PHYSICS 140A : STATISTICAL PHYSICS
MIDTERM EXAM

(1) ν moles of an ideal diatomic gas are used as the working material for a reversible engine whose cycle ABCDA is depicted in fig. 1. Segments AB and CD are isotherms at temperatures T_2 and T_1 , while segments BC and DA are isochores at volumes V_2 and V_1.

Important: Express all your answers in terms of ν, T_1, T_2, V_1, and V_2 (and not either of the pressures p_1 or p_2).

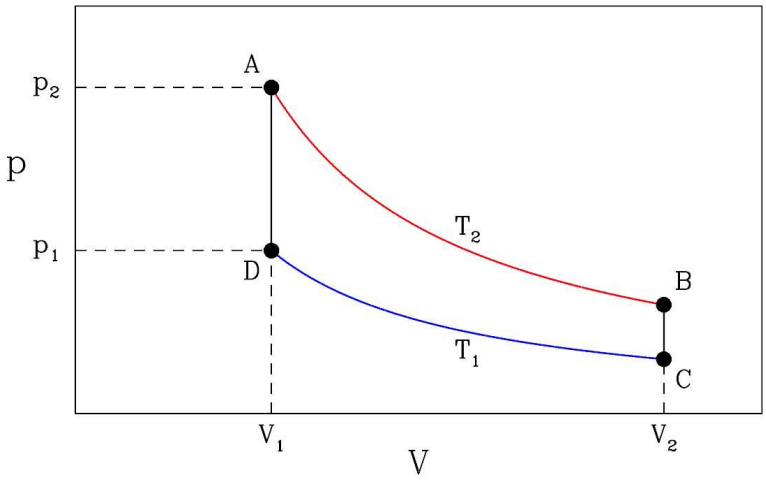

Figure 1: The engine cycle.

(a) What is the work $W_{\rm AB}$ done by the engine and the heat $Q_{\rm AB}$ absorbed by the engine on segment AB? `[10 points]`

(b) What is the work $W_{\rm BC}$ done by the engine and the heat $Q_{\rm BC}$ absorbed by the engine on segment BC? `[10 points]`

(c) What is the work $W_{\rm CD}$ done by the engine and the heat $Q_{\rm CD}$ absorbed by the engine on segment CD? `[10 points]`

(d) What is the work $W_{\rm DA}$ done by the engine and the heat $Q_{\rm DA}$ absorbed by the engine on segment DA? `[10 points]`

(e) What is the efficiency $\eta = W_{\rm cyc}/Q_{\rm AB}$? `[10 points]`

(2) Consider the equation of state for a monatomic nonideal gas,

$$\left(p + \frac{\sigma N^2}{V^2}\, k_{\rm B}T\right)(V - N\omega) = Nk_{\rm B}T \quad ,$$

where σ and ω are constants. (Note that this is not quite the van der Waals equation of state.)

(a) What are the dimensions of σ and ω? `[10 points]`

(b) Show that the equation of state can be rearranged in the form $p(T,V,N) = k_{\rm B}T\phi(V/N)$, and find the function $\phi(u)$ (where $u = V/N$). `[15 points]`

(c) Find $E(T,V,N)$. *Hint: Consider the low density limit after you ascertain the volume dependence.* `[15 points]`

(d) Find $S(E,V,N)$. `[10 points]`

(e) N atoms of this gas undergo adiabatic free expansion from an initial volume $V_1 = 5N\omega$ to a final volume $V_2 = 2V_1 = 10N\omega$. Find ΔS. `[100 quatloos extra credit]`