Phys 114 **Week 2: Amy's reading advice** **2021**

Preamble: As requested by some of you, this is a short and totally not-objective view of how to navigate the two texts this week.

Generic advice: Read the whole assignment for *either* B&B *or* G&T. Read closely ... which for me involves taking notes, looking at images and captions, and being sure I can get between equations and can follow examples. Write down anything that confuses you.

Then take a break. (Nap, eat, exercise, let the sun set and rise again, ...)

Then read from the other textbook, with your notes next to you. Linger on things that confused you, are new, or really interest you. Skim or skip other things.

My observations about reading this week:

1. Topics that are common to both books:
• These statements of the second law: Kelvin-Planck and Clausius. Also, the assertion that entropy, S, exists; and $S_{universe}$ is a nondecreasing function for any process, with S remaining constant only for a reversible process. (Subtle: Reversible means we consider the system *and* its surroundings as isolated from everything else.)
• Proofs that these three statements are interconnected; either with examples that show one implies the other or rigorous proofs.
• Both books talk about the entropy of an ideal gas, and processes in which entropy changes.
• Both do engines, heat pumps and fridges (though G&T kindly uses "η" for the efficiency of an engine and "COP" for the measure of goodness of a heat pump or fridge, whereas B&B use " η " for all three.)
• Both books do a good job with the definition of entropy and its changes (B&B Ch. 14 and G&T 2.15). Both talk about having a big bath and a small system (G&T Ex. 2.16 and B&B Ex. 14.1)
• Both books derive the fundamental thermodynamic relation: dU = T dS - p dV.

2. Topics that might be unique to one book:
• B&B Is more rigorous this week. For example:
  13.4 proves the equivalence of Clausius and Kelvin's statements of the 2nd law
  13.3 states and proves Carnot's theorem (that its efficiency of $\eta = 1 - T_L/T_H$ is the maximum possible for any engine working between two temps, T_L and T_H).
  13.7 proves something called Clausius' theorem.

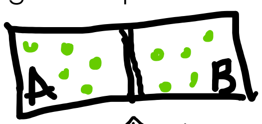
> **Clausius' theorem**
> For any closed cycle, $\oint \frac{dQ}{T} \leq 0$, where equality necessarily holds for a reversible cycle.

This is beautiful but perhaps not too useful to us. E.g. The example that follows it, work done by a Carnot cycle between two finite baths, can be done in a different way (see G&T Eq. 2.109).
•G&T Ex. 2.19 talks about the maximum work and they give you a problem on it. it is done in B&B Example 13.5.
• G&T 2.16 talks about the ideal gas and thermodynamic temperature scales as being equivalent. (If you accept this, no need to read it :-)

3. Generic things Amy likes about one book or the other

• Entropy changes are an important topic and I like the range of example in both books. The free (aka Joule) expansion is treated in both, but I like the shorter version in B&B 14.4.

• I lean toward G&T 2.13 and 2.17 for the thermodynamic definitions of T and P, because they talk you through examples of boxes with a partition between the halves.



↑ diathermal, fixed

$$\Delta S = 0 \Rightarrow \left.\frac{\partial S_A}{\partial E_A}\right|_{V_A,N_A} = \left.\frac{\partial S_B}{\partial E_B}\right|_{V_B,N_B}$$

$$\left.\frac{\partial S_A}{\partial E_A}\right|_{V_A,N_A} \equiv \frac{1}{T_A}, \qquad \left.\frac{\partial S_B}{\partial E_B}\right|_{V_B,N_B} \equiv \frac{1}{T_B}$$

Similar argument with moveable partition $\Rightarrow \left(\frac{\partial S_i}{\partial V_i}\right)_{E_i,N_i} = \frac{P_i}{T_i} \quad i = A, B$

But if you are comfortable starting with the fundamental thermodynamic relation: dE = T dS - pdV and taking partial derivatives .. you can come to the same conclusion by reading B&B 14.3

$$T = \left(\frac{\partial E}{\partial S}\right)_V \; ; \quad P/T = \left(\frac{\partial S}{\partial V}\right)_E$$

Here, N is just assumed to be constant.

• I like B&B Ch. 13, the engines chapter. It is welcome to see both the Carnot Cycle in Fig. 13.1 in the PV plane and Fig. 13.2 in the T, S plane. It is helpful to have little figures with engines and heat baths repeated several times to show different setups, including some rigorous proofs.

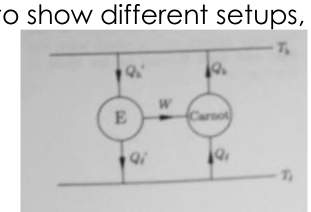


Fig. 13.4 A hypothetical engine E, which is more efficient than a Carnot engine, is connected to a Carnot engine.

• G&T does a lot more of supporting the reader with examples around engines. B&B is terse, emphasizes theory, and leaves the examples to the end-of-chapter problems.

• Both books derive the fundamental thermodynamic relation. I like B&B's box in section14.3

Summary

$dU = đQ + đW$	always true
$đQ = T\,dS$	only true for reversible changes
$đW = -p\,dV$	only true for reversible changes
$dU = T dS - p dV$	always true
For irreversible changes:	$đQ \le T\,dS, \quad đW \ge -p dV$

• I like the fact that G&T section 2.18 pitches this relation both as dE = ... and as dS = ... and also that they include the term in the chemical potential dE = T dS - p dV + μ dN (2.128)

4. Problematic

• For the 3rd law of thermo: G&T 2.20 is only 1 page. Do we want more? If so, Ch. 18 of B&B treats it But ...

• In B&B 18.1, Amy doesn't understand the words "internal degrees of freedom in equilibrium" in Planck's and Simon's formulation of the 3rd law. These words are slightly misleading, suggesting that a particle changes its internal state ... exchanging microscopic quantities with other particles in the kind of 'equilibrium' we already know about.

A better form of **Planck** statement of 3rd law "When temperature falls to absolute zero, the entropy of any pure crystalline substance tends to a universal constant (which can be taken to be zero)"

A better statement of **Nernst-Simons**: "The change in entropy which occurs when a homogeneous system undergoes an isothermal reversible process approaches zero as the temperature approaches absolute zero."

• A Better plan? As an alternative to B&B Ch. 18, read Wikipedia:
https://en.wikipedia.org/wiki/Third_law_of_thermodynamics