PHAS1228: Thermal Physics
Department of Physics and Astronomy, University College London.

Problem Sheet 4 (2008)

Answers should be handed in or put into Prof. A. Shluger's pigeonhole in P&A by 6 pm on Wednesday 19 March, 2008. Penalty for late submission is 10% of the total obtained mark per each day of delay.

1. 1 mole of an ideal gas at a pressure of 2×10^5 Pa and a temperature of 273 K expands adiabatically to a final pressure of 1×10^5 Pa. Calculate: the initial and final volume; final temperature; work; heat and change in internal energy for this process if the gas is (i) helium, and (ii) nitrogen.

[8]

2. How much water at 100 ^{o}C could be evaporated per hour by the heat transmitted through a 1 cm × 1 cm steel plate 0.2 cm thick, if the temperature difference between the plate faces is 100 ^{o}C. For steel, the coefficient of thermal conductivity K = 0.11 cal$\cdot$s$^{-1}\cdot$cm$^{-1}\cdot$ K^{-1}. Heat of vaporization of water is 540 kcal/kg.

[5]

3. Two brass plates, each 0.5 cm thick, have a rubber spacer sheet between them, which is 0.1 cm thick. The outer side of one brass plate is kept at 0 ^{o}C, while the outer side of the other is at 100 ^{o}C. Find the temperature of the two sides of rubber spacer if the thermal conductivity of brass is approximately 500 times higher than that of rubber.

[5]

4. A steam engine operating between a boiler temperature of 500 ^{o}C and a condenser temperature of 45 ^{o}C is using 500 J per cycle. Its efficiency is 30% of that for a Carnot engine operating between these temperature limits and using the same amount of heat.

i) Calculate the amount of work performed and the amount of heat wasted by the *real* engine per cycle.
ii) Calculate the net entropy change of the boiler and condenser for the real engine per cycle.

[5]

5. (a) 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^{o}C. 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) Draw a P-V diagram of this cycle. Show in this diagram where heat enters and leaves the gas.
ii) What is the thermal efficiency of the engine?
iii) What must be the temperature of the cold reservoir?
iv) How much heat energy does the engine waste per cycle?
v) What is the maximum pressure that the gas chamber will have to withstand?

(b) Explain how the efficiency of a *real* engine will differ from that of the *ideal* Carnot engine.

[10]

6. A paddle wheel provides 200 kJ of work to the air contained in a 0.2 m^3 rigid and thermally insulated container. The initial pressure of air inside the container is 400 kPa and temperature 40 ^{0}C. The molar heat capacity of air is 20.8 J mol^{1} K^{-1} .

i) Determine the entropy change of the air.
ii) Explain why the entropy of the air is increased.

[7]