Problem #1

A system composed of 5 moles of an ideal gas monatomic gas undergoes a quasistatic process at a constant pressure $1.0 \times 10^5$ Pa, in which the temperature change from 300°K to 500°K.

(a) Calculate the change in internal energy, $\Delta U$. (3%)

(b) Obtain the external work done on the gas. (3%)

(c) The volume is returned to its initial value while keeping the internal energy, $U$, constant. Calculate the external work done on the gas in this process, assuming it to be quasistatic. (3%)

(d) The gas is finally cooled to 300°K while the volume stays fixed. Determine the work done on the gas in this process. (3%)

Problem #2

A volume contains 4 kg of helium initially. The temperature is 2000°K and the pressure is 1 MPa. The gas is cooled while the volume changes quasistatically in a process conducted so that $PV^\gamma = \text{constant}$. The final temperature is 500°K.

Determine the change in entropy by calculating $\int \frac{Q}{T}$ over the path of the process. (8%)

Problem #3

(a) Given a heat source at 1500°C which can provide heat at a rate of 500 MW, and a heat sink at 20°C, what is the maximum rate of performing mechanical work on an external system? What are the maximum and minimum rates at which heat may be input to the sink at 20°C? (5%)

(b) Repeat (a) for a source temperature of 50°C. What do you infer about the effect of the temperature of the source of heat on the opportunity to perform work? (5%)

(c) Given source and sink temperatures of 327°C and 27°C, classify the following cycles (referring to attached figure) as reversible, irreversible, or unphysical, given reasons. All quantities are in joule.

(i) $Q_1 = 1000$, $W = 300$, $Q_2 = 700$;
(ii) $Q_1 = 500$, $W = 250$, $Q_2 = 350$;
(iii) $Q_1 = 700$, $W = 400$, $Q_2 = 300$;
(iv) $Q_1 = 800$, $W = 400$, $Q_2 = 400$;
(v) $Q_1 = 400$, $W = 800$, $Q_2 = -400$. (5%)
Problem #4
A system with heat capacity at constant volume of \( C_v = AT \), where \( A = 0.02 \) cal/°K, is originally at 200°C. A thermal reservoir at 50°C is available. What is the maximum amount of work that can be recovered as the system is cooled down to the temperature of the reservoir? (8%)
Problem #8

Joule and Thomson showed experimentally that when stream of non-ideal gas passed through a thermally insulated tube, in which is inserted a throttle valve, the temperature of the gas changes and the state of the gas is changed from \((P_1, T_1)\) to \((P_2, T_2)\). Show that this process is isenthalpic. The change in \(T\) is described in terms of the Joule-Thomson coefficient, \(\mu_{J-T}\), as

\[
\mu_{J-T} = \left( \frac{\partial T}{\partial P} \right)_H.
\]

Show that

\[
\mu_{J-T} = -\frac{V}{c_p} (1 - \alpha T)
\]

and show that the Joule-Thomson coefficient for ideal gas is zero. (20%)