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Problems set # 5 **Physics 303** October 7, 2014

1. *(i)* Show that the entropy change in the cyclic process of an ideal gas, that is represented by a rectangle in the (P, V) diagram, is zero. *(ii)* Show that the entropy change in the cyclic process of an ideal gas that include an isobar, an isochore, and an isotherm is zero. See Fig. 1.

2. Calculate the entropy of a perfect gas as a function of (V, T) by integration using $S = \delta Q/T$.

3. Express the energy of a perfect gas in the natural variables, $U = U(S, V)$, and check the relations:

$$T = \left(\frac{\partial U}{\partial S}\right)_V , \qquad -P = \left(\frac{\partial U}{\partial V}\right)_S , \qquad \left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial P}{\partial S}\right)_V .$$

4. Express thermodynamic potentials F and G of the perfect gas in terms of their natural variables and check the relations:

$$-S = \left(\frac{\partial F}{\partial T}\right)_V , \qquad -P = \left(\frac{\partial F}{\partial V}\right)_T , \qquad \left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial P}{\partial T}\right)_V .$$

5. The Helmholtz free energy of a certain gas has the form

$$F = -\frac{n^2 a}{V} - nRT\ln(V - nb) + J(T).$$

Find the equation of state of this gas, as well as its internal energy, entropy, heat capacities C_P and C_V and, in particular, their diference $C_P - C_V$.

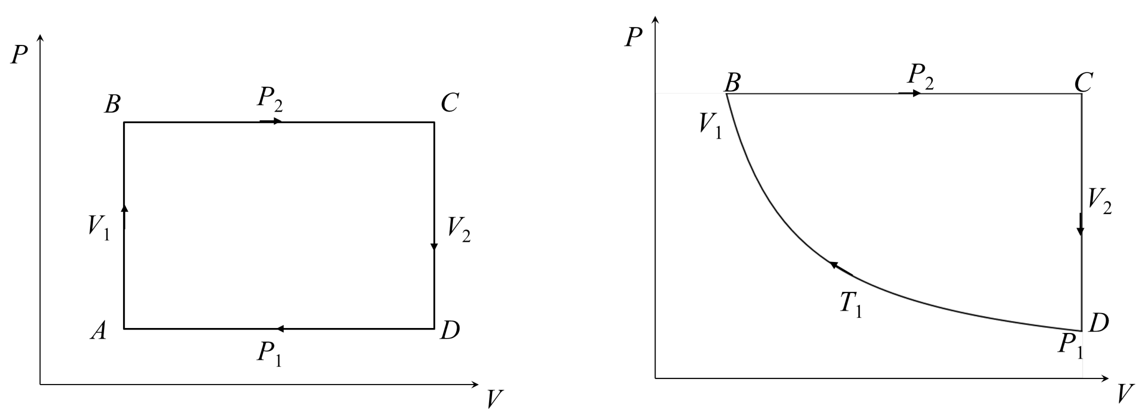

Figure 1: Isobar-isochore cycle (left) and iIsobar-isochore-isotherm cycle (right).