Foundations of Physics 2B/3C 2019-2020

Thermodynamics – Workshop 5 Problems

Week Commencing 11th November

1. Unavailable work

This problem considers work that becomes unavailable when heat is transferred to gas in a piston, which expands against a resistive force. The final part shows how this is equivalent to the "lost" work in a Carnot engine and fridge pair.

A cylinder, orientated vertically in the atmosphere at a temperature of $300\ \mathrm{K}$, has a heavy piston head covering it. The piston is of area $0.05\ \mathrm{m}^2$ and the piston head's mass is $50\ \mathrm{kg}$. The piston contains $0.05\ \mathrm{m}^3$ of ideal gas at a pressure of $500\ \mathrm{kPa}$ and temperature of $350\ \mathrm{K}$, and it is connected to a furnace at a temperature of $1000\ \mathrm{K}$, allowing heat to be transferred from the furnace to the piston. During this heat transfer, the volume of gas in the cylinder quadruples, isothermally. The furnace and cylinder are thermally isolated, meaning that no heat gets transferred to the environment during this expansion.

a) How much work is done by the gas in the piston altogether?
b) How much work must be done to overcome any resistive forces? [Hint: think what the resistive forces are before starting this, there are two!]
c) How much useful work is done in this process?
d) What is the irreversibility of the process?
e) Calculate the irreversibility using two appropriately connected reversible heat cycles, one engine and one heat pump. [Hint: A heat engine takes in the required heat energy from the furnace to produce some work. A proportion of the work is used to drive a heat pump, putting the required amount of heat energy into the gas.]