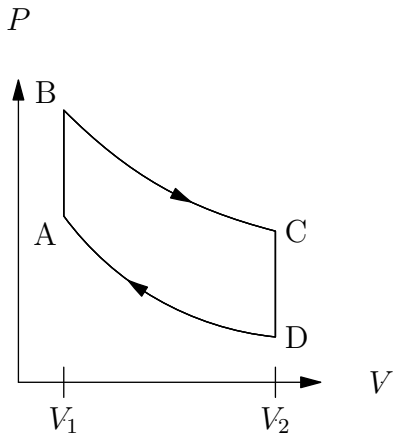
M99T.1—The Otto Cycle

Problem

Calculate the efficiency of a car engine modeled by the Otto cycle depicted in the diagram. The cycle consists of two isochorous and two adiabatic processes between volumes V_1 and V_2.



The working medium's equation of state is given by:

$$p = \frac{n}{V}\left(RT + \frac{n\alpha RT}{V}\right) \ , \quad (-V_1/2 < n\alpha < V_1)$$

(the ideal gas law corrected by the first virial coefficient $RT\alpha$), and the medium's molar heat capacity C_V (at constant volume) remains approximately unchanged through the cycle. Find the efficiency of the depicted cycle in terms of V_1, V_2, R, C_V, and $n\alpha$.