Nayana SD.
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MS13127.

PHY202: End-Sem Examination
2014-2015 Even Semester

Time to finish: Three hours — Max. Marks: 60

1. (a) A two-level atom with energies $(-\epsilon, \epsilon)$ is in contact with a reservoir at temperature T. Both the energy levels are then shifted to values $(-\epsilon + \Delta, \epsilon + \Delta)$. Show the effect on (i) probabilities p_j to occupy a level j, and (ii) mean energy of the atom.

   (b) The partition sum of a quantum harmonic oscillator is given as $Z = 1/[\exp(\beta h\nu/2) - \exp(-\beta h\nu/2)]$. Find expression for the mean energy of the oscillator. [4+3]

2. A collection of N atoms, where each atom has a doubly-degenerate ground level and an excited level. The level energies are $(0, \epsilon)$. From the partition function, calculate the entropy of the system. Verify the thermodynamic relation $F = U - TS$. [7]

3. Calculate and show the total entropy change is positive definite in the process in which a monoatomic ideal gas at temperature T_A is put in thermal contact with a heat reservoir at temperature T_B. Take $T_A > T_B$. [4]

4. A system is described by equations of state:

$$T = 3As^2/v, \quad P = As^3/v^2.$$

   Find μ as a function of s and v. [6]

5. A cylinder contains an internal piston on each side of which is one mole of monoatomic ideal gas with volume 10 litres and 1 litre, respectively. The cylinder is in thermal equilibrium with a reservoir at temperature 273K. The piston is now moved reversibly, so that the final volume on either side of piston is 6 litres and 5 litres, respectively.

   (a) Calculate pressure on each side of the internal piston for arbitrary position of the piston. By integration, find the work done in the process.

   (b) What is the appropriate representation or thermodynamic potential for the system? Can you derive work performed by any other method? [3+3]

6. (a) Given a function: $y(x) = A\exp(Bx)$, where A, B are constants. Find $\psi(P)$ where $P = dy/dx$. Calculate the inverse Legendre transform of $\psi(P)$.

(contd.)

(b) Enthalpy is given by $H = U + PV$. Also H is given to be a function only of the variables S, P, N. Show that

$$\frac{\partial H}{\partial P} = V, \quad \frac{\partial H}{\partial N} = \mu,$$

where the symbols have their usual thermodynamic meanings. [4+3]

7. An ideal Van der Waal fluid is described by the following equations of state:

$$\frac{1}{T} = \frac{cR}{u + a/v}, \quad \frac{P}{T} = \frac{R}{v - b} - \frac{acR}{uv^2 + av},$$

where a, b, c are constants. Find the fundamental relation $s(u, v)$ for the fluid. Show the limiting behavior of a classical ideal gas. [6]

8. (a) From the fundamental relation $S(U, V, N)$, derive the expression for $d\hat{s}$ in terms of $d\hat{u}$ and $d\hat{n}$, where $\hat{s} = S/V, \hat{u} = U/V, \hat{n} = N/V$.

(b) Calculate the work done in isobaric expansion of two moles of monoatomic ideal gas from temperature 200K to 350K. [4+3]