Year 3 General Physics — Thermal Physics

1. One mole of a monatomic ideal gas has initial temperature T and pressure P. It is compressed isothermally from a volume V to a volume $V/2$
What is the change in the following quantities?

(i) the pressure
(ii) the internal energy
(iii) the entropy
(iv) the temperature

Repeat the exercise for isentropic (i.e. reversible adiabatic) compression.

2. The thermal conductivity of aluminum is 200 W m^{-1} K^{-1}. What will be the rate of heat flow along a cylindrical aluminum bar of length 10 cm and diameter 10 mm when the temperature difference between the ends is 20 K.

3. An object of heat capacity C and high temperature T_h is thermally connected to a second identical object of heat capacity C and low temperature T_c. When the two masses have come into thermal equilibrium, what is the change in entropy of the universe and what is its sign?

4. A box contains ten distinguishable atoms which each have two possible energy levels, 0 and ε, in thermal equilibrium. What is the entropy of the system when the number of atoms having energy ε is 3. How many atoms would need to have energy level ε for the entropy to be a maximum?

5. An atom of mass m is in a 1-dimensional quantum harmonic oscillator potential with spring constant k_S. The atom is in thermal contact with a reservoir of temperature T. What is the ratio of the probabilities of finding the atom in the third excited vibrational state to that in the ground state?

6. A reversible heat pump is used to take heat from a river at temperature 10°C into building at temperature 20°C. If the power dissipated in the building is 100 kW, how much electrical power is required to drive the pump?

7. Two large flat plates are parallel and are separated by a distance very much less than their lateral dimensions. If one plate is at temperature T_1 and the other at temperature T_2 what is the rate of thermal energy transfer between them per unit area, assuming the emissivity of both plates is unity? By how much would the rate be affected if the emissivity of both plates were 0.5?

8. A thin horizontal circular disc of mass m and radius r is suspended by a torsion wire with torsional stiffness k_S attached to its centre, so that the disc oscillates about the vertical axis. What is the oscillation frequency and what is the rms angular velocity when the system is at temperature T?