

**PHYS20352: Thermal and Statistical Physics**  
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**Example Sheet 5**

1. For each of the following three **reversible** processes calculate (a) the work done on the system; (b) the entropy change of the system; and (c) the entropy change of the universe (i.e., the system and its surroundings with which it is in contact thermally or energetically):
  - (i) Isothermal compression of 1 mole of an ideal gas at a temperature of 273 K from 1 to 2 atmosphere (atm) of pressure.
  - (ii) Adiabatic compression of 1 mole of an ideal monatomic gas at an initial temperature of 273 K from 1 to 2 atmosphere (atm) pressure. [Take  $\gamma \equiv C_P/C_V = 5/3$ . You may use the result of Q2(a) of Example Sheet 2.]
  - (iii) Isothermal magnetization of 1 mole of a paramagnetic sample at a temperature of 273 K by an increase in the value of an external magnetic field  $B$  from 1 T to 2 T. Use that the equation of state relating the magnetization  $M$  to the field  $B$  and the temperature  $T$  is

$$M = \frac{CB}{\mu_0 T}$$

where  $C = 0.1$  K, and the molar volume is  $3 \times 10^{-5}$  m<sup>3</sup>. [Note: As discussed in class notes, use  $dW = -VMdB$  and the internal energy  $E = -VMB$ .]

2. Using the definition of entropy,  $dS \equiv dQ^{\text{rev}}/T$ , show that the entropy difference between two states of  $n$  moles of an ideal gas with constant heat capacities,  $C_P$  and  $C_V$ , may be written, in either of the following forms:
  - (a)  $S(T, V) - S(T_0, V_0) = C_V \ln(T/T_0) + nR \ln(V/V_0)$ ,
  - (b)  $S(P, V) - S(P_0, V_0) = C_V \ln(P/P_0) + C_P \ln(V/V_0)$ .
3. A 10 kg block of copper at a temperature of 100 °C is cooled to 10 °C. Calculate the change in entropy of the block, and the corresponding change in entropy of the universe, if the cooling is performed: (a) reversibly; and (b) irreversibly, by immersing the block in a lake of 10 °C. [Note: The specific heat capacity of copper may be regarded as constant over the temperature range indicated, with a value of 375 J/(kg K)]
4. Calculate the entropy change of the universe [i.e., water plus heat bath(s)] when 1 kg of water at 20 °C is heated to 80 °C by

- (a) placing it into thermal contact with a heat bath at 80 °C and waiting until equilibrium has been reached; and
- (b) successively placing it into heat baths at 50 °C and 80 °C, waiting each time until equilibrium has been reached.

[Note: The specific heat capacity of water may be regarded as constant over the temperature range indicated, with a value of 4.2 J/(g K).]