TEMPERATURE

Known definition : it is the measure for how hot or cold something is, and it is measured in ^{O}C or degree cekcius

Scientific definition : it is the average kinetic energy of moving (vibration amount) particles in a substance, so the faster the particles are going, the hotter they are

TEMPERATURE SCALES

Kelvin Scale

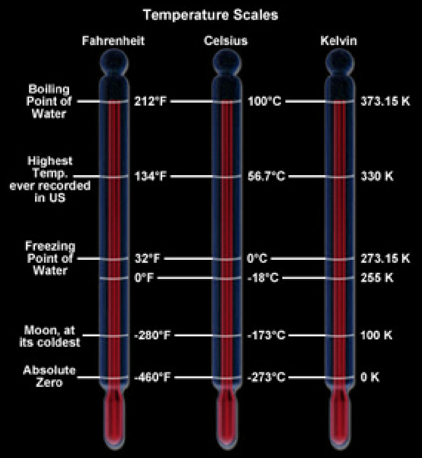
It starts with 0 K being **absolute zero** “zero kinetic energy”, with water freezing at **273 K** and boiling at **373 K**

Celsius Scale (Centigrade)

It starts with **-237 C** being **absolute zero,** with water freezing at 0 C and boiling at 100 C

Fahrenheit Scale

It starts with **-460 F** being absolute zero, with water freezing at **37 F** and boiling at **212 F**



temperature units:
- Celsius to Kelvin: K = °C + 273.15
- Kelvin to Celsius: °C = K - 273.15
- Celsius to Fahrenheit: °F = (°C * 9/5) + 32
- Fahrenheit to Celsius: °C = (°F - 32) * 5/9
- Kelvin to Fahrenheit: °F = ((K - 273.15) * 9/5) + 32
- Fahrenheit to Kelvin: K = ((°F - 32) * 5/9) + 273.15

INTERNAL ENERGY (U)

the energy of a substance due to both random motions from its particles and the potential energy coming from bonds/alignments, etc

Internal energy $\propto$ temperature

THERMAL ENERGY

The kinetic energy of all molecules in a system added together

It refers to the amount of internal energy (U) contained in a system, that is responsible for the change in temperature

Q is used to represent the amount of energy transferred between a system and its environment through **heat**

HEAT

The flow of thermal energy added/removed from a system due to a difference In temperature between them

It is a form of energy so we can use **joules**

BUT

- Thermodynamics prefers **calories (cal)**, where a **(calorie is the amount of heat required to change the temperature of 1 gram of water by 1 C)**
- The English unit of heat is the **BTU**, where a **(BTU is the amount of heat required to change the temperature of 1 lb of water by 1 F)**

(1 calorie = 3.968 * 10^3 Btu = 4.1868 J)

(1Btu = 252 cal)

There is a difference between calorie (cal) and dietary Calorie (Cal)

Thermodynamics is a branch of physics that deals with how heat is transferred between different systems

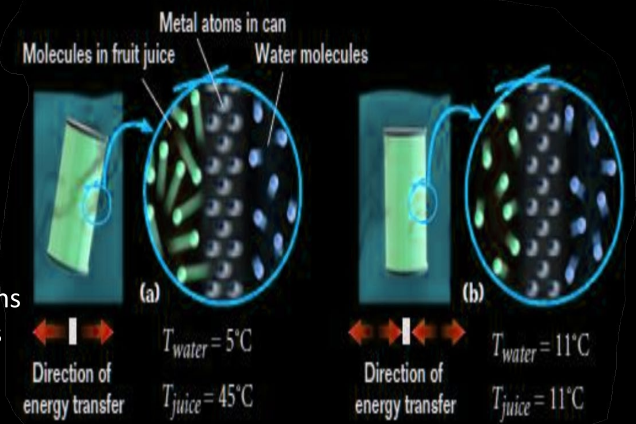
Table 3 **Thermal Units and Their Values in Joules**

Heat unit	Equivalent value	Uses
joule (J)	equal to 1 kg • $\left(\frac{m^2}{s^2}\right)$	SI unit of energy
calorie (cal)	4.186 J	non-SI unit of heat; found especially in older works of physics and chemistry
kilocalorie (kcal)	4.186×10^3 J	non-SI unit of heat
Calorie, or dietary Calorie	4.186×10^3 J = 1 kcal	food and nutritional science
British thermal unit (Btu)	1.055×10^3 J	English unit of heat; used in engineering, air-conditioning, and refrigeration
therm	1.055×10^8 J	equal to 100 000 Btu; used to measure natural-gas usage

HEAT TRANSFER

Heat energy is transferred between materials by the kinetic energy being moved from each other

For example, a hot juice in a can with cool water around it, the kinetic energy from the juice is transported to the can, then the water, if the can is conductive, the kinetic energy with quickly move away to the water and not stay in the can for too long



THERMAL EXPANSION

When stuff are heated, the molecules move, leading to an increase in volume

“when gasses increase in temperature in constant pressure, they heat up”

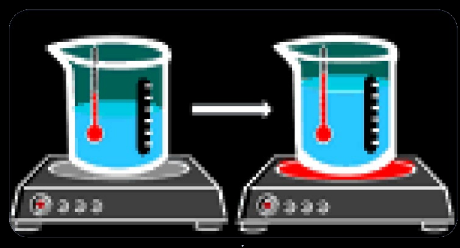
Gasses have the highest coefficients of thermal expansions

Solids have the lowest coefficients of thermal expansions

Liquids have higher coefficients than solids

so when a container with liquid is heated, the liquids expand a lot more than the solid, this property can be used to measure changes in temperature, this is basically how **a thermometer works**

The expansion of the liquid (probably mercury) shows us the changes in temperature

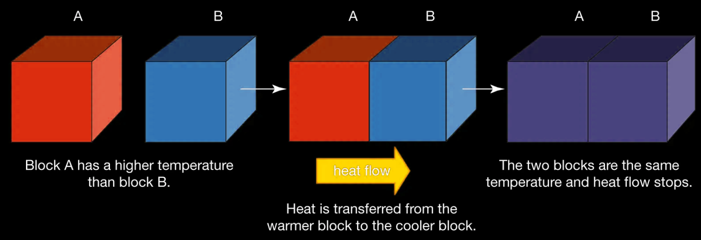


THERMAL EQUILIBRIUM

It when two bodies have the same molecular kinetic energy (temperature)

Heat always flows from higher temperatures to lower temperatures until thermal equilibrium

ZEROTH LAW OF THERMODYNAMICS

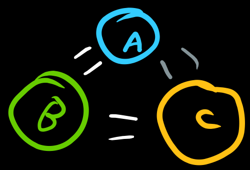


If

- **A** in thermal equilibrium with **B**
- **B** in thermal equilibrium with **C**

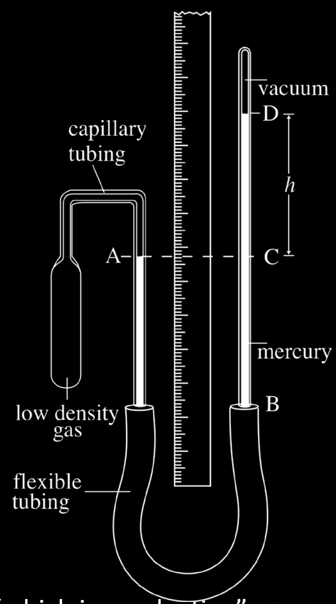
Then

A in thermal equilibrium with **C**



GAS THERMOMETERS

When the low density gas is heated, it expands, pushing the flexible tubing down while also pushing the mercury in point B up



Measuring gas thermometers

Measure the marked temperature that the mercury in point B reached

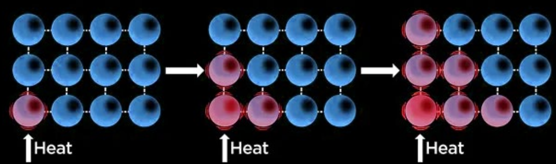
HEAT TRANSFER MECHANISMS

HEAT CONDUCTION

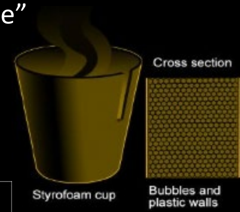
Temperature is just vibrations, heat is these vibrations moving from one particle to another

In conduction, molecules are near the heat source, and the vibrations from the hot molecule causes it to collide with other molecules, giving them some of the heat energy, eventually, all the molecules would have the same amount of vibration (thermal equilibrium)

A **thermal insulator** is a material that conducts heat poorly, because its particles do not vibrate/ transmit the vibrations to other particles as good as conductive particles



NOTE : insulators don't rely on the type of material, but more on the structure of it, like how insulator glass is just the same material "which is conductive" but has air spaces that are not that good of a conductor



Material	Thermal cond. (W/m°C)
IIa diamond	2,650
Copper	401
Aluminum	226
Steel	43
Rock	3
Glass	2.2
Ice	2.2
Liquid water	0.58
Wood	0.11
Wool fabric	0.038
Fiberglass insulation	0.038
Styrofoam	0.025
Air	0.026

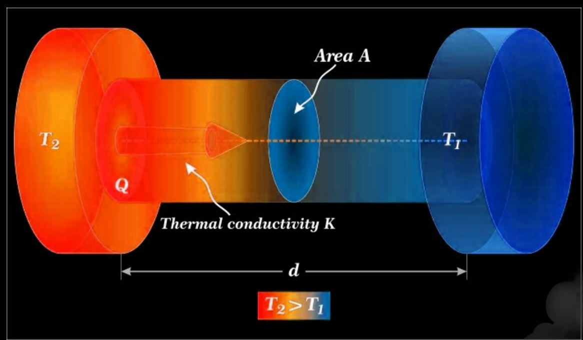
THERMAL CONDUCTIVITY (K)

It describes how good is a material at conducting heat

$$k = \frac{Qd}{A\Delta T}$$

where

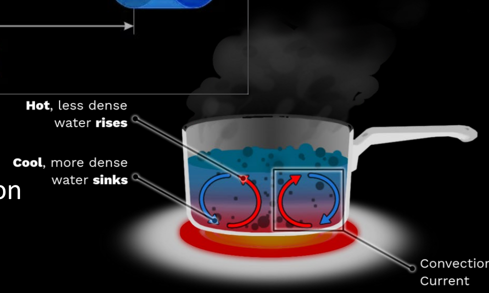
- **K** = Thermal conductivity
- **Q** = amount of heat transferred
- **d** = distance between two isothermal panels
- **A** = area of surface
- **ΔT** = Difference in temperature



HEAT CONVECTION

The transfer of heat by the motion of heated fluids (liquids, gasses)

Hot fluids rise because of the lower density and are replaced by **cold fluids**, causing a circulation



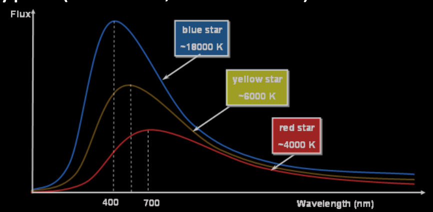
HEAT RADIATION

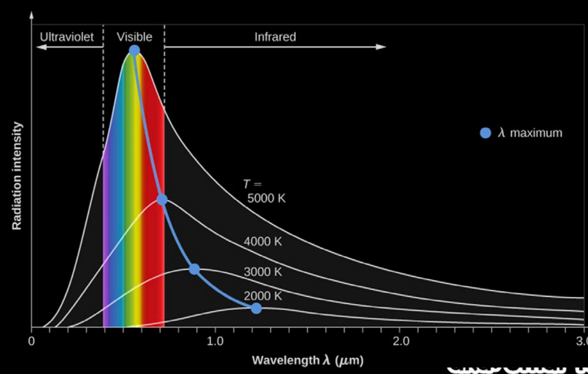
It is the energy transmitted by electromagnetic waves from hot objects, the hotter the object the more thermal radiation it gives off

BLACK BODY RADIATION

A black body is a body that **reflects nothing and emits pure thermal radiation**, for example a star is a near-perfect blackbody, a lightbulb is a good blackbody because the most we see out of it is pure light generated from it and not reflected by other sources

Visible light has the highest thermal radiation, while other types (infrared, ultraviolet) have low radiation, that's why the coldest starts are **red** and the hottest are **blue**



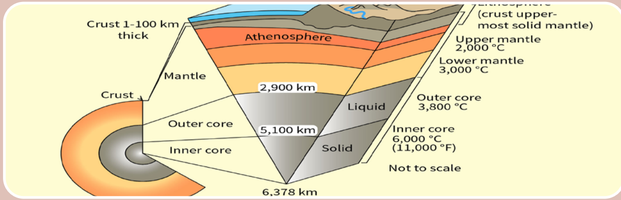


NATURAL SOURCES OF HEAT

Solar heat collector
Is a device for capturing radiation

The quantity of solar energy striking earth is about 1000 watts per square meter under clear skies

Solar water heating systems have 2 parts
Collector : to capture the radiation in water
Storage tank : to store and insulate the hot water



Solar

Heat arrives from the sun as electromagnetic radiation

It varies depending on the time of day and season, but it is enough to support light

Fun fact : the sun is the main source of energy for life on earth

Geothermal

It comes from the hot core of the earth through **conduction**

The core of the earth is hotter than the **surface of the sun**

Over a very long time, all geothermal energy on the earth will be depleted

Geothermal energy can be utilized by hot springs and underground water to heat up homes

Heat capacity (J/^{O}C)	Specific Heat Capacity (J/g.^{O}C)	Molar Heat Capacity (J/mol.^{O}C)
The amount of heat (expressed in joules mostly) needed to **raise the temperature of a system by 1 degree**	The amount of heat (expressed in joules mostly) needed to **increase the temperature of 1 gram of a substance by 1 degree**	The amount of heat (expressed in joules mostly) needed to **raise the temperature of 1 mole of a substance by 1 degree**

QUANTITY OF HEAT

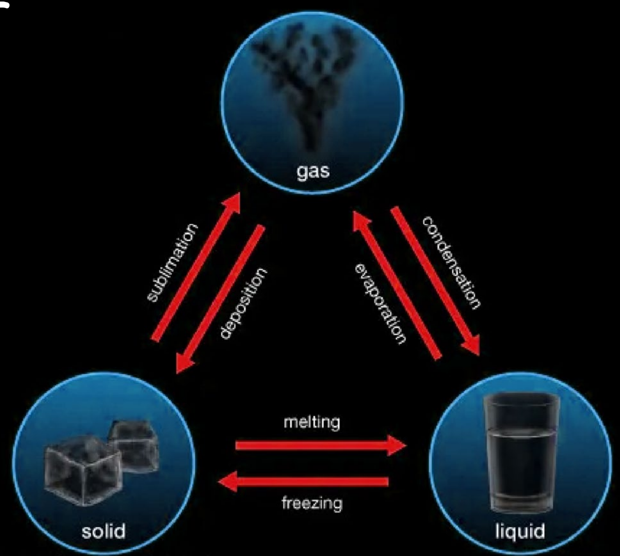
It's the measurement for the amount of heat present in a system

- **Q** = amount of heat
- **m** = mass of system
- **c** = specific heat capacity
- **ΔT** = change in temperature

$$Q = mc\Delta T$$

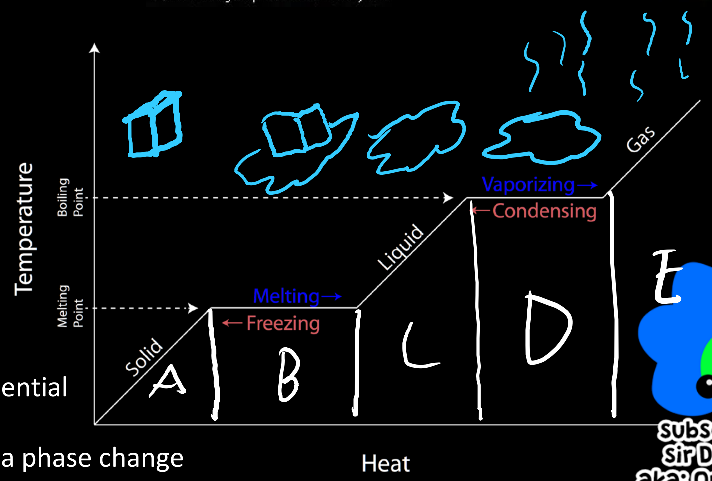
PHASE CHANGE

- **Melting ->** solids turn into liquids when the temperature rises to the melting point
- **Freezing ->** Liquids turn into solids when temperature cools down to the freezing point
- **Evaporation ->** Liquids turn into gases on the surface of the liquid, and it occurs at any temperature, even if it's smaller than the boiling point, here is the reason for it
- **Vaporization ->** Liquids turn into gases throughout the entire body of the liquid, and it occurs at the boiling point of the liquid, and it occurs rapidly compared to evaporation as the whole body of liquid is getting converted
- **Condensation ->** Gases turn into liquids when the temperature cools down
- **Sublimation ->** Solids turn into gases when the temperature is so hot that It doesn't even bother going through the liquid phase
- **Deposition ->** Gases turn into solids when the temperature is so cold that it doesn't even bother going through the liquid phase



WATER PHASE CHANGE GRAPH

1. You can see that temperature steadily increases from −25°C to 0°C (segment A of the graph).
2. At 0°C, the temperature stops increasing. Instead, the ice begins to melt and to change into water (segment B).
3. The ice-and-water mixture remains at this temperature until all of the ice melts. Suppose that you now heat the water in a pan on a stovetop. From 0°C to 100°C, the water's temperature steadily increases (segment C).
4. At 100°C, however, the temperature stops rising, and the water turns into steam (segment D).
5. Once the water has completely vaporized, the temperature of the steam increases (segment E).



in **A, C, E**, the temperature is increasing without a phase change, because we are just increasing the potential energy between the intermolecular forces connecting a substance
In **B, D**, we have added too much potential energy for the intermolecular forces, so they break, causing a phase change

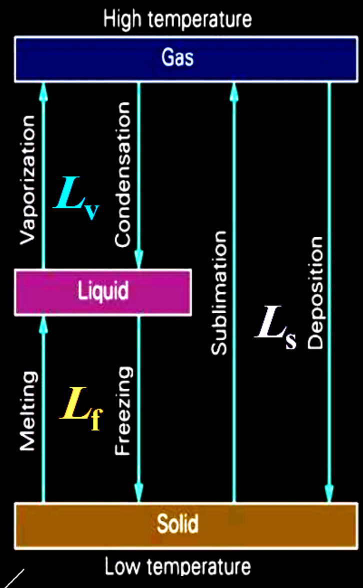
LATENT HEAT (L)

Is the energy (Q) required for a substance to finish changing phases

$$L = \frac{Q}{m}$$

Where

- **L** = Latent heat
- **Q** = amount of heat absorbed/emitted
- **m** = unit mass of a substance or mole amount of a substance

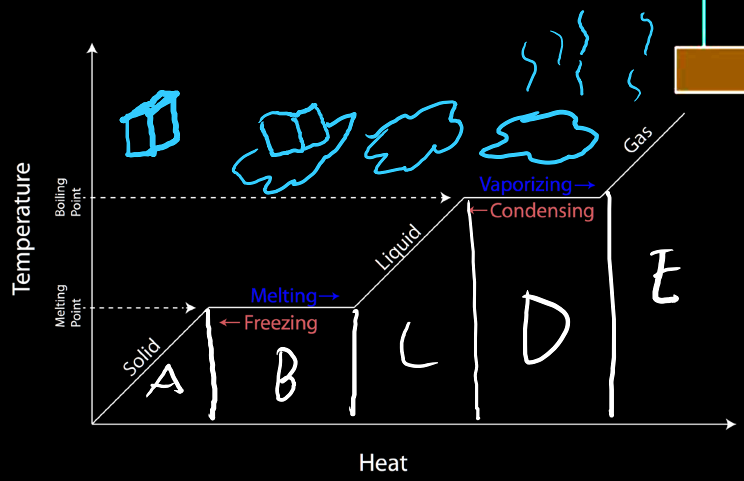


SPECIFIC LATENT HEAT

1. **Latent heat of fusion**
   - It describes the change between solid and liquid phases by melting a solid or freezing a liquid
2. **Latent heat of vaporization**
   - It describes the change between gas and liquid phases by vaporizing a liquid or condensing a vapor
3. **Latent heat of sublimation**
   - It describes the change between solid and gas phases by subliming a solid or deposing a gas

Latent heat helps understand the water phase change diagram

- **phase B**
  - When ice melts, it remains at 0 degrees until it is all liquid water, because the heat energy will be absorbed into the latent heat of fusion
- **Phase D**
  - When water is kept boiling , the temperature of the liquid will stop at 100 degrees and continue like that until the last drop of water is evaporated, because **the heat energy is being absorbed into the latent heat of vaporization**



SPECIFC LATENT HEAT OF SOME SUPSTANCES

Material	Heat of fusion L_f (J/kg)	Heat of vaporization L_v (J/kg)
copper	2.05 X 10^5	5.07 X 10^6
mercury	1.15 X 10^4	2.72 X 10^5
gold	6.30 X 10^4	1.64 X 10^6
methanol	1.09 X 10^5	8.78 X 10^5
iron	2.66 X 10^5	6.29 X 10^6
silver	1.04 X 10^5	2.36 X 10^6
lead	2.04 X 10^4	8.64 X 10^5
water (ice)	3.34 X 10^5	2.26 X 10^6