Thermal Physics II

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Assignment I

Q.1) Systems A, B, and C are gases with coordinates $(P, V), (P', V'), (P'', V'')$. When A and C are in thermal equilibrium, the equation

$$PV - nbP - P'V' = 0$$

is found to be satisfied. When B and C are in thermal equilibrium, the relation

$$P'V' - P''V'' + \frac{nB'P''V''}{V'} = 0$$

holds. The symbols n, b and B' are constants. (a) What are the three functions which are equal to one another at thermal equilibrium and each of which is equal to an empirical temperature T? (b) What is the relation expressing thermal equilibrium between A and B?

Q.2) A liquid is irregularly stirred in a well-insulated container and thereby undergoes a rise in temperature. If we regard the liquid as the system, (a) Has heat been transferred? (b) Has work been done? (c) What is the sign of ΔU?

Q.3) 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.4) 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.5) 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.6) 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.7) An inventor claims to have developed an engine working between $600K$ and $300K$ to deliver an efficiency of 52%. Using Carnot's theoretm, can you decipher whether this claim is valid?

Q.8) 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.9) 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.10) 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

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