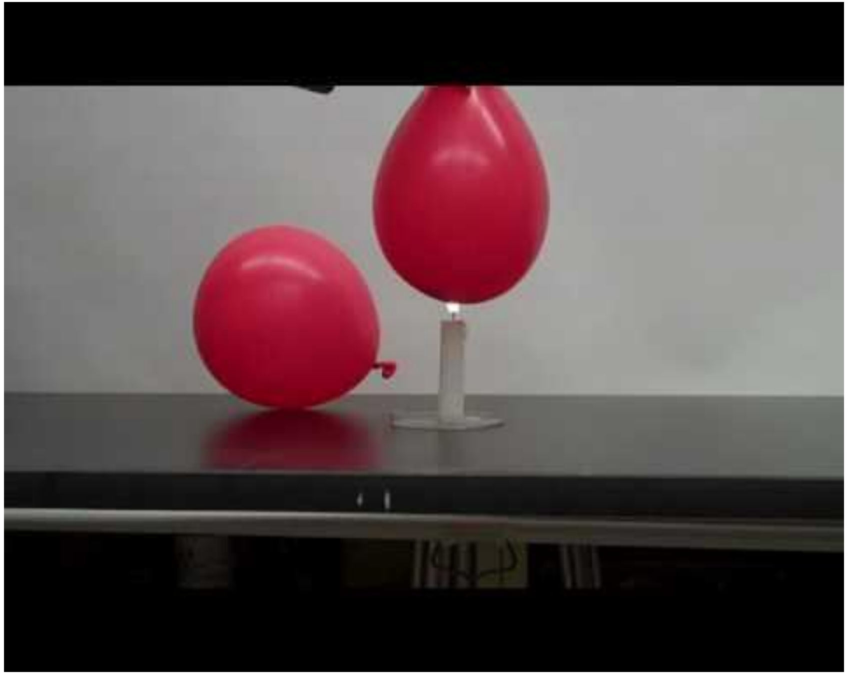
6.8 SPECIFIC HEAT CAPACITY

At the end of a sunny day at the beach, you often notice that while the sand has become quite hot, the water has stayed cool. Why do we think that is?



Putting the SAME AMOUNT OF HEAT into some materials gives a BIGGER TEMPERATURE RISE than in other materials

Balloon Demo



What does the demonstration with the balloons tell us about the specific heat capacity of water?

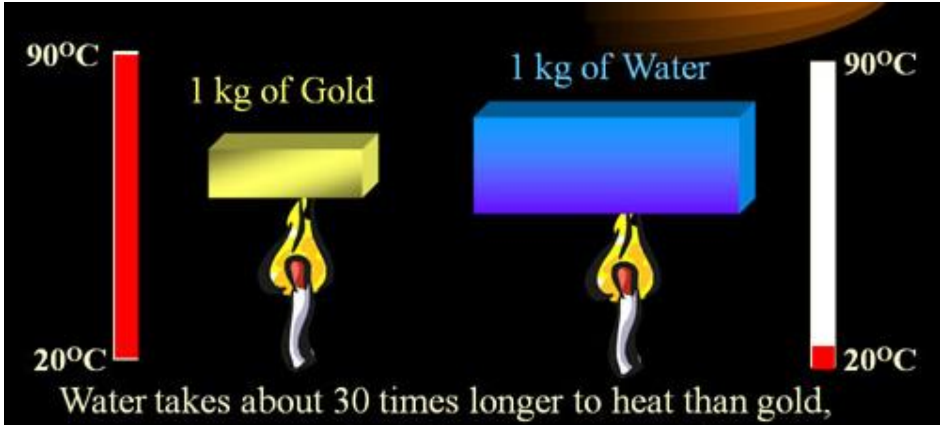
Why do we use hot water bottles?

Specific Heat

Specific Heat is the amount of energy that raises the temperature of 1 kg of a substance by 1 K.

The higher the specific heat, the more energy is needed to change the temperature.

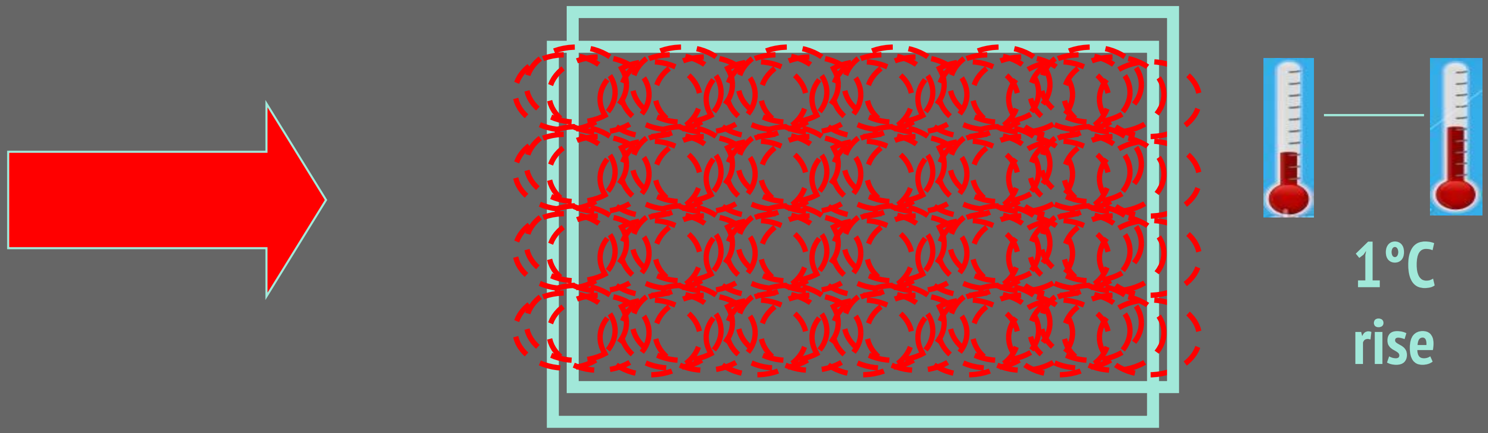
example



How to MEASURE HEAT CAPACITY?

To compare the heat capacity of materials, we need to measure:

How many **JOULES of heat energy**
are needed to make each degree temperature
rise



Equation using specific heat capacity WATCH

$$Q = m\,c\,\Delta T$$

Q = energy transfered (J)
m = mass of substance (kg)
c = specific heat capacity
ΔT = temperature change (K or °C)

Substance	c (J/kg K)
Solids	
Aluminum	900
Copper	385
Iron	449
Gold	129
Lead	128
Ice	2090
Liquids	
Ethyl alcohol	2400
Mercury	140
Water	4190

*We can see from the table on the right that it takes much more energy to heat up **ice** than it does to heat up **lead***

Example Questions

How much energy is needed to increase the temperature of 500 g of lead from 20ºC to 45ºC? The specific heat capacity of lead is 128 J/kg ºC.

$$Q = m c \Delta T$$

Q = energy transfered (J)
m = mass of substance (kg)
c = specific heat capacity
ΔT = temperature change (K or °C)

mass of lead = 500 ÷ 1000 = 0.5 kg

temperature change = 45 – 20 = 25ºC

energy needed = 0.5 × 128 × 25 = **1600 J** (1.6 kJ)

....you try one!

A 20kg concrete block is at 20°C and is heated to 65°C. What is the energy used to heat this block?

$$Q = m\,c\,\Delta T$$

Q = energy transfered (J)
m = mass of substance (kg)
c = specific heat capacity
ΔT = temperature change (K or °C)

Substance	Specific heat capacity (J/kg°C)
Water	4200
Air	990
Copper	390
Iron	450
Concrete	3400
Cotton	1400

Case of the Burning Pizza

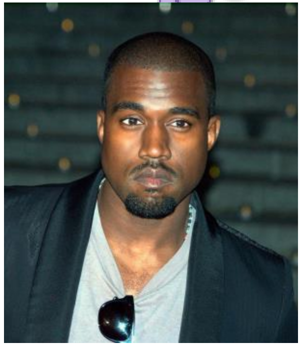
The pizza has been in the oven at 200 ^{o}C for 15 minutes.

You take the pizza out of the oven and eat a slice. ‘OUCH!’ you’ve burnt your mouth on the cheese – but not the crust.

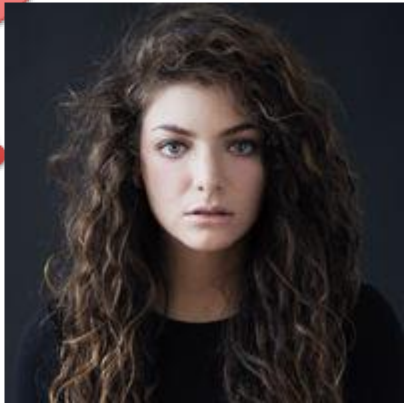
(Specific heat capacities: cheese 3270 J/kg^{o}C and crust 2800 J/kg^{o}C.)

The cheese is hotter than the crust when it comes out of the oven as it has a higher specific heat capacity.

The cheese can transfer more energy to your mouth when it cools down as it has a higher specific heat capacity.

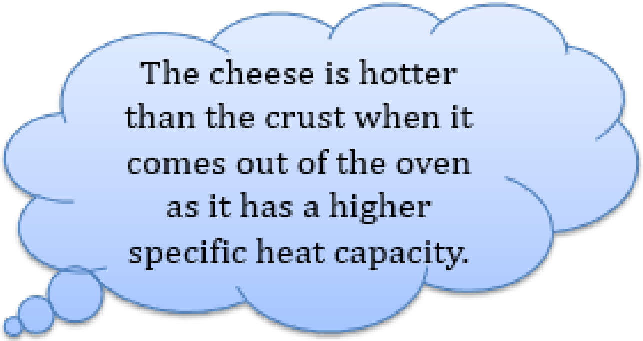


The cheese and crust particles are at the same temperature so have the same amount of energy. They should burn equally!

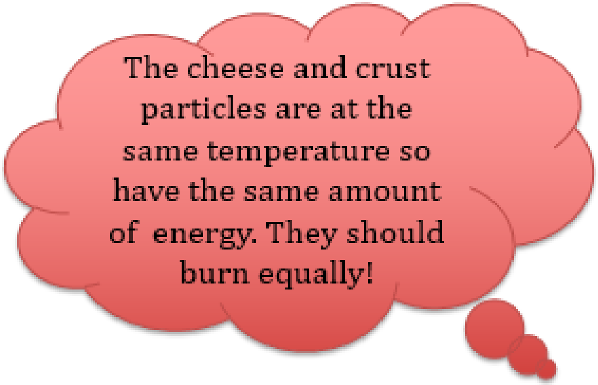


WHO IS CORRECT? DISCUSS………..

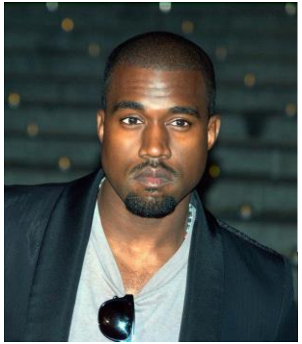
	WHO IS CORRECT?
	This is incorrect. Assuming the pizza has been in the oven for long enough, both the cheese and the crust will have reached the same temperature. The cheese will just have taken longer to reach that temperature as it has a higher specific heat capacity – more energy is needed to raise it’s temperature.



The cheese and crust are at the same temperature and therefore have the same kinetic energy – they have the same amount of energy in their kinetic energy stores, but they will have different amounts of energy in their thermal energy stores due to their different specific heat capacities.



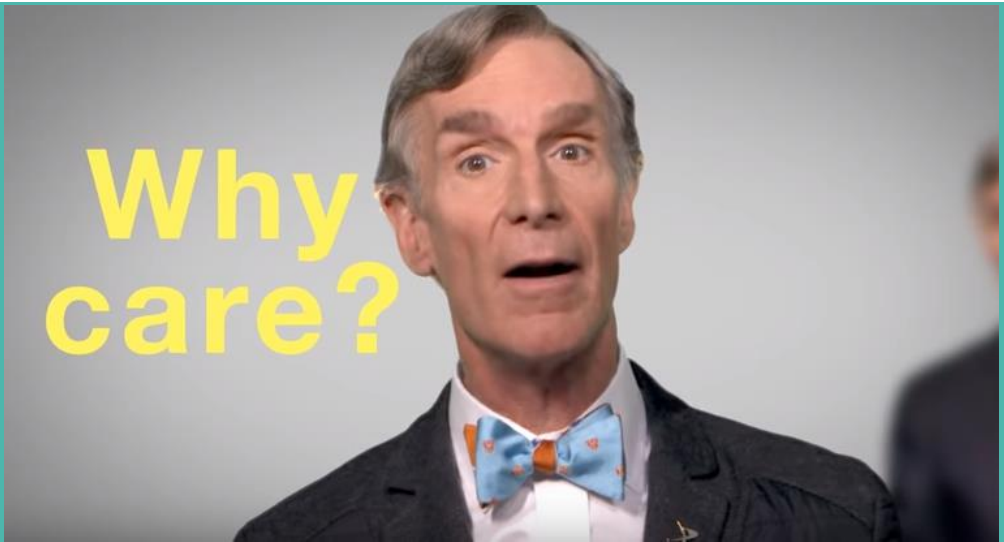
When you put a given mass of cheese or crust in your mouth the change in temperature between your mouth and the food causes energy transfer by heating. The amount of energy that can be transferred depends on the specific heat capacity of the substance. So the cheese, with its high specific heat capacity, transfers more energy than the crust when it cools down and hence burns your mouth more.



The cheese can transfer more energy to your mouth when it cools down as it has a higher specific heat capacity.

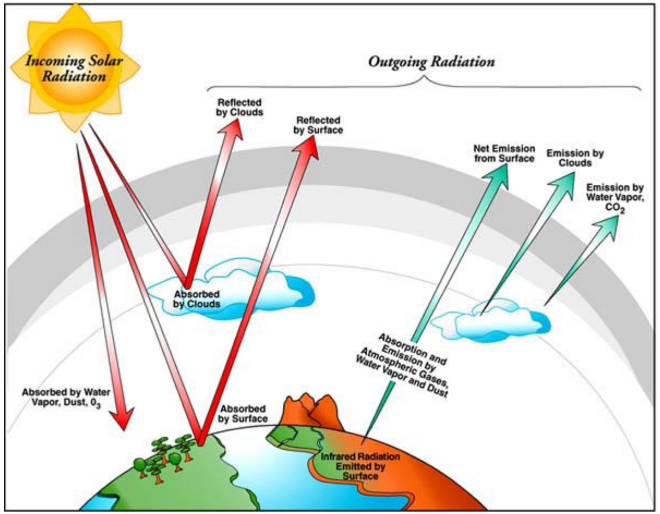
Specific Heat Capacity and Global Warming

Watch the following video, since it's almost EARTH WEEK!
https://www.youtube.com/watch?v=EtW2rrLHs08



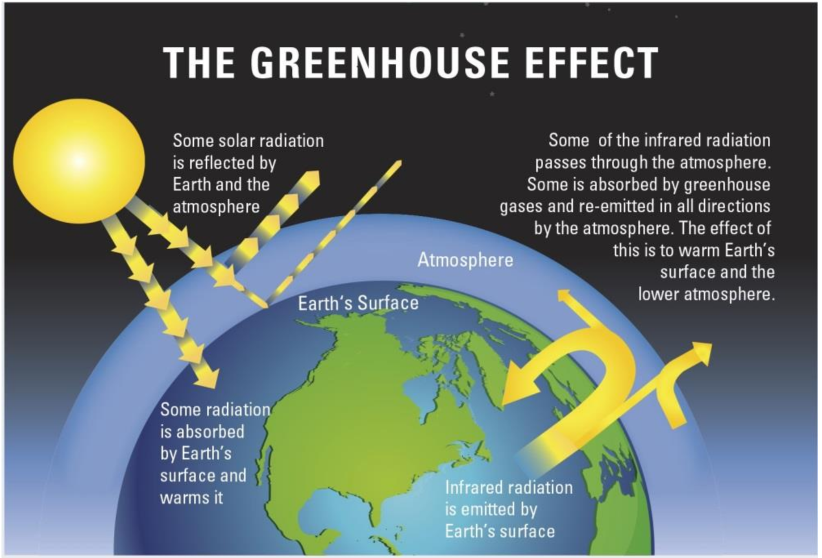
....a little background on Global Warming

Like any planet, the Earth absorbs some radiation and emits some radiation back into space. If the amount of energy Earth emits matches the amount it absorbs, the planet's energy budget is in balance, and its temperature remains steady.



....a little background on Global Warming

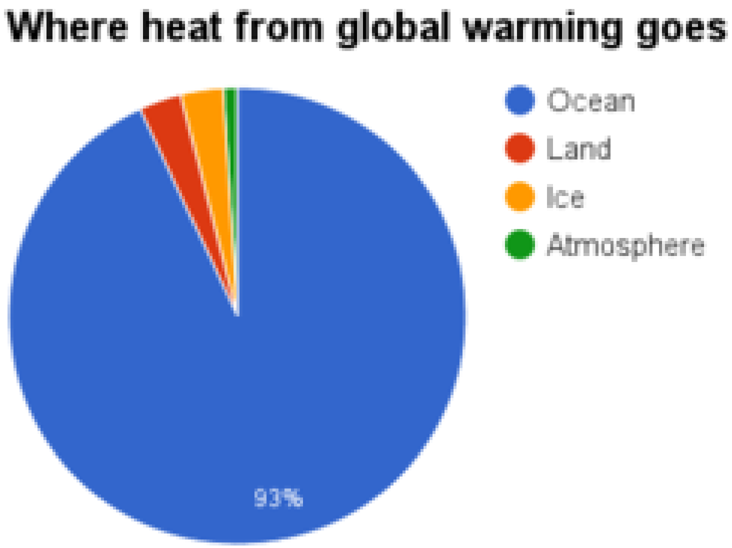
If the incoming and outgoing energy don't match, the planet is either warming or cooling over time, even if the change isn't immediately obvious.



....a little background on Global Warming

If greenhouse gases are forcing Earth to **absorb more energy** than it emits, why wouldn’t global surface temperatures increase right away?

- If greenhouse gases are causing Earth to absorb more energy than it reflects back into space, then shouldn’t it heat up the atmosphere first?
- Something that many people find odd—but climate scientists have long known—is that **most excess energy would really hide elsewhere.**



Excess energy might not make itself immediately obvious by strongly warming the atmosphere. Instead, that energy might hide in the ocean, in the form of warmer ocean temperatures. WATCH

Group Exploration

In **groups of 2-3**, you will be assigned one of the 7 items on the right. We now know that the *specific heat capacity* of water impacts the climate. Your task is to explain how this change in climate has an influence over your topic.

Using the whiteboards, draw and label a diagram that explains how a changing climate impacts your topic.

- **Salmon run**
- **La nina**
- **Coastal cities**
- **Weather patterns**
- **Ice caps**
- **Wildlife**
- **Ocean acidification**