



Uva Wellassa University, Sri Lanka
B.Tech. Degree Programme
End Semester Examination- Semester 1
January - 2009



SCT 254-1 THERMODYNAMICS

Answer four (4) questions only

Time: One (01) Hour

1. (a) What do you mean by a thermodynamic system, surrounding, boundary, state of a system, thermodynamic variables and a process.
- (b) Use an indicator diagram (p - v diagram) to show the initial and final states of a system undergoing an expansion.
- (c) A reversible process is an ideal process which can never be achieved in reality. Explain.

(25 marks)

2. State the Zeroth law of thermodynamics and show how it enables us to define the concept of *temperature*, T . For an isochoric process of a substance, obtain the relationship

$$dp = \alpha E_T dT.$$

starting from the equation of state $p = p(v, T)$, where all the parameters have their usual meanings.

In an experiment, a high purity block of Copper whose expansivity $\alpha = 48.0 \times 10^{-6} \text{ K}^{-1}$ and isothermal elasticity $E_T = 1.30 \times 10^{11} \text{ Nm}^{-2}$, is used as a heat reservoir to control the temperature of a sample kept in a vacuum. The sample is attached mechanically directly to the Copper block using small Copper rod with the same purity. Initially the sample, Copper block and the rod are at 130 K and the system is in thermal equilibrium. Subsequently the temperature of the Copper block is increased and is allowed to reach the room temperature. Given there is no change in the volume of the Copper block in this process, calculate the change in pressure felt by the sample in mbars. State any assumptions you made in your calculations.

(1 mbar = 100 Nm^{-2})

(25 marks)

3. Write the first law of thermodynamics for a non-diffusively interacting system explaining each term in the expression.

For an ideal gas enclosed in a perfectly insulated cylinder by an insulated, frictionless and weightless piston, obtain an expression for the total work done during an expansion.

1Kg of water is boiled under a pressure of 2 atm at 120 °C. If the volumes occupied by water and steam is under given conditions are respectively 10^{-3} m^3 and 0.824 m^3 , calculate the increase in internal energy in this process given $L = 2.24 \times 10^6 \text{ Jkg}^{-1}$, and $1 \text{ atm} = 1.013 \times 10^5 \text{ Nm}^{-2}$. ($L =$ latent heat of vaporization).

(25 marks)

4. Explain what do you mean by an adiabatic change in a system? Show that if a gas is allowed to expand adiabatically, a cooling is produced in the gas due to the fall of temperature.

Using the results you obtained above or otherwise, obtain the relationship

$$TV^{\gamma-1} = \text{constant}$$

for an adiabatic transformation of one mole of an ideal gas where γ is the ratio between the two specific heat capacities of the gas, $\left(\gamma = \frac{C_p}{C_v}\right)$, T is the temperature and V is the volume of the gas.

A sample of gas initially at 300 K is suddenly compressed to one third of its initial volume. If the rise in the temperature (i.e., $\Delta T = T_2 - T_1$) of the gas is 187 K, calculate the value of γ .

(25 marks)

5. State the Kelvin-Planck and the Clausius forms of the second law of thermodynamics.

Explain the operation principle of a heat engine and show that the efficiency, η , of such a heat engine depends only on the quantity of heat absorbed (Q_1) from and rejected (Q_2) to the respective heat reservoirs where $Q_1 > Q_2$.

An ideal refrigerator can be constructed by reversing the processes of a Carnot's heat engine where heat is extracted from the lower temperature reservoir and transferred to the higher temperature reservoir. The working principle of the domestic refrigerators is also the same as described above and are operated between the temperatures of melting ice (0°C) and that of atmosphere at 25°C . Calculate the energy required to freeze 500 g of water at 0°C for a domestic refrigerator, if the latent heat of fusion of water is equal to 333 kJ/kg .

(25 marks)

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6. Write the mathematical form of the second law of thermodynamics developed by Clausius explaining each term in the equation.

Calculate the entropy change (ΔS) occurs in every step (isothermal and isentropic) in a reversible Carnot's cycle and illustrate the typical Carnot's cycle (P - V diagram) in a T - S diagram.

Show that the increase in entropy, ΔS , of a reversible heat transfer process of a materials is equal to

$$\Delta S = mc \ln \left(\frac{T_2}{T_1} \right) \quad \text{where } m \text{ is the mass and } c \text{ is the}$$

specific heat capacity of the material over the temperature range T_1 to T_2 .

1kg of ice at 0°C is heated to 100°C and converted into steam at the same temperature. Calculate the total entropy change in this process and draw a T - S diagram given the specific heat capacity and the latent heat of vaporization of water are $4.18 \times 10^3 \text{ Jkg}^{-1}\text{K}^{-1}$ and $2.24 \times 10^6 \text{ Jkg}^{-1}$ respectively.

(25 marks)

