PHYS 301
Thermodynamics and Statistical Mechanics

Worksheet #19

Tuesday May 5 2026

Question 1.

Idealized Diesel Engine: Consider the PV diagram in the figure below for an idealized Diesel engine. Here we will assume the engine is reversible and works with an ideal gas with adiabatic index $\gamma = C_P/C_V$. First, air alone is compressed adiabatically from volume V_1 to V_2, heating up the air. Then, fuel is injected and immediately ignites (the air is hot!) at constant pressure (isobaric), with volume changing from V_2 to V_3. The gas then expands adiabatically (power stroke) until the volume goes back to V_1. Finally, the heat is rejected (exhaust) at constant volume until the pressure is back to the starting point.

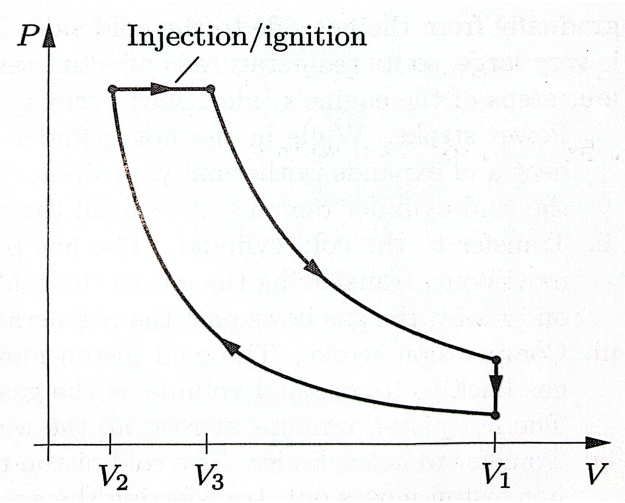

Figure 1: The diesel cycle

(a) Derive a formula for the efficiency of the Diesel cycle, in terms of the adiabatic index γ, compression ratio $r = V_1/V_2$ and the cutoff ratio $\alpha = V_3/V_2$. Remember that for an adiabatic process, we have $TV^{\gamma-1} =$ constant. What is the equivalent relation for an isobaric process? Your efficiency should be

$$\eta_{\text{Diesel}} = 1 - \frac{1}{r^{\gamma-1}}\left[\frac{\alpha^\gamma - 1}{\gamma(\alpha-1)}\right]. \tag{1}$$

(b) Show that for a given compression ratio, the Diesel cycle is less efficient than the Otto cycle.

(c) Evaluate the theoretical efficiency of a Diesel engine with a compression ratio of $r = 18$, a cutoff ratio of $\alpha = 2$, and air with $\gamma = 7/5$.