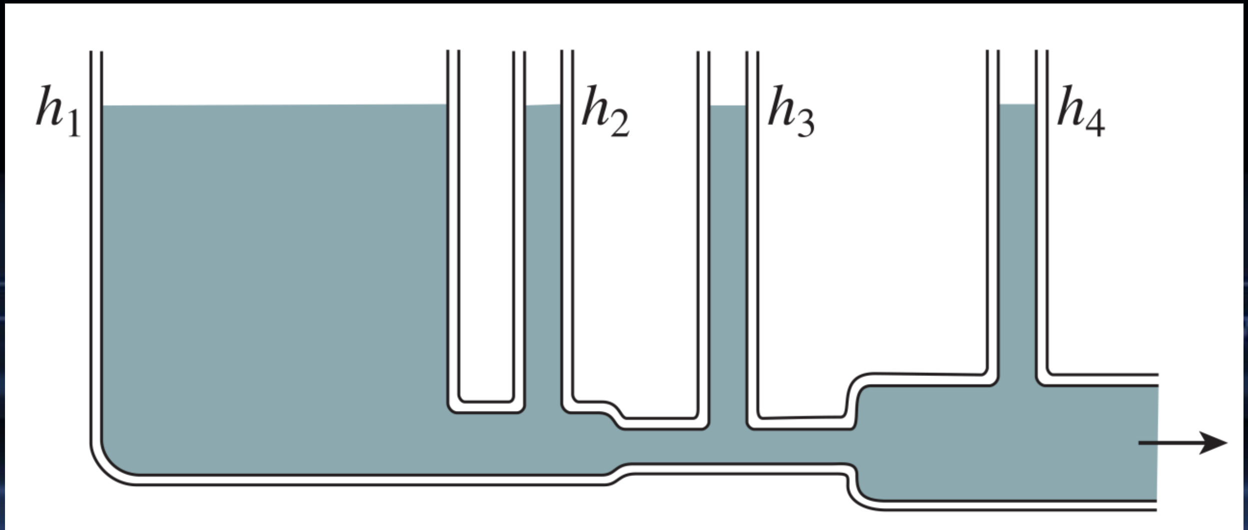
Course announcement

- The second midterm exam’s solution will be posted on eLearn today.

Think about it…

$$p + \frac{1}{2}\rho v^2 + \rho g h = \text{constant}$$

- v large, then h is small. For pipe area is small, v is large. Combining with continuity equation: $h_1 > h_4 > h_2 > h_3$



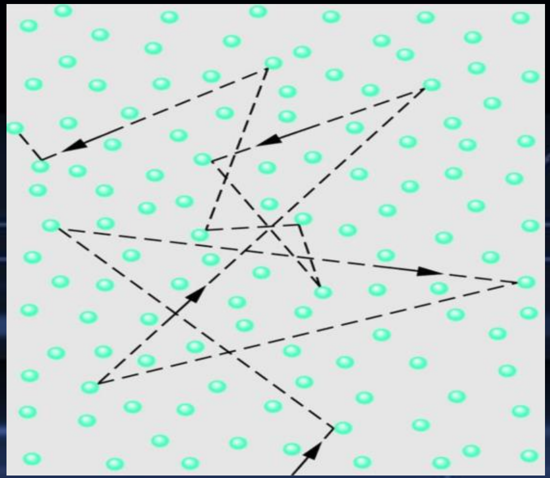
GENERAL PHYSICS B1
TEMPERATURE AND HEAT

2022/12/09

Temperature, Heat, and Thermal Equilibrium

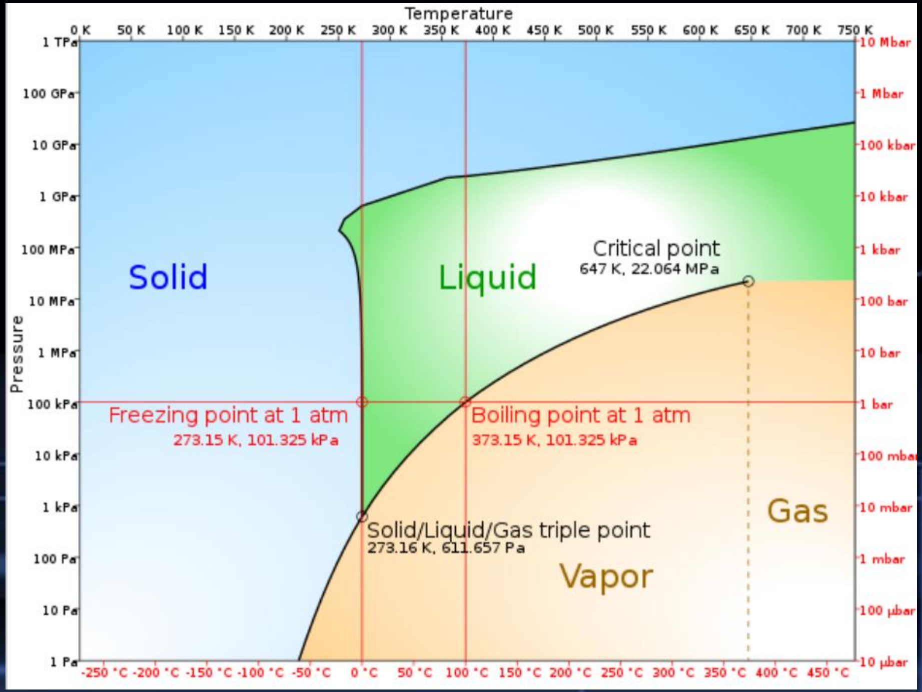
Thermodynamics: bridge between microscopic and macroscopic world

- We studied physics about dynamics of single or many body (not a huge number) systems.
- For a system contained huge numbers of particles, we need new method to describe such system. Example: gas molecule of a tank of gas.



Application of thermodynamics

- Heat engine
- Phase transitions between solid, liquid, and gas



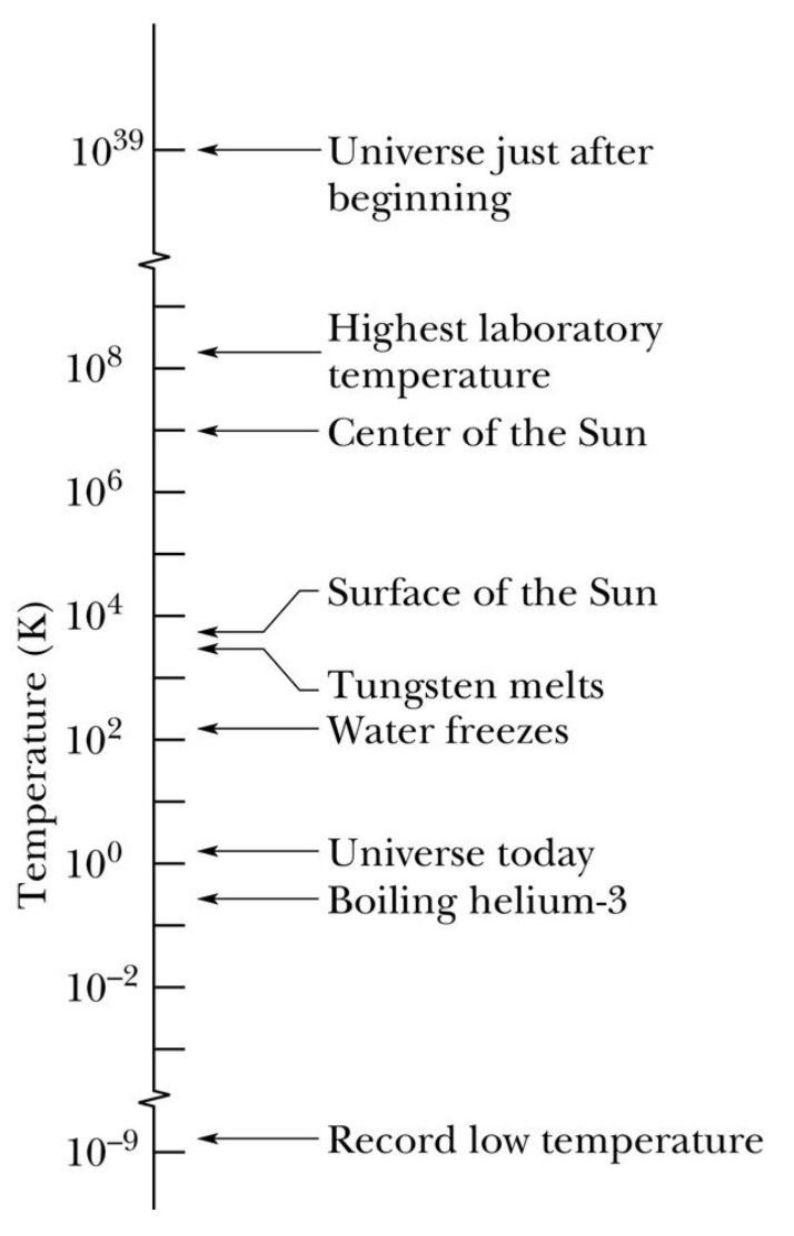
https://en.wikipedia.org/wiki/Phase_diagram

Thermodynamics that we will discuss

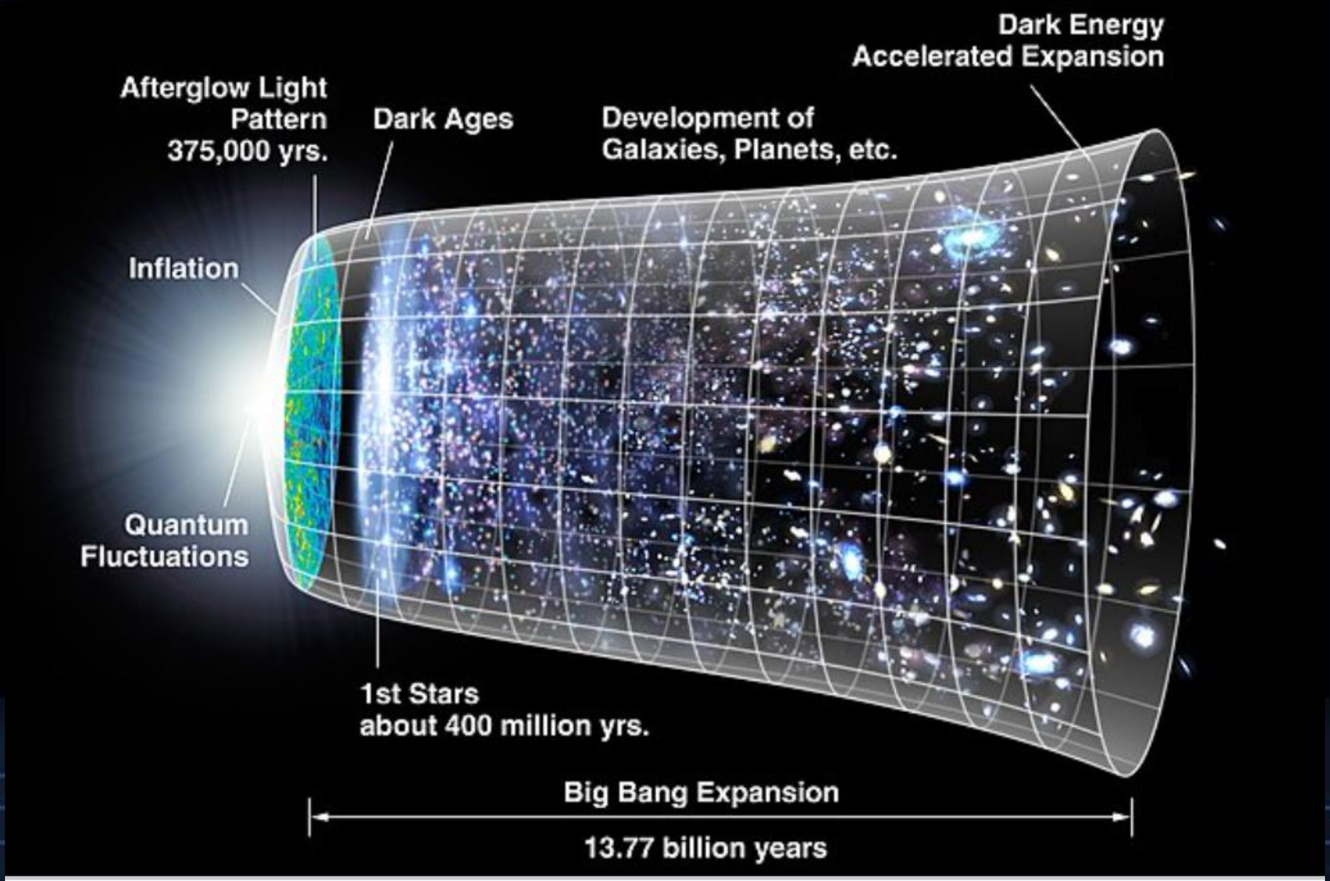
- Temperature, Heat, and heat conductions (Chap. 16)
- The thermal behavior of Matter(Chap.17)
- Heat, Work, and The First Law of Thermodynamics (Chap.18)
- Entropy and the Second Law of Thermodynamics (Chap. 19)

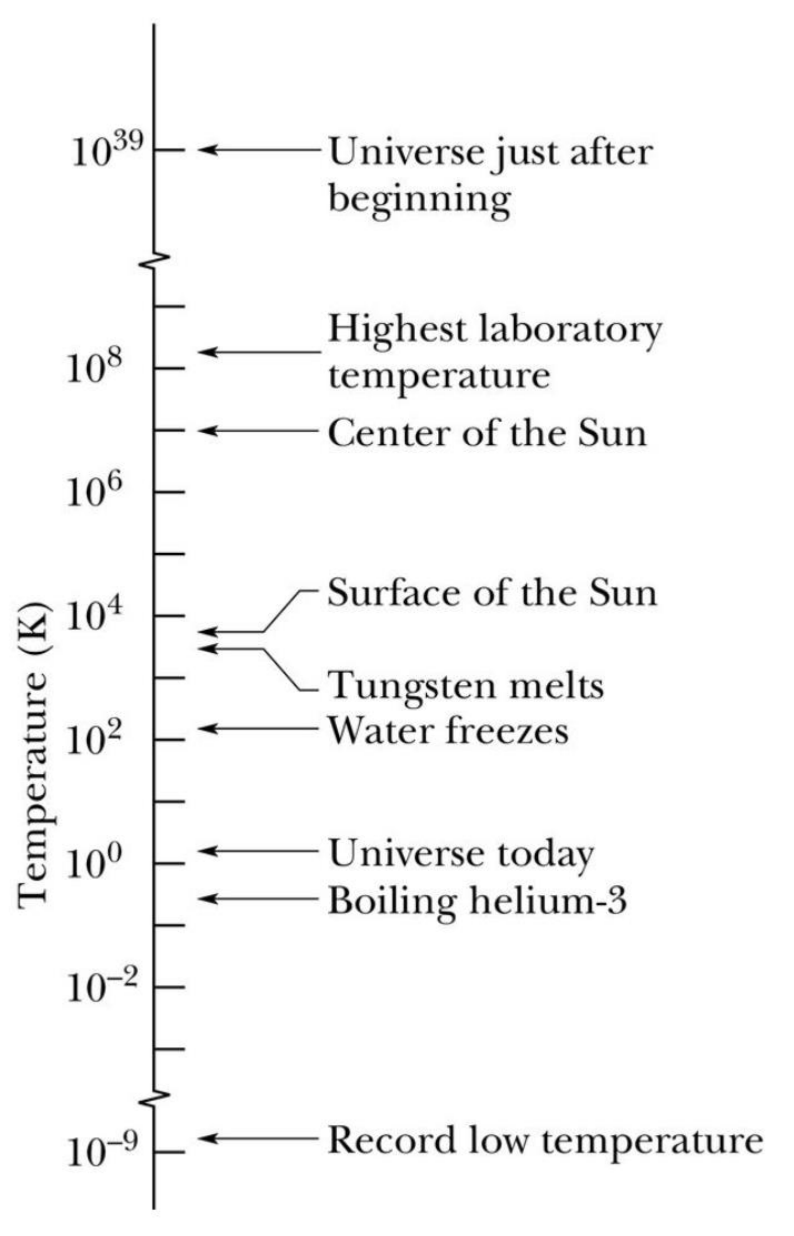
Temperature

- Temperature is one of the seven SI base quantities. Physicists measure temperature on the Kelvin scale, which is marked in units called kelvins. The definition of kelvins is given by Boltzmann constant $k=1.3806505\times10^{-23}$ J/K.
- The temperature of a natural system apparently has no upper limit, it does have a lower limit; this limiting low temperature is taken as the zero of the Kelvin temperature scale.

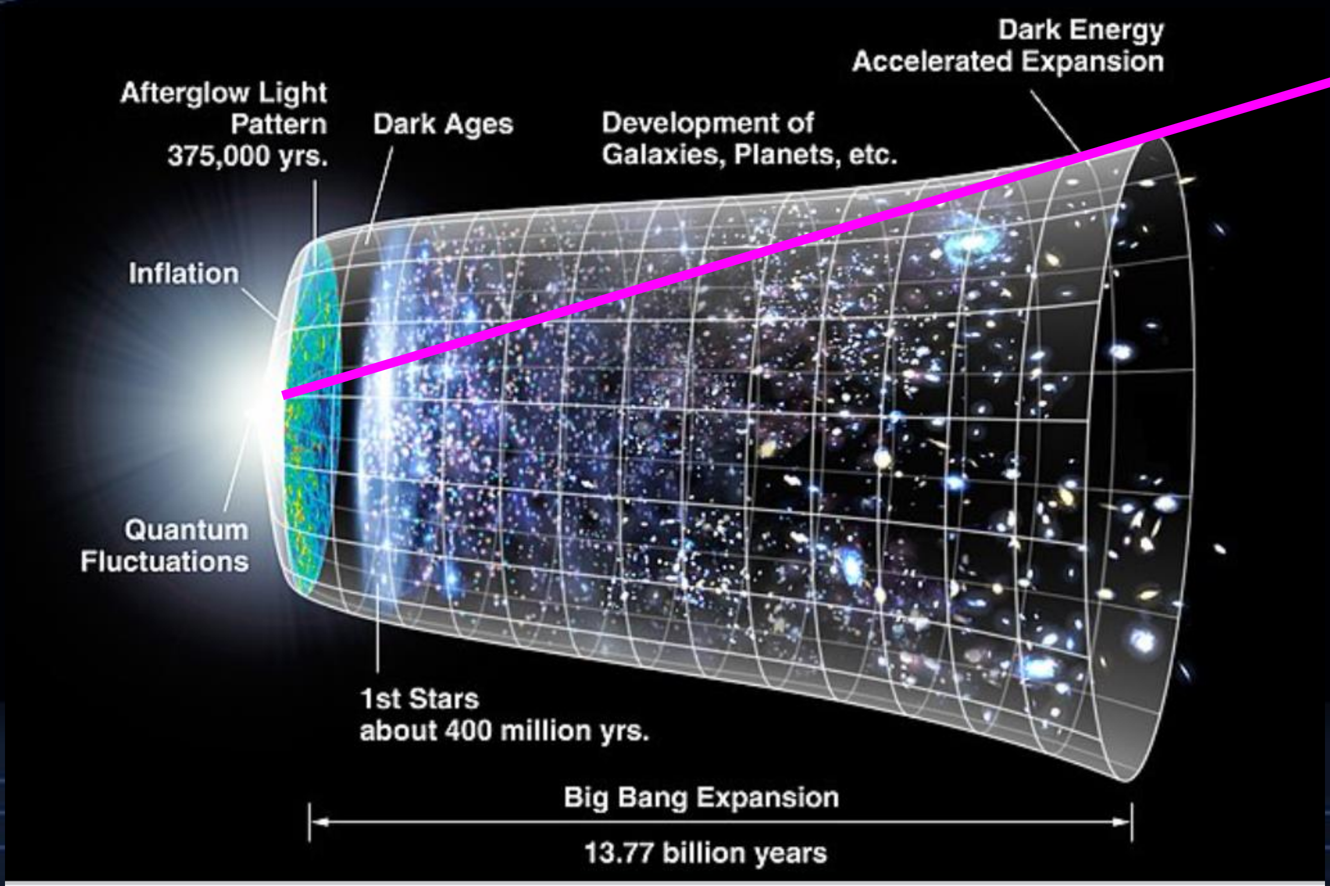


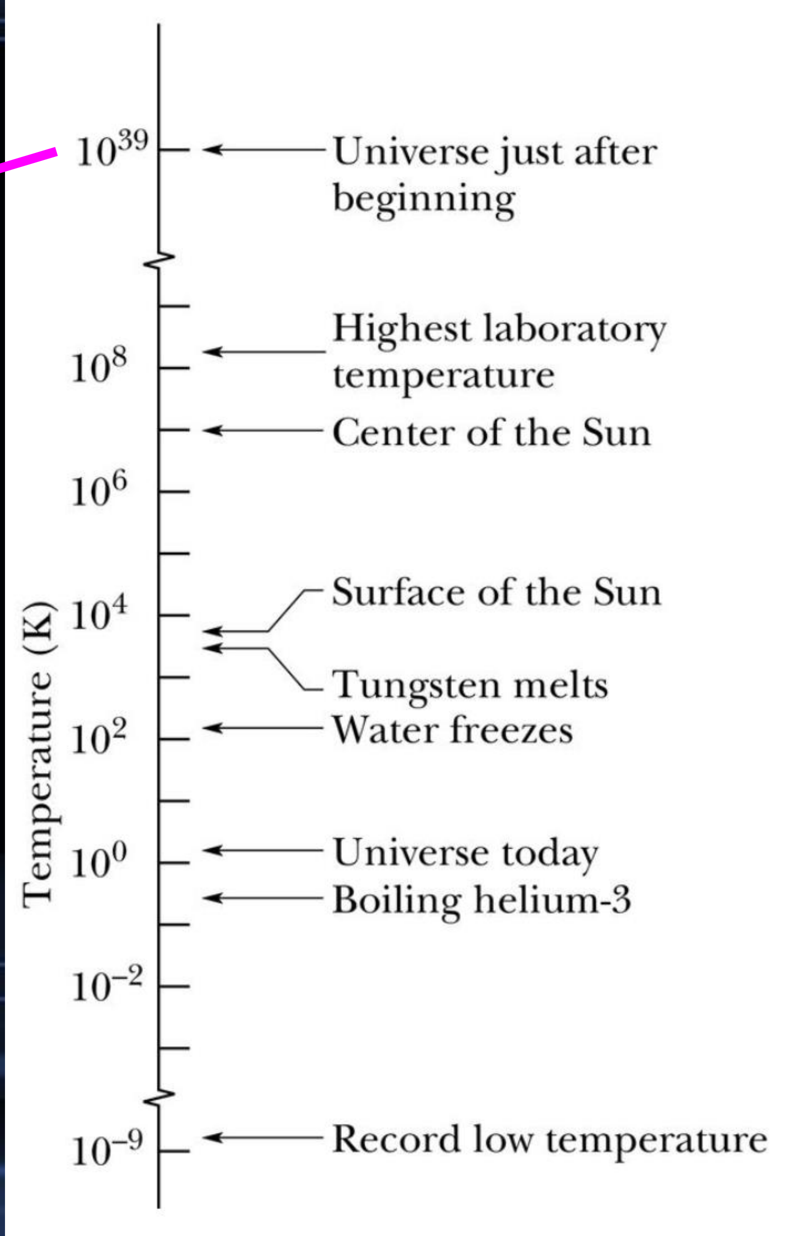
Temperature



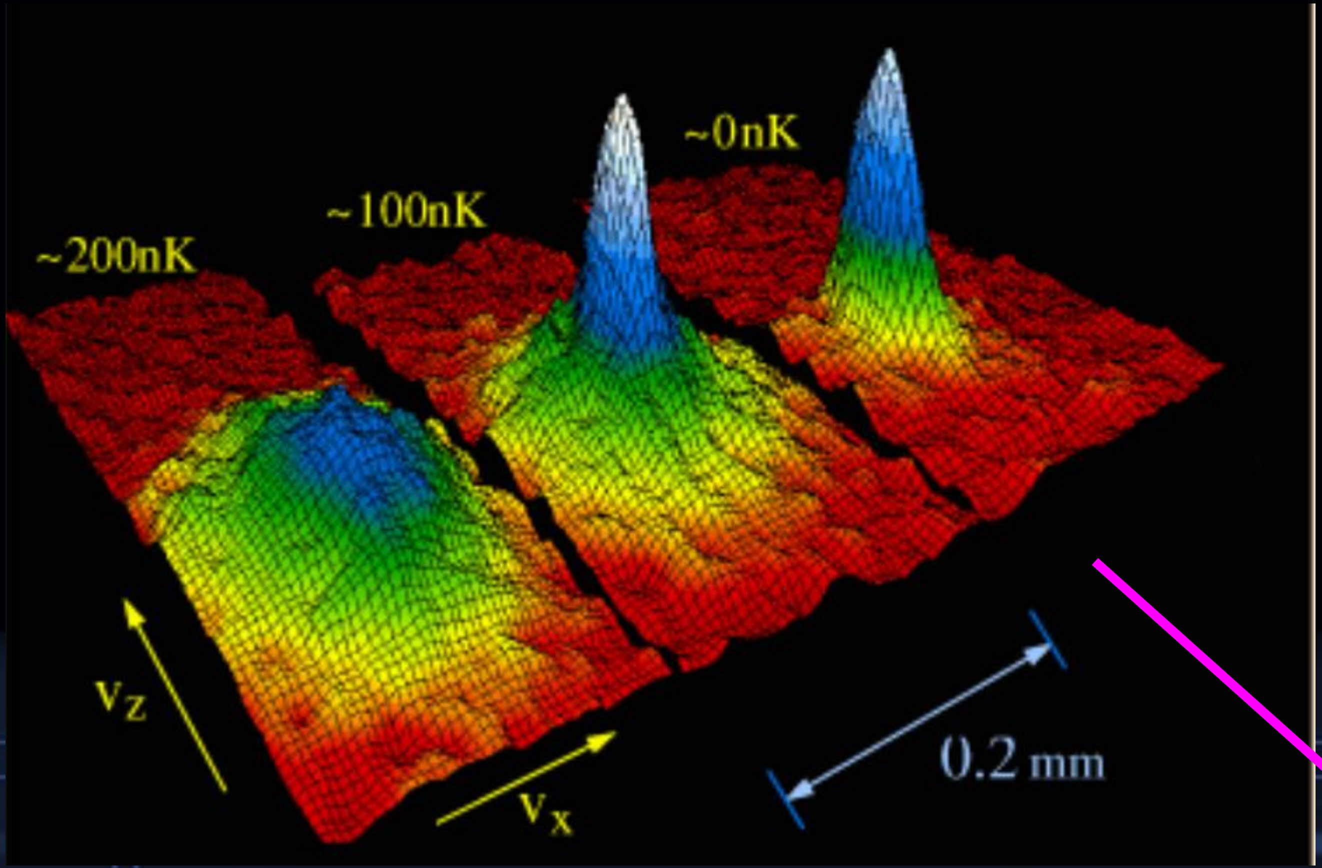


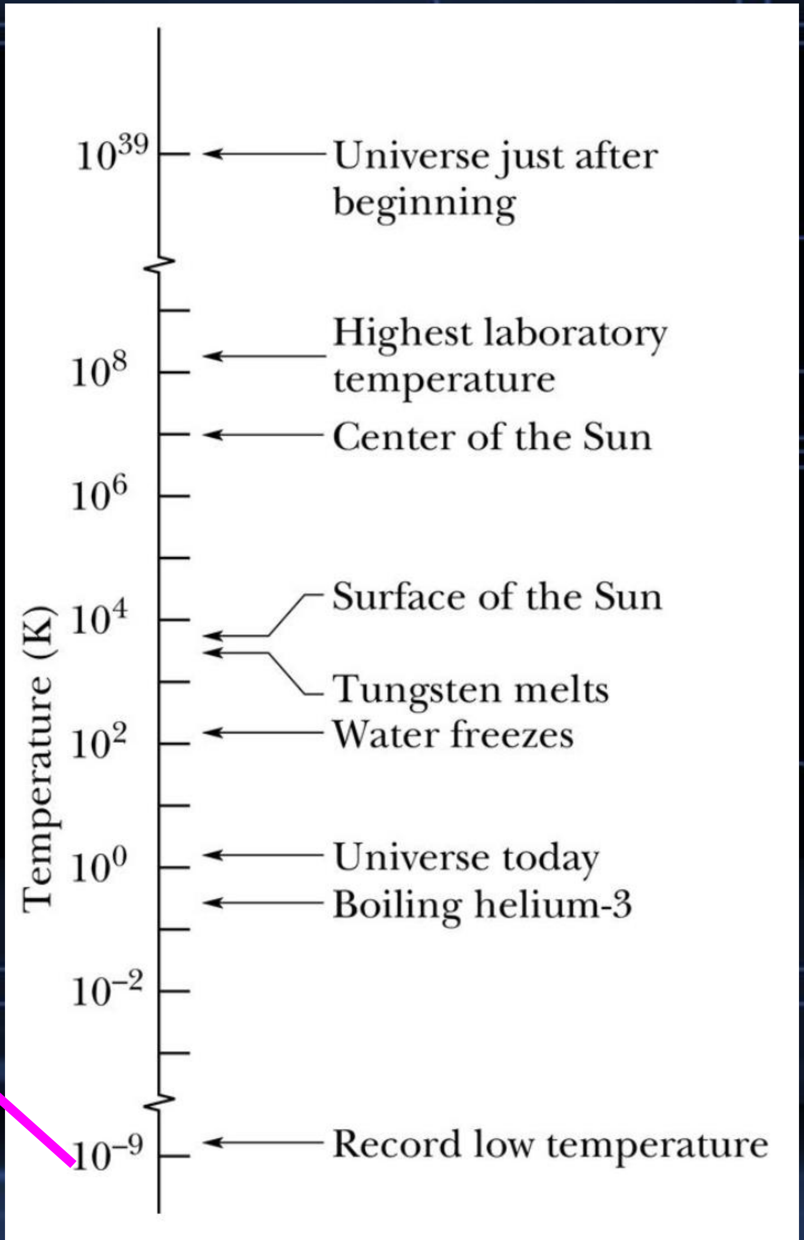
Temperature





Temperature





http://hyperphysics.phy-astr.gsu.edu/hbase/quantum/rubbec.html

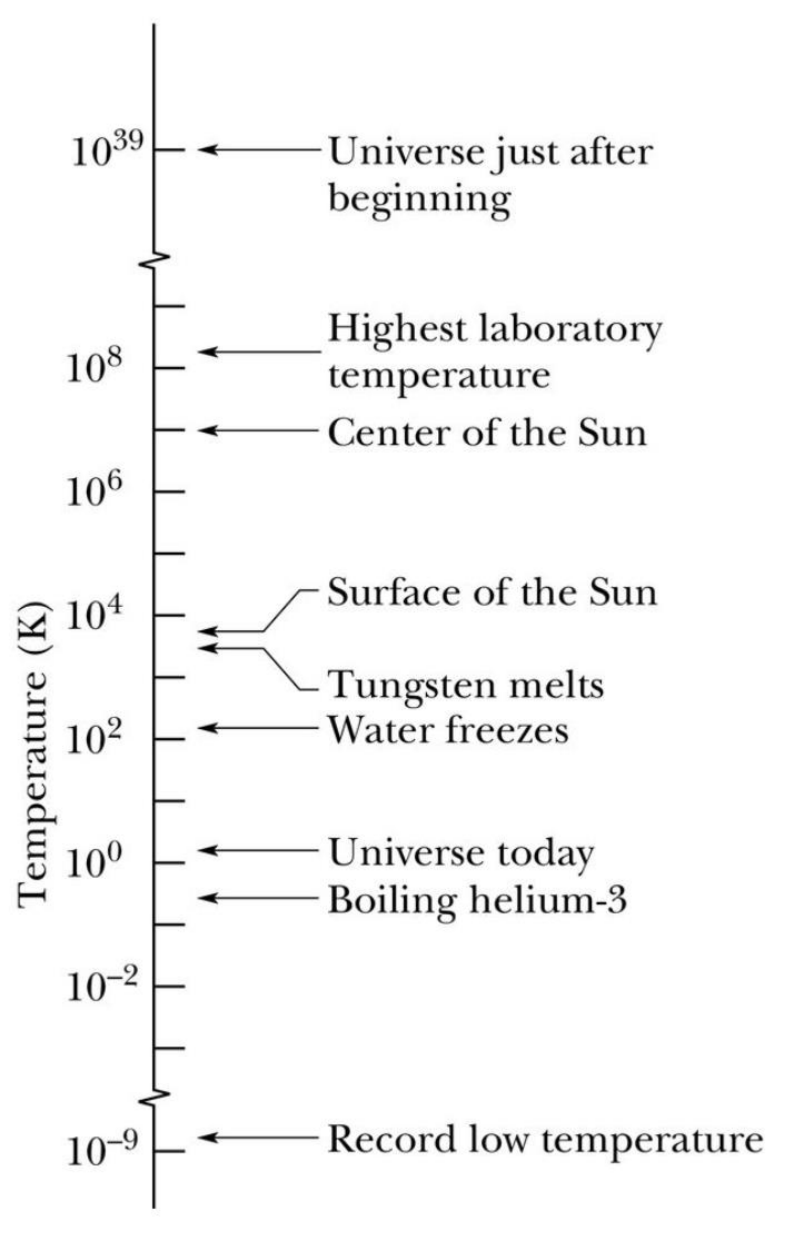
Temperature

- A first look of the meaning of temperature is associated with how much energy containing in the system.

System with

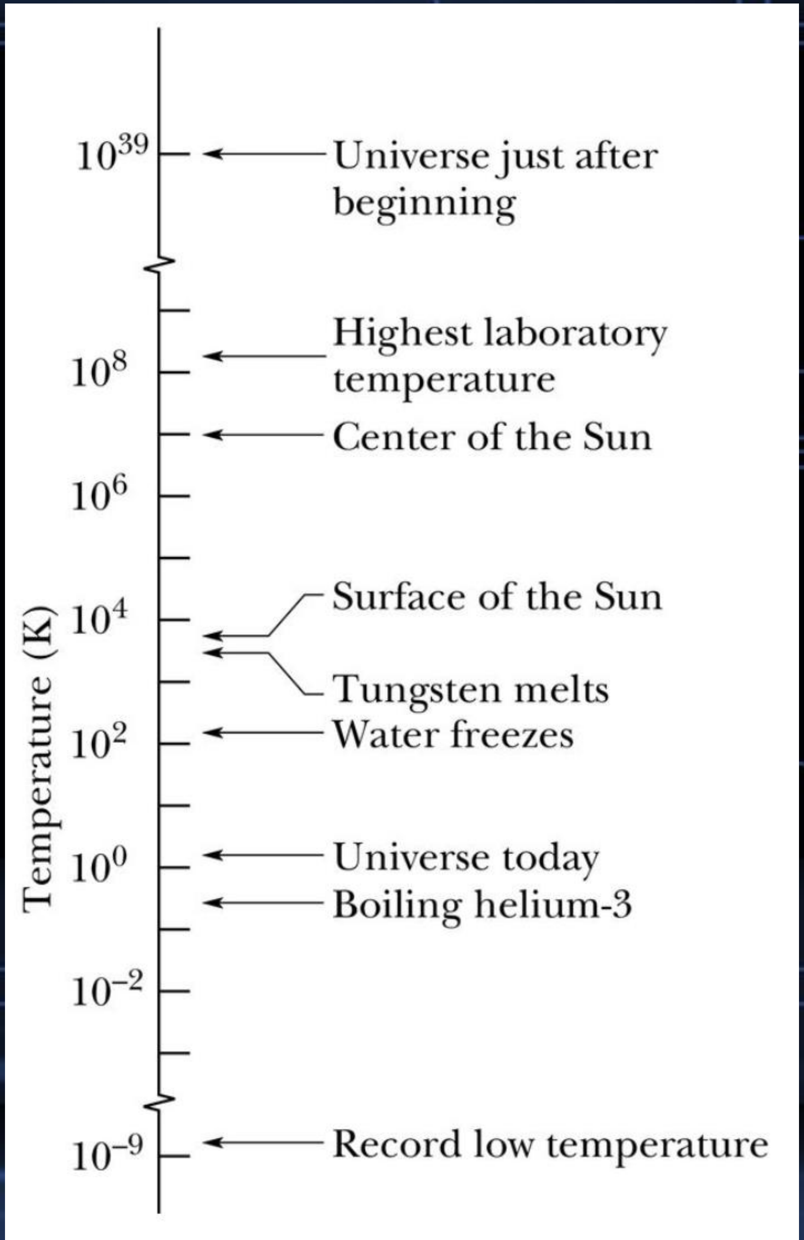
high energy: high temperature

Low energy: low temperature



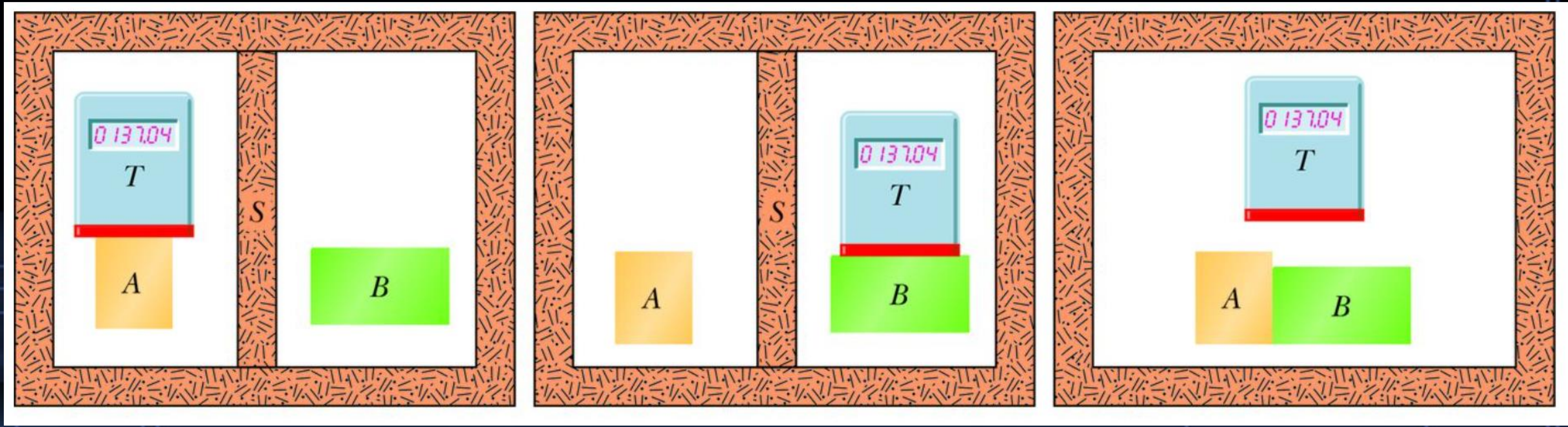
Temperature

- If two systems with different temperature contact to each other, there will be a heat energy flow from the system with high temperature to the system with low temperature.
- If there is no net heat energy flow, we called the two systems in thermodynamic equilibrium (or thermal equilibrium).



The Zeroth Law of Thermodynamics

- If bodies A and B are each in thermal equilibrium with a third body T, then A and B are in thermal equilibrium with each other.

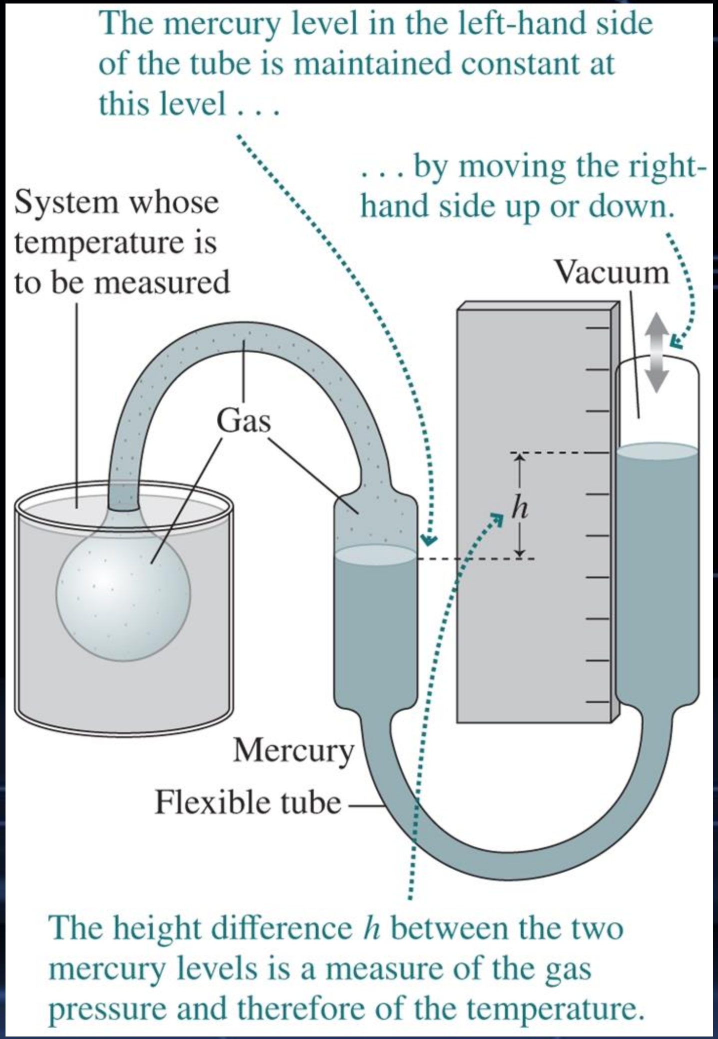


The Zeroth Law of Thermodynamics

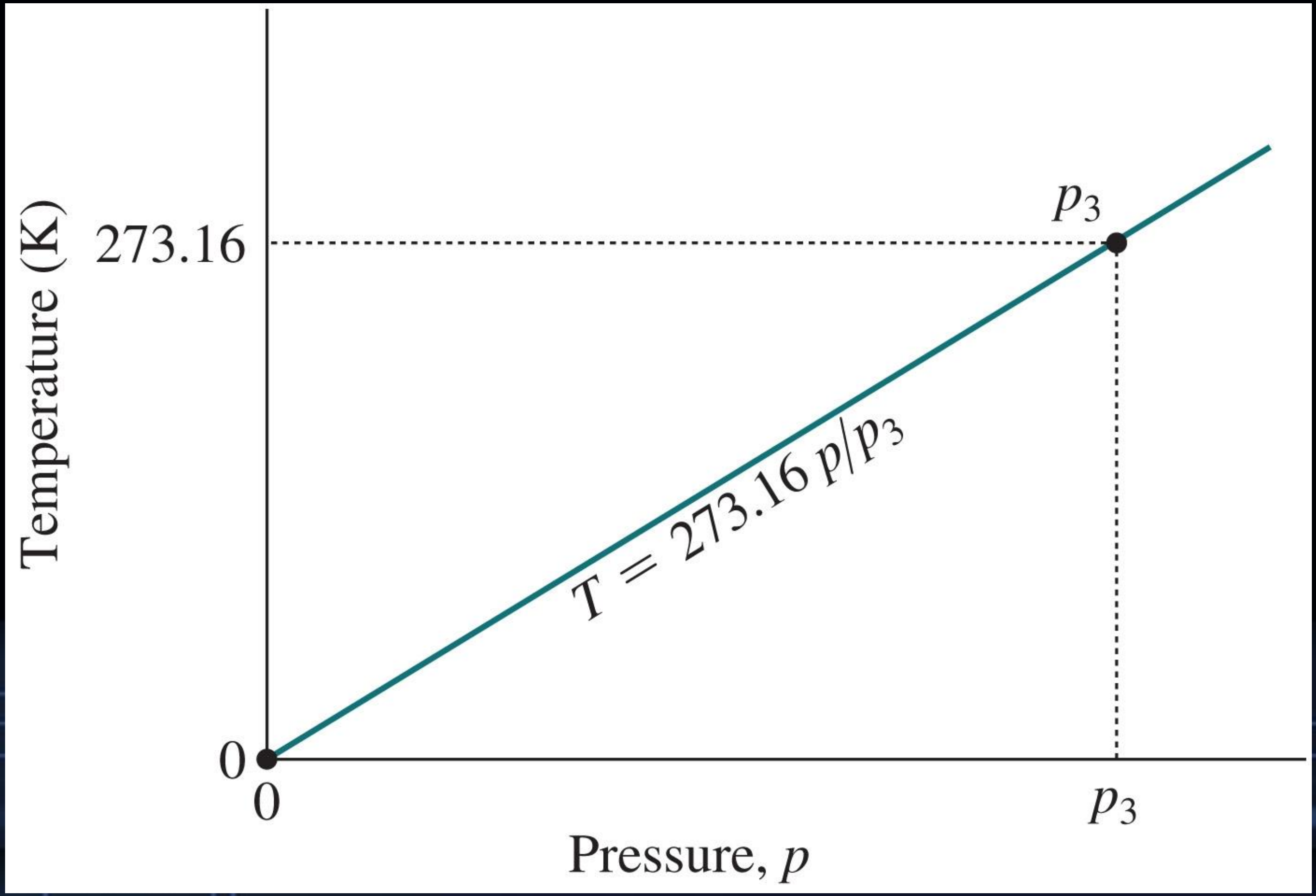
- Every object has a property called temperature. When two bodies are in thermal equilibrium, their temperatures are equal. And vice versa.
- We can now make our thermoscope (the third body T) into a thermometer, confident that its readings will have physical meaning. All we have to do is calibrate it.
- The zeroth law, which has been called a logical afterthought, came to light only in the 1930s, long after the first and second laws of thermodynamics had been discovered and numbered.

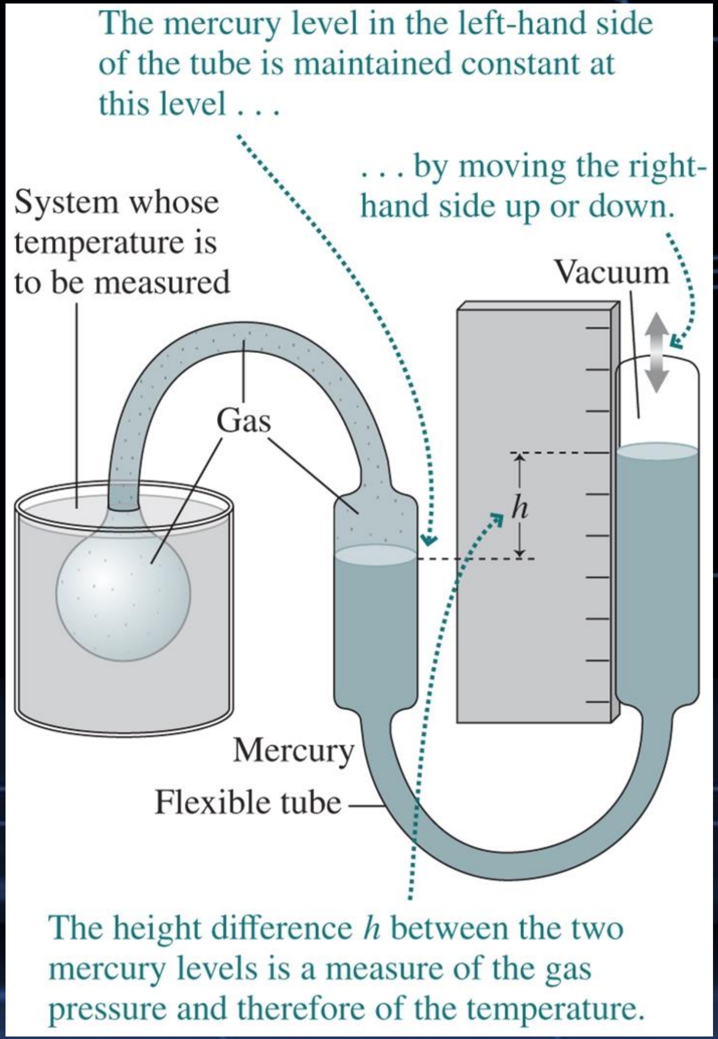
Measurement of Temperature

- One of the most versatile thermometers: constant-volume gas thermometer.
- The pressure of a gas provides an indication of temperature. Gas thermometers function over a wide range, including very low temperature, and before 2019 they provided the definition of Kelvin temperature scale in the SI units



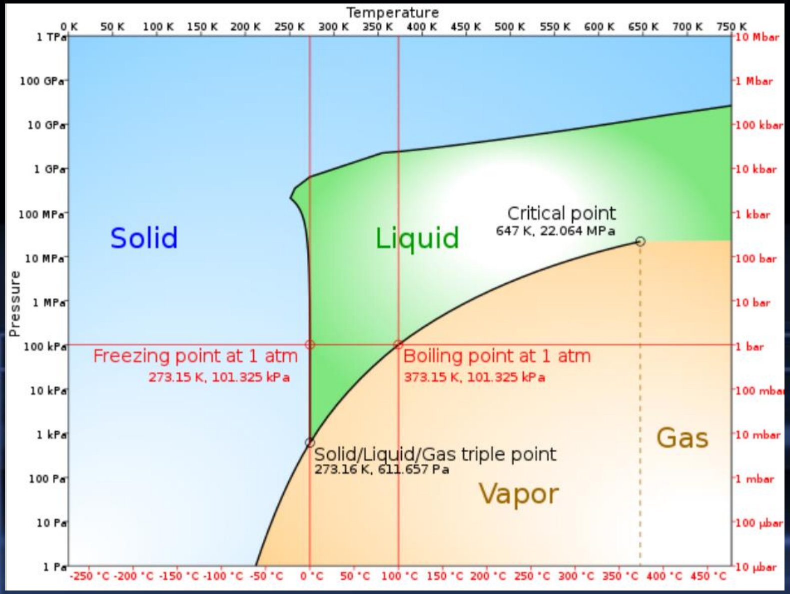
Measurement of Temperature

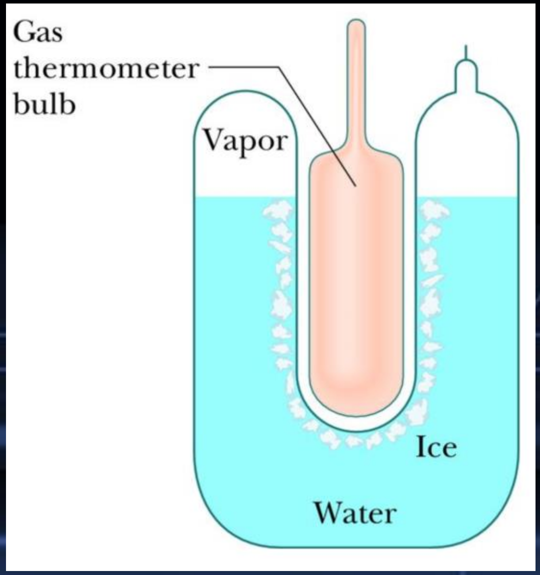




Measurement of Temperature

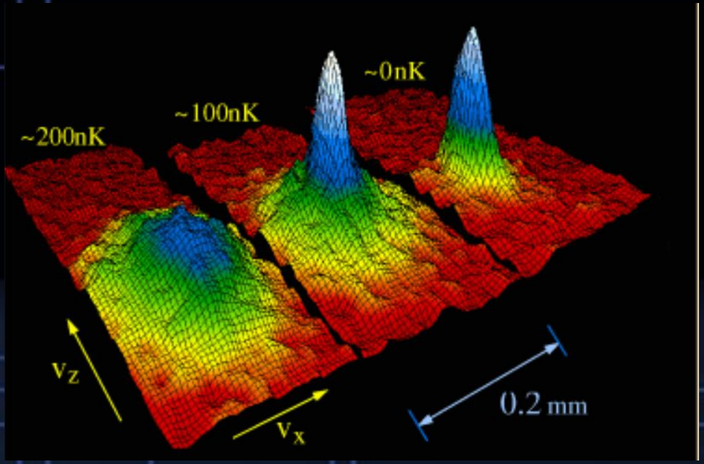
- Triple point of water: Liquid water, solid ice, and water vapor (gaseous water) can coexist, in thermal equilibrium, at only one set of values of pressure and temperature. The triple point of water has been assigned a value of 273.16 K

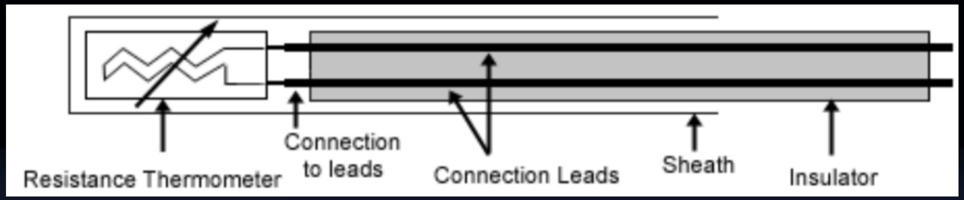




Measurement of Temperature

- Method of measuring temperature depends on the range of the temperature and condition.





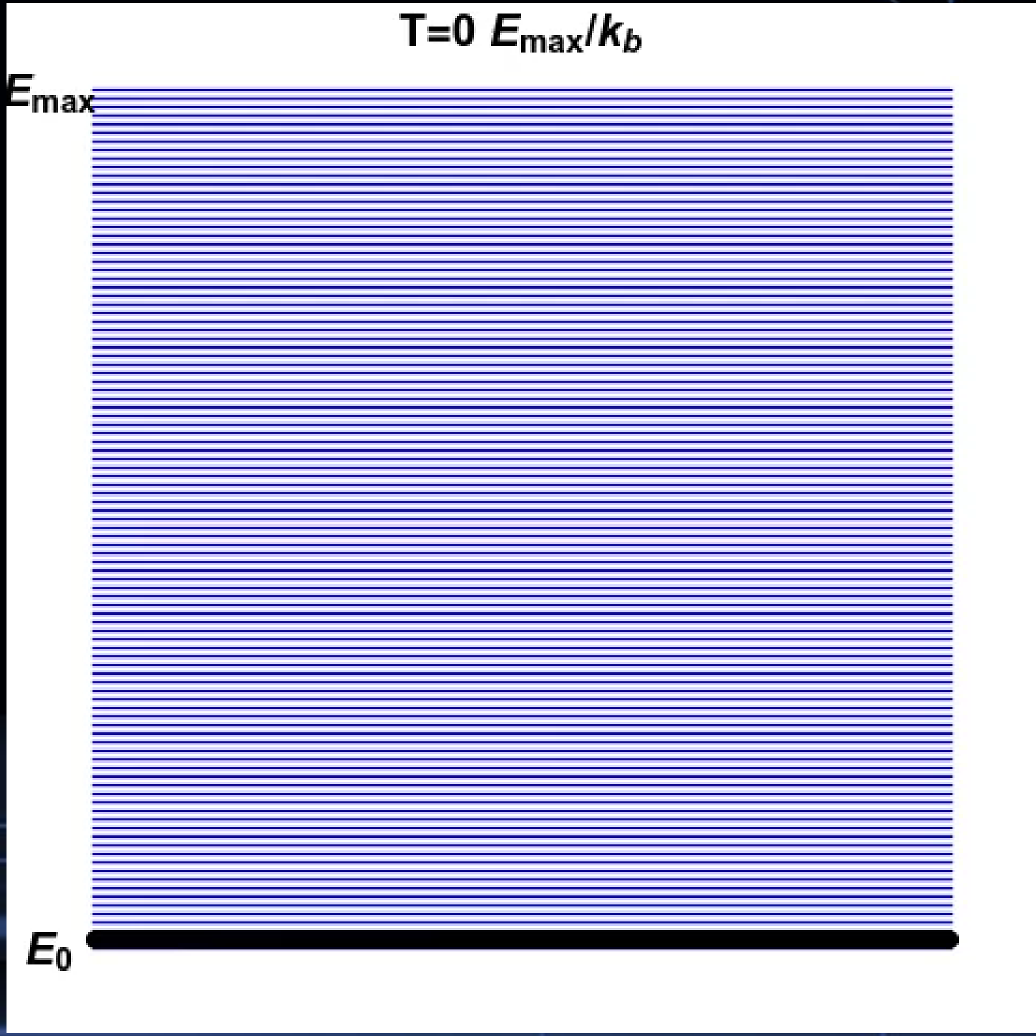
https://en.wikipedia.org/wiki/Infrared_thermometer

Kelvin scale of temperature

- Note that we do not use a degree mark in reporting Kelvin temperatures. It is 300 K (not 300°K), and it is read “300 kelvins” (not “300 degrees Kelvin”).

Negative temperature

- Negative temperatures can exist in an artificially defined system where there are a limited number of energy states.
- A system with negative temperature is actually “hot”,



https://en.wikipedia.org/wiki/File:NegativeTemperature.webm

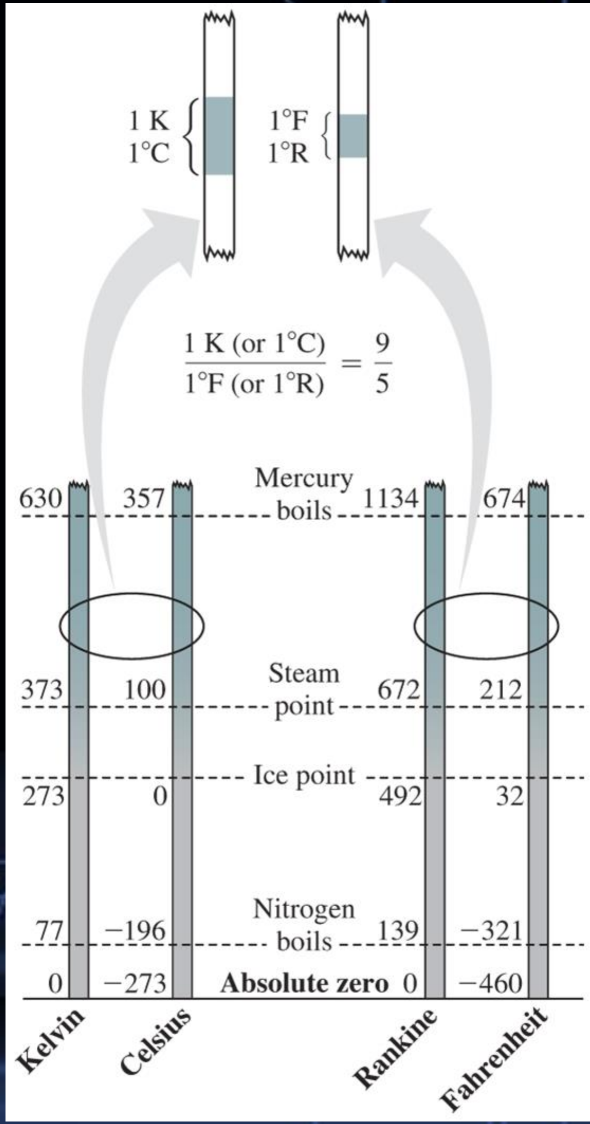
The Celsius and Fahrenheit scales

- Other frequently used temperature scale: Celsius, Fahrenheit, and Rankine scale.
- Conversion between scales:

$$T_C = T - 273.15^\circ$$

$$T_F = \frac{9}{5}T_C + 32^\circ$$

Temperature	°C	°F
Boiling point of water[a]	100	212
Normal body temperature	37.0	98.6
Accepted comfort level	20	68
Freezing point of water[a]	0	32
Zero of Fahrenheit scale	≈ –18	0
Scales coincide	–40	–40



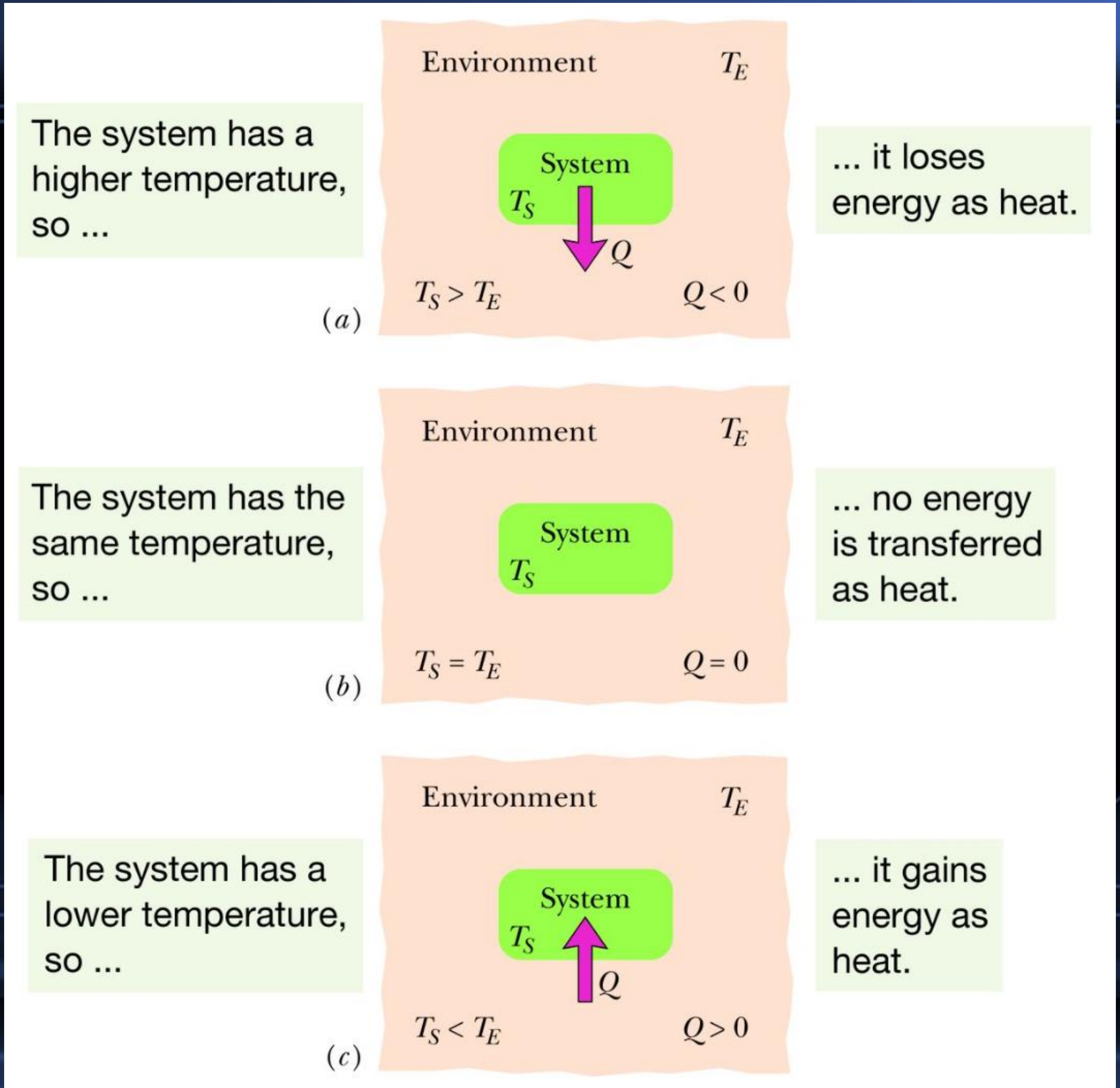
Transfer of Heat

- In generalizing this situation, we describe a system (with temperature T_S) and the environment (with temperature T_E) of that system. Our observation is that if T_S is not equal to T_E, then T_S will change (T_E can also change some) until the two temperatures are equal and thus thermal equilibrium is reached.

https://huskybrand.com.au/product/48l-coca-cola-glass-door-bar-fridge-ckk48-130/

Transfer of Heat with environment

- The transferred energy is called heat and is symbolized Q. Heat is positive when energy is transferred to a system's thermal energy from its environment (we say that heat is absorbed by the system). Heat is negative when energy is transferred from a system's thermal energy to its environment (we say that heat is released or lost by the system).


Environment
T_E
The system has a higher temperature, so ...
System
T_S
Q
... it loses energy as heat.
$T_S > T_E$
$Q < 0$
(a)
Environment
T_E
The system has the same temperature, so ...
System
T_S
... no energy is transferred as heat.
$T_S = T_E$
$Q = 0$
(b)
Environment
T_E
The system has a lower temperature, so ...
System
T_S
Q
... it gains energy as heat.
$T_S < T_E$
$Q > 0$
(c)

Heat

- Heat is the energy transferred between a system and its environment because of a temperature difference that exists between them.
- Before scientists realized that heat is transferred energy, heat was measured in terms of its ability to raise the temperature of water. Thus, the calorie (cal) was defined as the amount of heat that would raise the temperature of 1 g of water from 14.5°C to 15.5°C.
- In 1948, the scientific community decided that since heat (like work) is transferred energy, the SI unit for heat should be the one we use for energy—namely, the joule. 1cal = 4.1868J