Physics 224A **Problem Set 7** May 2007

Due Friday, May 25, 2007, by 10:30

Questions for grading:

1. (From Giancoli, Problem 20-4.) A four-cylinder gasoline engine has an efficiency of 0.25 and delivers 180 J of work per cycle per cylinder. The engine fires at 25 cycles per second.

(a) Determine the work done per second.

(b) What is the total heat input per second from the gasoline?

(c) If the energy content of gasoline is 130 MJ per gallon, how long does one gallon last?

2. A laboratory deep freeze is kept in a room at 27 C, and the freezing compartment is maintained at -73 C. If a liter of water at 0 C is put into the freezer, and then removed as soon as the water becomes frozen, (a) what is the least amount of work that could be done by the compressor of the freezer in the process, and (b) what is the least amount of heat that could be put out into the room? Remember that any heat removed from the water by the freezer must then be pumped out again by the compressor operating between the freezer temperature and the laboratory temperature.

3. The Stirling engine was analyzed before Carnot's time. Its cycle, described in problem 20-67 and Figure 20-17 of Giancoli, has an isothermal expansion from V_a to V_b at the high temperature T_H, then a constant volume cooling at V_b from T_H to the low temperature T_L, then an isothermal compression at T_L from V_b to V_a, then, finally, a constant volume heating at V_a from T_L to T_H. Take the working substance to be an ideal monatomic gas such as argon. There are diagrams of the Stirling engine on the class web site.

(a) What is its efficiency, as a ratio of the work done to the heat taken in, and how does it compare with the Carnot cycle?

(b) What would be its coefficient of performance if it is used to pump heat out of a refrigerator at temperature T_L?

Assume that any heat removed during the isochoric cooling has to flow to the low temperature side at T_L, and any heat added during the isochoric heating flows from the high temperature side at T_H.

4. (From Giancoli, Problem 20-26) A heat pump is used to keep a house warm at 22 C. How much work would be required to deliver 2800 J of heat to the house, if the pump were an ideal reversible Carnot engine, (a) when the outside temperature is 0 C, and (b) when the outside temperature is -15 C?

Other questions, not for grading:

5. What would be the efficiency of the Stirling engine of question 4(a) if any heat emitted in the isochoric cooling stroke at temperature T is stored at that temperature and then returned to the engine as the isochoric heating stroke passes through temperature T. This would be the effect of an ideal heat exchanger.

6. Show that if the constant pressure specific heat per unit mass c_p of a material is constant in the temperature range $T_L < T < T_H$, where T is measured in kelvin, the entropy per unit mass $s(T)$ in that temperature range can be written as

$$s(T) = s(T_L) + c_p \ln(T/T_L) \ .$$

7. (From Giancoli, Problem 20-58.) A 0.120 kg insulated cup at 15 C is filled with 0.210 kg of water at 20 C. After a few minutes equilibrium is reached. Determine (a) the final temperature, and (b) the total change in entropy of the system.

8. (From Giancoli, Problem 20-61.) Suppose a power plant delivers energy at 900 MW using steam turbines. The steam goes into the turbines superheated to 600 K and deposits its unused heat in river water at 285 K. Assume the turbine operates as an ideal Carnot engine.

(a) If the river flow rate is 37 m^3/s, calculate the average temperature increase of the river water downstream from the power plant.

(b) What is the entropy increase per kilogram of the downstream river water?

9. (From Giancoli, Problem 20-48.) The specific heat per mole of potassium at low temperatures is given by $c_V = aT + bT^3$, where $a = 2.08$ mJ/mol K^2, and $b = 2.57$ mJ/mol K^4. Calculate the entropy change of 0.25 mol of potassium when its temperature is lowered from 3.0 K to 1.0 K.