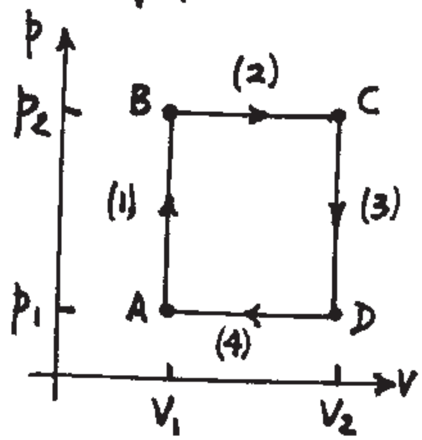
Physics 7B (Sec. 2) Midterm Exam #1 Feb. 25, 2003

You may use one (1) card, not larger than 3"×5" (both sides) as a memory aid, but no other papers, and no books. Exam = 220 points

(40) (1) Given one mole of an ideal monatomic gas undergoing the cyclic series of processes shown on the pV diagram. (a) Describe in words the process (1) which takes the gas from state A to state B. Describe also a method of realizing this process experimentally; (b) Do the same for process (2) taking the gas from state B to state C; (c) Calculate the total work W done by the gas during the cycle A → B → C → D → A; (d) From your answer to part (c), state whether positive work is done by the gas on the surroundings, or by the surroundings on the gas. Justify your answer; (e) Calculate the temperatures T_A, T_B, T_C, T_D of the gas in the states A, B, C, D; (f) Calculate the changes ΔU_1, ΔU_2, ΔU_3, ΔU_4 in the internal energy U of the gas in the processes (1), (2), (3), (4), in terms of pressures and volumes; (g) Calculate the heat Q_1, Q_2, Q_3, Q_4 in each of the processes, in terms of pressures and volumes; (h) From your answer to part (g), state whether heat energy enters or leaves the gas during each of the four processes; (i) Calculate the efficiency e of a heat engine based on this cycle; (j) Calculate the change ΔS in the entropy S of the gas during the cycle. [Each part = 4 points]



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(30) (2) One mole of helium (an ideal gas) is at 120K with a volume of 0.10 m^3 at a pressure of 10^4 Nm^{-2}. The gas undergoes a three-step process: (1) compression to a volume of 0.05 m^3 at a constant pressure of 10^4 Nm^{-2}; (2) heating at a constant volume of 0.05 m^3 to a pressure of 2×10^4 Nm^{-2}; (3) reversible isothermal expansion to a volume of 0.10 m^3. (a) Draw a pV diagram showing the three steps of this process; (b) Calculate the temperature of the gas at the beginning and end of each step, and show the temperatures on the pV diagram; (c) Calculate the work done by the gas during the three-step process; (d) Calculate the change in the entropy of the gas during the three-step process [a = d = 5; b = c = 10]

(30) (3) One mole of an ideal monatomic gas, initially at volume V_0, pressure p_0, and temperature T_0, undergoes a reversible two-step process as follows: (1) the gas is heated at constant volume until its pressure is $2p_0$ and its temperature is T_1; (2) the gas then expands isothermally until its volume is V_1 and its pressure is again p_0. (a) Draw the pV diagram for this process, labeling all axes and points clearly; (b) Calculate the internal energy change ΔU_1, heat involved Q_1, and work and work W_1 done by the gas, for step (1) in terms of T_0 and constants; (c) Calculate ΔU_2, Q_2, and W_2 for step (2) in terms of T_0 and constants; (d) In the two-step process, does the gas do work on the surroundings, or do the surroundings do work on the gas? Justify your answer. [a=5, b=10, c=10, d=5 pts]

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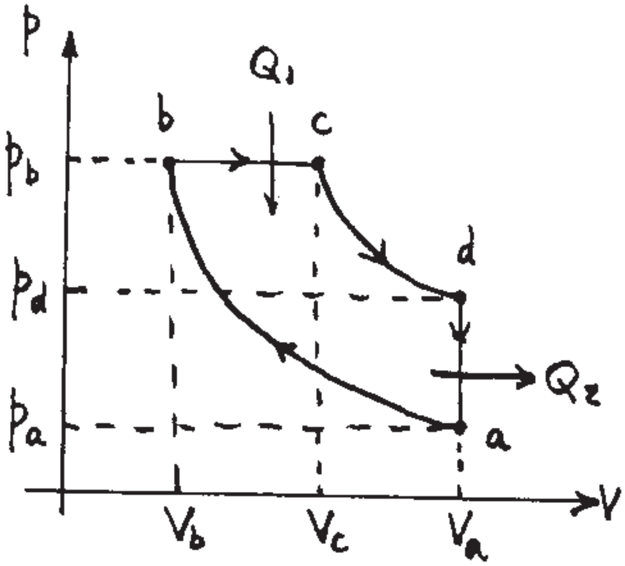
(45) (4) The pV diagram below shows a reversible quasi-static cycle in which paths cd and ab are adiabatic. The working substance for a heat engine using this cycle is an ideal gas. An amount of heat Q_1 enters the engine during path bc (at constant pressure p_b) and an amount of heat Q_2 leaves the engine during path da (at constant volume V_a). Show that the efficiency e of a heat engine using this cycle is



$$e = 1 - \left\{ \frac{(V_a/V_c)^{-\gamma} - (V_a/V_b)^{-\gamma}}{\gamma\left[(V_a/V_c)^{-1} - (V_a/V_b)^{-1}\right]} \right\}$$

where $\gamma \equiv (c_p/c_V)$ for the working substance.

(30) (5) Consider n moles of a hypothetical <u>non-ideal</u> gas which obeys the equation of state $pV = nRT + \alpha p$, where α is a positive constant with dimensions of volume; α is small (but non-negligible) compared to any volume in this problem. Suppose that, for this gas, its internal energy depends only on temperature. The gas expands reversibly and isothermally from volume V_1 to volume V_2. (a) Calculate the change ΔS in the entropy S of the gas during the expansion; (b) Is ΔS positive or negative? Justify your answer with an explanation. [a = 20, b = 10 pts]

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