PHYS1B28: Thermal Physics
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<u>Problem Sheet 5 (2005)</u>

Answers to questions 1 – 4 should be handed in by Wednesday, January 11, 2006.

1. Sketch an ideal Carnot cycle, operating between two temperatures $T_1 > T_2$, as a p-V and T-S diagram. Label the processes involved, and indicate the heat flow and work done during the cycle.

[5]

2 (a) Show that the entropy change during a reversible Carnot cycle is zero.

(b) An ideal Carnot cycle uses a mole of ideal monatomic gas and operates between 400 K and 300 K. At 400 K the extreme pressures are 2×10^5 Pa and 1.5×10^5 Pa. Calculate the heat input at 400 K and total work during the cycle. Calculate the efficiency of this cycle working as an engine, and the coefficient of performance if the above Carnot cycle is used as (a) a refrigerator, and (b) a heat pump.

(c) You are called upon to design a Carnot engine that has 2.00 moles of a monatomic ideal gas as its working substance and that operates from a high temperature reservoir at 500^oC. The engine is to lift at 15 kg weight 2.00 m per cycle, using 500 J of heat input. The gas in the engine chamber can have a minimum volume of 5.00 L during the cycle.

- i) What is the thermal efficiency of the engine?
- ii) What must be the temperature of the cold reservoir?
- iii) How much heat energy does the engine waste per cycle?
- iv) What is the maximum pressure that the gas chamber will have to withstand?

[10]

3. Obtain a general expression for the entropy change in an ideal monatomic gas undergoing a reversible change of state.

Calculate the entropy changes during the following processes:

(i) A mole of ideal monatomic gas decreases in temperature from 320 K to 200 K, at constant pressure

1.0×10^5Pa.

(ii) A 50 g block of copper at 370 K is placed in a 100g beaker of water at 280 K. The heat capacities of copper and water are independent of temperature over the relevant range, and are 387 $Jkg^{-1}K^{-1}$ and

4186 $Jkg^{-1}K^{-1}$ respectively.

(iii) The100g of water evaporates at 373 K. The latent heat of evaporation of water is $2.26\times10^6 Jkg^{-1}$.

[10]

4. A 2 kg block of ice at 0.0^oC melts inside a large room that has a temperature of 25.0^oC. Treat the ice and the room as an isolated system and neglect the change of the room temperature due to the ice melting and warming up to room temperature. Calculate the net entropy change of the system during this process.
The latent heat of melting ice is $L_f = 334\times10^3$ $J\cdot kg^{-1}$ and the specific heat of water is
$C = 4190$ $J\cdot kg^{-1}\cdot K^{-1}$.

[5]