Name _____   Student ID _____

Thermal Physics, Physics 224   **Midterm exam 2**   **March 1, 2003**
Winter 2003
Instructor: David Cobden   **4 pages (2 sheets printed on both sides)**

You have 50 minutes to answer two questions. **Move on to question 2 after 25 minutes!** Begin and end on the buzzer. Be sure to write your name and ID on every page. Answer all questions. Write all your working on these question sheets. Watch the blackboard for corrections during the exam. This is a closed book exam.   You are allowed one sheet (two sides) of notes.   You are allowed a simple calculator. *Throughout this exam, you will get credit for giving algebraic answers wherever possible as well as numerical answers.*

Question 1. [50 points total]

List and count the q quadratic degrees of freedom of a free carbon dioxide (CO_2) molecule. [9]

Say why at room temperature ($T_0 = 300$ K) only $q_{eff} = 6$ of these are thermally excited. [2]

What is the internal energy of one mole of CO_2 at $T_0 = 300$ K? The gas constant $R = 8.3$ J/mol/K. [3]

What are its molar isochoric and isobaric specific heats, c_v and c_p, at 300 K? [6]

One mole of CO_2 has initial volume V_0 at pressure $p_0 = 1.0 \times 10^5$ Pa and temperature $T_0 = 300$ K. It is then compressed adiabatically and reversibly to half its initial volume. Given that an adiabatic can be characterised by $TV^{g-1} = $ constant, deduce the final temperature [6]

What is the change in its internal energy, ΔU, during the process? [6]

What is the total work done by the gas, W, during the process? [3]

What is the total change in entropy, ΔS, of the gas during the process? [3]

If the diameter of a CO_2 molecule is about 0.4 nm, estimate the mean free path at pressure $p_0 = 1.0 \times 10^5$ Pa and temperature $T_0 = 300$ K. [8]

If the diffusion constant is $D = 2 \times 10^{-5}$ m^2/s, what is the typical time taken for a molecule of CO_2 to diffuse across the 1 cm gap between the two panes of a cavity window? [4]

Question 2. [50 points total]

Estimate the characteristic wavelength of radiation emitted by living human skin in a dark room. [5]

A dark, thermally insulated room is full of (live) students having some kind of party. Sketch and annotate the intensity distribution function of radiation as a function of wavelength inside the room. [5]

They get excited for some reason, and the temperature rises by 3° C. Be approximately what fraction does the total intensity of the radiation inside the room increase? [7]

State the Clausius form of the Second Law of thermodynamics. [3]

Also, state precisely the Second Law in terms of entropy. [3]

What limits does the Second Law put on the efficiency e of any heat engine operating between reservoirs at temperatures T_H and T_L? [3]

A Carnot engine operates between a hot reservoir at $T_H = 500°$ C and a cold reservoir at $T_L = 100°$ C. If heat is deposited in the cold reservoir at a rate of 1000 kW, what is the rate at which the engine produces useful work? [12]

To keep the cold reservoir at T_L it is cooled by flowing water through it. The water enters as liquid at 20° C and leaves as steam at 100° C. How many liters per second of liqid water must be used? (Specific heat of water $c_p = 4.2$ J/g/ °C; latent heat of vaporization $L_v = 2260$ J/g). [12]