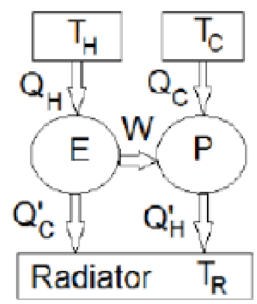
AS1300: Thermodynamics for Aerospace Engineers
TUTORIAL 5: Second Law of Thermodynamics

1. A steady state refrigerator whose COP is 2.5 removes energy by heat transfer from a freezer cabinet at 0°C at the rate of 8000kJ/h and discharges energy by heat transfer to the surroundings, which is at 20°C. Determine the power input to the refrigerator and compare with the power required by a reversible refrigerator cycle operating between reservoirs at these two reservoirs.

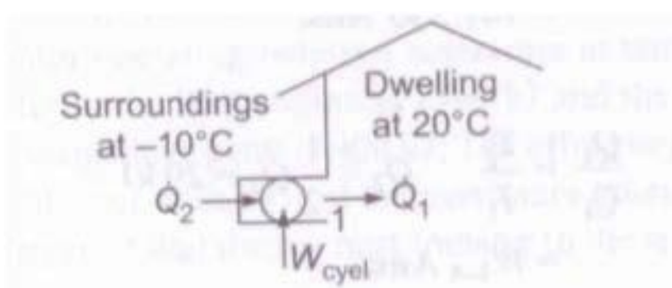
2. An inventor claims to have developed an engine that takes in 105 MJ at a temperature of 400 K, rejects heat at a temperature 200 K, and delivers 17.5 kWh of mechanical work. Would you advise investing money to put this engine in the market?

3. A reversible power cycle operates between a reservoir at temperature T and a lower temperature reservoir at 200 K. At steady state, the cycle develops 40 kW of power while rejecting 1000 kJ/min of energy by heat transfer to the cold reservoir. Determine T.

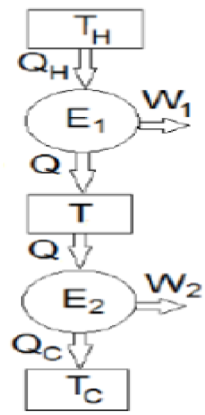
4. A heat engine is used to drive a heat pump. The heat transfers from the heat engine and from the heat pump are used to heat water circulating through the radiators of a building. The efficiency of the heat engine is 29% and the COP of the pump is 3.5. Evaluate the ratio of heat transfer to the radiator water to the heat transfer to the heat engine.



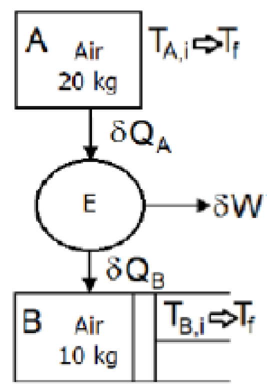
5. When the outside temperature is -10 $°C$,a residential heat pump must provide $3.5 \times 10^6\ kJ$ per day to a dwelling to maintain its temperature at 20 $°C$. If the electricity costs Rs. 5.0 per kWh, determine the minimum theoretical operating cost for each day operation.



6. Two reservoir power cycles are arranged in series. The first cycle receives energy from a reservoir at T_H and rejects heat at an intermediate temperature T. The second cycle receives the energy rejected by the first cycle to the reservoir at T and rejects energy to reservoir at a temperature T_C lower than T. Derive an expression for the intermediate temperature T in terms of T_H and T_C when:
   (a) the net work of the two cycles are equal
   (b) the thermal efficiencies of the two cycles are equal.



7. A constant volume tank contains 20kg of air at 1000K and a constant pressure device contains 10kg of air at 300K. A heat engine placed between the tank and the device extracts heat from the high temperature tank, produces work and rejects heat to the low temperature device. Determine the maximum work that can be produced by the heat engine and the final temperatures of the air in the tank and the device.



8. A refrigeration cycle having a COP of 3 maintains a computer laboratory at 18°C on a day when the outside temperature is 30°C. The thermal load at steady state consists of energy entering through the walls and windows at a rate of 30,000 kJ/hr and from the occupants, computers and lighting at a rate of 6000 kJ/hr. Determine the power required by this cycle and compare with the minimum theoretical power required for any refrigeration cycle operating under the conditions.

9. A reversible engine works between 3 thermal reservoirs A, B and C as shown in the figure. The engine absorbs an equal amount of heat from the thermal reservoirs A and B kept at temperatures T_A and T_B respectively, and rejects heat to the thermal reservoir C kept at temperature T_C. The efficiency of the engine is α times the efficiency of the reversible engine, which works between the 2 reservoirs A and C. Prove that $\frac{T_A}{T_B} = (2\alpha - 1) + \frac{2(\alpha-1)T_A}{T_C}$.