

Problem Set 8

Problems

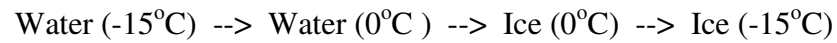
1. What is the maximum possible efficiency of a heat engine that has a hot reservoir of water boiling under pressure at 125°C and a cold reservoir at 25°C?
2. A modern steam turbine operates at a temperature of 811K. The cold reservoir is at 310K. Calculate the theoretical efficiency of the turbine. For every 100J of heat input to the turbine at the hot reservoir, how many Joules of work are produced, and how many Joules of heat are ejected to the cold reservoir? To increase the theoretical efficiency by 2%, to what temperature would the hot reservoir have to be raised if the temperature of the cold reservoir were constant?
[Ans. 837.8 K]
3. Consider a General Motors 425 in³ V8 engine with a compression ratio of 8/1. Take the gas in the engine's cylinders to be Ideal with a heat capacity of $C_v \sim 21$ Joule/K mole. Assume the engine is operating reversibly as an ideal Otto Cycle. What is the efficiency of the engine?
4. Consider the following cycle using 1 mole of an Ideal Gas, initially at 25°C and 1 atm pressure.

Step 1: Isothermal expansion against zero pressure to double the volume.
Step 2: Isothermal, reversible compression from 0.5 atm to 1 atm.

a) Calculate the value of:
$$\oint \frac{\delta Q}{T}$$

b) Calculate ΔS_2 .
c) Find ΔS_1 given that $\Delta S_{\text{cycle}} = 0$.
d) Show that ΔS_1 is not equal to Q_1 divided by T.
5. Show that two adiabats on a P-V diagram cannot cross. (Hint: Show that if they did cross, a cyclic engine could be constructed that would violate the Second Law.)
6. Consider freezing 100g of Supercooled Water in a flask immersed in an Ice-Salt bath at -15°C.

a) Calculate ΔS for this process. A reversible path for this process is:



b) Calculate Q_{irr}/T for this process. You can use the Reversible path to calculate Q_{irr} because the pressure is constant, hence $Q = \Delta H$, and the Enthalpy is a state function.

Hint: For a constant pressure process, $\delta Q = C_p dT$.

Needed data:

$$\begin{array}{lll} C_p^{\circ} & = & 1.01 \text{ cal/gK} \quad \text{for Supercooled Water} \\ C_p^{\circ} & = & 0.50 \text{ cal/gK} \quad \text{for Ice} \\ \Delta H_{\text{fus}}^{\circ} & = & 79.7 \text{ cal/g} \quad \text{for Water} \end{array}$$