PHYS430 - Thermal Physics

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Chapter 1

Energy in Thermal Physics

1.1 Thermal Equilibrium

- After two objects have been in contact long enough, we say that they are in **thermal equilibrium**.
- The time required for a system to come to thermal equilibrium is called the **relaxation time**.
- **Temperature** is a measure of the tendency of an object to spontaneously give up energy to its surroundings.
- The flow of energy is from the object with a higher temperature to the lower on.
- For low-density gas at constant pressure, the volume should go to *zero* at approximately $-273°$C. which defines the **absolute zero**, in the **absolute temperature scale**, in K (kelvin).

1.2 The Ideal Gas

$$PV = nRT; \qquad R = 8\,31 J/mol.K \tag{1.1}$$

- A **mole** of molecules is Avogadro's number of them, 6.02×10^{23}.
- Number of molecules is $N = n \times N_A$
- Ideal gas law becomes $PV = NkT$, where k is Boltzmann's constant.
- The average transnational kinetic energy is $\bar{K}_{\text{trans}} = \frac{3}{2}kT$, where $kT = \frac{1}{40}$eV

1.3 Equipartition of Energy

Equipartition theorem At a temperature T, the average energy of any quadratic degree of freedom is $\frac{1}{2}kT$.

For a system of N molecules, each with f degree of freedom, and there are no other (non-quadratic) temperature-dependent forms of energy, then its **total thermal energy** is

$$U = Nf\frac{1}{2}kT \tag{1.2}$$

Note, This is the *average* total thermal energy, but for large N, fluctuations become negligible.

1.4 Heat and Work

- Total amount of energy in the universe never changes, **Conservation of energy**
- **Heat** any spontaneous flow of energy form on e object to another, caused by difference in temperature.
- **Work**, in thermodynamics, is any other transfer of energy into or out of a system.
- Work and heat refer to energy *in transit*.
- The total energy in a system is determined, but not the work nor the heat, it's meaningless.
- We ask about how much heat *entered* a system and how much work *was done on* a system.
- $\Delta U = Q + W$ is just a statement of the law of conservation of energy, but it's still called **first law of thermodynamics**.

1.5 Commpression Work

- From classical mmechanics work is $W = \vec{F} \cdot d\vec{r}$
- Consider compressing gas with a piston of area A a distance Δx, the change in volume is $\Delta V = -A\Delta x$
- Volume change should be quasistatic, meaning very slow so that the pressure defined is uniform. then $W = PA\Delta V$, but $\Delta x = -\Delta V$; minus since the volume decreases.
- $W = -PA\Delta V$ - quasistatic.
- If P is not constant,

$$W = -\int_{V_i}^{V_f} P(V)dV$$

Chapter 2

The Second Law

2.1 Two-State system