Department of Physics
University of California, Berkeley
Physics 7b Section 2
Spring semester 2007
Mid-term examination 1
Tuesday Feb. 20, 6:00 – 8:00 PM

1) (15 points) A cabin in the sierra mountains has walls, floor and ceiling of total area 200 m^2 covered with insulation having an R value of 1.0 $m^2C°/W$ ($R \equiv L/K$, K = thermal conductivity). The cabin is heated by a wood-burning stove. The temperature outside on a winter night is -20 C° while the temperature in the cabin is 20 C°.

   a) Assuming the walls, floor and ceiling all lose heat equally, how much heat/second is lost from the cabin?

   b) The stove provides half its heat through thermal radiation and the other half through conduction+convection. If the stove has an outer surface area of 2 m^2 and is painted black (emissivity = 0.9) what temperature does it have to keep the interior cabin temperature constant?

c) When burned, the wood provides 1720 kcal/kg. If 1 log of wood weighs 3 kg, how many logs/hour are needed to keep the stove at the required temperature?

2) (15 points) A large SUV of mass M_{SUV} is traveling at V_{SUV} when it must stop suddenly due to a traffic jam. Its brakes consist of 4 steel disks (rotors) weighing m_{disk} each.

a) Assuming all the SUVs kinetic energy is absorbed by its brake disks, equally by each disk, by how much will their temperature increase? Evaluate your result taking M_{SUV} = 2000 kg, V_{SUV} = 100 km/hour, and m_{disk} = 5kg.

b) If the disks initially have diameter 40 cm, by what amount will their diameter increase due to this temperature change?

c) Assuming the initial temperature of the brakes was 20 C°, by how much does the entropy of the entire SUV change in coming to a stop?

3) (15 points) A real heat engine working between heat reservoirs at temperatures T_h = 600 K and T_l = 300 K produces 400 J of work per cycle for a heat input of 1000 J.

a) Compare the efficiency of this real engine to that of a Carnot engine operating between the same temperatures

b) Calculate the total entropy change of the universe (engine + environment) for one cycle of the real engine

c) Calculate the total entropy change of the universe for a Carnot engine operating between the same temperatures

d) Show that the difference in work done by these two engines per cycle is $T_l \, \Delta S$, where T_l is the temperature of the low-temperature reservoir (300 K) and ΔS is the entropy increase per cycle of the real engine.

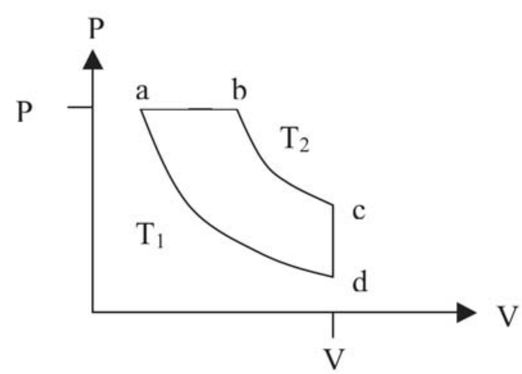
4) (15 points) An ice maker takes in water through a pipe at room temperature T_r and produces ice at $T_i < 0$ C°. When running steadily the ice maker consumes power P and can produce M_i mass of ice in 1 hour. The heat generated from the refrigeration unit of the ice maker is exhausted into the room.

a) How much heat is exhausted by the ice maker in 1 hour of steady running? Evaluate your result using T_r=20 C°, T_i = -10 C°, P = 200 W, and M_i = 5kg.

b) Using the above values, what is the Coefficient of Performance (CP) of the refrigeration unit? Compare that to the ideal CP for these temperatures.

c) Assuming the actual CP scales as the ideal (ie that CP_{actual}/CP_{ideal} = constant), how much extra power is needed to generate ice at the same rate if the room temperature increases 5 C°?

5) (20 points) A system of n moles of ideal gas with constant-volume molar specific heat C_V is made to undergo a cycle (see figure below) with the following stages: (a→b) an isobaric expansion at pressure P, (b→c) an isothermal expansion at temperature T_2, (c→d) an isochoric depressurization at volume V, and (d→a) an isothermal compression at temperature T_1.

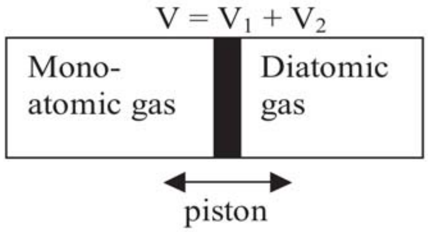


a) What are the change in internal energy of the gas ΔU, the work done by the gas W, and the heat added to the gas Q for each stage of this cycle? Express the results using T_1, T_2, and $T_3 \equiv PV/nR$.

b) What is the efficiency of this cycle?

6) (20 points) A sealed, insulated cylindrical container of volume V contains 1 mole each of monoatomic and diatomic ideal gases. The two gases are separated into opposite ends of the cylinder by a heat-conducting piston that is free to move (see figure). Initially the monoatomic gas has temperature T_m K, the diatomic gas has

temperature T_d K, with $T_d < T_m$. The system is then allowed to reach thermal



equilibrium.

a) What fraction of the volume V is occupied by the different gases initially?

b) If we neglect the heat capacity of the piston, what is the final temperature of the gases at thermal equilibrium?

c) What fraction of the volume V is occupied by the different gases at thermal equilibrium?

d) What is the change in entropy of each gas going from the initial condition to thermal equilibrium? (hint: use a reversible path between the same initial and final states to compute ΔS).