Problem Set #8
Physics 436

Friday, 11 March 2022

The following problems come from Schroeder's *An Introduction to Thermal Physics*:

- Problem 4.14 on page 130 (*10 points*) ⇒ Apply the laws of thermodynamics to a heat pump in this problem. For the "numerical estimates" in part (d), use $T_c = 273\,\mathrm{K}$ (roughly 0°C) and $T_h = 298\,\mathrm{K}$ (roughly 25°C). Note that for real heat pumps, the COP is roughly in the range 2 - 7.

- Problem 4.15 on page 130 (*10 points*) ⇒ You study the absorption refrigerator in this problem. After completing part (c), comment on what the relative sizes of the three temperatures should be in order to get a large COP.

- Problem 4.18 on page 133 (*15 points*) ⇒ You derive the efficiency of the Otto cycle in this problem. Use Figure 4.5 on page 131 and its corresponding notation. We know that a Carnot cycle is more efficient than an Otto cycle. Derive an expression for the efficiency of a Carnot cycle operating between the extreme temperatures of the Otto cycle (see the middle of page 132). Express your result in terms of the compression ratio and the ratio of pressures at the ignition step. Verify that the Carnot efficiency is indeed larger than the Otto efficiency.

- Problem 4.20 on page (*20 points*) ⇒ You derive the efficiency of the Diesel cycle in this problem. Use Figure 4.6 on page 133 and appropriate notation for pressures, volumes, and temperatures. Write your result as

$$e = 1 - \left(\frac{V_2}{V_1}\right)^{(\gamma-1)} \cdot \eta\left(\gamma, \frac{V_3}{V_2}\right) ,$$

  where η is a factor that only depends on the adiabatic exponent, γ, and the cutoff ratio, V_3/V_2. The factor η represents how the Diesel efficiency is different from the Otto efficiency you found in Problem 4.18. To prove that "... for a given compression ratio, the Diesel cycle is less efficient than the Otto cycle," make a nice computer plot of $\eta\left(\gamma, \frac{V_3}{V_2}\right)$ versus the cutoff ratio V_3/V_2 for $1 \leq V_3/V_2 \leq 5$. After finding the Diesel efficiency for $V_1/V_2 = 18$ and $V_3/V_2 = 2$, find the Otto efficiency for the same compression ratio. As mentioned in class, the compression ratio for a real gasoline engine is not larger than about 10; otherwise, preignition occurs. Calculate the Otto efficiency again, this time with $V_1/V_2 = 10$. How does that new efficiency compare to the Diesel efficiency with the larger compression ratio?

Due date: **Friday, 25 March 2022**