

# Thermodynamics

## Thermodynamic terms

**Intensive:** These do not depend upon quantity of matter. e.g.,  $T, P$ .

**Extensive:** These depend upon quantity of matter. e.g., mass, volume, energy.

## Thermodynamic laws

**Properties of system:** Physical quantities which are used to define the system.

**Thermodynamic processes**

- If  $dq = 0$ , process is adiabatic.
- If  $dT = 0$  and  $dE = 0$ , the process is isothermal.
- If  $dV = 0$ , process is isochoric.
- If  $dP = 0$ , process is isobaric.

**Heat ( $q$ ) and heat capacity ( $C$ )**

- Heat capacity,  $C = dq/dT$
- $C_v = \left(\frac{\partial U}{\partial T}\right)_V$ ;  $C_p = \left(\frac{\partial H}{\partial T}\right)_P$
- When  $n_1$  moles of gas A and  $n_2$  moles of gas B are mixed.

$$(C_v)_{\text{mix}} = \frac{n_1 C_{v1} + n_2 C_{v2}}{n_1 + n_2}$$

- $C_p - C_v = nR$

**Work ( $W$ )**

- $W = -P_{\text{ext}} \Delta V$   
[irreversible isothermal expansion]
- $W = -2.303nRT \log(P_1/P_2)$
- $W = -2.303nRT \log(V_2/V_1)$   
[reversible isothermal expansion]
- $W = nC_v dT = \frac{nR}{\gamma - 1}(T_2 - T_1)$   
[reversible adiabatic expansion]  
where,  $\gamma = C_p/C_v$
- $W = -P_{\text{ext}} R \left( \frac{T_2 P_1 - T_1 P_2}{P_1 P_2} \right)$   
[irreversible adiabatic expansion]

**Bond enthalpy**  
It is the enthalpy change accompanying the breaking of one mole of covalent bonds.  
Bond enthalpy =  
 $\sum$  Bond enthalpies of reactants  
 $- \sum$  Bond enthalpies of products

**Enthalpy ( $H$ )**  
Total heat of the system

- $H = U + PV$
- $\Delta H = \Delta U + P\Delta V = C_p \Delta T = \Delta U + \Delta n_p RT$  (at constant pressure)
- $\Delta H = \sum H_{\text{product}} - \sum H_{\text{reactant}}$   
= -ve (exothermic)  
= +ve (endothermic)

**Gibbs Free Energy ( $G$ )**  
Useful work done by the system

- $G = H - TS$
- $\Delta G = \Delta H - T\Delta S$   
(Gibbs - Helmholtz equation)
- $\Delta G^\circ = \sum G_f^\circ(\text{product}) - \sum G_f^\circ(\text{reactant})$
- $\Delta G^\circ = -2.303 RT \log K_{\text{eq}}$
- If  $\Delta G = +ve$  (Non-spontaneous)
- If  $\Delta G = -ve$  (Spontaneous)

**Enthalpy of combustion,  $\Delta_c H$**   
It is the enthalpy change when 1 mole of a substance burnt completely in air.

**Hess's law of constant heat summation**  
 $\Delta H = \Delta H_1 + \Delta H_2 + \Delta H_3$

**Enthalpy change of a reaction**  
It is the enthalpy change when a given reactant reacts completely.

**Enthalpy of formation**  
It is the enthalpy change occurring during the formation of 1 mole of a substance from its elements.

**Enthalpy of solution**  
 $\Delta_{\text{sol}} H = \Delta_{\text{ionise}} H + \Delta H_{\text{hyd}}$   
where,  $\Delta_{\text{ionise}} H = S + I + \frac{1}{2} D - \Delta_f H + E.A.$

**Zeroth law:** System in thermal equilibrium with each other have same temperature.

**First law:** The total energy of the universe remains constant although it may undergo transformation from one form to the other.  
 $\Delta U = q + w$  ( $\Delta U =$  internal energy)

**Second law:** In a spontaneous process total energy of the universe increases.  
 $\Delta S_{\text{universe}} = \Delta S_{\text{system}} + \Delta S_{\text{surrounding}} > 0$

**Entropy ( $S$ )**  
Measure of randomness or disorder

- $\Delta S = \frac{q_{\text{rev}}}{T}$  (reversible process)
- $\Delta S = 2.303n C_v \log\left(\frac{T_2}{T_1}\right) + 2.303nR \log\left(\frac{V_2}{V_1}\right)$
- $\Delta S = 2.303n C_p \log\left(\frac{T_2}{T_1}\right) + 2.303nR \log\left(\frac{P_1}{P_2}\right)$
- $\Delta S = 2.303nR \log\left(\frac{V_2}{V_1}\right)$  } isothermal
- $\Delta S = 2.303nR \log\left(\frac{P_1}{P_2}\right)$  }
- $\Delta S = 2.303n C_p \log\left(\frac{T_2}{T_1}\right)$  [isobaric]

**Third law**

- Entropy of all pure crystals is zero at the absolute zero temperature.
- $\lim_{T \rightarrow 0} S = 0$
- Residual Entropy  
 $S_R = k \ln W$   
( $W =$  thermodynamic probability)

# Thermodynamics Mechanical Engineering Notes

**David Raymond Curtiss**



## **Thermodynamics Mechanical Engineering Notes:**

Lecture Notes for Thermodynamics for Engineers and Chemists Massachusetts Institute of Technology. Department of Mechanical Engineering, Massachusetts Institute of Technology. Special Summer Program on Thermodynamics for Engineers and Chemists, 1958, 1958\* Thermodynamics and Energy Conversion Henning Struchtrup, 2014-07-02 This textbook gives a thorough treatment of engineering thermodynamics with applications to classical and modern energy conversion devices Some emphasis lies on the description of irreversible processes such as friction heat transfer and mixing and the evaluation of the related work losses Better use of resources requires high efficiencies therefore the reduction of irreversible losses should be seen as one of the main goals of a thermal engineer This book provides the necessary tools Topics include car and aircraft engines including Otto Diesel and Atkinson cycles by pass turbofan engines ramjet and scramjet steam and gas power plants including advanced regenerative systems solar tower and compressed air energy storage mixing and separation including reverse osmosis osmotic power plants and carbon sequestration phase equilibrium and chemical equilibrium distillation chemical reactors combustion processes and fuel cells the microscopic definition of entropy The book includes about 300 end of chapter problems for homework assignments and exams The material presented suffices for two or three full term courses on thermodynamics and energy conversion Engineering Thermodynamics M. Kassim, 2022-03-29 No detailed description available for Engineering Thermodynamics Thermodynamics Notes J. Patterson, 1970 **Annual Catalogue of the Stevens Institute of Technology** Stevens Institute of Technology, 1921 **Engineering Thermodynamics** David J. Timoney, 2000 *Solutions to Problems in Heat Transfer. Transient Conduction Or Unsteady Conduction* Osama Mohammed Elmardi, 2017-03 Many heat transfer problems are time dependent Such unsteady or transient problems typically arise when the boundary conditions of a system are changed For example if the surface temperature of a system is altered the temperature at each point in the system will also begin to change The changes will continue to occur until a steady state temperature distribution is reached Consider a hot metal billet that is removed from a furnace and exposed to a cool air stream Energy is transferred by convection and radiation from its surface to the surroundings Energy transfer by conduction also occurs from the interior of the metal to the surface and the temperature at each point in the billet decreases until a steady state condition is reached The final properties of the metal will depend significantly on the time temperature history that results from heat transfer Controlling the heat transfer is one key to fabricating new materials with enhanced properties The author s objective in this textbook is to develop procedures for determining the time dependence of the temperature distribution within a solid during a transient process as well as for determining heat transfer between the solid and its surroundings The nature of the procedure depends on assumptions that may be made for the process If for example temperature gradients within the solid may be neglected a comparatively simple approach termed the lumped capacitance method or negligible internal resistance theory may be used to determine the

variation of temperature with time The entire book has been thoroughly revised and a large number of solved examples and additional unsolved problems have been added This book contains comprehensive treatment of the subject matter in simple and direct language The book comprises eight chapters All chapters are saturated with much needed text supported and by simple and self explanatory examples Lectures in Classical Thermodynamics with an Introduction to Statistical Mechanics Daniel Blankschtein,2021-03-15 This textbook facilitates students ability to apply fundamental principles and concepts in classical thermodynamics to solve challenging problems relevant to industry and everyday life It also introduces the reader to the fundamentals of statistical mechanics including understanding how the microscopic properties of atoms and molecules and their associated intermolecular interactions can be accounted for to calculate various average properties of macroscopic systems The author emphasizes application of the fundamental principles outlined above to the calculation of a variety of thermodynamic properties to the estimation of conversion efficiencies for work production by heat interactions and to the solution of practical thermodynamic problems related to the behavior of non ideal pure fluids and fluid mixtures including phase equilibria and chemical reaction equilibria The book contains detailed solutions to many challenging sample problems in classical thermodynamics and statistical mechanics that will help the reader crystallize the material taught Class tested and perfected over 30 years of use by nine time Best Teaching Award recipient Professor Daniel Blankschtein of the Department of Chemical Engineering at MIT the book is ideal for students of Chemical and Mechanical Engineering Chemistry and Materials Science who will benefit greatly from in depth discussions and pedagogical explanations of key concepts Distills critical concepts methods and applications from leading full length textbooks along with the author s own deep understanding of the material taught into a concise yet rigorous graduate and advanced undergraduate text Enriches the standard curriculum with succinct problem based learning strategies derived from the content of 50 lectures given over the years in the Department of Chemical Engineering at MIT Reinforces concepts covered with detailed solutions to illuminating and challenging homework problems Biothermodynamics Mustafa Ozilgen,Esra Sorguven Oner,2016-11-18 Over the past several decades there has been increasing research interest in thermodynamics as applied to biological systems This concerns topics such as muscle work and internal energy such as fat and starch Applications of the first and second laws of thermodynamics to the human body are important to dieticians and health science experts and applications of these concepts to the animal body are a major concern of animal scientists This book covers these key topics which are typically not covered in classic or traditional thermodynamics texts used in mechanical and chemical engineering

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