Phys 350: Thermodynamics
Study Guide for Part II **(Ch. 2 and Ch. 3)**

Chapter 2 deals with calculating multiplicity of microstates (Ω) and relating it to entropy (S) via the equation $S = k \ln \Omega$. The 2nd law of thermodynamics simply states that **the entropy of a system tends to increase.** The models use in chapter 2 are the Einstein solid, a paramagnet and the ideal gas.

Chapter 3 defines temperature (T), pressure (P) and chemical potential (μ) as partial derivatives of entropy (S). See table 3.3 in page 120 for a summary.

This study guide is not exhaustive. Its aim is to point out important topics and procedures we covered based on chapters 2 and 3.

Ch. 2 2nd Law of Thermodynamics

Be able to:

1. Distinguish between a macrostate and microstate

2. Calculate the multiplicity [Ω(N,n)] for a two-state system such as flipping coins or a paramagnet.

3. Describe what an Einstein solid is .

4. Calculate the multiplicity of microstates [Ω(N,q)]for a small and large Einstein solids. Using a spreadsheet such as Excel (for large q & N) and with out Excel (for small q & N).

5. Calculate the combined or total multiplicity(Ω_A Ω_B) for two Einstein solids.

6. Use Stirlings approximation to approximate N!, ln N!, q!, ln q!,etc. (See equations 2.14, 2.15 and 2.16) and be able to derive equations such 2.21 when q>> N and equations such as those in problems 2.22(b) and (c).

7. Using Heisenberg's Principle ($\Delta x \, \Delta p \approx h$)show that for a single atom $\Omega = V(2mU)^{3/2}/h^3$ and for N atoms $\Omega(U,V,N) = [V(2mU)^{3/2}/h^3]^N$. ($p^2 = 2mU$)

8. Define entropy based on statistical mechanics and based on thermodynamics .

9. State the second law of thermodynamics in terms of entropy.

10. Express entropy (S) in terms of the number of multiplicities (Ω).

11. Derive an expression for entropy for an Einstein solid, and ideal gas, a paramagnet. erc, when Ω is given.

12. Show the entropy change (ΔS) of an ideal gas undergoing a quasistatic and isothermal expansion from V_f to V_f is $\Delta S = NkT \ln (V_f / V_f)$ using the macroscopic definition S = Q/T as well as usinng $S = k \ln \Omega(V,N,U)$. .Ω(V,N,U) for an ideal gas is defined by the Sackur-Tetrode equation

13. Distinguish between reversible and irreversible processes. Study the examples in problem 2.40 and come up with similar examples of your own.

12. State what the significance of the Maxwell Demon is.

13. State what a paramagnet is. Obtain Ω(3.27), S/k (3.28), T(3.30), U(3.31), and M (3.32)for a paramganet

14. Show that at high T eq 3.32 reduces to Curie's Law (eq.3.35)

15. Show that the expression for P step 3 in the Ch 3 procedure leads to the ideal gas law

16. Derive the thermodynamic identity du =Tds-Pdv. How does this relate to the 1st law of thermodynamics.

17. Derive the generalized thermodynamic identity (eq. 3.66)

Using a spreadsheet such as Excel be able to reproduce:

18. Tables 3.1and 3.2 as well as fig. 3.1, 3.8, & 3.12

Ch.3 Interactions and Implications:
Definition of T, P, and μ as partial derivatives of S

(See table 3.3 for a summary.)

In this chapter entropy (S) is taken to be the fundamental quantity from which the thermodynamic variables **T, P, μ, & C_v** can be obtained for realistic examples such a the ideal gas, Einstein solid, a paramagnet etc.

The procedure followed in chapter 3 to obtain the variables T, P, μ, & C_v is:

1. Use combinatorics and some quantum mechanics to obtain the multiplicity of microstates $\Omega(U,V,N)$.

2. Use the relation $S = k \ln \Omega(U,V,N)$ to obtain entropy (S).

3. Obtain T form the relation $\frac{1}{T} = \left(\frac{\partial S}{\partial U}\right)$ with V and N fixed.

4. Obtain P from the relation $\frac{P}{T} = \left(\frac{\partial S}{\partial V}\right)$ with U and N fixed.

5. Obtain μ form the relation $\frac{\mu}{T} = -\left(\frac{\partial S}{\partial N}\right)$ with U and V fixed.

6. Solve for U from the expression for T and compare it with the prediction of the equipartition theorem when T is large.

7. Obtain Cv using $C_v = \left(\frac{\partial U}{\partial T}\right)$ with V and N fixed.

Let's call the procedure 1 to 7 **Ch3 procedure.**

Be able to:

8. Define temperature (T) in terms of entropy (S).

9. Calculate temperature using step #3 of ch3 procedure above from tables such as 3.1 for a specific q or U ($U = \epsilon q$) for an Einstein solid.

10. Do the large Einstein solid problem- problem 3.25

11. Calculate entropy using the macroscopic relation $dS = Q/T$. (Do problems 3.10 and 3.11)