Basic Physics

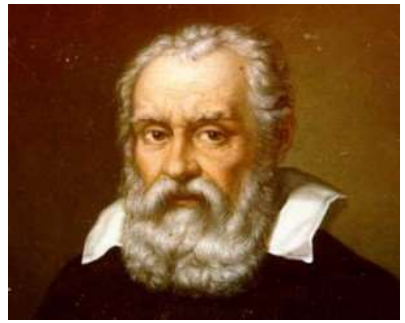
Lecture 3: Temperature and Heat

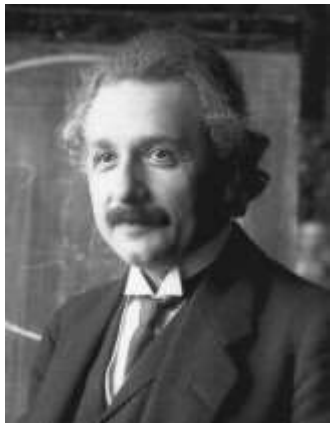
รวบรวมและเรียบเรียงโดย
อ. วรรณพงษ์ เตรียมโพธิ์
ภาควิชาฟิสิกส์ คณะวิทยาศาสตร์ ม. มหิดล

Many of the following figures or pictures are copied from open sources at the Web or Else. I do not claim any intellectual property for the following materials.

Topics

0. Nature of Science and physics
1. Mechanics
2. Temperature and Heat
3. Fluid
4. Waves
5. Sound and hearing
6. Optics and visualization
7. basic electromagnetism
8. basic quantum mechanics
9. atomic physics
10. basic nuclear physics and radioactivity





Energy and human life

Chemical energy

- Carbohydrates
- Fats
- Others

Chemical waste

- Carbon dioxide
- Water

Heat

ATP

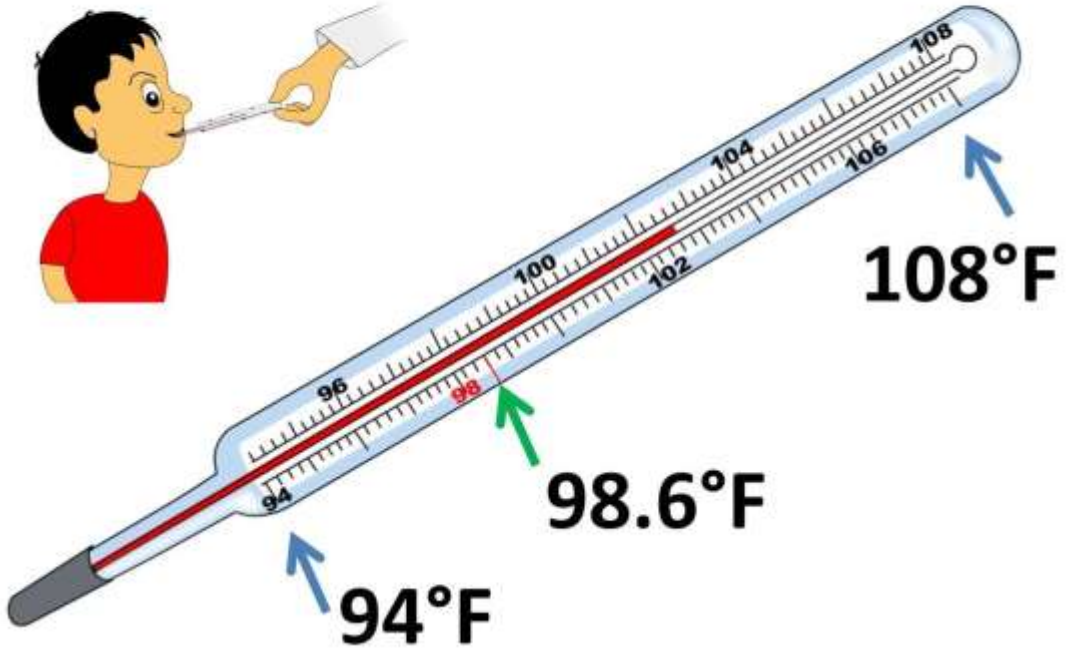
- body's "energy currency"

metabolism

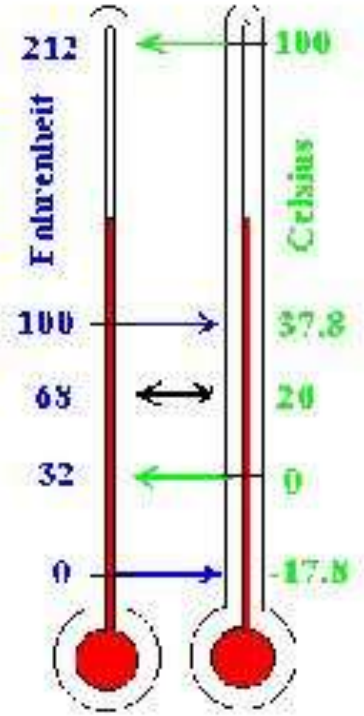
Heat

What is temperature?

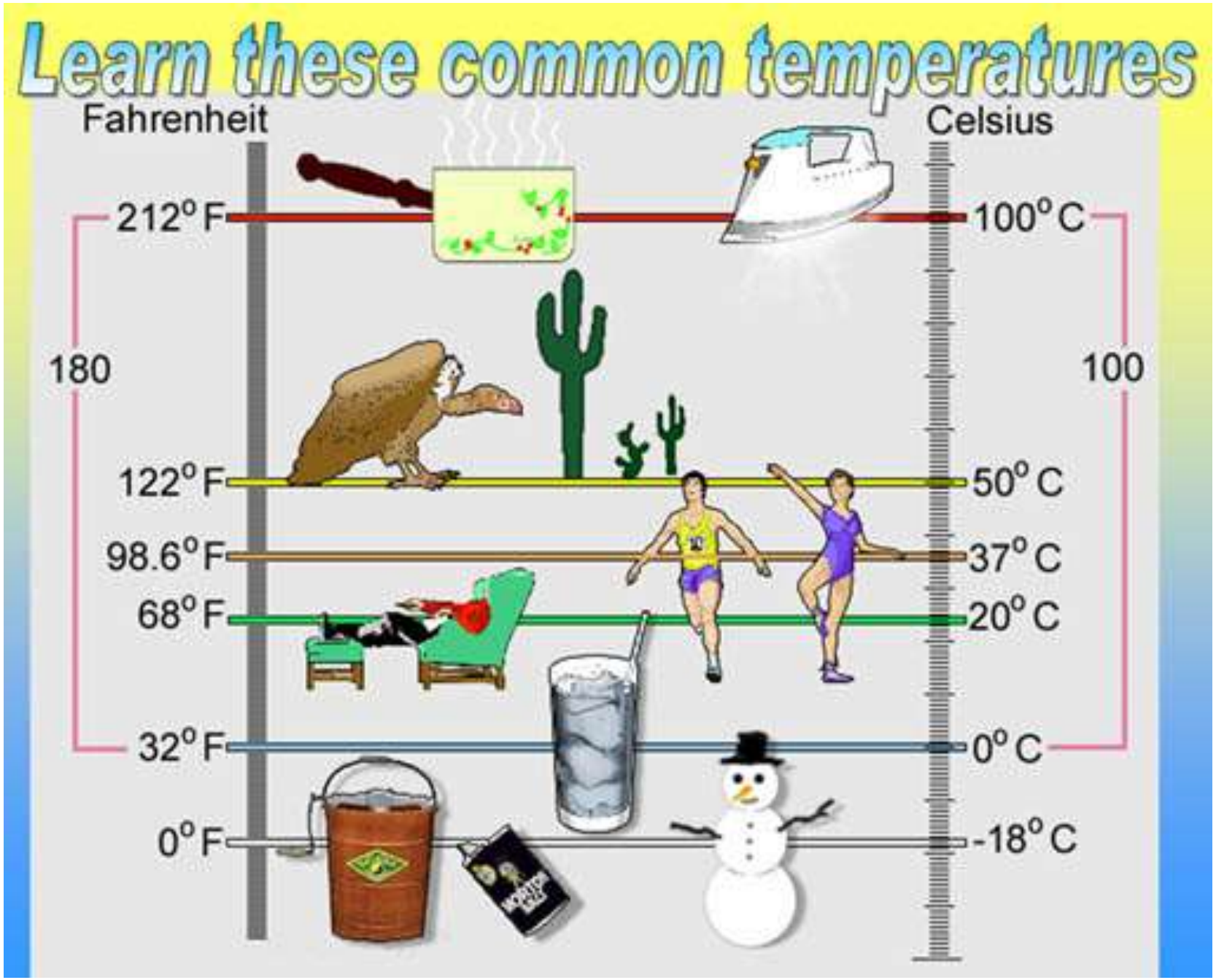
Fahrenheit clinical thermometer

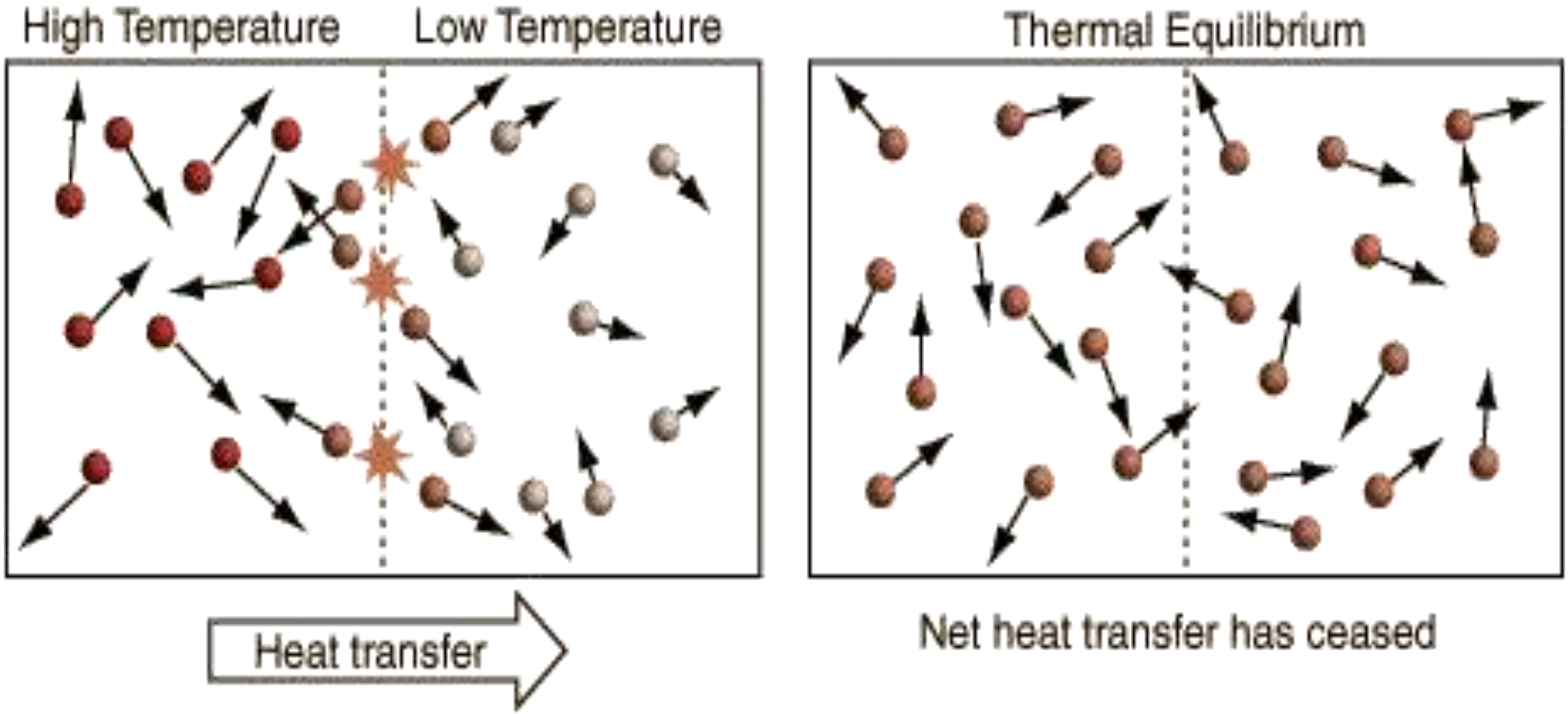


What is Temperature, Really?



- Absolute Kelvin temperature is proportional to the average kinetic energy of the atoms in a macroscopic system.
- When atoms collide they tend, on the average, to equalize kinetic energy, so kinetic energy spreads equally over all atoms, when there is thermal equilibrium.
- Zeroth Law of Thermodynamics is a macroscopic consequence of this spreading of kinetic energy through atomic collisions.


Learn these common temperatures
Fahrenheit
Celsius
212° F
100° C
180
100
122° F
50° C
98.6° F
37° C
68° F
20° C
32° F
0° C
0° F
-18° C


High Temperature
Low Temperature
Thermal Equilibrium
Heat transfer
Net heat transfer has ceased

INTRODUCTION

- What is Temperature?

Temperature is defined as the degree of hotness or coldness measured on a definite scale. Hotness and coldness are the result of molecular activity. As the molecules of a substance move faster, the temperature of that substance increases.

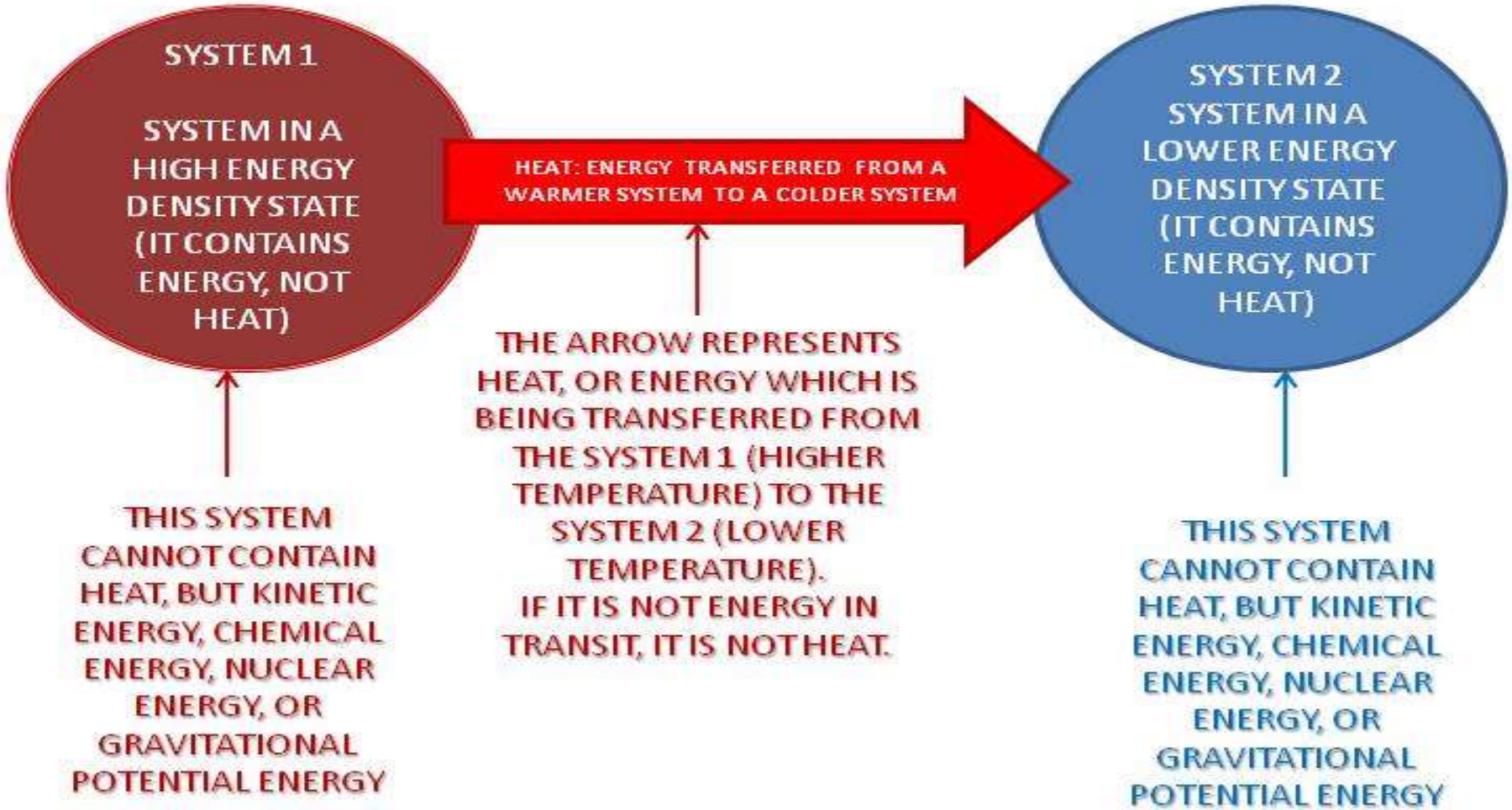
- What is Heat?

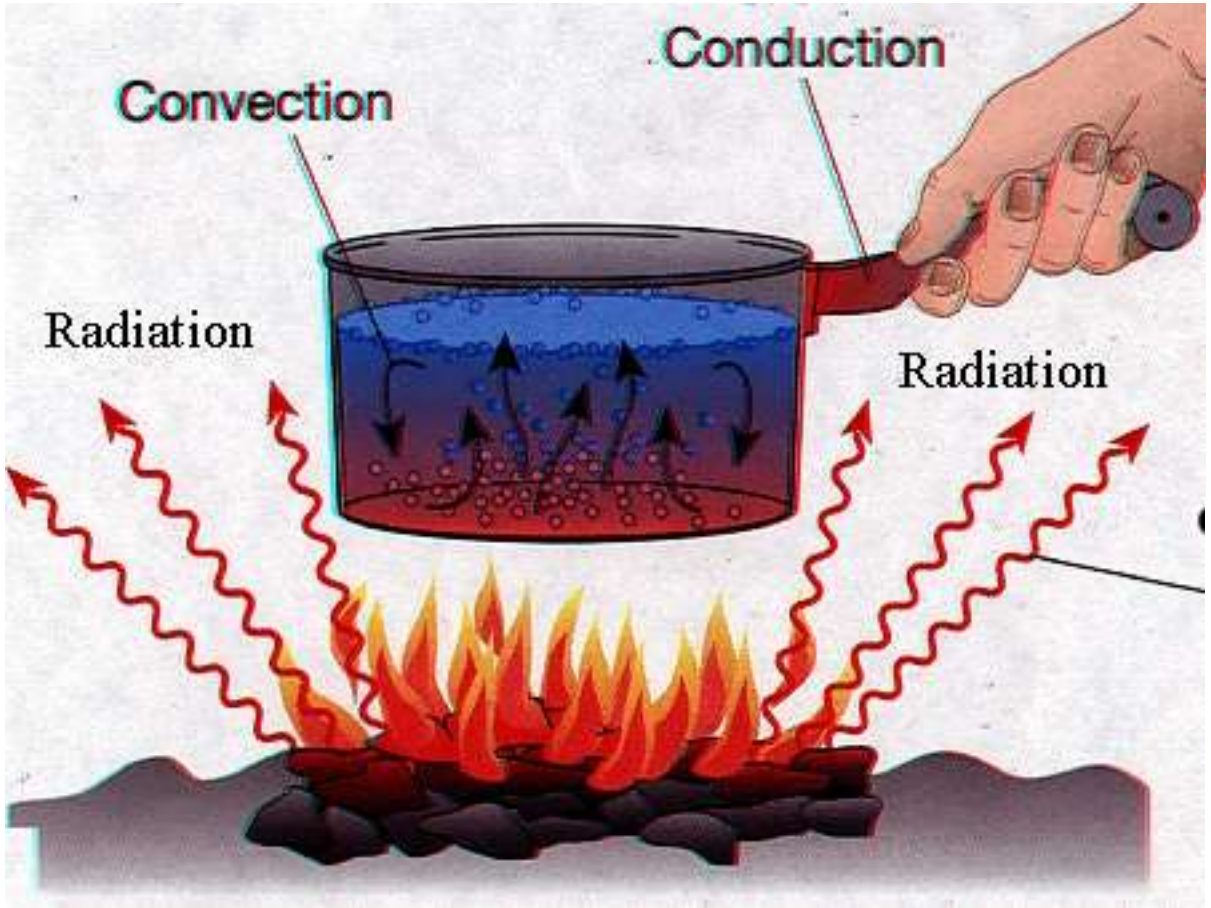
Heat is a form of energy and is measured in calories or BTU's (British Thermal Units).

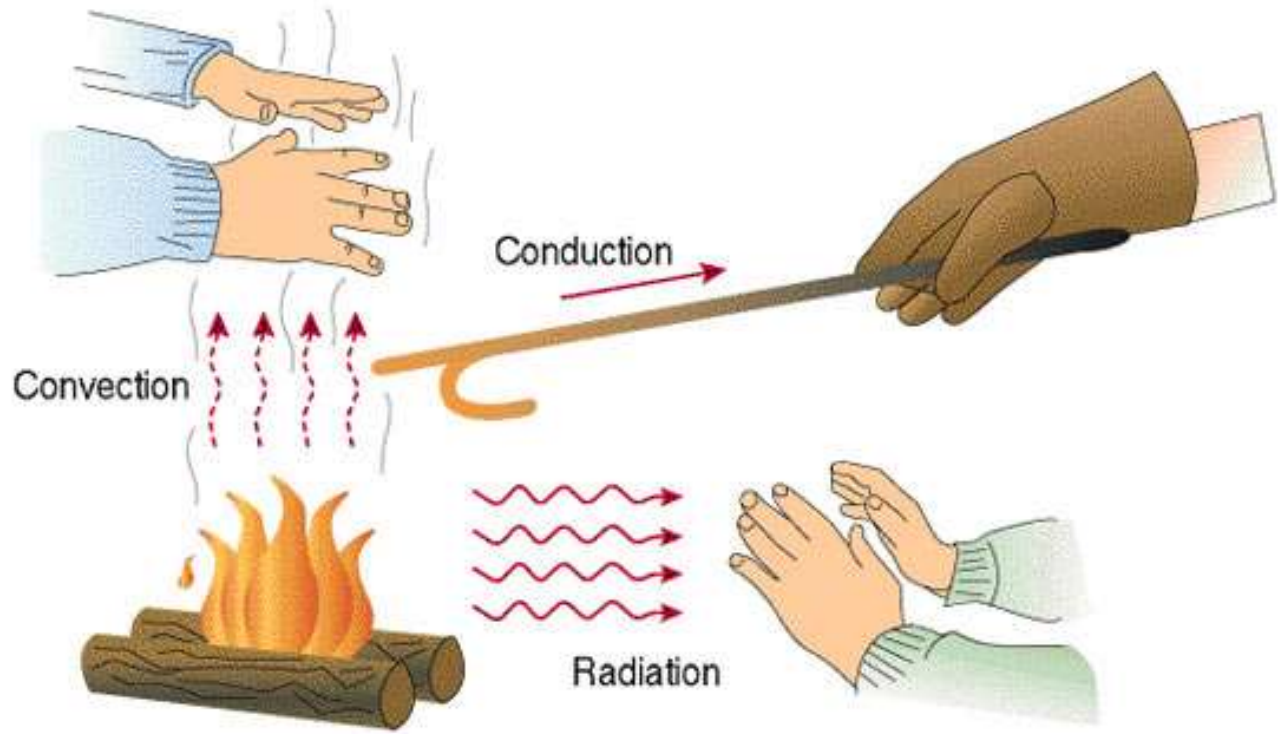
- Why temperature is measured as a process variable?

There are changes in the physical or chemical state of most substances when they are heated or cooled. The measurement of temperature is also important for protection of the equipment, as uncontrolled high or low temperatures can cause structural deterioration of pipelines and vessels.

WHAT IS HEAT?

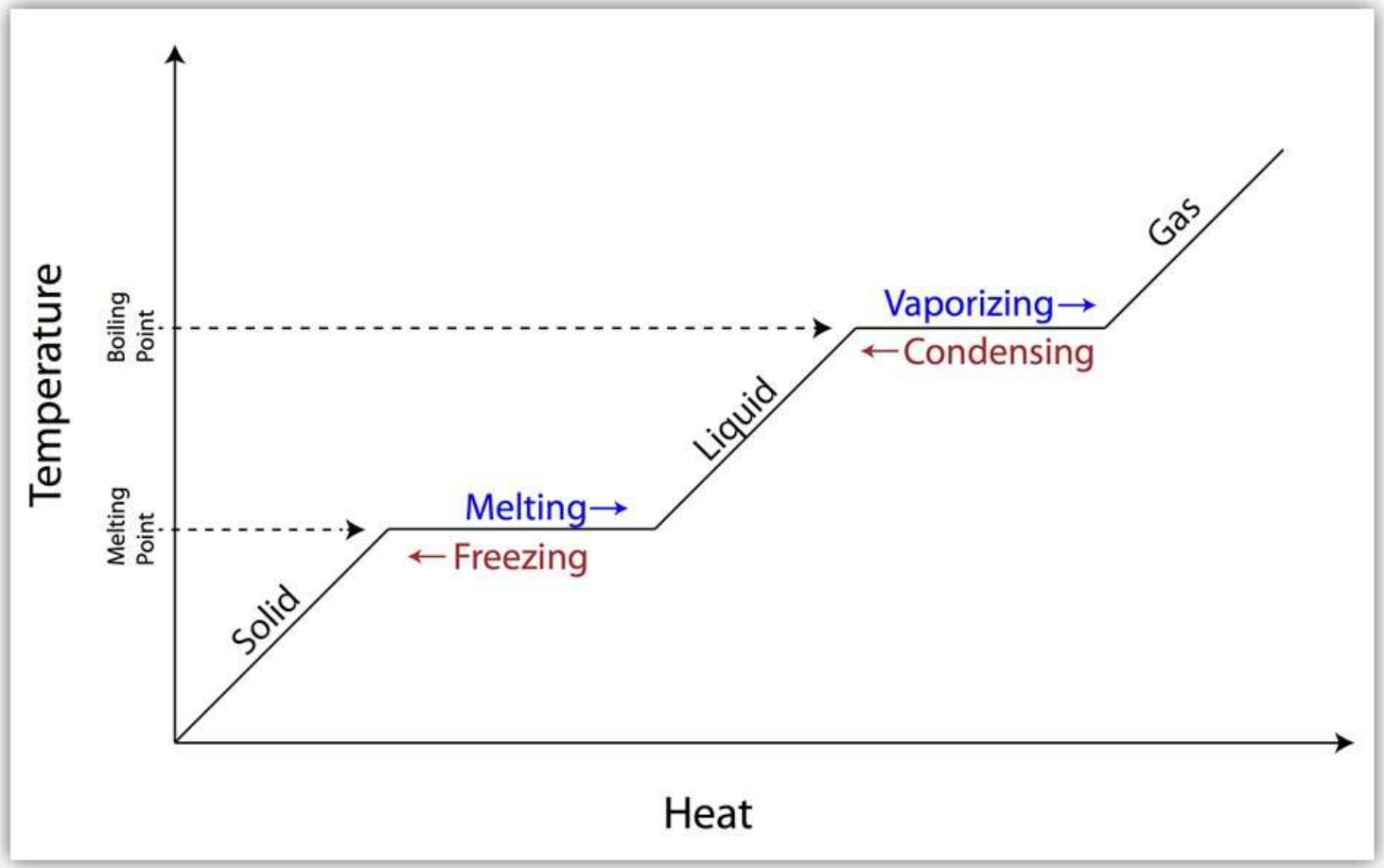



Conduction
Convection
Radiation
Radiation

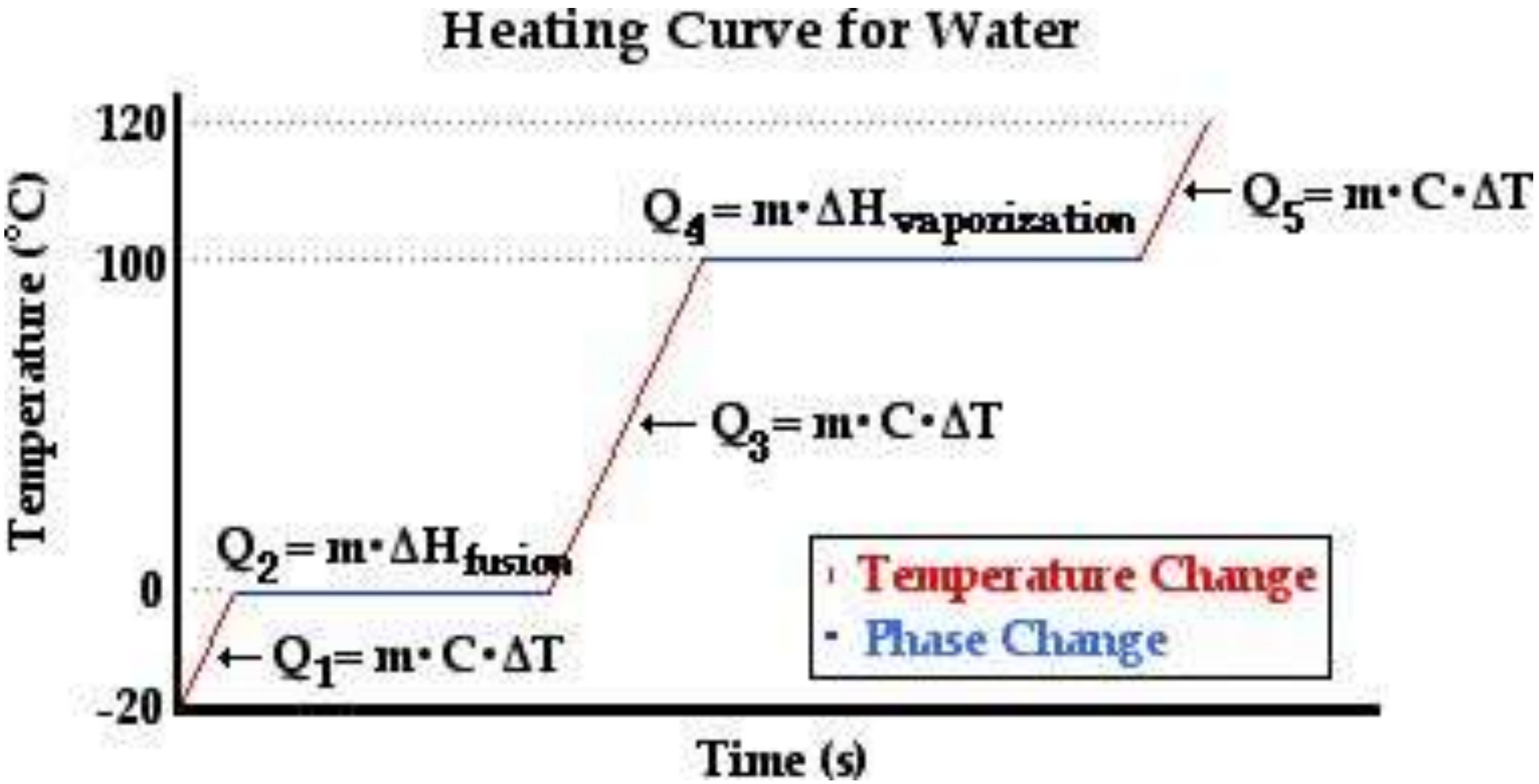

Conduction
Convection
Radiation

Latent Heat

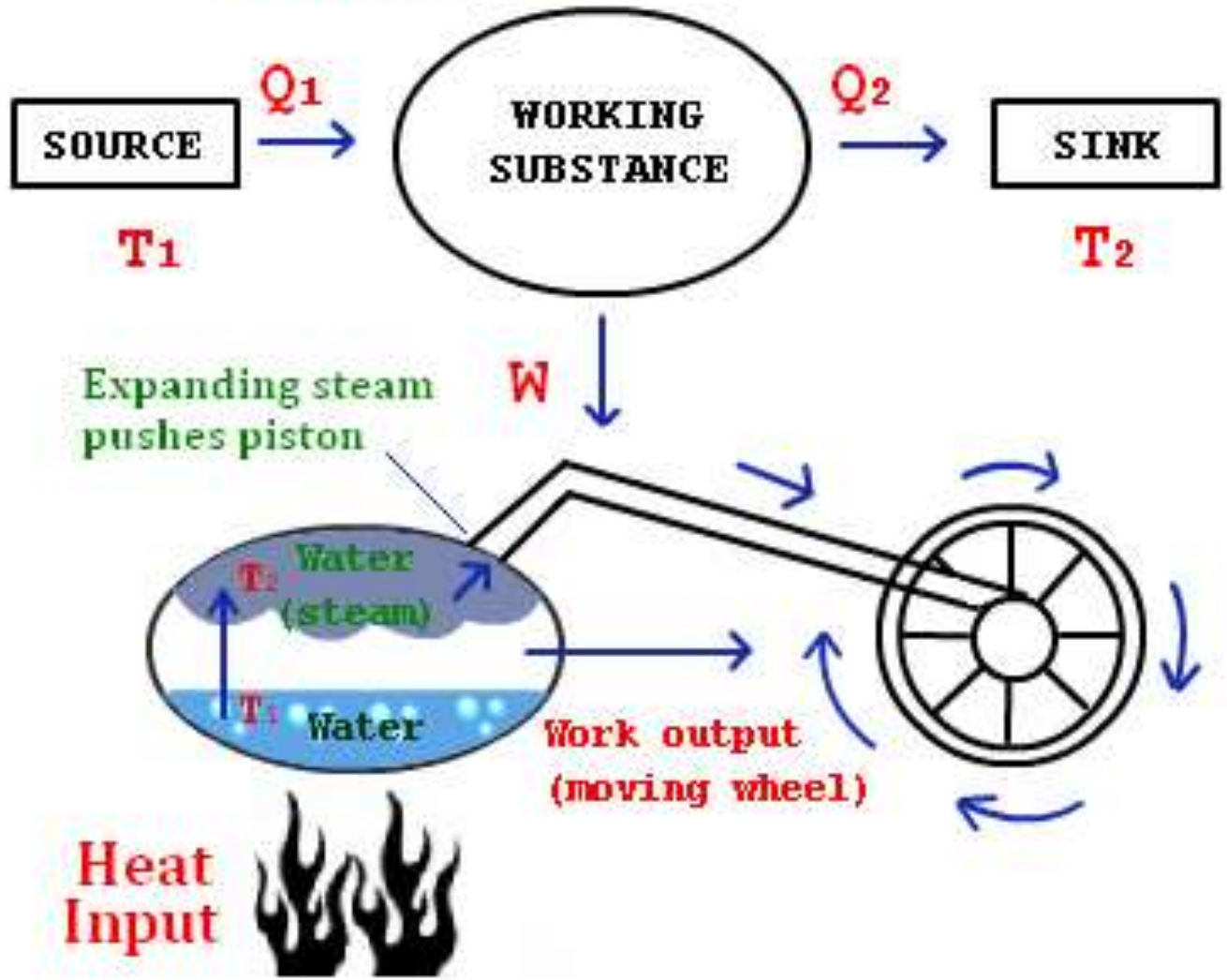
Climatology

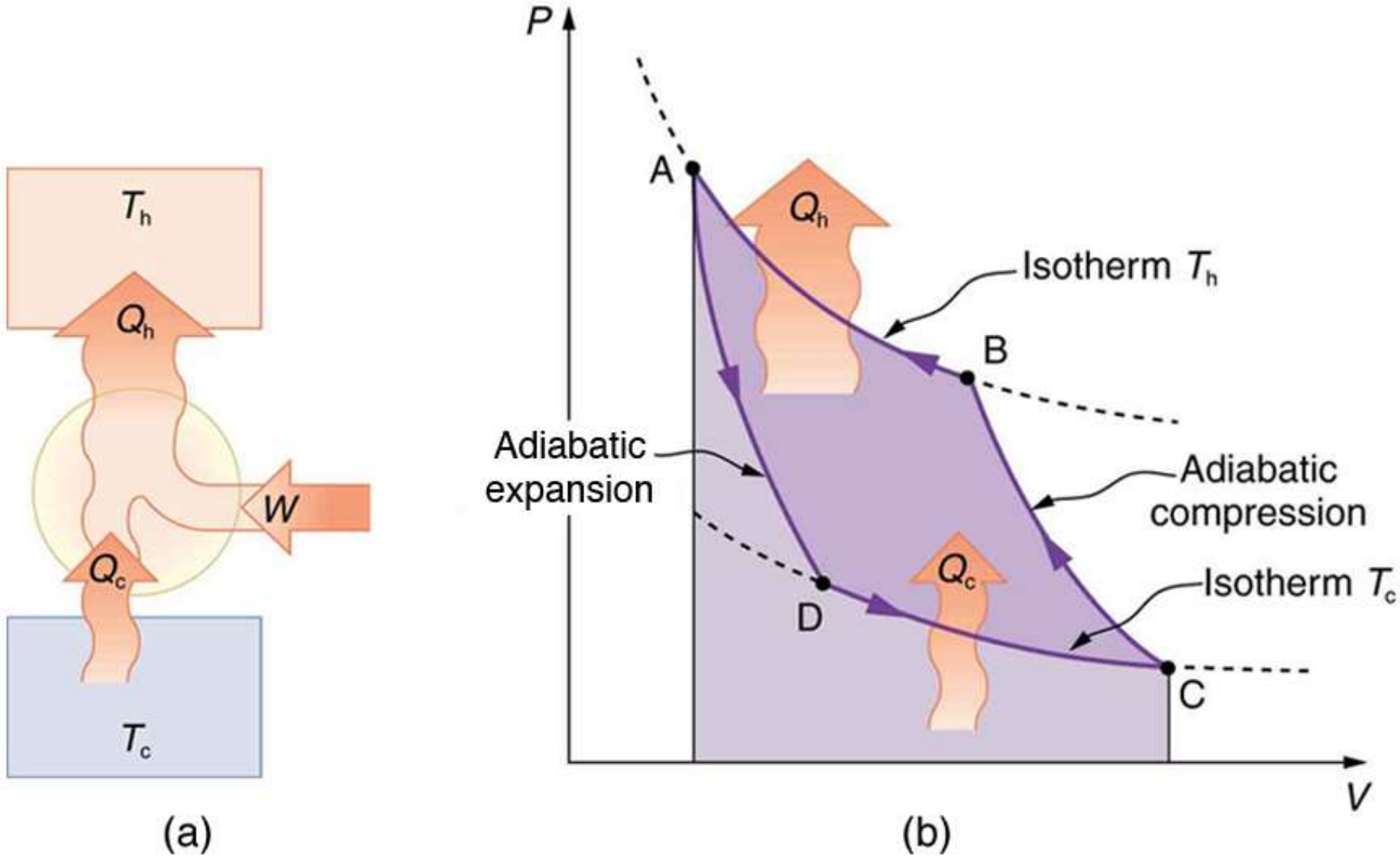


www.poormansfriend.org


Heating Curve for Water
120
100
0
-20
Temperature (°C)
Time (s)
$Q_4 = m \cdot \Delta H_{vaporization}$
$\leftarrow Q_5 = m \cdot C \cdot \Delta T$
$\leftarrow Q_3 = m \cdot C \cdot \Delta T$
$Q_2 = m \cdot \Delta H_{fusion}$
$\leftarrow Q_1 = m \cdot C \cdot \Delta T$
Temperature Change
Phase Change

HEAT ENGINE


SOURCE
Q1
WORKING SUBSTANCE
Q2
SINK
T1
T2
W
Expanding steam pushes piston
T2
Water (steam)
T1
Water
Work output (moving wheel)
Heat Input


T_h
Q_h
W
Q_c
T_c
(a)
P
A
Q_h
Isotherm T_h
B
Adiabatic
expansion
Adiabatic
compression
Q_c
Isotherm T_c
D
C
V
(b)

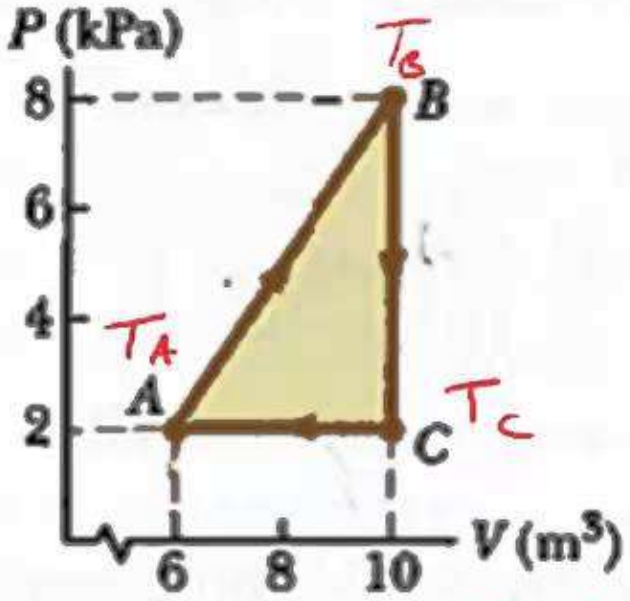
The change in internal energy of a system is equal to the heat added to the system minus the work done by the system.

$$\Delta U = Q - W$$

Change in internal energy

Heat added to the system

Work done by the system



1ST Law of Thermodynamics

$$\Delta U = Q + W$$

$$U = \frac{3}{2} NkT$$

$$\Delta U \propto \Delta T$$

$$PV = nRT$$

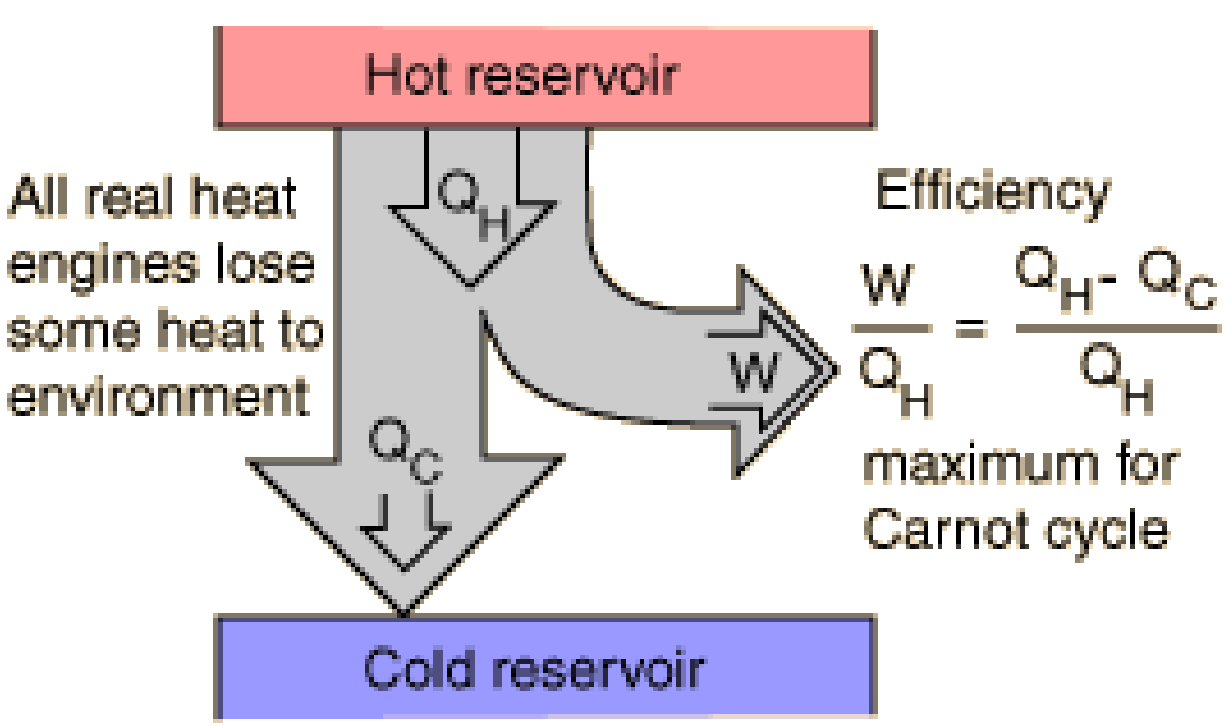
$$PV = NkT$$

Isochoric

	A→B	B→C	C→A	Entire Cycle
ΔU	+	−		
Q				
W	−	0	+	

$$P_A V_A < P_C V_C < P_B V_B$$

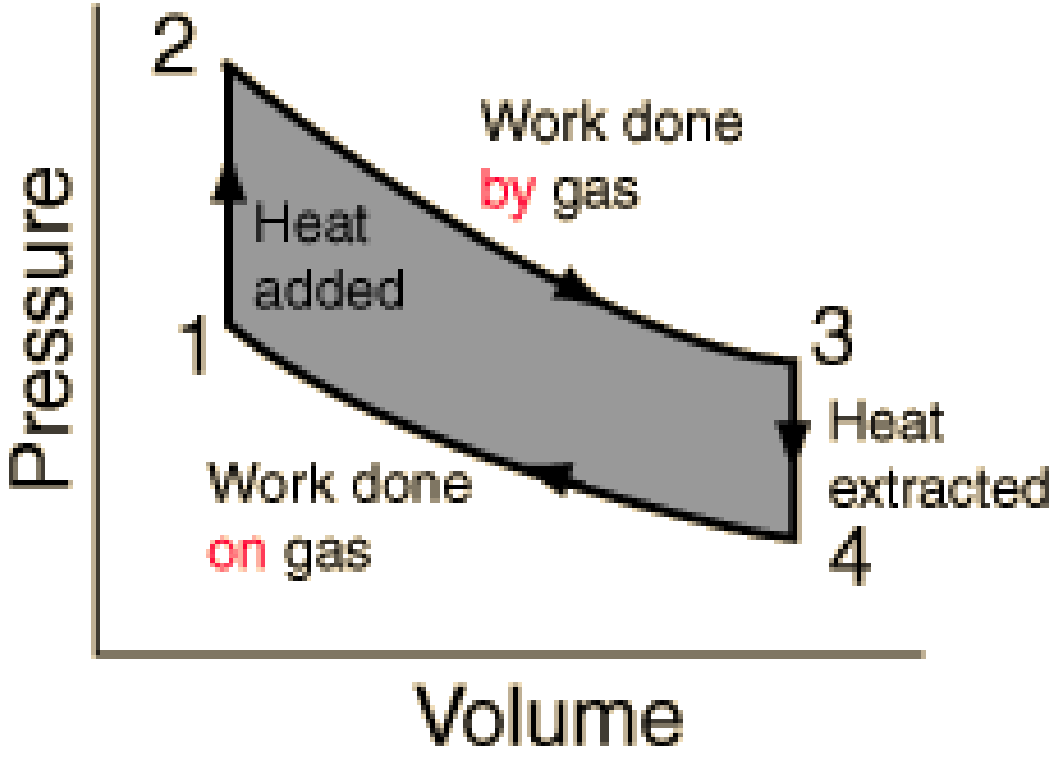
$$T_A < T_C < T_B$$

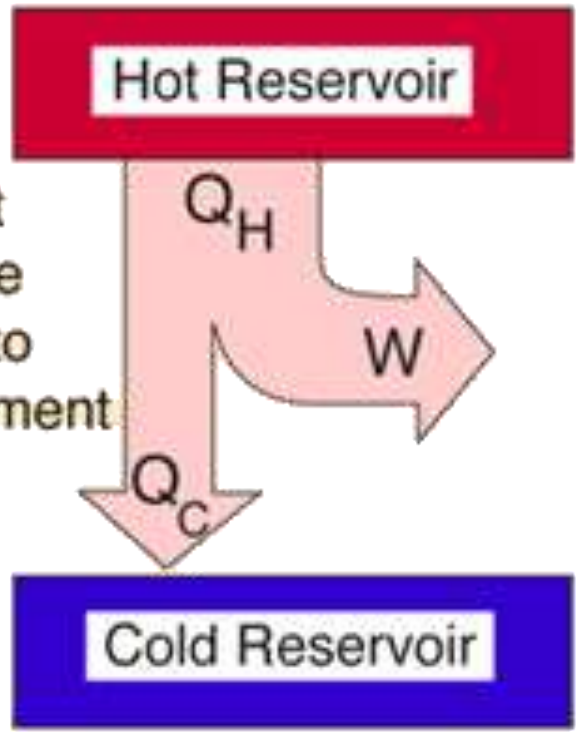


Efficiency

$$\frac{W}{Q_H} = \frac{Q_H - Q_C}{Q_H}$$

maximum for Carnot cycle



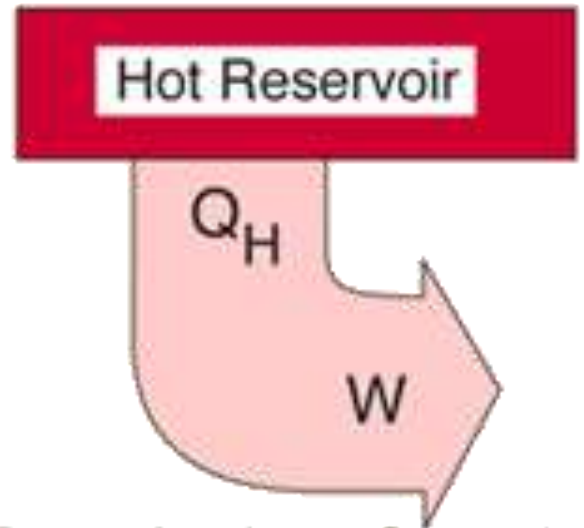


All real heat engines lose some heat to the environment

Efficiency

$$= \frac{W}{Q_H} = \frac{Q_H - Q_C}{Q_H}$$

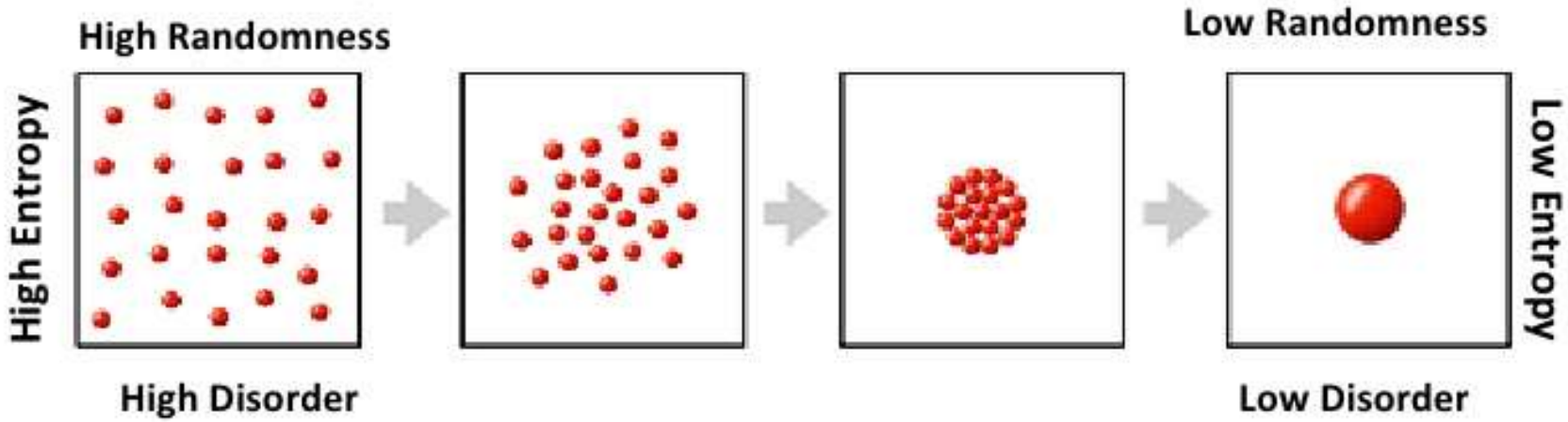
Maximum for the Carnot cycle



Extracting heat Q_H and using it all to do work W would constitute a perfect heat engine, forbidden by the second law.

What is Entropy

- A measurement of the **degree of randomness** of energy in a system.
- The lower the entropy the more ordered and less random it is, and vice versa.



Examples: gallon of gas, prepared food, sunlight have low entropy.
When these are "used" their entropy increases

Mingus, C. (2005, April 15). Two opposing types of order. Retrieved from http://www.everythingforever.com/st_order3.htm

Entrophy

- the degree of disorder or uncertainty in a system

Progressive Loss of Energy in Food Chain

HOW HEAT IS LOST FROM AN UNINSULATED HOME

Heat is lost from buildings through the wall, ceiling, windows and doors or through gaps and crevices, in older buildings heat also escapes through gaps in the lining and outside cladding or through the chimney

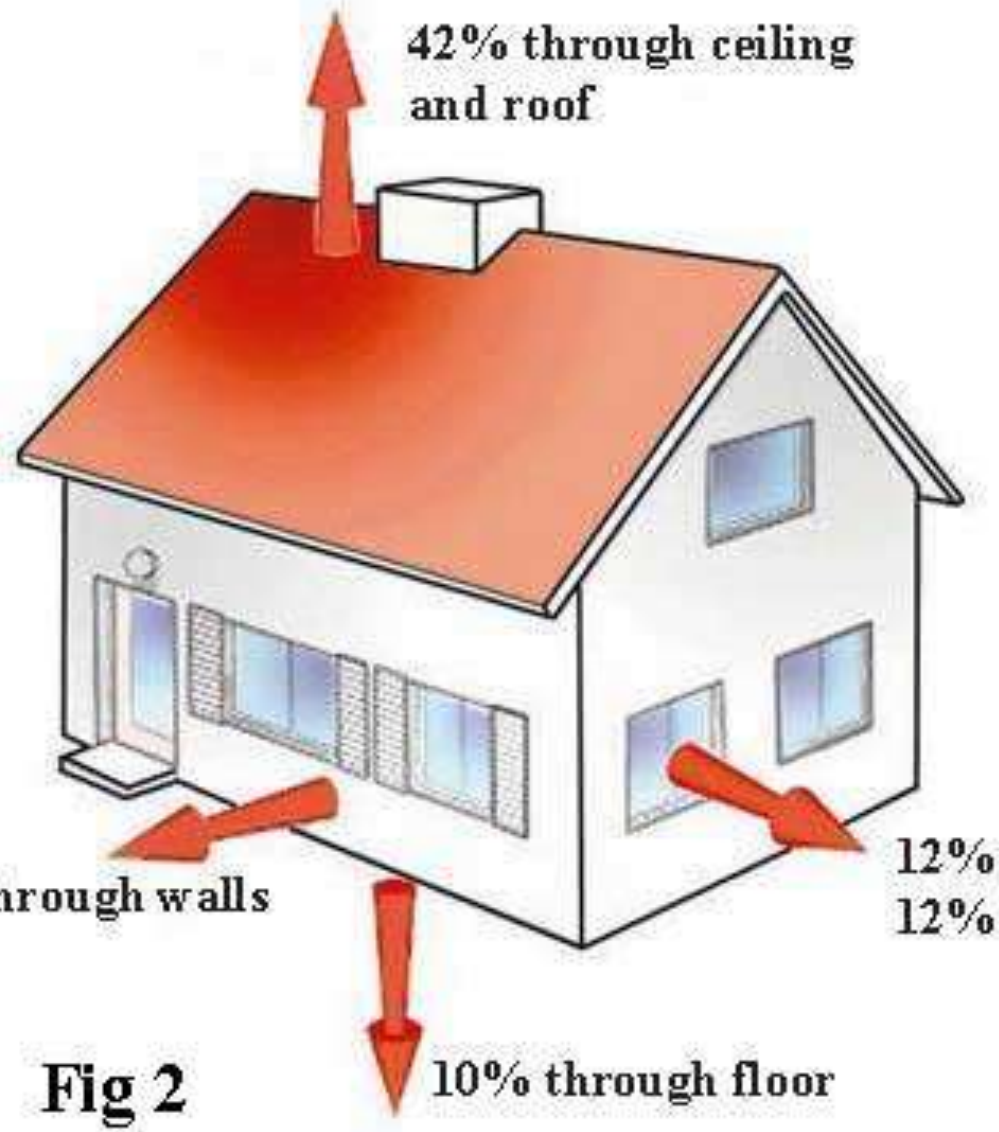
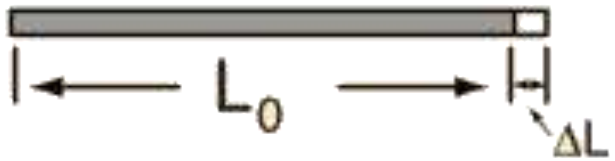


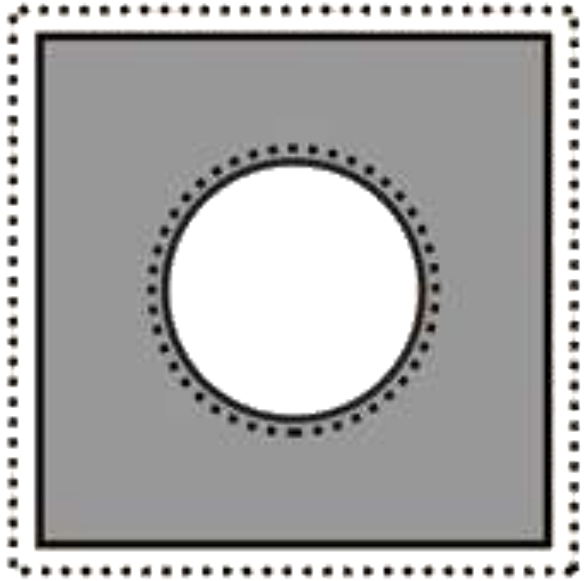
Fig 2

Thermal Expansion



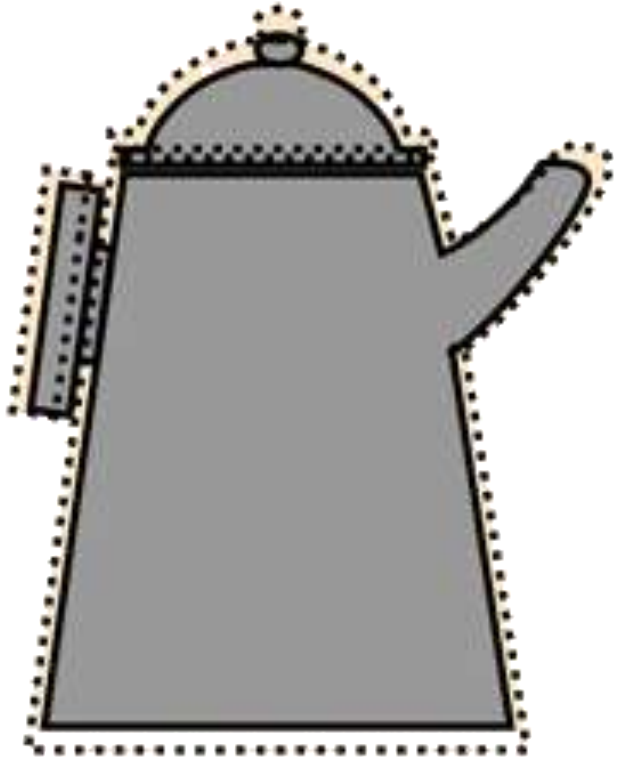
Linear expansion

$$\frac{\Delta L}{L_0} = \alpha \Delta T$$



Area expansion

$$\frac{\Delta A}{A_0} = 2\alpha \Delta T$$



Volume expansion

$$\frac{\Delta V}{V_0} = 3\alpha \Delta T$$

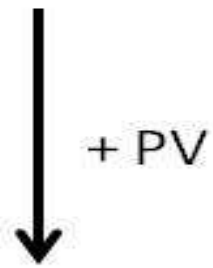
Thermal Expansion Formulas

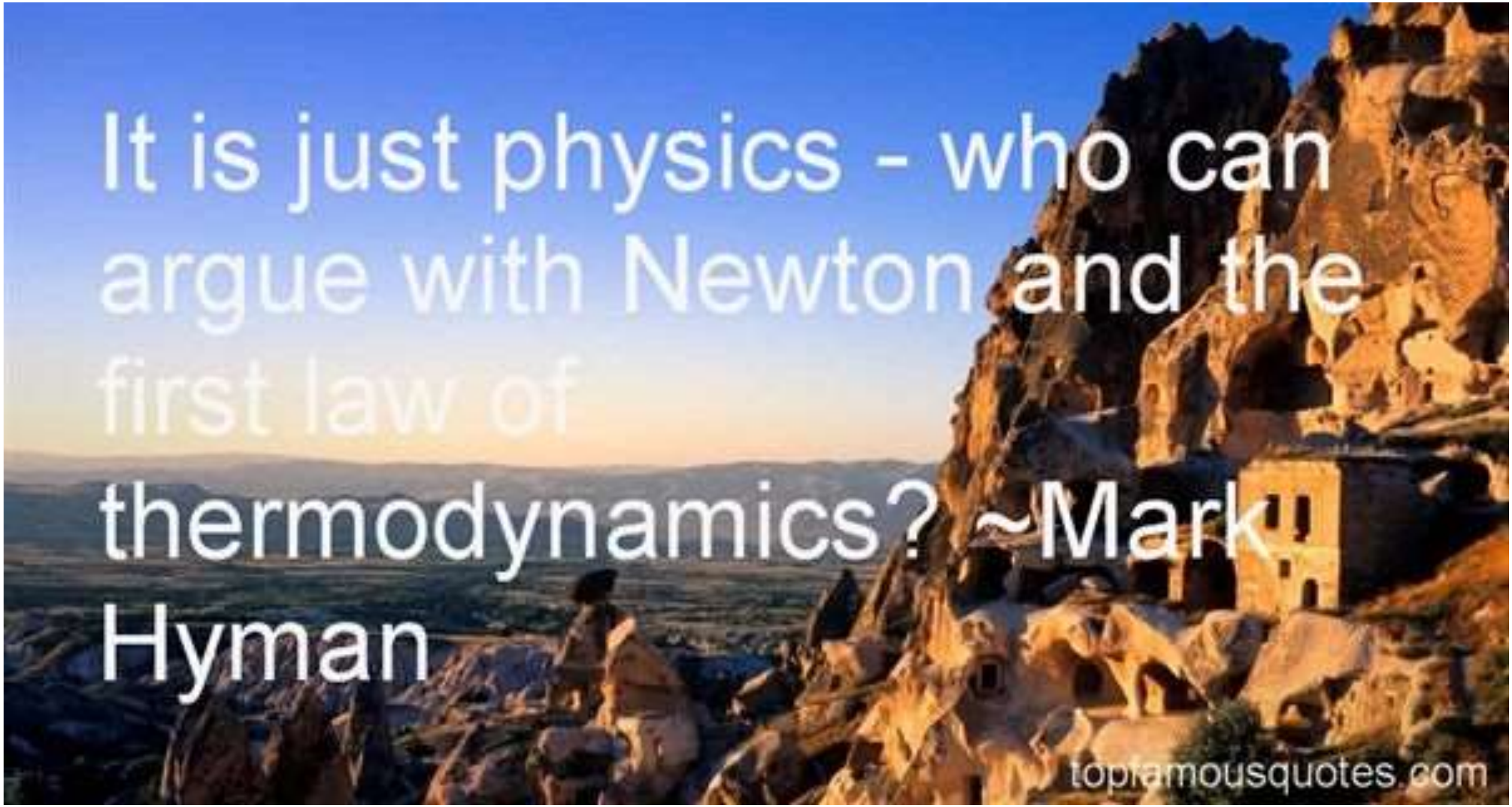
- Linear: $\Delta L = L_o \alpha \Delta T$
- Area: $\Delta A = 2A_o \alpha \Delta T$
- Volume: $\Delta V = 3V_o \alpha \Delta T$ or $\Delta V = V_o \beta \Delta T$

- How much taller is the Eiffel Tower on the hottest day of the summer (25 °C) than the coldest day of the winter (2 °C)? The tower is 324 m tall measured (on the coldest day) from the top of the flagpole. Assume the tower is built of structural steel $\alpha = 12 \times 10^{-6}\ ^oC^{-1}$.

Approximate Coefficients of Thermal Expansion at 20°C		
Material	**α (10^{-6}/°C)**	**β (10^{-6}/°C)**
Aluminum	23	69
Concrete	12	36
Diamond	1	3
Glass	9	27
Stainless Steel	17	51
Water*	69	207

	Temperature (T)	**Entropy (S)**
Volume (V)	Helmholtz Free Energy: $A(T,V) = U - TS$	Internal Energy: $U(S,V)$
Pressure (P)	Gibbs Free Energy: $G(T,P) = U + PV - TS$	Enthalpy: $H(S,P) = U + PV$




It is just physics - who can argue with Newton and the first law of thermodynamics? ~Mark Hyman
topfamousquotes.com