

**Thermal Physics 224
Autumn 2008****Second midterm 9.30 am, Monday 17 November, 2008**
Instructor: David Cobden

Do not turn this page until the buzzer goes at 9.30. You must hand your exam to me by the time I leave the room at 10.25.

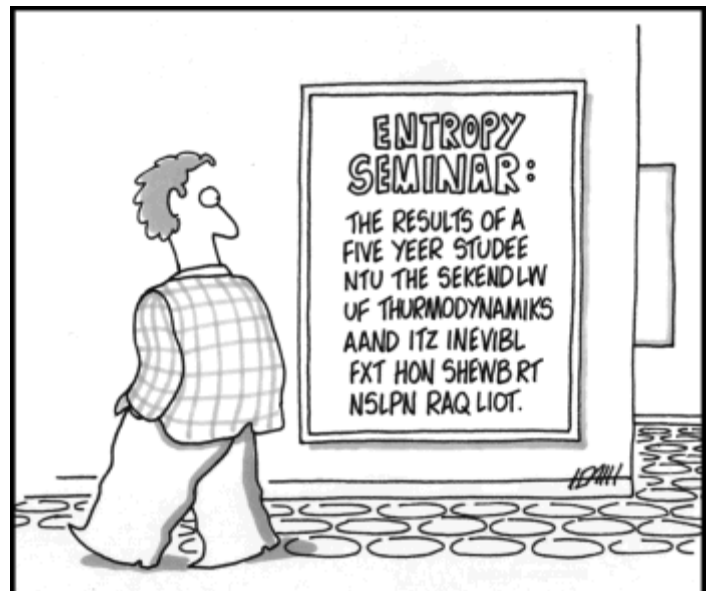
Attempt all the questions.

Please write your name on every page and your SID on the first page.

Write all your working on these question sheets. Use this front page for extra working. It is important to show your calculation or derivation. Some of the marks are given for showing clear and accurate working and reasoning.

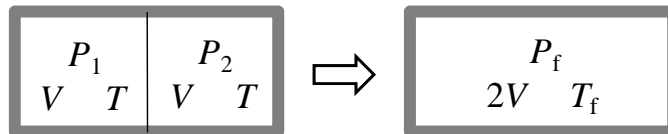
Watch the blackboard for corrections or clarifications during the exam.

This is a closed book exam. *No books, notes or calculators allowed.*



1. [5] State the “generalized thermodynamic identity” relating U , T , S , P , V , μ and N .
2. [2] How many independent variables are needed to specify the state of a system for which this identity applies?
3. [5] Deduce an equation relating the chemical potential μ to a partial derivative of S .
4. [8] Find an expression for μ for an ideal gas using Sackur-Tetrode, $S = Nk \left[\ln \left\{ \frac{V}{N} \left(\frac{4\pi m U}{3N h^2} \right)^{\frac{3}{2}} \right\} + \frac{5}{2} \right]$.

Two portions of the same ideal gas, each with volume V , are initially in thermal equilibrium separated by a thin wall within a thermally isolated chamber in a room at temperature T . The pressure P_1 on the left is higher than the pressure P_2 on the right. The thin wall between them is then suddenly removed, and after a short time the gas reaches a steady pressure P_f .



5. [6] Is this process adiabatic? Is it quasistatic? Is it reversible?
6. [6] Using the expression for μ from Question 4, and the proper interpretation of μ , show that there is initially a net flow of molecules from left to right.

7. [10] Using the First Law of thermodynamics, and the fact that the gas is ideal, show that the process is isothermal (ie, that the final temperature T_f is equal to T).
8. [5] Explain the absence of a temperature change from a kinetic theory point of view.
9. [5] Find P_f .
10. [8] Find the total change in entropy, ΔS_{gas} .
11. [8] Describe a modified process that would take this system from its initial to its final state *reversibly*. How much heat would flow into the chamber during this process?

12. [12] A glass containing a mixture of 100 g of water and 100 g of ice at $0\text{ }^{\circ}\text{C} = 273\text{ K}$ is placed in a room at 300.3 K . The ice takes half an hour to melt. Calculate the total change in entropy of the *universe* due to this melting. (The latent heat of melting of ice is $L_m = 334\text{ J/g}$).

13. [10] Show that if the efficiency of a heat engine is greater than the ideal limit (of a Carnot engine) then when it operates it decreases the total entropy of the universe. What does this say about such an engine?

14. [10] What is the minimum rate, set by thermodynamics, at which an electrical power station generating 100 MW of electricity from steam at $327\text{ }^{\circ}\text{C}$ could be dumping heat into a river at $27\text{ }^{\circ}\text{C}$?