

# Physics

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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 zeroth law 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

$$dU = \delta Q + \delta W$$

-This will be explained further on.

**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  $\delta X$ , which allows us to show work transforming over time.

Work can be defined as:

$$dW = \vec{F} \times \vec{dh} \quad (1)$$

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 it's 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  $dW = pdV$

$$dU = dQ + dW \quad \swarrow pdV$$

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

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**