Name:_____

Physics 3410

Sample Exam 2 2016

~~April 11, 2014~~

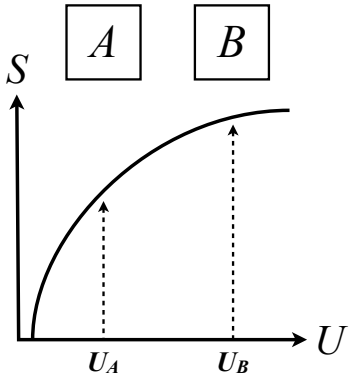
- Turn off your cell phone NOW, if you have one, and put it away. Avoid the appearance of impropriety.
- This is a closed-book exam. You may use two sheets of notes (two-sided) and your own calculator (not a cell phone or other wireless device, and not shared with another student).
- This test contains 17 questions and 72 points. The point value of each question may be found in a little box, like so: [3].
- If any question seems ambiguous, ask me about it. Raise your hand (and maybe clear your throat if I'm not looking) and I will come to you; please remain seated.
- Partial credit is available *everywhere*; when in doubt, explain your reasoning. If you need more room to write, use the back of a sheet, but tell me that you are continuing on the back. Show your work.
- In the event that I have to make a correction or clarification to the exam, I will announce it and write it on the board; if I do so, you are responsible for taking these corrections into account.
- Look out for *emphasized* and **bolded** words; they are usually important.
- Make sure that all answers that need units, get units.
- Please use the little blank (_____) for your answers, where provided. If there is no blank, please [box] or circle your final answer.
- When you're done, place the exam in the appropriate pile, and leave quietly; please do not stand outside the doors talking about the exam.

$$k = 1.38 \times 10^{-23}\,\mathrm{J/K}$$

$$dU = T\,dS - P\,dV + \mu\,dN \qquad dF = -S\,dT - P\,dV + \mu\,dN$$
$$dH = T\,dS + V\,dP + \mu\,dN \qquad dG = -S\,dT + V\,dP + \mu\,dN$$

Good luck!

1. This graph shows the entropy of a system as a function of its energy. There are two copies of the system next to each other, one with energy U_A and one with energy U_B.

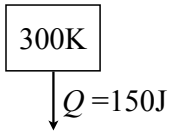


3 (a) _____ If the systems are put into contact, heat will flow
A) from A to B (A is "hotter")
B) from B to A (B is "hotter")

3 (b) _____ These systems have
A) negative temperature
B) negative heat capacity
C) neither of these

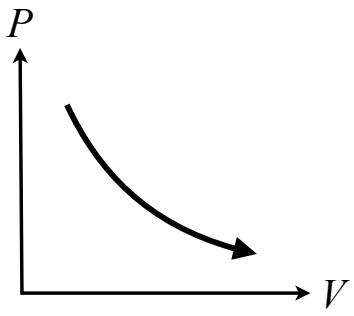
3 2. _____ A system absorbs 50 J of heat, and its temperature drops by 1 K. This system has
A) negative temperature **B)** negative heat capacity **C)** neither of these

3 3. _____ 150 J of heat flows out of a thermal reservoir at temperature $T =$ 300 K. Find the change ΔS in the reservoir's entropy.



2 4. By what process can a system decrease in entropy? (And I don't mean "by increasing the entropy somewhere else").

5. Consider this process of an ideal gas on a PV diagram.



[3] (a) _____ This process is
A) constant-volume **B)** isobaric **C)** isothermal

[3] (b) _____ During this process,
A) work flows into the system
B) work flows out of the system
C) no work is involved

[3] (c) _____ During this process,
A) heat flows into the system
B) heat flows out of the system
C) no heat is involved

6. Answer the following true/false questions about an adiabatic process. Feel free to explain your answer.

[1] (a) _____ An adiabatic process is never quasistatic.

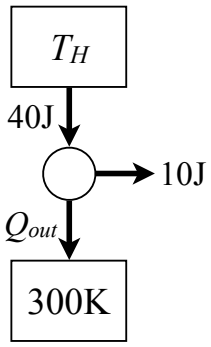
[1] (b) _____ An adiabatic process does not change a system's entropy.

[1] (c) _____ During an adiabatic process, no heat flows into or out of the system.

[1] (d) _____ An adiabatic process is relatively slow.

7. This figure shows a heat engine operating between two reservoirs.

3 (a) What is its efficiency?

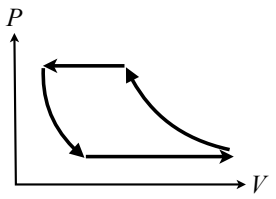


3 (b) How much heat Q_{out} flows into the cold reservoir?

2 (c) If this is a Carnot engine, what is the temperature T_H of the hot reservoir?

3 8. _____ This figure shows a cyclic process on a PV diagram. The net work of flow during this cycle is

A) outward **B)** inward **C)** zero



3 9. _____ When a liter of a certain fuel burns, its internal energy decreases by 80 J ($\Delta U = -80$ J) and its Helmholtz free energy F decreases by 50 J ($\Delta F = -50$ J). How much work could be done on the environment by burning this liter of fuel?

A) 0 J **B)** 30 J **C)** 50 J **D)** 80 J

3 10. A system at standard temperature and pressure (300 K, 10^5 Pa) expands from 2 m^3 to 2.1 m^3. What is the change in the Helmholtz free energy ΔF? The temperature and pressure remain constant throughout the expansion.

3 11. _____ When you burn wood, its enthalpy
A) increases **B)** stays the same **C)** decreases

3 12. I slowly expand a gas in contact with a thermal reservoir. Write the derivative (in the form $\left(\frac{\partial A}{\partial B}\right)_C$) you would use to find the change in the system's entropy.

13. Consider the new thermodynamic potential $\Phi = F - \mu N$, which has the thermodynamic identity

$$d\Phi = -S\,dT - P\,dV - N\,d\mu$$

3 (a) What are the natural variables of Φ? _____ _____ _____

3 (b) Find $\left(\frac{\partial \Phi}{\partial \mu}\right)_{T,V}$.

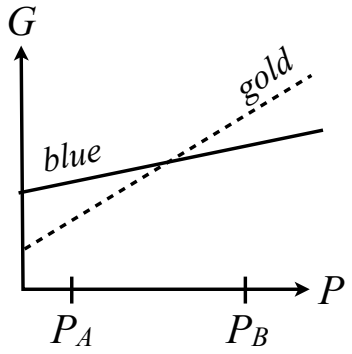
3 (c) Find a derivative which is equal to this one, using a Maxwell relation related to Φ.

$\left(\frac{\partial S}{\partial \mu}\right)_{T,V} =$

[2] 14. _____ At $-10°$ C at standard pressure, ice has a ... Gibbs free energy than liquid water.
A) higher **B)** lower

[2] 15. When does the Gibbs free energy of ice equal the Gibbs free energy of liquid water?

16. This graph shows the Gibbs free energy of two crystal structures (called "blue" and "gold") of toledium, as a function of pressure.



[3] (a) _____ At which pressure is blue toledium more stable?
A) P_A **B)** P_B

[3] (b) _____ Which type of toledium is less dense?
A) blue **B)** gold

[3] 17. In the van der Waals model of an ideal gas, $\left(P + a\frac{N^2}{V^2}\right)(V - Nb) = NkT$. Explain what the quantity Nb describes in physical terms.