

Physics 1

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Early Kinematics

SDR and Galilean relativity

Late Kinematics

Special Relativity

Thermodynamics

"It's no use going back to yesterday, because I was a different person then."
— Alice, Alice in Wonderland

The Laws of Thermodynamics

Macrostates and Microstates

A Macrostate is a macroscopic description of a system using the 4 main thermodynamic variables pressure (p), temperature (T), volume (V), and number of particles (N). These variables are averages e.g the pressure of a gas is the average force per unit area exerted by particles, temperature reflects the average kinetic energy of particles. A Microstate is a complete, detailed description of every particle in the system, including their positions and momenta. MICROSTATES WILL NOT BE COVERED.

The zeroth law

"If A, B and C are different thermodynamical systems and A is in thermodynamical equilibrium with B, and B is in thermodynamical equilibrium with, then A is in the thermodynamical equilibrium with C"

The first law

"The internal energy of an isolated system is conserved under any thermodynamical change"

The second law

Under any thermodynamical change:

$$\Delta U = Q + W$$

And in differential form using inexact derivatives

$$dU = dQ + dW$$

-This will be explained further on.

Working in a perfect gas

Fundamental Gas Laws

Pressure, Volume, Temperature, moles:

Boyle's Law:

$$P_1 V_1 = P_2 V_2 \quad (1)$$

If T is a constant

Charles's Law:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad (2)$$

If P is constant

Lussac's Law:

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \quad (3)$$

If V is a constant

Avogadro's Law:

$$\frac{V_1}{n_1} = \frac{V_2}{n_2} \quad (4)$$

If P and T are constant

Ideal Gas Law

Using the fundamental gas laws, you can derive the following equation:

$$PV = nRT \quad (5)$$

Work

Work is energy being transferred between one system. Due to this it cannot be tied to a thermodynamical process, and therefore is a function of path. A system doesn't store work, therefore it can't be measured in the exact differential equation at the start or end of a reaction. This is why it is represented in an inexact differential written as δX , which allows us to show work transforming over time.

Work can be defined as:

$$dW = \vec{F} \times d\vec{h} \quad (6)$$

For the first law of thermodynamics, $W > 0$ if work is done on the system, such as compression and $W < 0$ work done by the system, usually expansion.

Pressure and Work. If work is done by the system is negative F , if instead its work done on the system the F is positive.

$$dW = \pm F dh$$

Force in terms of pressure is determined by:

$$F = p_{surr} \times A$$

Where A is the relevant surface area

To represent the change in volume

$$dV = A \times dh \implies dh = \frac{dV}{A}$$

Now when we substitute F and dh

$$dW = \pm (p_{surr} \times A) \left(\frac{dV}{A} \right)$$

$$dW = -p_{surr} dV$$

Therefore the total work is the integral of dW :

$$W = \int_{V_i}^{V_f} \pm p_{surr} dV$$

Heat

Heat is calculated in a much easier manner. Using the second law of thermodynamics:

$$\Delta U = Q + W$$

Solve for Q

$$Q = \Delta U - W$$

Keep in mind that this is only valid for closed systems.

Heat capacity at a constant volume (C_V). For context the internal energy for ideal gas is:

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

I will explain this better later, but for reference n is number of moles and R is the gas constant.

Lets take the first law, where dW is 0 because the volume is constant.

$$dU = dQ + dW \xrightarrow{0}$$

$$C_V = \left(\frac{\partial Q}{\partial T} \right)_V = \left(\frac{\partial U}{\partial T} \right)_V$$

$$C_V = \frac{\partial}{\partial T} \left(\frac{3}{2}nRT \right)_V$$

$$C_V = \frac{3}{2}nR$$

Heat capacity at a constant pressure (C_P). For this problem work is done because gas can expand. Since $dW = pdV$

$$dU = dQ + dW \xrightarrow{pdV}$$

$$C_P = \left(\frac{\partial Q}{\partial T} \right)_P = \left(\frac{\partial U}{\partial T} \right)_P + p \left(\frac{\partial V}{\partial T} \right)_P$$

Because we are working with a ideal gas, U is dependent on only T so we can simplify it C_V .

THIS SECTION NEEDS WORK, MISSING A LOT OF CRITICAL STEPS

$$V = \frac{nRT}{p}$$

$$\left(\frac{\partial V}{\partial T} \right)_P = \frac{nR}{p}$$

$$C_P = C_V + p \left(\frac{nR}{p} \right)$$

$$C_P = C_V + nR$$

$$C_P = \frac{3}{2}nR + nR$$

$$C_P = \frac{5}{2}nR$$

Internal Energy

Thermodynamic processes

The Definition of Efficiency

The efficiency represented by η of a heat engine is the ratio of the work output to the heat absorbed from the hot reservoir Q

$$\eta = \frac{\sum W}{Q_H} \quad (7)$$

By using the first law of thermodynamics we can change the Work with

$$\eta = \frac{Q_H - Q_C}{Q_H} \implies 1 - \frac{Q_C}{Q_H} \quad (8)$$

The Carnot cycle

This thermodynamic cycle is based on the theoretical piston with zero friction.

The Cycle: There are 4 steps:

1. Isothermal expansion. The gas absorbs heat from a hot reservoir at temperature T_H , expanding slowly to keep T constant.

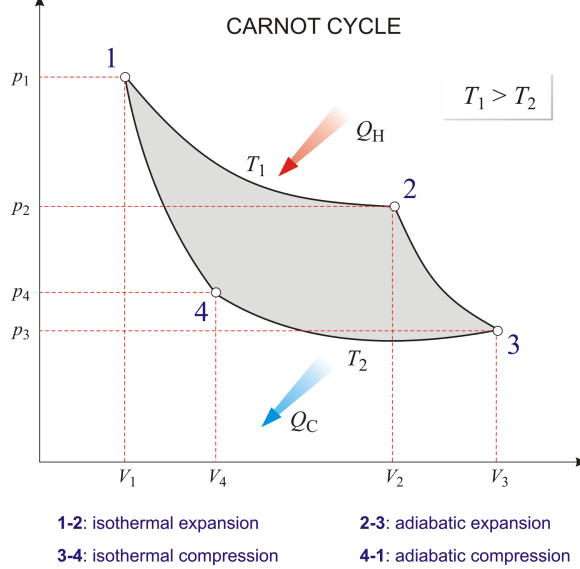
$$Q_H = W_{1 \rightarrow 2} = nRT_H \ln \left(\frac{V_2}{V_1} \right)$$

2. Adiabatic Expansion. The gas continues expanding, but the system is insulated. The temperature decreases from T_H to T_C

3. Isothermal Compression. The gas is compressed at constant T_C , releasing heat Q_C to the cold reservoir.

4. Adiabatic Compression. The gas is compressed further without heat exchange ($Q=0$), raising its temperature back to T_H .

THIS IS A DIAGRAM OF THE CARNOT CYCLE FOR REFERENCE:



The Carnot engine: It is a theoretical engine which takes maximum advantage of the Carnot cycle.

The primary principle is that, heat is transferred from a hot to a cold reservoir, doing work in the process. It is also fully reversible, but I will talk more on that later.—explain

Carnot and Efficiency: Efficiency is measured using η , where I will explain this more later.

However for Carnot's engine its efficiency is given by

$$\eta = 1 - \frac{T_C}{T_H}$$

Where T is the absolute temperature. To reach 100% efficiency the coldest temperature must be 0K which is physically impossible to reach.

Isothermal Expansion

$$Q_H = nRT_H \ln \left(\frac{V_2}{V_1} \right)$$

Isothermal Compression

$$Q_C = nRT_C \ln \left(\frac{V_3}{V_4} \right)$$

Using the fact that $TV^{\gamma-1} = C$

$$\frac{V_2}{V_3} = \frac{V_1}{V_4} \implies \frac{V_2}{V_1} = \frac{V_3}{V_4}$$

$$\eta = 1 - \frac{T_C}{T_H}$$