PHYS20352: Thermal and Statistical Physics

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Example Sheet 4

1. Calculate the work done on the system in each of the following two *reversible* processes:

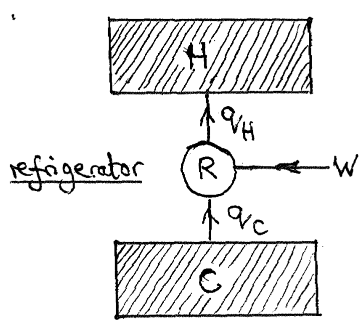
   (i) Isothermal compression of 1 mole of water at a temperature of 273 K from 1 to 2 atmosphere (atm) of pressure (taking 1 atm = 1.013×10^5 N m^{-2}). Use that the density of water is 1000 kg m^{-3} and may be regarded as constant in the pressure range indicated, and that its isothermal bulk modulus, $B \equiv -V(\partial P/\partial V)_T$, at 273 K in the pressure range indicated may be regarded as constant equal to 2×10^9 N m^{-2}. [Hints: Clearly, water is *not* an ideal gas, and therefore you must not use the ideal gas equation of state. Use instead the definition of B and write, $dV = -V_i dP/B$, with constant initial volume V_i and B.]

   (ii) Isothermal stretching of an elastic string from a length of 0.1 m to 0.2 m at a temperature of 273 K. Use that the equation of state relating the tension Γ to the length l at temperature T is given by

$$\Gamma = KT\left[\frac{l}{l_i} - \left(\frac{l_i}{l}\right)^2\right],$$

   where $K = 0.1$ N K^{-1}, and $l_i = 0.1$ m is the unstretched length.

2. (a) In class, the working principle of a refrigerator is shown in the following abstract diagram (physicist's refrigerator). Find out how a real refrigerator in our kitchen works by sketching a diagram, briefly explaining the cycle process, and relating your diagram to our physicist's refrigerator. You may also like to investigate how a power station, a car gasoline engine work in real life and tell us about them.



(b) A refrigerator operates in a room at 20 °C so as to keep the temperature of its interior cabinet at a constant 4 °C. The leakage of heat through the walls of the cabinet is 30 W per degree Kelvin of temperature difference between the interior and exterior. What is the minimum power theoretically required to run the refrigerator? See if you can find data on what a typical modern real refrigerator costs to run, and compare with your answer.

3. (Challenge Question) A vessel with adiabatic walls is initially empty (i.e., it contains a perfect vacuum). It is fitted with a valve to the atmosphere, where the pressure is P_0 and the temperature is T_0. The valve is now opened slightly so that air flows *quasistatically* into the vessel until the pressure within is also P_0. Assuming that the air behaves as an ideal gas with constant heat capacities C_P and C_V, show that the final temperature of the air in the vessel is γT_0, where, as usual, $\gamma \equiv C_P/C_V$.