

Week 5, Meeting 1 Problems

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9/18

1 Looking Forward to Spring(s)?

1.1 Springs and Expansions

Suppose N molecules of a monoatomic ideal gas at (P_1, T_1) are held inside a container by a piston with cross-sectional area A . The motion of the piston is resisted by a spring with spring constant k . The spring exerts no force in the initial state. The helium is then heated until $T_2 = 3T_1$. Express your answers in terms of the variables given in the problem and fundamental constants. Do not neglect atmospheric pressure — $P_1 \neq 0!$. Determine:

- (a) the final volume of the system.
- (b) the total work done by the gas.
- (c) how much heat was added to the gas.
- (d) Some answers are *very messy*. It is a good strategy in cases like this to define your own new variables and use those to keep everything looking nicer. Which *one* new variable should you chose to make your final answers look nice? Write them out in terms of this new variable.

Source: Former GSI Lenny Evans.

2 Test-like and other Interesting Problems

2.1 Interlude on Entropy

Suppose a 10 kg piece of iron ($c = 450 \text{ J/kg}\cdot\text{K}$) at initial temperature 1000 K is placed in a 100 kg water bath initially at temperature 300 K.

- (a) Estimate the change in entropy for the iron, water, and system.
- (b) Now actually calculate it. Compare your answer to part (a).

2.2 Derivations

Derive the efficiency of:

- (a) a Carnot cycle. This consists of an isothermal expansion, adiabatic expansion, isothermal compression, and adiabatic compression. (See Figure 20-7 on pg. 533 of the text, but try not to just copy their derivation. After all, this is for you, as a frequently seen test problem.)
- (b) an Otto cycle. This approximates a car engine and consists of an adiabatic compression, isovolumetric heat increase, adiabatic expansion, and isovolumetric heat loss. (See Figure 20-8 on pg. 535 as well as the accompanying explanation.)

2.3 Net Efficiency of Two Engines

Consider two heat engines, Engine A and Engine B, with efficiencies e_A and e_B . We will create a composite engine, Engine C, by letting the heat output from Engine A be the heat input Engine B, as shown schematically on pg. 30 of the workbook.

- (a) If a heat $Q_{in,A}$ is fed into Engine A, what is the net work output and the total heat output from Engine A, W_A and $Q_{out,A}$ in terms of $Q_{in,A}$ and e_A ?
- (b) If the heat input for Engine B is equal to the heat output of Engine A ($Q_{out,A} = Q_{in,B}$), what is the net work output and the total heat output from Engine B, W_B and $Q_{out,B}$ in terms of $Q_{in,A}$ and e_A ?
- (c) What is the total work that is output from both engines as a result of feeding the engines the heat $Q_{in,A}$?
- (d) What is the net efficiency, e_C , of the combined engine system?
- (e) Show that if both $e_A < 1$ and $e_B < 1$, then $e_C < 1$.
- (f) Suppose Engine A is a Carnot engine operating between temperatures T_H and T_M and Engine B is a Carnot engine operating between temperatures T_M and T_C ($T_H > T_M > T_C$). Show that the net efficiency, e_C , is just the efficiency of a Carnot engine operating between temperatures T_H and T_C .

Source: Workbook pg. 30

2.4 Preparing for the Test?

Just for a note, there are quite a few decent problems in the workbook, specifically between pgs. 19-43 for cycles, processes on gases, entropy, etc. Taking a look at these might be useful in preparing for the exam.