## Sem-II - Thermal Physics

**(Instructor: AKB, Department of Physics, Asutosh College)**

**Assignment III: $1^{st} - 2^{nd}$ law of Thermodynamics & Pure Substances**

**Submission due date: 06/07/2025**

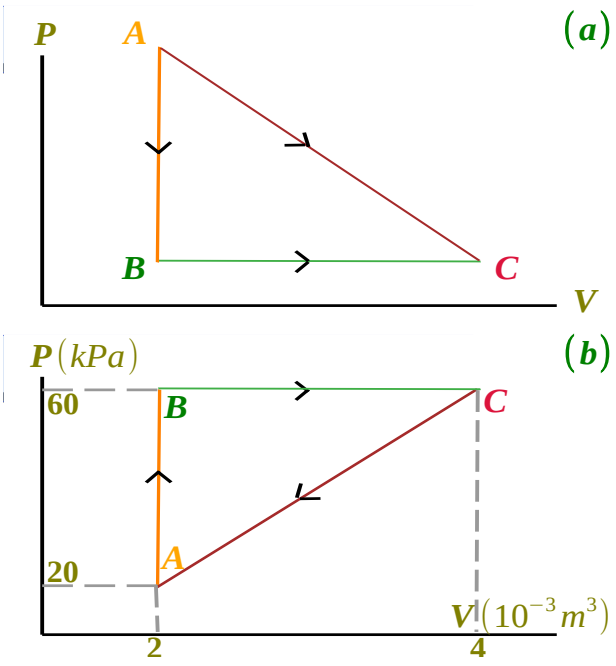
**Q.1)** If a gas is both ideal and paramagnetic obeying Curie's law, show that the entropy is given by

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

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

**Q.2)** **(a)** A given quantity of gas is taken from the state $A \rightarrow C$ by two different paths as shown beside in the upper half panel of the figures, $A \rightarrow C$ and $A \rightarrow B \rightarrow C$. During the process $A \rightarrow C$ the work done by the gas is $100J$ and the heat absorbed is $150J$. If during the process $A \rightarrow B \rightarrow C$, the work done by the gas is $30J$, what will be the heat absorbed?

**(b)** In the cycle $ABC$ shown beside in the lower panel of the figures beside, heat is added to a thermodynamic system in the process $AB$ and $BC$ are $400J$ and $100J$ respectively. Heat rejected during the process $CA$ is $460J$. Find its efficiency.




**Q.4)** 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.5)** 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.6)** 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.7)** 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.8)** 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.9)** A thermally conducting bar of length $L$, area $A$, density $\rho$ 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

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

**Q.10)** A heat engine is operated between two bodies that are kept at constant pressure. The constant pressure heat capacity $C_p$ of the reservoirs is independent of temperature. Initially the reservoirs are at temperature $300K$ and $402K$. If after some time come to a common final temperature $T_f$, the process remaining adiabatic, what is the value of $T_f$ in Kelvin?