Physics Department
Paderborn University

Theoretical Physics - Thermodynamics
Dr. H.T. Duc, Prof. Dr. W.G. Schmidt, WS 2008/2009

Sheet I
Preparation until Tuesday, 21.10.2008

1. dV Total

A characteristic feature of thermodynamic systems is that, in spite of many microscopic degrees of freedom, they can be described by a few variables.

a) Sum up the notations "thermodynamic parameter" and "minimal ensemble of thermodynamic parameters".

b) A homogeneous system is defined by the thermodynamic parameters p and T. Are the following variables V and Q thermodynamic parameters as well?

$$\delta V = \frac{\nu R}{p} dT - \frac{\nu RT}{p^2} dp \tag{1}$$

$$\delta Q = \frac{5}{2} \nu R dT - \frac{\nu RT}{p} dp \tag{2}$$

c) Determine, if necessary, for V and for Q respectively, an integrating factor $\mu(p,T)$ and calculate the integrals μV (μQ). *Hint:* the integrals are path-independent. (Why?)

2. Van der Waals gas

The thermal equation of state of van der Waals gas is given by

$$\left(p + \frac{N_A^2}{V^2} a\right)(V - N_A b) = N_A k_B T. \tag{3}$$

From the relation between thermal and caloric equation of state in pVT-systems, it can be shown (Section 5.1 in the Lecture) that

$$dU = C_V(V,T) dT + \left(T \left(\frac{\partial p}{\partial T}\right)_V - p\right) dV. \tag{4}$$

Use this and the fact that dU is an exact differential, to prove the dependence of the internal energy $U = U(V,T)$ on temperature and volume.

3. Black body

The radiation field in a black body with volume V is in equilibrium with the walls which are kept in constant temperature T. The radiation energy density is simply a function of temperature, so that the internal energy has a general form

$$U(V,T) = V f(T), \tag{5}$$

where the function f depends only on T. The radiation pressure is given by

$$p = \frac{1}{3} b T^4. \tag{6}$$

How does the function f look like? *Hint:* use Eq. (4).