Physics Department
Paderborn University

Theoretical Physics - Thermodynamics

Dr. H.T. Duc, Prof. Dr. W.G. Schmidt, WS 2008/2009

Sheet III

Preparation until Tuesday, 04.11.2008

7. Black body again

a) Derive the Maxwell relations

$$\left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial p}{\partial T}\right)_V \quad \text{and} \quad \left(\frac{\partial U}{\partial V}\right)_T = T\left(\frac{\partial p}{\partial T}\right)_V - p. \tag{11}$$

b) From his electromagnetic theory Maxwell found that the pressure p from an isotropic radiation field is equal to 1/3 the energy density $u(T)$:

$$p = \frac{1}{3}u(T) = \frac{U(T)}{3V}, \tag{12}$$

where V is the volume of the cavity. Show that u obeys the equation

$$u = \frac{1}{3}T\frac{du}{dT} - \frac{1}{3}u. \tag{13}$$

c) Solve this equation and obtain Stefan's law relating u and T.

8. Thermodynamic potential of an ideal gas

a) "Google" the notion "Guggenheim-Quadrat" in connection with thermodynamics, internalize the saying and draw the implied Quadrat. Which natural variables do the thermodynamic potential U (internal energy) and F (free energy) depend on?

b) So far, the thermal and caloric equation of state for the ideal gas are known:

$$pV = Nk_BT, \quad U = C_V(T - T_0) + U_0, \; C_V = \text{const.} \tag{14}$$

Calculate the thermodynamic potential U for ideal gas with the help of Gibb's fundamental equation. Final result:

$$U = C_V T_0 \left[\left(\frac{V}{V_0}\right)^{-\frac{Nk_B}{C_V}} \exp\left(\frac{S - S_0}{C_V}\right) - 1\right] + U_0. \tag{15}$$

c) Also calculate the thermodynamic potential F for ideal gas.

9. Third law of thermodynamics

a) What does the third law of thermodynamics say?

b) Check whether the thermal equation of state

$$M = \frac{C}{T}H, \tag{16}$$

combining the magnetization M and the magnetic field H via the constant C, is compatible with the third law of thermodynamics.