Physics 052

L7

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CH 10&11:Thermodynamics

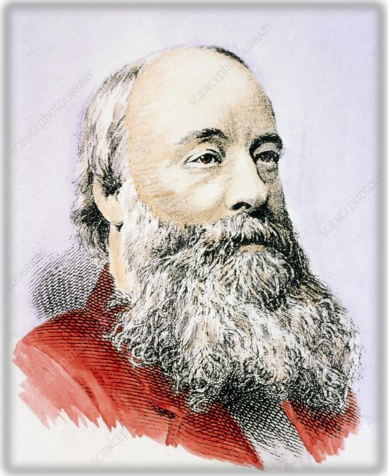
In this photograph, we see evidence of water in all three phases. In the lake is liquid water, and solid water in the form of snow appears on the ground. The clouds in the sky consist of liquid water droplets that have condensed from the gaseous water vapor in the air. Changes of a substance from one phase to another are a result of energy transfer.

What are we going to talk about today?

CH 10 &11: Thermodynamics

- 10.1 Temperature Scales.
- 11.0 Introduction:
  - Equation of state.
  - Zeroth Law of Thermodynamics.
  - Heat.
  - Internal Energy.
- 11.1 Mechanical Work.
- 11.2 The First Law Of Thermodynamics.

Thermodynamics is the study of energy relationships that involve heat, mechanical work, and other aspects of energy and heat transfer.



James Prescott Joule
British physicist
(1818–1889)

10.1 Temperature Scales

Temperature is an SI base quantity related to our sense of hot and cold.

It is measured with a thermometer, which contains a working substance with a measurable property, such as length or pressure, that changes in a regular way as the substance becomes hotter or colder.

How is temperature measured?

- The temperature scales are Celsius (with a unit °C), Fahrenheit (with a unit °F) and Kelvin (with a SI unit K)
- The temperature difference between boiling and freezing of water are divided into smaller units called degrees.
- On the Celsius scale and Kelvin scale there are 100 degrees between the boiling and freezing points of water.
- On the Fahrenheit scale, there are 180 degrees between the boiling and freezing points of water.

10.1 Temperature Scales

Conversion formulas:

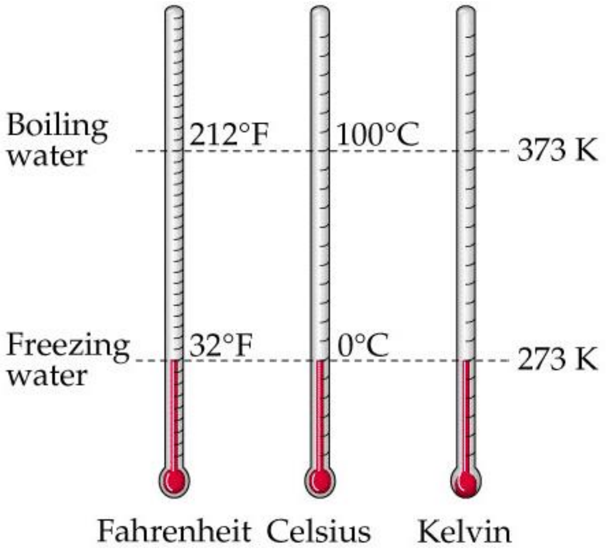
The conversion between Celsius scale and Kelvin scale is:

$$T_K = T_C + 273.15$$

The conversion between Fahrenheit scale and Celsius scale is:

$$T_F = \frac{9}{5} T_C + 32°F$$

The coldest temperature possible is –273 °C. On the Kelvin scale, this is called absolute zero and is represented as 0 K



Temperature Comparison

Example	Fahrenheit (°F)	Celsius (°C)	Kelvin (K)
Sun	9937	5503	5776
A hot oven	450	232	505
A desert	120	49	322
A high fever	104	40	313
Normal body temperature	98.6	37.0	310
Room temperature	70	21	294
Water freezes	32	0	273
A northern winter	−66	−54	219
Nitrogen liquefies	−346	−210	63
Helium boils	−452	−269	4
Absolute zero	−459	−273	0

Checkpoint 1:

A. What is the temperature at which water freezes?

1) 0 °F
2) 0 °C
3) 0 K

B. What is the temperature at which water boils?

1) 100 °F
2) 32 °F
3) 373 K

C. How many Celsius units are between the boiling and freezing points of water?

1) 100
2) 180
3) 273

Examples

1) **What is the temperature in C if the temperature is 68°F?**

2) **What is the temperature in F if the temperature is – 10 °C?**

https://www.youtube.com/watch?v=l5xbgNTxApo&amp=&feature=relmfu

11.0 Introduction

- **Equation of state:**

Suppose an ideal gas is confined to a cylindrical container whose volume can be varied by means of a movable piston. If we assume the cylinder does not leak, the n (the number of moles) of the gas remains constant.

For such a system, experiments provide the following information:

- When the gas is kept at a constant temperature, its pressure is inversely proportional to the volume $P \propto \frac{1}{V}$.
- When the pressure of the gas is kept constant, the volume is directly proportional to the temperature $V \propto T$.
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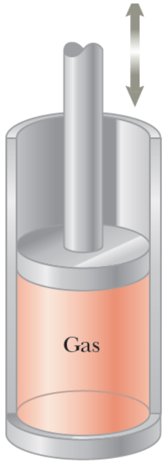
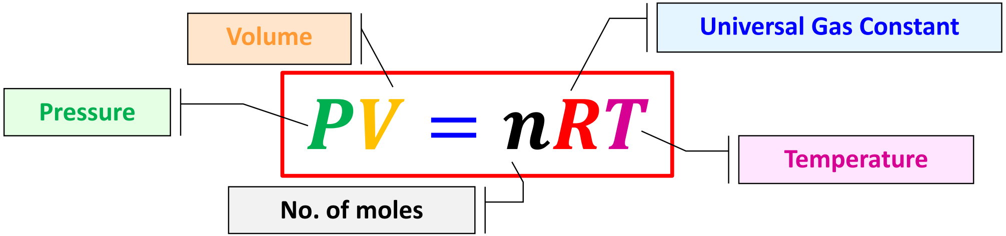
These observations are summarized by the equation of state for an ideal gas:

$$PV = nRT$$



An ideal gas confined to a cylinder

11.0 Introduction



P pressure is measured in pascals (Pa)

V volume is measured in (m^3)

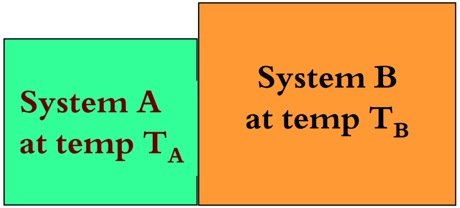
n amount of matter is measured in (mol)

T temperature is measured in (K)

R gas constant R= 8.314 J/K.mol

Heat

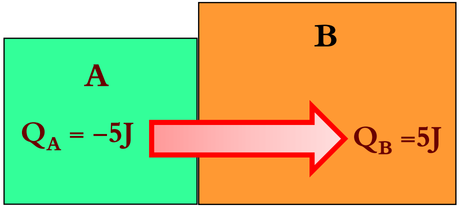
- Heat (Q) is the energy that flows from one system (A) to another (B) because of their temperature difference ($T_A \neq T_B$).
- Heat stops flowing when the two systems come to the same temperature ($T_A = T_B$).



- Heat is always transferred from the object at the higher temperature to the object with the lower temperature

Sign Convention of Heat:

Positive Heat (+Q): Positive if energy is transferred to the system by heat.
Negative Heat (Q): Negative if energy is transferred out of the system by heat



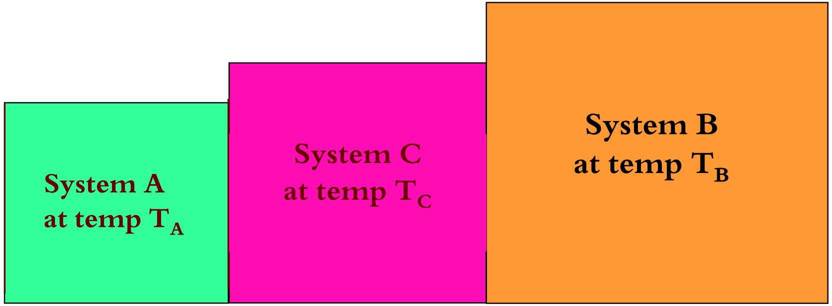
If $T_A > T_B$

11.0 Introduction

Two bodies are in thermal equilibrium if they are at the same temperature throughout and therefore no heat will flow from one body to the other.

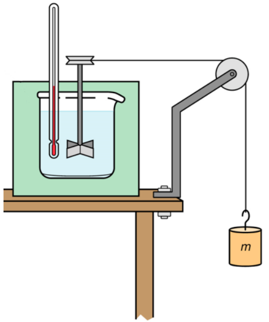
Zeroth Law of Thermodynamics

If bodies A and B are each in thermal equilibrium with a third body C, then A and B are in thermal equilibrium with each other. ($T_A = T_C = T_B$).



The Mechanical Equivalent of Heat :

- Heat is a form of energy. It is measured in energy units. The SI unit of heat is joule (J). Another unit commonly used is the calorie.
- A calorie is the amount of heat required to raise the temperature of I g of water through 1 °C. Experiments have shown that 4.18 J of mechanical work produce one calorie of heat. Thus 1 calorie = 4.18 joules or

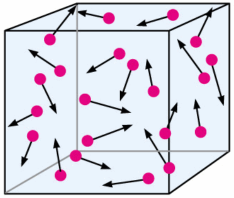


$$1 \text{ ca1} = 4.18 \text{ J}$$

Internal Energy

Internal Energy (U) is the energy associated with the microscopic components of the system includes kinetic and potential energy associated with the random translational, rotational and vibrational motion of the atoms or molecules, also includes any potential energy bonding the particles together. For n amount of matter the total **internal energy** (U) is

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



On a microscopic level, a gas consists of moving molecules.

11.0 Introduction

11.1 Mechanical Work.

Isobaric process is a thermodynamic process in which the **pressure** stays constant, figure 1 shows a gas at a pressure P in a closed cylinder. A movable piston of cross–sectional area A forms one end of the enclosure. The gas exerts a force $F = PA$ on the piston. When the piston moves a small distance Δx parallel to the force, the work done by the gas is $W = F\Delta x = PA\Delta x$. Since $\Delta V = A\Delta x$ is the change in volume of the gas, the work done by the gas is

$$W = P\Delta V = P(V_f - V_i)$$

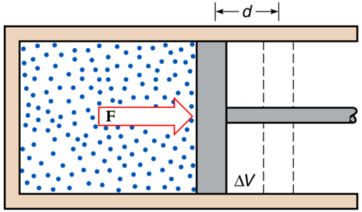


Figure 1

When the system undergoes change from **initial** thermodynamic state to **final** state due change in properties like temperature, pressure, volume etc, the system is said to have undergone thermodynamic process.

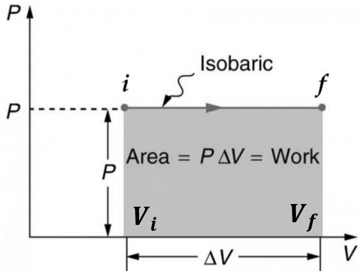


Figure 2

Sign Convention of Work:

Positive Work (+W): If the volume expands ($V_f > V_i$), then $W > 0$. (work done by the system)

Negative Work (–W): If the volume compresses ($V_f < V_i$), then $W < 0$. (work done on the system)

11.1 Mechanical Work.

Work in general is defined as the area under the PV curve between initial and final states. (Fig.3)

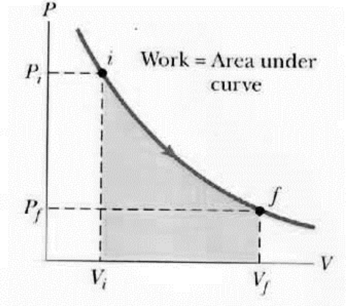


Figure 3: General Case

Example 11.1 P 261

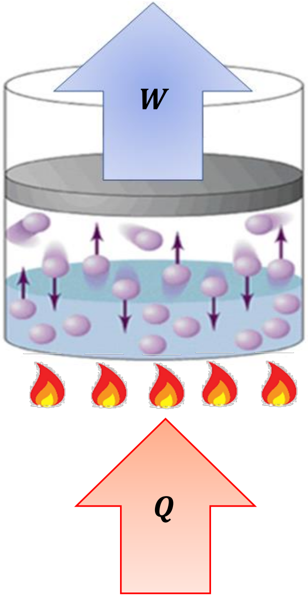
A gas at a pressure of $2\,\text{atm} = 2.02 \times 10^5$ Pa is heated and is allowed to expand against a frictionless piston at constant pressure. If the volume change is 0.5 m^3 , how much work is done by the gas?

(Ans: $1.01 \times 10^5 J$)

11.2 The First Law Of Thermodynamics.

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

$$\Delta U = Q - W$$



Signs of the terms in the equation

Q

Positive if energy is transferred to the system by heat

Negative if energy is transferred out of the system by heat

W

Positive if work is done by the system

Negative if work is done on the system

ΔU

Positive if the temperature increases

Negative if the temperature decreases)

11.2 The First Law Of Thermodynamics.

Example 11.2 P 263

In Example 11.1, a gas is heated and allowed to expand, doing $1.01 \times 10^5 J$ of work. If $3 \times 10^5 J$ of heat enters during the expansion, what is the change in the internal energy of the gas? (Ans: $1.99 \times 10^5 J$)