Tutorial 1:

- Laws of thermodynamics,
- reversible and irreversible processes,
- entropy;
- Isothermal, adiabatic, isobaric, isochoric processes and entropy changes;
- Otto and Diesel engines

Q1:

A thermally insulated ideal gas is compressed quasi-statically from an initial state with volume V_0 and pressure P_0 to a final state of volume V_f and pressure P_f. Show that the work done on the gas in the process is given by

$$W = \frac{C_v}{R}(P_f V_f - P_o V_o)$$

where C_v and R having standard meanings. *10*

2013

Q2:

In Leh, temperature of ice on a cold winter night is measured as – 20°C. Calculate the change in entropy when 1 kg of ice is converted into steam at 100°C. Given specific heat capacity of ice is 500 cal kg^{-1} K^{-1}, latent heat of ice is $3{\cdot}36 \times 10^5$ J kg^{-1}, latent heat of steam is $2{\cdot}26 \times 10^6$ J kg^{-1} and J = 4·2 J cal^{-1}. *15*

2013

Q3:

One kg of water at 20°C is converted into ice at –10°C at constant pressure. Heat capacity of water is 4,200 J/kg.K and that of ice is 2,100 J/kg.K. Heat of fusion of ice at 0°C is 335×10^3 J/kg. Calculate the total change in entropy of the system. *15*

2014

Q4:

m gram of water at temperature T_1 is isobarically and adiabatically mixed with an equal mass of water at temperature T_2. Show that the change in entropy is given by $\Delta S = 2m\, C_p \ln\left(\frac{T_{av}}{T_{geo}}\right)$, where $T_{av} = \frac{T_1 + T_2}{2}$ and $T_{geo} = \sqrt{T_1 T_2}$. 10

2016

Q5.

A student is working in a physics laboratory, which is at temperature 27 °C, on a sonometer to study formation of stationary waves. The cross-sectional area of the sonometer wire is $0 \cdot 85 \times 10^{-6}\ \mathrm{m}^2$ and a tension of 20 N is applied on it. If the rigid supports are $1 \cdot 2$ m apart and the temperature of the wire drops by 7 °C, calculate the (i) final tension and (ii) fundamental frequency of vibration of the wire. Take, coefficient of linear expansion and isothermal Young's modulus as $1 \cdot 5 \times 10^{-5}\ \mathrm{K}^{-1}$ and $2 \cdot 0 \times 10^{11}\ \mathrm{N\,m}^{-2}$ respectively. 10

2016

Q6:

1 litre of hydrogen at 127 °C and 10^6 dynes/cm^2 pressure expands isothermally until its volume is doubled and then expands adiabatically until its volume is redoubled. Calculate the resulting pressure. ($\gamma = 1 \cdot 42$) 10

2017

Q7:

A reversible engine converts 1/6 of the heat input into work. When the temperature of the sink is reduced by 62 °C, its efficiency is doubled. Find the temperatures of source and sink. 10

2017

Q8:

If the temperature variation of heat capacity is known, how do you calculate the change of entropy during an isochoric process ?
According to Debye's theory of specific heat of a solid, the molar heat capacity of diamond crystal at constant volume varies with temperature (T) as follows :

$$c_v = \frac{12}{5} \pi^4 R \left(\frac{T}{\Theta}\right)^3$$

where R is the molar gas constant = 8·315 J/mol-K and Θ = 2230 K for diamond.
Calculate the change in entropy of diamond of 0·36 g mass when it is heated at constant volume from 0 K to 300 K. *20*

2018

Q9:

The pressure on 100 g of solid copper is increased quasi-statically and isothermally at 0°C from 0 to $0{\cdot}5 \times 10^8$ Pa. Assuming the density and isothermal compressibility to remain at constant values of 8·96 g/cm^3 and $7{\cdot}16 \times 10^{-12}$ Pa^{-1}, respectively, calculate the work done. Comment on the sign and magnitude of work. *15*

2018

Q10:

What is Carnot's theorem ? Prove that Carnot's reversible engine is the most efficient one and no other engine can be more efficient than Carnot's engine. *15*

2019

Q11:

State the first law of thermodynamics for a diffusively interacting system. The temperature of 10 g of air is raised by 2°C at constant volume. Calculate the increase in its internal energy.

Given : $C_v = 0{\cdot}172$ cal g^{-1} °C^{-1} *10*

2020

Q12:

Explain the characteristics of the following thermodynamic processes for a perfect gas :

(i) Isothermal process

(ii) Adiabatic process

(iii) Isobaric process

(iv) Isochoric process

Obtain the expression for the work done by the gas during the above processes. *20*

2021

Q13:

(i) The melting point of tin is 232°C, its latent heat of fusion is 14 cal/g and the specific heat of solid and molten tin are 0·055 and 0·064 cal/g °C respectively. Calculate the change in entropy when 1·0 gm of tin is heated from 100°C to 300°C.

(ii) Calculate the efficiency of an engine having compression ratio 13·8 and expansion ratio 6 and working on diesel cycle. Given $\gamma = 1{\cdot}4$. *10+5*

2021

Q14:

A body of constant heat capacity C_p and a temperature T_i is put into contact with a reservoir at temperature T_f. Equilibrium between the body and the reservoir is established at constant pressure. Determine the total entropy change and prove that it is positive for either sign of $[(T_f - T_i)/T_f]$. Consider $\frac{|T_f - T_i|}{T_f} < 1$. 10

2022

Q15:

A compressor designed to compress air is used instead to compress helium. It is found that the compressor overheats. Explain this effect, assuming that the compression is approximately adiabatic and the starting pressure is same for both the gases. $\left[\gamma_{\text{He}} = \frac{5}{3},\ \gamma_{\text{Air}} = \frac{7}{5}\right]$ 10

2022

Q16:

A gas of interacting atoms has an equation of state and heat capacity at constant volume given by the expressions

$$p(T, V) = aT^{1/2} + bT^3 + cV^{-2}$$
$$C_v(T, V) = dT^{1/2} + eT^2V + f\,T^{1/2}$$

where a through f are constants which are independent of T and V. Find the differential of the internal energy $dU(T, V)$ in terms of dT and dV. 15

2022

Q17:

A thermally insulated cylinder, closed at both ends, is fitted with a frictionless heat-conducting piston which divides the cylinder in two parts. Initially, the piston is clamped in the centre, with one litre of air at 200 K and 2 atm pressure on one side and one litre of air at 300 K and 1 atm pressure on the other side. The piston is released and the system reaches equilibrium in pressure and temperature, with the piston at a new position. Compute the final pressure and temperature. 15

2022

Q18:

A piston-cylinder device initially contains air at 150 kPa and 27°C. At this state, the piston is resting on a pair of stops, as shown in the figure, and the enclosed volume is 400 L. The mass of the piston is such that a 350 kPa pressure is required to move it. The air is now heated until the volume is doubled. Determine :

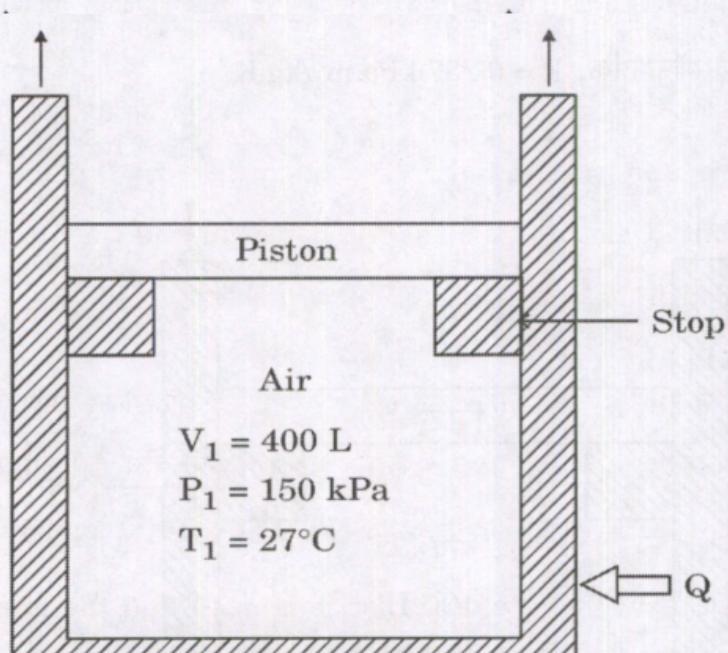
(i) the final temperature,

(ii) the work done by the air, and

(iii) the total heat transferred to air. *20*

Given : $U_{300\ K} = 214$ kJ/kg and $U_{final} = 1113$ kJ/kg

Gas constant of air, $R = 0{\cdot}287$ kPa.m^3/kg.K



2023

Q19:

Using Zeroth law of thermodynamics, introduce the concept of temperature. Explain how the isotherms of two different systems can be drawn. *10*

2023

Q20.

Prove that the work done by a perfect gas during a quasi-static adiabatic expansion is given by

$$W = \frac{P_i V_i}{\gamma - 1}\left[1 - \left(\frac{P_f}{P_i}\right)^{\left(\frac{\gamma-1}{\gamma}\right)}\right]$$

where γ is the ratio of specific heats. 10

2024

Q21.

Explain the T-s diagram for the reversible Carnot cycle and hence obtain the expression for the efficiency of the Carnot engine. 10

2024

Q22.

The specific heat of a solid at low temperatures is given by the relation $C_V = AT^3$, where A is a constant and T is the absolute temperature. How much heat will be required to raise the temperature of m gm of the solid from 300 K to 500 K? 5

2024

Q23.

A reversible heat engine operates with three reservoirs at 300 K, 400 K and 1200 K. It absorbs 1200 kJ energy as heat from the reservoir at 1200 K and delivers 400 kJ work. Determine the heat interactions with the other two reservoirs. *10*

2025