Sem-III - Thermal Physics II

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Assignment II: 1^{st} & 2^{nd} law of Thermodynamics

Submission due date: 23/08/2019

Q.1) If a gas is both ideal and paramagnetic obeying Curie's law, show that the entropy is given by

$$S = c_{V,M} lnT + nRlnV - \frac{M^2}{2C_c'} + constant,$$

where $c_{V,M}$ is the heat capacity at constant volume, magnetization assumed constant and C_c' is Curie's constant.

Q.2) The equation of state of a novel matter is $PV = AT^3$ with A a constant. The internal energy of the matter is $U = BT^n ln(V/V_0) + f(T)$. Using first law of thermodynamics, find B and n.

Q.3) Suppose an engine works between two reservoirs at T_1 and $T_2 (T_2 > T_1)$ until both reservoirs attain final temperature T_c. Show that $T_c > \sqrt{T_1 T_2}$. What is the maximum amount of work obtainable from this engine?

Q.4) A Carnot engine has an efficiency of 30% when the sink temperature is $27°C$. What must be the change in temperature of the source to make its efficiency 50%?

Q.5) An inventor claims to have developed an engine working between $600K$ and $300K$ to deliver an efficiency of 52%. Using Carnot's theorem, can you decipher whether this claim is valid?

Q.6) Two Carnot engines X and Y are operating in series. X receives heat at $1200K$ and rejects to a reservoir at temperature TK. The second engine Y receives the heat rejected by X and inturn rejects to a heat reservoir at $300K$. Calculate the temperature T for the situation when, (i) The work output of two engines are equal, (ii) The efficiency of two engines are equal.

Q.7) A Carnot's refrigerator takes heat from water at $0°C$ and discards it to a room temperature. $1Kg$ of water at $0°C$ is to be changed into ice at $0°C$. How many calories of heat are discarded to the room? What is the work done by the refrigerator in this process? What is the coefficient of performance $[P = Q_{cold}/(Q_{hot} - Q_{cold})]$ of the machine? Given, room temperature is $27°C$ and $1Cal = 4.2Joule$.

Q.8) A thermally conducting bar of length L, area A, density ρ is brought to a nonuniform temperature distribution by sandwiching between hot (temperature T_h) and cold reservoir (temperature T_c). The bar is removed from reservoirs, thermally insulated and kept at constant pressure. Show that the change in entropy of the bar is

$$\Delta S = c_p \rho AL \Big\{ 1 + ln\Big(\frac{T_h + T_c}{2}\Big) + \frac{T_c}{T_h - T_c} lnT_c - \frac{T_h}{T_h - T_c} lnT_h \Big\}.$$