

What is Thermodynamics?

We are in this world and we want to survive. One of our main requirements for life is having energy. We need energy in every aspect of our life.

- Thermodynamic is the knowledge of “extracting” energy and using it for “work”
- Thermodynamic is science of energy

Whole ideas of thermodynamic

- How much available energy we have in hand?
- How can we extract that energy (and convert it to work)?
- What is the efficiency of this extract and how can we maximize this efficiency and up to which point?

Where is energy?

Total Energy inside of each “thing” = macroscopic energy + microscopic energy

Total Energy inside of each “thing”=	Macroscopic energy		+Microscopic energy			
E =	E_k	+ E_p	+U			
Total Energy inside of each “thing”=	Kinetics Energy	+Potential Energy	+Sensible Energy	+Latent Energy	+Chemical Energy	+Nuclear Energy
E =	E_k	+ E_p				
Energy source	Energy per its movement	Energy per its location	+Molecular Energy(No phase Change)	+Molecular Energy-phase Change)	+ Energy within atoms	+ Energy inside of atoms
Science dealing with it	Mechanics		(Physical)Thermodynamics		Chemical Thermodynamics	Nuclear Physics
Energy can be manipulated through:	Mechanical Systems		Changing the “state” of material		Chemical Reactions	Nuclear reactions
Work principal formula	$W= F. \Delta d$		$W= P. \Delta V$ (not accurate)			
Extracting energy in form of work	Can be converted 100% to work in an ideal mechanical system (Ideal: no loss of energy in form of heat)		Cannot be converted 100% to work even in an ideal thermodynamic system			

Thermodynamics Laws

Why law?

Thermodynamic laws are such basic that cannot be proven by any “simpler” facts.

Statement of Thermodynamics Laws

Approach 1:

Zerth law of Thermodynamics: Temperature is a concept which can make (the abstract concept of) energy as “tangible”.

First Law of Thermodynamics: Where is energy? (U: internal energy)

Second Law of Thermodynamics: With which efficiency energy can be extracted? (S: entropy)

Third Law of Thermodynamics: Entropy- in contrast to other properties- is not relative; in absolute zero temperature, Entropy is zero: $T = 0 \Rightarrow S = 0$

Approach 2:

Zerth Law gives a basis to “measure” energy (which is intangible) through a parameter which is named “temperature”. This is basis for all Thermodynamics. Without that we cannot move on. Thermodynamic is the science of energy and the extraction methods and as a first step we need to measure the energy. The problem is energy is non-touchable. The 0th law provides a ground for quantifying energy.

First Law pointing out the source of energy in Thermodynamic, which it is internal energy, U. Energy however can be extracted from macroscopic type energy (kinetic and potential energy) too but it is the subject of Mechanics and not Thermodynamics.

Second Law says that even in an ideal Thermodynamic system, the efficiency is not 100%. It is in contrast to Mechanical systems. In those cases, with an idea system, 100% of energy (in form of kinetic and potential energy) can be extracted. The Thermodynamic loss is because of Thermodynamics inefficiency and is introduced by Entropy. Entropy(S) basically says energy has a quality, the higher quality, (the less Entropy and) the more extractable energy. In more down-to-earth terms, energy has quantity, which can be mentioned by U and quality, which can be mentioned by S.

Third Law says in contrast with all other (energy related) Thermodynamics parameters, Entropy is NOT a relative parameter, in zero kelvin temperature, the entropy is zero. Internal energy, Enthalpy etc. are all relative parameters and can be manipulated in the form of difference, Δ .

Extracting Energy

To be able to extract the energy it should be transferred. Transferring energy is in one of the below forms:

1. Heat
2. Work

Therefore:

Difference in total internal energy = added/extracted heat – added/extracted work

Or:

$$\Delta E = Q + W$$

$$\Delta U + \Delta KE + \Delta PE = Q + W$$

In Thermodynamic systems which kinetic and potential energy change is negligible, the above equation can be reduced to:

$$\Delta U = Q + W$$

What is work?

Macroscopic	Microscopic
$W = F \cdot \Delta d$	$W = F \cdot \Delta d$ $= F/a \cdot \Delta d \cdot a$ $= P \cdot \Delta V$ (not accurate, is accurate for reversible processes)

How to extract the energy & convert it to W & not Q?

Based on above equation ($\Delta U = Q + W$), the maximum energy is available when $Q = 0$ or an adiabatic process. It means all the internal energy is available for “work” and no energy is wasted & converted to heat.

Hint: in compressors that you want to mobilize and pressurize a gas, to do a minimum work, you need to have a maximum Q (heat transfer), or the action should be an isothermal process (maximum heat gets transferred up to having equal temperatures).

However, what I said until now was “available” work, however not all of this “available” work is “extractable”.

The maximum work can be extracted when the extraction happens with the minimum “disturbance” in system. It means the extraction operation should be very smooth. The extraction is smooth when it happens in successive, slow, and small steps (and not few big jumps). This type of action is “reversible” action.

Help: How can I know if a process is reversible? In your imagination make a video recording of the process. Then reverse it; If it does make sense, the process is reversible.

Therefore to extract the maximum work the process should be adiabatic AND reversible or Isentropic.

Isentropic ($\Delta S = 0$) = Adiabatic ($Q = 0$) + Reversible

In such conditions:

$$\Delta U = Q - W$$

↓
0 Adiabatic

$$\Rightarrow \Delta U = W$$

It means all the internal energy is converted to work and efficiency (in an ideal mechanical system) is 100%.

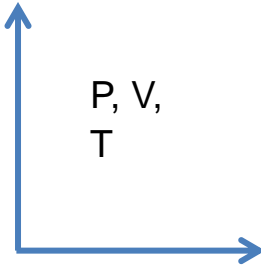
Thermodynamic “Tools”:

Primary state Parameters:

Primary state parameters are pressure (P), Temperature (T), and Specific Volume (v). By changing any of these parameters, the internal energy of the system probably will change.

Volume by itself is an extensive property; it means it depends on the mass of the material. To make the volume as a “useful” and general “state parameter” it should be converted to an intensive property. It can be done by dividing volume to mass and using “specific Volume” instead.

However, if we want to “observe” a system without trying to extract energy of it, three parameters are enough to give us sufficient information. These three parameters can be shown in an equation (state equations) or on diagrams (phase diagrams).



Hint: V is “specific volume” with the unit of e.g. m³/kg and not m³.

However, such equations or diagrams give just an idea about physical condition of system & not the information about energy transfer within the cycle.



If we want to monitor the energy of a system, we need to have energy diagrams. Let’s start talking about different energy parameters.

Energy Parameters:

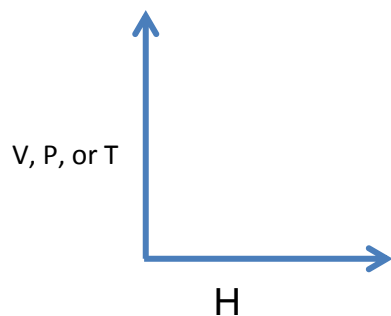
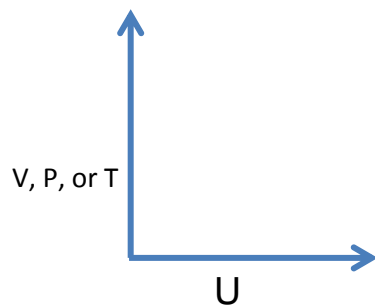
Until now, we talked about one parameter of energy, U. However, when we try to “measure” the internal energy of a material we do it in specific temperature and pressure. The product of temperature in pressure has a unit of energy. Basically we don’t measure internal energy (U) but a higher number which is $U + PV$. We can name this variation of internal energy as Enthalpy, H. Then:

$$H = u + pv$$

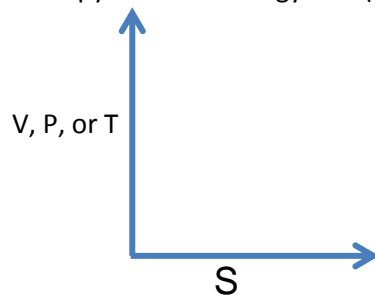
Enthalpy is a more practical way of introducing the internal energy of a matter/system.

All the energies are extensive properties and intensive version of them (energy per unit of mass) is used in charts.

When we decided to show the energy of a system, our tendency is to place primary state properties (P, V, or T) in horizontal axis and the energy parameters (U or more practically H) in vertical axis. However usually it is other way around; temperature or pressure (specific volume is not very popular as a parameter on the axis) is in vertical axis and the energy parameter on the horizontal axis.



Entropy is not an energy unit (it is clear from its unit which KJ/Kg.K which is not an energy unit: KJ/Kg)



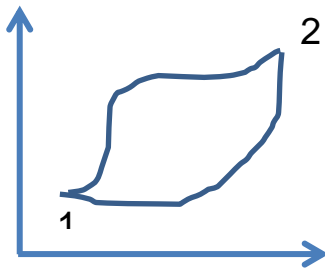
It is very popular to name a H-S diagram as Mollier diagram. Although the more correct concept is that Mollier diagram is a diagram with an energy parameter (mainly Enthalpy) in one axis.



Process vs. Cycle

A thermodynamic change can be seen in a “process”, which is the change in any state property, or a “cycle” which is successive processes with a final property identical to the initial one.

The thermodynamic machines are mainly “cycles” because they are reusable machines and not disposable ones. A non-cycle type machine works only once!



At the end it should be mentioned that the principles of thermodynamic should not be considered only for “energy extraction” operations, but wherever is the course of “manipulating” a material, in a way that their internal energy is “touched”, intentionally or unintentionally, in our favour of against our favor, Thermodynamics principles should be used. The examples are compressors or compressible flows.