BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE, PILANI (RAJ)
Second Semester (2017-2018)
BITS F111 Thermodynamics
Comprehensive Examination Conceptual (close book)

Max Mark 20+100=120 **Thursday, 3rd May 2018** **Duration 180 min**

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1. **This part of paper is of 20 marks. Five questions of 4 marks each.**
2. **Maximum time for this part of paper is 60 minutes.**
3. Use of Thermodynamics table is permitted.
4. **Space provided is sufficient to solve the question. Do not write anything outside of the box.**

Q 1. Consider two cases for increasing the efficiency of a Carnot Engine: (a) increase the source temperature (T_H) by ΔT while sink temperature (T_L) is constant, (b) Decrease the sink temperature (T_L) by ΔT while source temperature (T_H) is constant. Explain with proof which of these two cases is more effective.

Solution:

The Carnot engine efficiency is given by: $\eta = 1 - \frac{T_L}{T_H}$

Case (a) the Carnot efficiency can be written as: $\eta_I = 1 - \frac{T_L}{T_H + \Delta T}$ (1)

Case (b) The Carnot efficiency can be written as: $\eta_{II} = 1 - \frac{T_L - \Delta T}{T_H}$ (2)

Subtract equation (2) from equation (1)

$$\eta_I - \eta_{II} = \left(1 - \frac{T_L}{T_H + \Delta T}\right) - \left(1 - \frac{T_L - \Delta T}{T_H}\right) = +\frac{T_L - \Delta T}{T_H} - \frac{T_L}{T_H + \Delta T}$$
$$= \frac{(T_L - \Delta T)(T_H + \Delta T) - T_H T_L}{T_H(T_H + \Delta T)} = \frac{T_H T_L + (\Delta T)(T_L - T_H) - T_H T_L}{T_H(T_H + \Delta T)} = \frac{\Delta T(T_L - T_H)}{T_H(T_H + \Delta T)}$$

The denominator is always positive, since $\Delta T > 0$, and $T_L - T_H < 0$

Therefore, $\eta_I - \eta_{II} < 0 \quad or\ \eta_{II} > \eta_I$, we can conclude that case (b) is always better than case (a)

Q 2. A balloon filled with helium at 20 ^{0}C, 100 kPa and a volume of 0.5 m^3 is moving with a velocity of 15 m/s at an elevation of 0.5 km relative to an exergy reference environment for which T_0 = 20 ^{0}C, p_0 = 100 kPa. Using the ideal gas model, determine the specific exergy of the helium, in kJ/kg. Take acceleration due to gravity (g) equal to 9.8 m/s^2.

Conceptual Q1-solution [5 marks from Simanchal]

$e = u-u_0 + P_0(v-v_0) – T_0(s-s_0) + V^2/2 + gZ$

$e = C_v(T-T_0) + P_0(RT/P – RT_0/P_0) – T_0[C_p\ln(T/T_0) – R\ln(P/P_0)] + V^2/2 + gZ$ – 2 Marks

e = 15*15/2 + 9.8*500

e = 5.0125 kJ – 2 Marks (Ans.)

Q 3. Air is flowing steadily in an insulated duct the pressure and temperature measurement of air at two stations A and B are given below. Establish the direction of the flow of air in the duct. Assuming constant specific heat of the air

Properties	A	B
Pressure (kPa)	130	100
Temperature (^{0}C)	50	13

$s_B - s_A$ = 1.005 ln (T_B/T_A)-0.287 ln (pB/pA) =

= 1.005 ln (286/323)-0.287 ln (100/300)= -0.1223+0.0753=-0.047

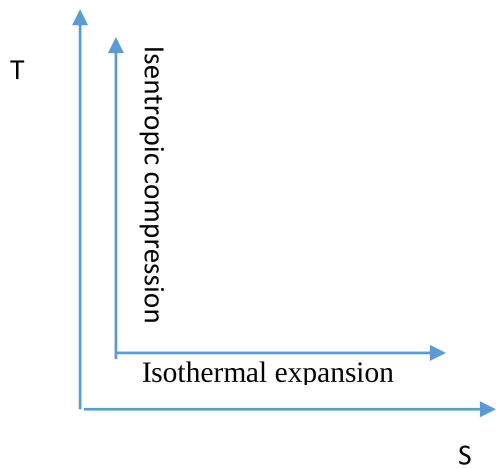
ΔSuniv = -0.047 kJ/kg

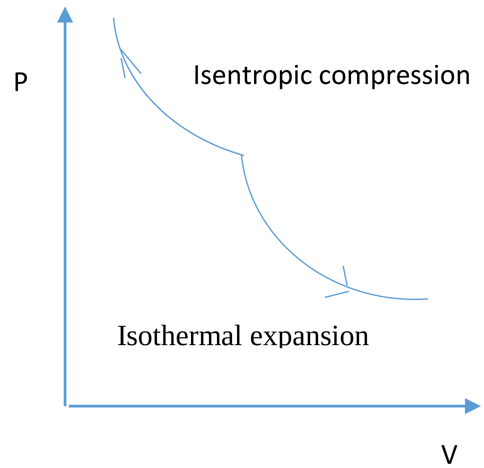
Hence the flow will be from B to A

Q 4. Sketch the T-S and P-V diagrams for an ideal gas undergoing the following transformations, all starting from the same state (V1, P1, T1, S1). **Draw and name** two curves on T-S and two curves on P-V diagram.

i) Isothermal expansion to double the initial volume

ii) Adiabatic and reversible compression to half the initial volume





Q 5. (a) Heat is lost through a plane wall steadily at a rate of 800 W. If the inner and outer surface temperatures of the wall are 20°C and 5°C, respectively, and the environment temperature is 0°C. What is the rate of exergy destruction within the wall?

(b) A block of ice melts when left in a sunny location. Does its exergy increase or decrease? Explain in one sentence.

a)

$$\frac{800}{278} - \frac{800}{293} = S_{gen} = 0.147322\ W/K$$

Exergy destruction= T0 Sgen = 40.22 W

b) Exergy of the system decreases as the system comes in thermodynamics equilibrium with the surrounding. Hence the exergy of the ice decreases as it melts.