

Unit Conversions - Temperature $T(^{\circ}\text{C}) = T(\text{K}) - 273.15$ $T(^{\circ}\text{F}) = 1.8 \cdot T(^{\circ}\text{C}) + 32$ $T(\text{K}) = T(^{\circ}\text{F}) + 459.67$ - Pressure $1 \text{ bar} = 10^5 \text{ Pa} = 100 \text{ kPa}$ $P_{\text{atm}} = 101 \text{ kPa} = 14.7 \text{ lbf/in}^2$ $6895 \text{ Pa} = 1 \text{ psi}$ - Energy + Power $1 \text{ Btu} = 778 \text{ ft} \cdot \text{lbf}$ $1 \text{ hp} = 550 \text{ ft} \cdot \text{lbf/s} = 2545 \text{ Btu/hr}$ $\text{N} = \text{kg} \cdot \text{m/s}^2$ - Volume $1 \text{ m} = 3.28084 \text{ ft}$ - Fluids $\rho_{H_2O} = 1000 \text{ kg/m}^3 = 1.94 \text{ slug/ft}^3$ $\gamma_{H_2O} = 9800 \text{ N/m}^3 = 62.4 \text{ lbf/ft}^3$ $\gamma_{Hg} = 133,200 \text{ N/m}^3$ - Mass $\text{Slug} = 32.174 \text{ lb}_{\text{mass}} = \text{lb}_{\text{mass}} \cdot \text{s}^2/\text{ft}$	Adiabatic: $\delta Q = \delta x = 0$ Isentropic: $\delta s = 0$ 1st Law $\Delta E = \Delta KE + \Delta PE + \Delta U = {}_1Q_2 - {}_1W_2$ Rate Form: $\dot{E} = \dot{Q} - \dot{W}$ Mixtures $X = \frac{M_{\text{mix}}}{M} = \frac{x - x_f}{x_g - x_f} \quad (x = v, u, h)$ $\beta = (1 - X)\beta_f + X \cdot \beta_g$	Ideal Gas $P\hat{v} = \hat{R}T$, \hat{R} is universal $Pv = RT$, where $R = \frac{\hat{R}}{M}$ $P = \rho RT$ $PV = mRT$ $\hat{R} = \begin{cases} 8.314 \frac{\text{kJ}}{\text{kmol} \cdot \text{K}} \\ 1.906 \frac{\text{Btu}}{\text{lbmol} \cdot ^{\circ}\text{R}} \\ 1545 \frac{\text{ft} \cdot \text{lbf}}{\text{lbmol} \cdot ^{\circ}\text{R}} \end{cases}$	Polytropic Ideal Gas $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} = \left(\frac{V_1}{V_2}\right)^{n-1}$ ${}_1W_2 = \begin{cases} \frac{mR(T_2 - T_1)}{(1-n)}, & n \neq 1 \\ mRT \ln\left(\frac{P_2}{P_1}\right), & n = 1 \end{cases}$ Compressed Liquid Approx. $x(T, P) \approx x_f(T)$, $x = (v, u, h, s)$	Polytropic Process $P \cdot V^n = c$ or $P \cdot v^n = c$ - Volume expansion work ${}_1W_2 = \begin{cases} \frac{(P_2V_2 - P_1V_1)}{(1-n)}, & n \neq 1 \\ P_1V_1 \ln\left(\frac{V_2}{V_1}\right), & n = 1 \end{cases}$ Real gas $z = \frac{Pv}{RT}$, where z = compressibility factor
Specific Heat (heat capacity) C used when incompressible, otherwise C_p and C_v $\Delta u = \int_{T_1}^{T_2} C_v(T) dT$ $\Delta h = \int_{T_1}^{T_2} C_p(T) dT + v(P_2 - P_1)$ Constant C , approximation $C_p \approx \frac{C_p(T_1) + C_p(T_2)}{2}$ $C_p = C_v + R$	Enthalpy $H = U + P \cdot V$ $h = u + P \cdot v$	Energy Conservation $\frac{dE_{\text{cv}}}{dt} = \dot{Q}_{\text{cv}} - \dot{W}_{\text{cv}} + \sum_i \dot{m}_i \left(h_i + \frac{1}{2} V_i ^2 + g \cdot z_i \right) - \sum_e \dot{m}_e \left(h_e + \frac{1}{2} V_e ^2 + g \cdot z_e \right)$ 1 Inlet, 1 Exit: $0 = \dot{Q}_{\text{cv}} - \dot{W}_{\text{cv}} + \dot{m} \left[(h_i - h_e) + \frac{1}{2} (V_i ^2 - V_e ^2) + g(z_i - z_e) \right]$		
	Entropy Balance (Cycle) $\frac{dS_{\text{cv}}}{dt} = \sum \frac{\dot{Q}}{T} + \sum \dot{m}_i \cdot s_i - \sum \dot{m}_e \cdot s_e + \dot{S}_{\text{cv}}$ 1 in, 1 out: $0 = \sum \frac{\dot{Q}}{T} + \dot{m}(s_1 - s_2) + \dot{S}_{\text{cv}}$ $\Delta s = s_2 - s_1 = \frac{1}{\dot{m}} \left(\sum \frac{\dot{Q}}{T} + \dot{S}_{\text{cv}} \right)$	Entropy and Ideal Gas $\Delta s = s(T_2, P_2) - s(T_1, P_1) = \int_{T_1}^{T_2} \frac{C_p(T)}{T} dt + R \cdot \ln\left(\frac{P_2}{P_1}\right)$ $\Delta s = s(T_2, P_2) - s(T_2, P_1) = \int_{P_1}^{P_2} \frac{C_p(T)}{P} dP - R \cdot \ln\left(\frac{P_2}{P_1}\right)$ $\Delta s = s^*(T_2) - s^*(T_1) - R \cdot \ln\left(\frac{P_2}{P_1}\right)$		
Mass Conservation $\frac{dM_{\text{cv}}}{dt} = \sum \dot{m}_i - \sum \dot{m}_e$ $\dot{m} = \rho A V = \frac{\rho Q_V}{v}$ Volumetric flow rate = $A V $ Flow work = $(P \cdot A) \cdot V $	Entropy $dS = \left(\frac{\delta Q}{T}\right)_{\text{rev}}$, $S = s \cdot m$ $S_2 - S_1 = \int_1^2 \left(\frac{\delta Q}{T}\right)_b$ $T \cdot ds = du + P \cdot dv$ $T \cdot ds = dh - v \cdot dP$ Rev: ${}_1Q_2 = \int_1^2 T ds = mT(s_2 - s_1)$	2nd Law and Cycle COP's $\text{COP}_{\text{refree}} < \text{COP}_{\text{ref}} = \text{COP}_{\text{max}}$ $\text{COP}_{\text{refree},1} = \text{COP}_{\text{refree},2}$ Power: $\eta_{\text{ref}} = \frac{\dot{W}}{\dot{Q}_{\text{in}}} = \frac{\dot{Q}_{\text{in}} - \dot{Q}_{\text{out}}}{\dot{Q}_{\text{in}}} = 1 - \frac{T_c}{T_h}$ Refrig: $\beta_{\text{ref}} = \frac{\dot{Q}_{\text{out}}}{\dot{W}} = \frac{\dot{Q}_{\text{out}}}{\dot{Q}_{\text{out}} - \dot{Q}_{\text{in}}} = \frac{T_c}{T_h - T_c}$ Heat Pump: $\gamma_{\text{ref}} = \frac{\dot{Q}_{\text{out}}}{\dot{W}} = \frac{\dot{Q}_{\text{out}}}{\dot{Q}_{\text{out}} - \dot{Q}_{\text{in}}} = \frac{T_h}{T_h - T_c}$		
Work and Power $W = \int F \cdot dr$ - Volume expansion work: $W = \int P dV$ $W = m \cdot \int P dv$ Power = $\frac{dW}{dt}$	Isentropic Efficiency Turbine: $\eta_1 = \frac{(W_1/m)}{(W_1/m)_s} = \frac{h_1 - h_{12}}{h_1 - h_{12s}} \leq 1$ Nozzle: $\eta_n = \frac{\frac{1}{2} V_2^2}{\left(\frac{1}{2} V_{2s}^2\right)} \leq 1$ Compressor/Pump: $\eta_{c/p} = \frac{(W_1/m)}{(W_1/m)_s} \leq 1$	Entropy Balance (Process) $S_2 - S_1 = \int_1^2 \left(\frac{\delta Q}{T}\right)_b + \sigma$ $S_2 - S_1 = \sum \frac{\dot{Q}}{T} + \sigma$ $\frac{dS}{dt} = \sum \frac{\dot{Q}}{T} + \dot{\sigma}$	2nd Law and Entropy $\oint_{\text{cycle}} \left(\frac{\delta Q}{T}\right)_b \leq 0$ S production: $\sigma = -\oint \left(\frac{\delta Q}{T}\right)_b \geq 0$ $\sigma > 0$: irreversible cycle $\sigma = 0$: reversible cycle $\sigma < 0$: impossible	
Velocity^2 to kJ/kg $\frac{\text{m}^2}{\text{s}^2} \cdot \frac{\text{N} \cdot \text{s}^2}{\text{kg} \cdot \text{m}} \cdot \frac{1}{\text{N} \cdot \text{m}} \cdot \frac{\text{kJ}}{10^3 \text{ J}}$		Energy $KE = \frac{1}{2} mV^2$ $PE = mgz$ 1st Law and Cycles Power: $Q_H - Q_C = W_{\text{cycle}}$ R+HP: $Q_{\text{out}} - Q_{\text{in}} = W_{\text{cycle}}$		

Thermodynamics Equations Cheat Sheet

Peeter Joot

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Basic Statistical Mechanics Peeter Joot, This document is based on my lecture notes for the Winter 2013 University of Toronto Basic Statistical Mechanics course PHY452H1S taught by Prof Arun Paramekanti Official course description Classical and quantum statistical mechanics of noninteracting systems the statistical basis of thermodynamics ensembles partition function thermodynamic equilibrium stability and fluctuations formulation of quantum statistics theory of simple gases ideal Bose and Fermi systems This document contains Plain old lecture notes These mirror what was covered in class possibly augmented with additional details Personal notes exploring details that were not clear to me from the lectures or from the texts associated with the lecture material Assigned problems two problem sets Some worked problems attempted as course prep for fun or for test preparation or post test reflection Links to Mathematica workbooks associated with these notes

Physics I For Dummies Steven Holzner, 2016-05-17 The fun and easy way to get up to speed on the basic concepts of physics For high school and undergraduate students alike physics classes are recommended or required courses for a wide variety of majors and continue to be a challenging and often confusing course Physics I For Dummies tracks specifically to an introductory course and keeping with the traditionally easy to follow Dummies style teaches you the basic principles and formulas in a clear and concise manner proving that you don t have to be Einstein to understand physics Explains the basic principles in a simple clear and entertaining fashion New edition includes updated examples and explanations as well as the newest discoveries in the field Contains the newest teaching techniques If just thinking about the laws of physics makes your head spin this hands on friendly guide gets you out of the black hole and sheds light on this often intimidating subject

A Condensed Collection of Thermodynamic Formulas Percy Williams Bridgman, 1925 [Bulletin of the Atomic Scientists](#) , 1970-12 The Bulletin of the Atomic Scientists is the premier public resource on scientific and technological developments that impact global security Founded by Manhattan Project Scientists

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Essential Engineering Thermodynamics Yumin Zhang, 2018-09-19 Engineering Thermodynamics is a core course for students majoring in Mechanical and Aerospace Engineering Before taking this course students usually have learned Engineering Mechanics Statics and Dynamics and they are used to solving problems with calculus and differential equations Unfortunately these approaches do not apply for Thermodynamics Instead they have to rely on many data tables and graphs to solve problems In addition many concepts are hard to understand such as entropy Therefore most students feel very frustrated while taking this course The key concept in Engineering Thermodynamics is state properties If one knows two properties the state can be determined as well as the other four properties Unlike most textbooks the first two chapters of this book introduce thermodynamic properties and laws with the ideal gas model where equations can be engaged In this way students can employ their familiar approaches and thus can understand them much better In order to help students understand entropy in depth interpretation with statistical physics is introduced Chapters 3 and 4 discuss control mass and control volume processes with general fluids where the data tables are used to solve problems Chapter 5 covers a few advanced topics which can also help students understand the concepts in thermodynamics from a broader perspective

Chemical Thermodynamics Leo Lue, 2009 **Thermodynamics** U. Kivi, 2020-06-02 The basic theory of thermodynamics is treated in the book using ideal gas as an example A clear explanation for the quantity entropy is given in the book Analytic formulas for the mutual functional dependence of the quantities volume pressure temperature and entropy

are given in the book in the case of an ideal gas A thorough treatment of ideal gas thermodynamic processes is presented in the book In a process two quantities are given as functions of time and other quantities are calculated as functions of time I hope that the thorough treatment helps especially those people for example students who take their first steps in learning thermodynamics The book includes a list of a computer program that calculates basic thermodynamic processes for an ideal gas An example calculation for every process is presented in the book input file is given and the result is presented as curves Every curve is given a thorough description

Equations for Calculating the Thermodynamic Properties of Fluids, Including Those in the Two-phase Region, from an Empirical Equation of State Robert E. Barieau,1967 *Methods of Thermodynamics* Howard Reiss,1996-01-01 Outstanding text focuses on physical technique of thermodynamics typical problems and significance and use of thermodynamic potential Mathematical apparatus first law of thermodynamics second law and entropy more 1965 edition

Thermodynamics: Principles And Applications (Second Edition) Ismail Tosun,2020-02-18 This method of teaching really helps the reader to understand these sometimes difficult concepts of thermodynamics especially with concepts such as Gibbs free energy enthalpy and entropy anyone who wants to either learn about thermodynamics or get a very good refresher will find this book to be one of the best at explaining these abstract concepts IEEE Electrical Insulation Magazine Thermodynamics is considered the core engineering course in many engineering disciplines Since the laws of thermodynamics are expressed in abstract terms it is the one of the most challenging courses encountered by students during their undergraduate education This eminent compendium provides a firm grasp of the abstract concepts and shows how to apply these concepts to solve practical problems with numerous clear examples Answers to all problems are provided Four additional chapters are illuminated to show students how to deal with the thermodynamic problems involving nonideal pure substances as well as multicomponent mixtures The concepts are highlighted with utmost clarity in simple language Mathcad worksheets are provided in problems dealing with the cubic equations of state This readable reference text is useful to researchers academics professionals undergraduate and graduate students in chemical engineering mechanical engineering and energy studies

Notes on Thermodynamics Henry Wilson Spangler,1908

A Condensed Collection of Thermodynamic Formulas Percy Williams Bridgman,1925-02-05 No detailed description available for A Condensed Collection of Thermodynamic Formulas

Thermodynamics and Chemistry Frank Henry MacDougall,1921

The Ultimate Cheat Sheet for Math and Physics WeSolveThem Team,2017-07-25 Everything a college STEM major needs

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Thermodynamic versus kinetic reaction control Excerpt Chemical thermodynamics is the study of the interrelation of heat and work with chemical reactions or with physical changes of state within the confines of the laws of thermodynamics
Chemical thermodynamics involves not only laboratory measurements of various thermodynamic properties but also the application of mathematical methods to the study of chemical questions and the spontaneity of processes The structure of chemical thermodynamics is based on the first two laws of thermodynamics Starting from the first and second laws of thermodynamics four equations called the fundamental equations of Gibbs can be derived From these four a multitude of equations relating the thermodynamic properties of the thermodynamic system can be derived using relatively simple mathematics This outlines the mathematical framework of chemical thermodynamics J Willard Gibbs founder of chemical thermodynamics In 1865 the German physicist Rudolf Clausius in his Mechanical Theory of Heat suggested that the principles of thermochemistry e.g. the heat evolved in combustion reactions could be applied to the principles of thermodynamics Building on the work of Clausius between the years 1873-76 the American mathematical physicist Willard Gibbs published a series of three papers the most famous Fundamental laws of thermodynamics, theory of gases Gustav Zeuner, 1906
Thermodynamics Josiah Willard Gibbs, 1906 Thermodynamics and Chemistry Frank Henry MacDougall, 1921

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