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Thermal Physics 224 **First midterm** **9.30 am, Monday October 27, 2008**
Autumn 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.

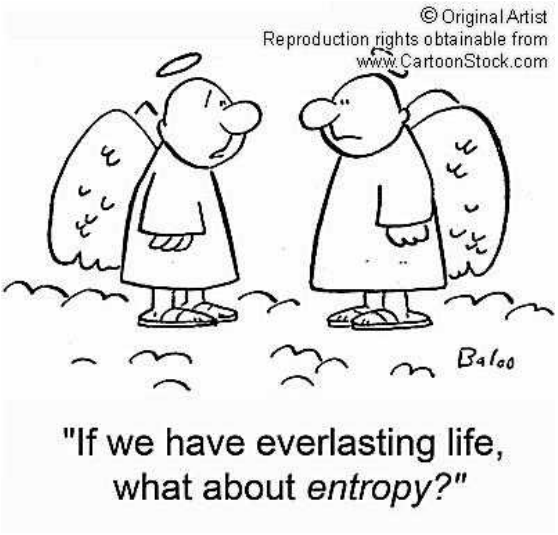
Attempt all the questions.

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.***



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1. [5] Define “thermal equilibrium”.

2. [4] State the equipartition theorem.

3. [4] State the Second Law of Thermodynamics.

4. [10] *Estimate* the rms velocity of the shaking of my hand due to bombardment by air molecules. ($kT \approx 0.4 \times 10^{-20}$ J at $T = 300$ K). Do not attempt to quantify effects of caffeine and exhaustion.

5. [5] What is the property of real gases that allows an absolute temperature scale to be obtained?

6. [10] Find the isothermal compressibility β of a gas obeying the ideal gas law, in terms of p, V, N and T.

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7. [10] A bubble of helium (monatomic) and a bubble of hydrogen (diatomic), each with volume V_0, are both initially held in thermal equilibrium at pressure p_b at the bottom of a pool of water with uniform temperature T_0. Both bubbles are then released, and they rise quickly and hence adiabatially to the surface where $p = p_s$. Sketch the variation of p with V for both bubbles on the same p-V diagram. (Note: γ=1+2/f, where f is the number of accessible degrees of freedom per molecule).

8. [6] What is the ratio of the final volumes of the two bubbles when they reach the surface?

9. [4] Which bubble reaches a lower temperature?

10. [4] Which bubble does more work against the water?

11. [4] If instead the bubbles had risen much more slowly and thus isothermally, what would the ratio of their final volumes have been?

12. [6] State Fourier's law for heat flow in one dimension, defining all quantities and giving their units.

13. [8] Define enthalpy H, and show that for a chemical reaction, where the reactants and products are at the same pressure, the heat released is equal to the change in enthalpy.

14. [8] The probability of a measurement of a variable x being between x and x+dx is $p(x)$dx. If $p(x) = ae^{-ax}$ and x is positive-definite, show that $p(x)$ is properly normalized, and say why it must be so.

15. [8] Two identical paramagnets, A and B, each having N spins, are in thermal contact and isolated from their environment so that their total energy $E = q\Delta = (q_A + q_B)\Delta$ is fixed. What is the multiplicity of the combined system, Ω, as a function q_A, q and N?

16. [6] Sketch Ω vs q_A for small N (say, 10) and large N (say, 100), showing where you expect its maximum to be.