Due: 13 Nov 2024

Energy: Science, Technology, and Society

Homework Set 5

1. Heat Capacity and Sensible Heat Storage

Several materials are considered for short-term storage of energy from intermittent power plants. The heat capacities of water, granite and molten $NaNO_3/KNO_3$ salt are

a) $C_{p,W}$=4190 J/kg^{0}C,

b) $C_{p,G}$=790 J/kg^{0}C, and

c) $C_{p,S}$=1550 J/kg^{0}C, respectively.

Calculate the heat that can be stored in 125m^3 of each of these materials **a)-c)** when heated from 30^{0}C to 100^{0}C.

2. Conversion of Energy and Power

Local weather during the summer months (June-August) produces often physiologically uncomfortably high air temperatures, which leads many home renters to invest in air conditioning (A/C) units. The pictured electrical (120V, 15A) window unit is advertised at a sale price of $399.- and should deliver a thermal cooling power of *10,000* **BTU**. Since this is considered sufficient to cool down a renter's room of size 18'x25'x9' the unit is purchased with the intention to utilize it during 4 summers, more or less continuously for 8 hrs per day.

a) How much energy *Q* (unit: **kWh**) is needed to cool the room air from 35^{0}C to 20^{0}C ?

b) For how much heat loss $\dot{Q} = dQ/dt$ (unit: **kW**)from the room air to the outside can the A/C unit compensate, if running continuously?

c) Given a local electricity price of $0.12/kWh, how much does the operation of the unit contribute to the monthly electricity bill during the summer months?

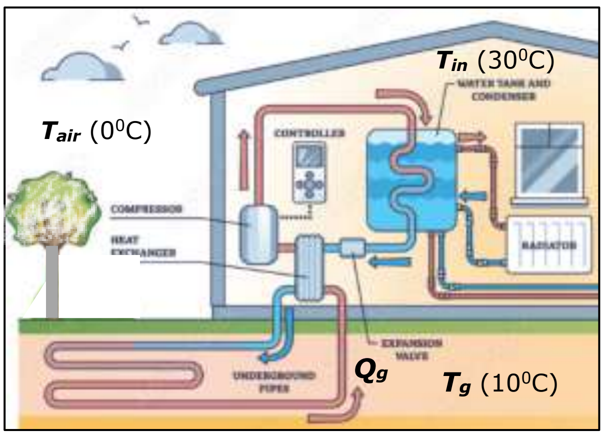
d) How much have acquisition and operation of the A/C unit cost over the entire 4 years?

Useful information: Heat capacity for air at 300 K at atmospheric pressure is C_P = ***1.00*** **kJ/kg**

The molar volume of air (*78*% N_2, *21*% O_2, 0.9% Ar) is V_M=***22.41*****L**.

3. <u>In-Ground Heat Pump</u>

The upper soil layer in most built-up regions in the country has a high heat capacity (1.5kJ/kg·°K) and thermal inertia. As a result, this layer does not exhibit large changes in temperature with the seasons. At d=10m depth, the ground has a fairly constant temperature of T_g (10^0C) throughout the year. Hence, the ground is colder than the air (T_{air}) during summer and warmer in winter. This temperature difference is used in heat pumps like the one illustrated. Such pumps are driven by externally supplied electricity. During winter, they work (w) to add heat energy Q_g recovered from the ground to a building and heat it to an inside temperature T_{in}. During summer, heat Q_{in} is subtracted from the building, to cool it, and dumped into the ground. Heat exchangers transport heat from the working fluid (or gas) to and from the building, and through the underground pipes. The compressor generates a working fluid at high pressure and high temperature, which transfers heat to an inside hot-water tank. The cooler work fluid is allowed to expand and cool further by passing through an expansion valve.



a) Calculate the heat Q_{in} required to sustain the temperature difference between inside and outside. (heat capacity of air C_{air}= 700 J/kg·°K)

b) Describe how the heat pump can be modeled in terms of a Carnot process moving heat between reservoirs.

c) Using this Carnot model, calculate the work the compressor has to perform, In order to sustain the inside temperature.