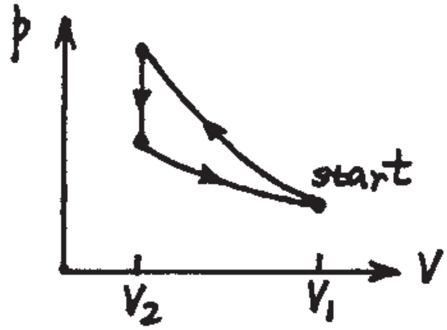
Physics 7B First Exam July 20, 1992

You may use one (1) card, not larger than 3"×5", as a memory aid, but no books except a Table of Integrals. The exam totals 100 points. Values of constants and useful integrals are given after the last problem.

(15)(1) An ideal gas that occupies 0.14 m^3 at a pressure of 2.047×10^5 $N m^{-2}$ is expanded isothermally to atmospheric pressure (1.013×10^5 $N m^{-2}$). The gas is then cooled at constant pressure until it reaches its initial volume. Calculate the work done by the gas.

(15)(2) A system composed of 1.00 kg of ice at 0°C melts irreversibly to water at the same temperature. The latent heat of fusion of ice is 3.332×10^5 J $(kg)^{-1}$. Calculate the entropy change of the system.

(20)(3) A cylinder contains a non-ideal gas and has in it a movable piston. The cylinder is submerged in a mixture of ice and water at 0°C. The piston is <u>very quickly</u> pushed down, so the volume of the gas changes from V_1 to V_2. The gas then remains at volume V_2 until its temperature is again 0°C. Then the piston is slowly raised so the volume of the gas is again V_1. The pV diagram of the process is shown below.



If 0.1 kg of ice is melted during this cycle, calculate how much work has been done <u>on</u> the gas. The latent heat of fusion of ice is 3.332×10^5 J $(kg)^{-1}$.

(continued →)

(20)(4) Given a monatomic gas in equilibrium at temperature T for which the atomic speeds obey the Maxwell distribution

$$f(v) = 4\pi N (m/2\pi k_B T)^{\frac{3}{2}} v^2 \exp(-mv^2/2k_B T)$$

where N is the number of atoms, each of mass m, and k_B is Boltzmann's constant. Calculate the mean-square speed $\overline{v^2}$ of the atoms in the gas.

(30)(5) Consider an electric dipole composed of charges $\pm Q$ separated by a distance $2a$. Consider a point P which is a distance r from the center of the dipole axis; $r > a$, and P is on the (extended) axis of the dipole. (a) Calculate the electric field vector $\underline{E}(r)$ at point P; (b) By expanding your answer for $|\underline{E}(r)|$ at P, using appropriate Taylor series, determine $|\underline{E}(r)|$ for distances $r \gg a$. [Each part = 15 points]

$$\int_0^\infty e^{-r^2x^2}dx = (\pi^{1/2}/2r) \qquad \int_0^\infty x^4 e^{-r^2x^2}dx = (3\pi^{\frac{1}{2}}/8r^5)$$

$$\int_0^\infty x e^{-r^2x^2}dx = (1/2r^2) \qquad \int_0^\infty x^5 e^{-r^2x^2}dx = (1/r^6)$$

$$\int_0^\infty x^2 e^{-r^2x^2}dx = (\pi^{\frac{1}{2}}/4r^3)$$

where $r > 0$ in the integrals above.

$$\int_0^\infty x^3 e^{-r^2x^2}dx = (1/2r^4)$$

$R = 8.31 \ J\,(\text{mole})^{-1}(K)^{-1}$

$\epsilon_0 = 8.85 \times 10^{-12}\ C^2 N^{-2} m^{-2}$

$k_B = 1.38 \times 10^{-23}\ J\,(K)^{-1}$