Physics 2700H: Assignment II

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February 3, 2025

Problem 1. Consider a mix of N_2 and O_2, which we may treat as an ideal gas, inside a car engine's cylinder that follows the idealized Otto cycle. Assume points a, b, c, d in Fig. 4.15(b) correspond to (V, P) values of: $\{(7V_1, 1\,\mathrm{atm}), (V_1, 15.25\,\mathrm{atm}), (V_1, 30.50\,\mathrm{atm}), (7V_1, 2\,\mathrm{atm})\}$, respectively.

(a) Confirm that these (V, P) values are consistent with the gas experiencing one adiabatic compression and one adiabatic expansion over each cycle.

(b) If the car's engine size (the displacement of here, four cylinders) due to compression/expansion is $2.4\,\mathrm{L}$, what is V_1?

(c) Find the net work done by the gas in all four cylinders of the engine over one cycle (you may use the relevant expression for work from either p. 44 or p. 77 of the textbook).

Solution 1.

Problem 2. An inventor claims to have developed an engine that takes in $1.1 \times 10^8\,\mathrm{J}$ at $400\,\mathrm{K}$, rejects $5.07 \times 10^7\,\mathrm{J}$ at $200\,\mathrm{K}$, and delivers $16.7\,\mathrm{kW}$ hours of work. Would you advise investing money in this project?

Solution 2.

Problem 3. Suppose a house requires 4.3 GJ of heating in a winter month. The utility company charges \$0.14 per kW h.

(a) Find the cost savings of using a heat pump versus a 95%-efficient natural gas furnace. Assume a Carnot heat pump with average temperatures of $20\,^\circ\mathrm{C}$ indoors and $0\,^\circ\mathrm{C}$ outdoors.

(b) Repeat part (a) using a more realistic coefficient of performance of 4.0 for the heat pump.

Solution 3.

Problem 4. A hypothetical engine, with an ideal gas as the working substance, operates in the cycle shown in Figure 4.17. Show that the efficiency of the engine is

$$\eta = 1 - \frac{1}{\gamma}\left(\frac{1 - \frac{P_3}{P_1}}{1 - \frac{V_1}{V_3}}\right)$$

Solution 4.