BITS, PILANI DUBAI CAMPUS
DUBAI INTERNATIONAL ACADEMIC CITY, DUBAI
I Year Second Semester 2012-2013

BITS F111 Thermodynamics

Comprehensive Examination [Closed Book]

Max.Marks:80 COMMON TO ALL BRANCHES **Date: 08-06-2013**
Weightage: 40 % **Time: 3 hours**

*Note: (i) Answer all Questions in a sequence (ii) Assume suitable value if required (iii) Thermodynamics Datebook is permitted (iv) Answer Every Question on a fresh page (v) Answer the questions of **Part A , Part B and Part C separately.** (vi) This question paper contains three pages.*

PART A

1. A car of mass 2500 kg travels with a velocity of 100 km/h. Find the kinetic energy. How high should the car be lifted in the standard gravitational field to have a potential energy that equals the kinetic energy? **(4 M)**
2. A tank has two rooms separated by a membrane. Room A has 1 kg of air and a volume of 0.5 m^3; room B has 0.75 m^3 of air with density 0.8 kg/m^3. The membrane is broken and the air comes to a uniform state. Find the final density of air. **(4 M)**
3. Saturated vapor R-134a at 50°C changes volume at constant temperature. Find the new pressure, and quality if saturated, if the volume doubles. Repeat the question for the case the volume is reduced to half the original volume. Plot Pv and Tv diagram. **(8 M)**
4. Air goes through a polytropic process from 125 kPa and 325 K to 300 kPa and 500 K. Find the polytropic exponent n and the specific work in the process. **(4 M)**
5. A piston cylinder has 1.5 kg of air at 300 K and 150 kPa. It is now heated up in a two step process. First constant volume to 1000 K (state 2) then followed by a constant pressure process to 1500 K, state 3. Find the final volume and the work in the process. **(4 M)**

PART B

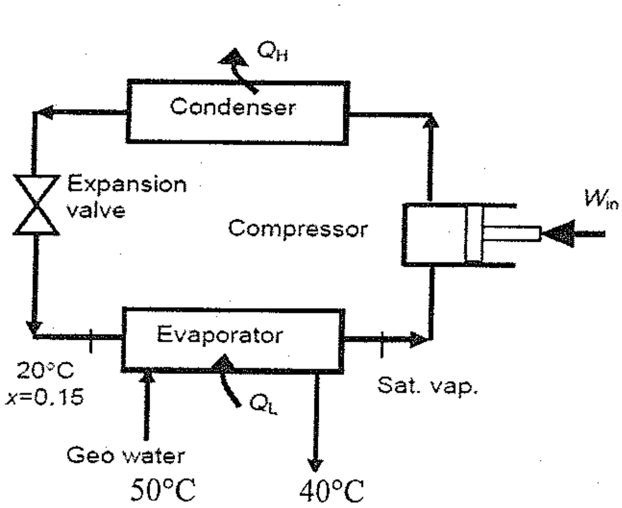
1. An emergency drain pump should be able to pump 0.1 m^3/s liquid water at 15°C, 10 m vertically up delivering it with a velocity of 20 m/s. The isentropic efficiency for the pump is 60%. How much power is needed to drive the pump? **(5 M)**
2. R-134a is throttled in a line flowing at 25°C, 750 kPa with negligible kinetic energy to a pressure of 165 kPa. Find the exit temperature and the ratio of exit pipe diameter to that of the inlet pipe (Dex/Din) so the velocity stays constant. **(6 M)**
3. A windmill with rotor diameter of 30 m takes 40% of the kinetic energy out as shaft work on a day with 20°C and wind speed of 30 km/h. What power is produced assuming the pressure 1 atmosphere? **(5 M)**
4. Water (2 kg) at 200 kPa with a quality of 25% has its temperature raised 20 °C in a constant pressure process. What are the heat transfer and work in the process?**(5 M)**
5. A spring loaded piston/cylinder contains 1.5 kg of air at 27 °C and 160 kPa. It is now heated to 900 K in a process where the pressure is linear in volume to a final volume of twice the initial volume. Plot the process in a P-v diagram and find the work and heat transfer. **(6 M)**

PART C

1. Show the available energy in a T-s diagram for a Carnot Heat Engine. **(2 M)**
2. Air at 1000 kPa, 300 K is throttled to 500 kPa. Find the specific entropy generation? **(4 M)**
3. A household refrigerator with COP of 1.2 removes heat from the refrigerated space at a rate of 60 kJ/min. Determine (a) the electric power consumed by the refrigerator and (b) the rate of heat transfer to the surrounding air. **(4 M)**

4. A geothermal supply of hot water at 476 kPa, 150°C is fed to an insulated flash evaporator at the rate of 1.5 kg/s. A stream of saturated liquid at 200 kPa is drained from the bottom of the chamber and a stream of saturated vapor at 200 kPa is drawn from the top and fed to a turbine. Find the rate of entropy generation in the flash evaporator. **(4 M)**

5. A heat pump with refrigerant-134a as the working fluid is used to keep a space at 25 °C by absorbing heat from geothermal water that enters the evaporator at 50 °C at a rate of 0.065 kg/s and leaves at 40 °C. Refrigerant enters the evaporator at 20 °C with a quality of 15% and leaves at the same pressure as sat.vapour. If 1.2 kW of power is consumed by the compressor, determine (a) the mass flow rate of the refrigerant (b) the rate of heat supply and (c) the COP of the heat pump. **(8 M)**



6. Cast iron blocks of masses 2 kg and 5 kg maintained at 250 °C and 25 °C respectively comes in thermal contact. Find the final temperature and total entropy generated in the process by assuming zero external heat transfer. **(7 M)**

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(1)

BITS PILANI, DUBAI

I Yr. – II SEM. – 2012 – 13.

BITS F111 – THERMODYNAMICS.

Max. Marks: 80.

Date: 8.6.'13.

COMPREHENSIVE EXAM.

ANSWER KEY.

PART A.

1) Std. K.E. of mass $= \frac{1}{2} m V^2$.

$= \frac{1}{2} \times 2500 \times \left(\frac{100 \times 1000}{3600}\right)^2 Nm.$

$= 964661 J = \underline{964.661 kJ}$. (2M)

Std. P.E. $= mgh$. ($\because \frac{1}{2} m v^2 = mgh$)

$\therefore h = \frac{1}{2} m v^2 / mg$.

$= \frac{964661}{2500 \times 9.81} = \underline{39.3 m}$. (2M)

2) $m = m_A + m_B$ ($\rho = m/V$; $\therefore m = \rho \times V$)

$= m_A + \rho_B V_B = 1 + 0.8 \times 0.75 = 1.6 kg$

$V = V_A + V_B = 0.5 + 0.75 = 1.25 m^3$.

$\therefore \rho = \frac{m}{V} = \frac{1.6}{} = 1.28 kg/m^3$. (1M)

3) R-134a.

Table B.5.1 (saturated R-134a vapor)

i) $v_1 = v_g = 0.01512 \ m^3/kg$;

$P_1 = P_{sat} = 1318 \ kPa$

ii) $v_2 = 2v_1$.

$= 2 \times 0.01512 = 0.03024 \ m^3/kg$

(Superheated vapor)

On interpolation between 600 kPa and 800 kPa,

$P_2 = 771 \ kPa$.

iii) $v_3 = v_1/2$

$= 0.01512/2 = 0.00756 \ m^3/kg < v_g$

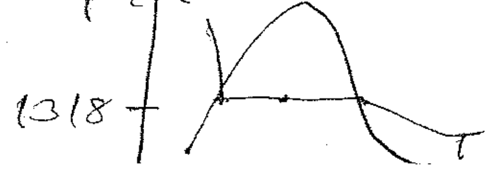
$\Rightarrow$ Two phase

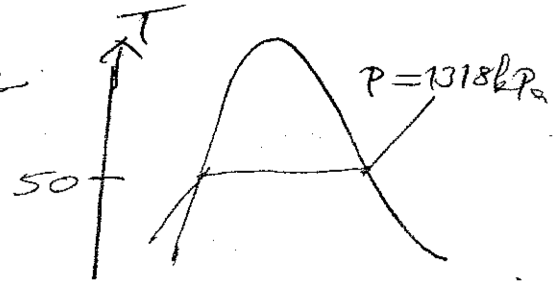
$\therefore x_3 = \dfrac{v_3 - v_f}{v_{fg}}$

$= \dfrac{0.00756 - 0.000908}{0.01422} = 0.4678$

$P_3 = P_{sat} = 1318 \ kPa$.

iv)





$p v^n = \text{constant} = P_1 v_1^n = P_2 v_2^n$ ③

4) Ideal gas eqn : $Pv = RT$.

$$\therefore v_1 = \frac{RT}{P} = \frac{0.287 \times 325}{125}$$

$$v_1 = 0.7462 \, m^3/kg.$$

$$v_2 = \frac{RT}{P} = \frac{0.287 \times 500}{300}$$

$$\therefore v_2 = 0.47833 \, m^3/kg.$$

From process eqn,

$$\left(\frac{P_2}{P_1}\right) = \left(\frac{v_1}{v_2}\right)^n$$

$$\Rightarrow \ln\left(\frac{P_2}{P_1}\right) = n \ln\left(\frac{v_1}{v_2}\right); \quad \therefore n = \ln\left(\frac{P_2}{P_1}\right) \Big/ \ln\left(\frac{v_1}{v_2}\right)$$

$$= \frac{\ln 2.4}{\ln 1.56} = \underline{1.969.}$$

$$W = \frac{P_2 V_2 - P_1 V_1}{1-n} = \frac{mR(T_2 - T_1)}{1-n} \quad (\because PV = mRT)$$

$$\therefore \text{specific work } (w) = \frac{W}{m}.$$

$$w = \frac{R(T_2 - T_1)}{1-n}.$$

$$\therefore w = \frac{0.287(500-325)}{1-1.969} = -51.8 \, kJ/kg$$

Air.

5) Two processes:

i) $1 \to 2$: Constant volume. $V_2 = V_1$.

ii) $2 \to 3$: Constant pressure. $P_3 = P_2$

Ideal gas (air) $\quad PV = mRT$

State 1: $V_1 = \dfrac{mRT_1}{P_1}$

$$V_1 = \frac{1.5 \times 0.287 \times 300}{150}$$

$$\therefore V_1 = 0.861\ m^3$$

State 2: $V_2 = V_1$.

$$\Rightarrow P_2 = P_1 (T_2/T_1).$$
$$= 150 \times (1000/300)$$
$$= 500\ kPa.$$

State 3: $P_3 = P_2$

$$\Rightarrow V_3 = V_2 (T_3/T_2)$$
$$V_3 = 0.861 (1500/1000)$$
$$\therefore V_3 = 1.2915\ m^3.$$

$${}_1W_3 = {}_1W_2 + {}_2W_3 = 0 + {}_2W_3.$$
$$= P_3 (V_3 - V_2)$$
$$\therefore {}_1W_3 = 500 (1.2915 - 0.861) = 215.3\ kJ$$

PART - B

1. Steady flow, no heat transfer.

Energy equation is,

$$\dot{m}_i\left[h_i + \tfrac{1}{2}V_i^2 + gZ_i\right] + \dot{W}_{in} = \dot{m}_e\left[h_e + \tfrac{1}{2}V_e^2 + gZ_e\right]$$

$h_i = h_e$; $\dot{m}_i = \dot{m}_e$; $V_i = 0$; $V_e = 20\ m/s$

$(Z_e - Z_i) = 10\ m$;

$$\therefore \dot{W}_{in} = \dot{m}\left[\tfrac{1}{2}V_e^2 + (g \times 10)\right] \qquad \dot{m} = \frac{\dot{V}}{v} = \frac{0.1}{0.001001} \simeq 100\ kg/s.$$

$$= 100\left[\tfrac{1}{2} \times 20^2 + 9.807 \times 10\right]$$

$$= 29.8\ KW.$$ (3M)

$$\dot{W}_{actual} = \frac{\dot{W}_{in}}{\eta} = \frac{29.8}{0.6} = 50\ KW.$$ (2M)

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2. Energy equation is,

$$h_1 + \tfrac{1}{2}V_1^2 + gZ_1 = h_2 + \tfrac{1}{2}V_2^2 + gZ_2$$

$Z_1 = Z_2$; $V_2 = V_1$

State ① B.S.L. ; $h_1 = 234.59\ (h_f)$; $V_1 = V_f = 0.000829\ m^3/kg.$

$h_2 = h_1$ (throttling process).

$\therefore h_2 = 234.59\ kJ/kg$

State ② $P_2 = 165\ kPa$; $h_2 = 234.59$; Two phase

$\therefore T_2 = T_{sat}\ (165\ kPa) = -15^\circ C$

$$\therefore x = \frac{h_2 - h_f}{h_{fg}} = \frac{234.59 - 180.19}{209} = 0.2603$$

$$V_2 = V_f + xV_{fg} = 0.000746 + 0.2603 \times 0.11932$$

$$= 0.0318\ m^3/kg.$$ (3M)

Continuity equation,

$$\dot{m}_1 = \dot{m}_2 = \rho_1 A_1 V_1 = \rho_2 A_2 V_2$$

ie $$\frac{A_1 V_1}{v_1} = \frac{A_2 V_2}{v_2} \quad ; \quad [V_1 = V_2]$$

$$\therefore \frac{A_2}{A_1} = \frac{v_2}{v_1} = \frac{D_2^2}{D_1^2} = \left(\frac{D_2}{D_1}\right)^2$$

ie $$\left(\frac{D_2}{D_1}\right) = \left(\frac{v_2}{v_1}\right)^{1/2} = \left(\frac{0.0318}{0.000829}\right)^{1/2}$$

$$\boxed{\frac{D_{exit}}{D_{inlet}} = 6.19}$$ (3 M)

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3. Steady state, Single flow, no heat transfer.

Continuity eqn, $\dot{m}_i = \dot{m}_e = \dot{m}$

Energy eqn; $\dot{m}\left[h_i + \frac{1}{2}V_i^2 + gZ_i\right] = \dot{m}\left[h_e + \frac{1}{2}V_e^2 + gZ_e\right] + \dot{W}$.

$$\boxed{\dot{W} = \frac{1}{2}\dot{m}V_i^2 \times 40\%}$$ (2M)

$$\dot{m} = \rho A V = \frac{A V_i}{v_i} \quad ; \quad A = \frac{\pi}{4}D^2 = \frac{\pi}{4} \times 30^2 = 706.85\ m^2$$

$$v_i = \frac{RT_i}{P_i} = \frac{0.287 \times 293}{101.3} = 0.83\ m^3/kg$$

$$V_i = 30\ Km/hr = 8.333\ m/s.$$

$$\therefore 40\% \left[\frac{1}{2}\dot{m}V_i^2\right] = \left[\frac{706.85 \times (8.3333)^3}{0.83} \times \frac{1}{2}\right] \times 0.4$$

(3M)

$$\dot{W} = 98.5\ kW$$

4. Energy equation : $m(u_2 - u_1) = {}_1Q_2 - {}_1W_2$

$P \to$ Constant ; ${}_1W_2 = \int P\,dV = m\,P(v_2 - v_1)$.

State – 1 Twophase ; Table B.1.2. ; $T_1 = T_{sat} = 120.23^\circ C$

$v_1 = v_f + x v_{fg} = 0.001061 + [0.25 \times 0.88467] = 0.2222\ m^3/kg$

$u_1 = 504 + 0.25 \times 2025.02 = 1010.7\ kJ/kg$. (2M)

State-2 $T_2 = T_1 + 20 = 140.23^\circ c$ - S.H. Vapor.

$v_2 = 0.88573 + \frac{20}{(150-120.23)} \times (0.95964 - 0.88573)$ [Interpolate]

150 – 120.23

$v_2 = 0.9354\ m^3/kg$;

$u_2 = 2529.49 + \frac{20}{150-120.23}(2576.87 - 2529.49) = 2561.32$

${}_1W_2 = m P(v_2 - v_1) = 2 \times 200[0.9354 - 0.2222] = 285.3\ kJ$

${}_1Q_2 = 2(2561.32 - 1010.7) + 285.3$ (2M)

$= 3286.5\ kJ$ (1M)

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5. Continuity equation ; $m_2 = m_1 = m$

Energy equation ; $m(u_2 - u_1) = {}_1Q_2 - {}_1W_2$

Pressure is linear in volume ; $T_1 = 300\ K\ (27^\circ c)$.

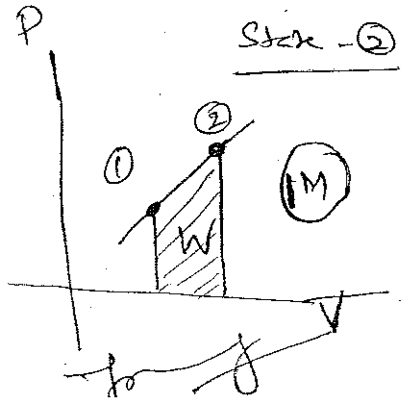
$T_2 = 900\ K$

$\therefore {}_1W_2 = \frac{(P_1 + P_2)}{2} \times (V_2 - V_1)$ $\boxed{V_2 = 2V_1}$

State 1 Ideal gas $\therefore V_1 = \frac{mRT_1}{P_1} = \frac{1.5 \times 0.287 \times 300}{160} = 0.8072\ m^3$

Tab. A.7 $u_1 = u(300\,K) = 214.36\ kJ/kg$. (1M)

State – 2 $P_2V_2 = mRT_2$; $\frac{P_2V_2}{P_1V_1} = \frac{P_2 \times 2}{P_1} = \frac{T_2}{T_1}$



(1M)

$\therefore P_2 = P_1 \times \frac{T_2}{T_1} \times \frac{1}{2} = 160 \times \frac{900}{300} \times \frac{1}{2} = 240\ kPa$ (1M)

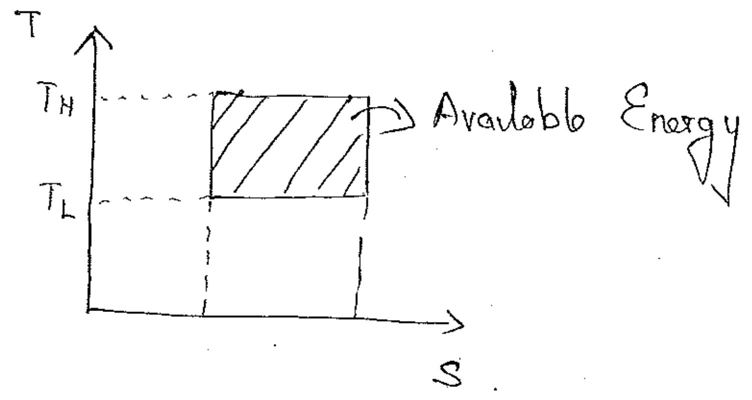
${}_1W_2 = \frac{(160 + 240)}{2} \times 0.8072 = 161.4\ kJ$ (2M)

${}_1Q_2 = 1.5(674.824 - 214.36) + 161.4 = 852.1\ kJ$ (1M)

Part C.

(8)

1)



2) Air ① 1000 kPa $\xrightarrow{\text{throttled}}$ ② 500 kPa.
300 k

∵ throttled under ideal condition, $h_1 = h_2$ ie $(T_1 = T_2)$
$_1Q_2 = 0$.

$$\therefore \quad \Delta S = \cancel{\frac{_1Q_2}{T}}^{0} + {_1S_2}_{gen}.$$

$$\Delta S = C_p \cancel{\ln T_2/T_1}^{0} - R \ln P_2/P_1 = -0.287 \ln \frac{500}{1000}$$

$$= 0.199\ \text{kJ}/\text{kg.k}.$$

$$\therefore \quad {_1S_2}_{gen} = 0.199\ \text{kJ}/\text{kg.k}.$$

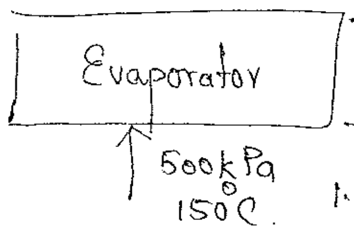
)

$$\beta = \frac{Q_L}{W} = 1.2 \quad ⓐ\ \therefore W = \frac{Q_L}{\beta} = \frac{60\ \text{kJ}/\text{min}}{1.2}$$

$$= 50\ \text{kJ}/\text{min}$$

ⓑ $W = Q_H - Q_L$

$$\therefore Q_H = W + Q_L = 50\ \text{kJ}/\text{min} + 60\ \text{kJ}/\text{min}$$



$\longrightarrow$ Sat Vap at 200 kPa. $h_2 = 2706$ kJ/kg
$S_2 = 7.1271$ kJ/kg K

$\longrightarrow$ Sat. liq at 200 kPa.

1.5 kg/s.

$h_3 = 504.68$ kJ/kg
$S_3 = 1.53$ kJ/kg.k.

4) $h_1 = 632.18$ kJ/kg
$S_1 = 1.8417$ kJ/kgk.

$$\Delta S = \cancel{\frac{{}_1Q_2}{T}}^{\,0} + {}_1S_{2\,gen}.$$

$$\dot m_1 h_1 = \dot m_2 h_2 + \dot m_3 h_3.$$

$$\dot m_1 = \dot m_2 + \dot m_3 . \quad \therefore \dot m_2 = \dot m_1 - \dot m_3 .$$

$$\dot m_1 h_1 = \dot m_2 h_2 + \dot m_3 h_3$$

$$1.5\,(632.18) = \dot m_1 - \dot m_3\,(504.68) + \dot m_3\,(2706)$$

$$\therefore \dot m_3 = 0.087 \text{ kg/s}. \quad \therefore m_2 = 1.5 - 0.087 = 1.413 \text{ kg/s}$$

$$\Delta S = \dot m_2 S_2 + \dot m_3 S_3 - \dot m_1 S_1 = {}_1S_{2\,gen} = 0.0194 \text{ kJ/k}.$$

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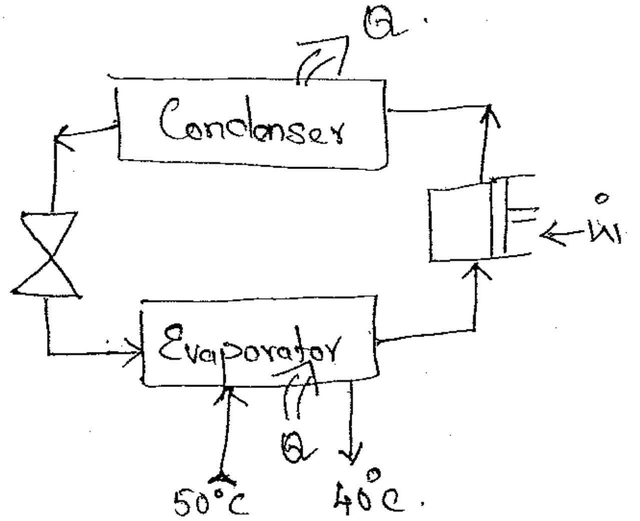
5)



(a). Amt of heat transfered from Geothermal water

$$\dot Q = \dot m\,(h_{50°C} - h_{40°C})$$

$$= 0.065\,(209.31 - 167.54)$$

$$= 2.715 \text{ kW}.$$

In evaporator, $2.715\ kW = \dot{m}\ (409.84 - 254.8)$ (10)

$$\therefore \dot{m} = 0.0175\ kg/s$$

(b) heat supplied by the heat pump

$\dot{W} = 1.2\ kW$; $\dot{Q} = 2.715\ kW$ (removed from geothermal water)

$$\dot{W} = \dot{Q}_H - \dot{Q}_L = \dot{W} + \dot{Q}_L = \dot{Q}_H = 3.915\ kW$$

(c) Cop $\beta' = \dfrac{\dot{Q}_H}{\dot{W}} = 3.915/1.2 = 3.2625\ kw$

A) 2kg 250°C | B) 5kg 25°C

$\Delta V = 0$

$_1Q_2 = 0.$ $\therefore -m_A C_v \Delta T = m_B C_v \Delta T$

as both the blocks are made of iron, $-m_A \Delta T = m_B \Delta$

(1e) $-2(T_2 - 250) = 5(T_2 - 25) \Rightarrow 7T_2 = 625°C \quad \therefore \underline{T_2 = 89°C}.$

$$\Delta S = \cancel{\frac{_1Q_2}{T}}^{\,0} + {}_1S_2\,\text{gen}.$$

$$\Delta S = m_A\, c \ln \frac{T_2}{T_{1A}} + m_B\, c \ln T_2/T_{1B}. \quad (\text{as } \Delta V = 0).$$

$$= 2 \times 0.46 \ln \frac{362}{523} + 5 \times 0.46 \ln \frac{362}{298}$$

$$= -0.3385 + 0.4475 = 0.10897\ kJ/k.$$

BITS, PILANI DUBAI CAMPUS

DUBAI INTERNATIONAL ACADEMIC CITY

SECOND SEMESTER 2012-13

COURSE: BITS F111 Thermodynamics

Test 2 (Open Book)

Max. Marks: 40 **Date: 05.05.13**

Weightage: 20% **Time: 50 min**

Note: Answer all the Questions and Assume suitable value if required

1. Refrigerant -134a enters the condenser of a refrigerator at 1200 kPa and 80 °C and leaves as saturated liquid at the same temperature. Determine the heat transfer from the refrigerant per unit mass. **(3 M)**

2. Steam enters a nozzle at 400° C and 800 kPa with a velocity of 10 m/s and leaves at 300°C and 200 kPa while losing heat at a rate of 25 kW.For an inlet area of 800 cm^2, determine the velocity and volume flow rate of the steam at the nozzle exit. **(8 M)**

3. Air flows steadily at 0.5 kg/s through an air compressor. It enters the compressor at 6 m/s with 100 kPa and 0.85 m^3/kg and leaves at 5 m/s with 700 kPa and 0.16 m^3/kg. The internal energy of the air leaving is 90 kJ/kg greater than that of the air entering. Cooling water in a jacket surrounding the cylinder absorbs heat from the air at the rate of 60 kJ/s. Calculate :

   i) The power required to drive the compressor.

   ii) The inlet and output pipe cross-sectional areas. **(7M)**

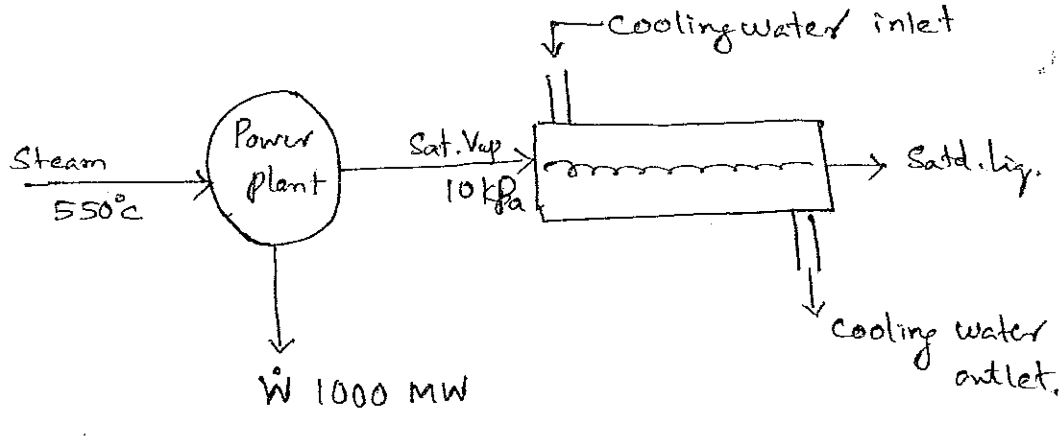
4. Saturated liquid R-134a at 25^0C is throttled to 133.7 kPa in a refrigerator. What is the exit temperature and the increase in the volume flow rate? **(6M)**

5. In a heat exchanger, saturated liquid water at 250 kPa with 60 kg/h enters and leaves as saturated vapor. The heat is supplied in an isothermal manner by a Carnot heat pump

[P.T.O]

operating from a low-temperature reservoir at 19°C. Find the rate of work into the heat pump. **(7 M)**

6. A steam operated 1000 MW Carnot power plant uses steam at 550°C which exits out as saturated vapor at 10 kPa. This is passed in to a condenser and exits as saturated liquid at the same pressure. Cooling water is flowing through the condenser at a rate of 80 kgs^{-1}. Estimate i) Thermal efficiency of the power plant ii) Amount of heat not converted in to work by the power plant iii) Temperature rise of the cooling water. **(9 M)**



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Thermodynamics T2 Open Book.

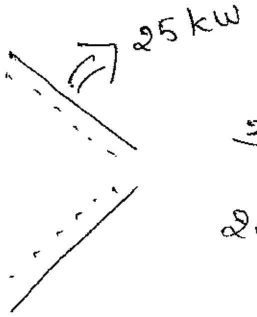
Date: 5.5.'13. Answer key. Max. marks: 40.

(1) (1) 1200 kPa & 80°C R-134a $h_1 = 459.92$ kJ/kg

(2) Sat liq at 80°C $h_2 = 322.79$ kJ/kg

at S.S, $q = h_2 - h_1 = -137.92$ kJ/kg. (3M)

(2). Steam
400°C
800 kPa
10 m/s
800 cm²



300°C
200 kPa

$v_2 = 1.31616\ m^3/kg$

$h_2 = 3071.79$ kJ/kg.

$h_1 = 3267.09$ kJ/kg

$v_1 = 0.38426\ m^3/kg$

$$\dot{m}_1 = \frac{V_1 A_1}{v} = \frac{10 \times 800 \times 10^{-4}}{0.38426} = 2.08\ kg/s$$

at S.S $\dot{m}_1 = \dot{m}_2$

$$\therefore \dot{Q} + \dot{m} h_1 + \tfrac{1}{2} \dot{m} V_1^2 = \tfrac{1}{2} \dot{m} V_2^2 + \dot{m} h_2$$

$$-\frac{25}{2.08} + (3267.09 - 3071.79) + \tfrac{1}{2} \frac{(10)^2}{10^3} = \tfrac{1}{2} V_2^2$$

$$\therefore \boxed{V_2 = 605.5\ m/s}$$

$$\therefore \dot{V}_2 = V.A = \dot{m} \times v = 2.08 \times 1.31616 = 2.74\ m^3/s.$$

(8M)

3.i) Using steady flow energy eqn:

$$u_1 + \frac{V_1^2}{2} + P_1 v_1 + Q = u_2 + \frac{V_2^2}{2} + P_2 v_2 + W$$

$$\therefore W = (u_1 - u_2) + \left(\frac{V_1^2}{2} - \frac{V_2^2}{2}\right) + (P_1 v_1 - P_2 v_2) + Q.$$

$$= -90 + \frac{1}{1000}\left(\frac{6^2}{2} - \frac{5^2}{2}\right) + (P_1 v_1 - P_2 v_2) + Q$$

$$(100 \times 0.85 - 700 \times 0.16) + (-120)$$

$$= \underline{-237 \text{ kJ/kg}}$$

$$\therefore W = 237 \times 0.5 \text{ kJ/s} = \underline{118.5 \text{ kW}}$$

(4M)

ii) $$\dot{m} = \frac{VA}{v}$$

$$\therefore A_1 = \frac{\dot{m} v_1}{V_1} = \frac{0.5 \times 0.85}{6} = \underline{0.0708 \text{ m}^2}$$

$$A_2 = \frac{\dot{m} v_2}{V_2} = \frac{0.5 \times 0.16}{5}$$

$$\therefore \underline{A_2 = 0.016 \text{ m}^2} \text{ (3M)}$$

4) $h_e = h_i = h_{f\,25°C} = 234.59\ kJ/kg$

$= h_{f(e)} + x_e h_{fg(e)}$ at 133.7 kPa

$\therefore T_e = T_{sat}(133.7\ kPa) = \underline{\underline{-20°C}}$.

$$x_e = \frac{h_{(e)} - h_{f(e)}}{h_{fg(e)}} = \frac{234.59 - 173.74}{212.34}$$

$\therefore x_e = \underline{\underline{0.2866}}$.

$v_e = v_f + x_e \cdot v_{fg}$

$= 0.000738 + (0.2866)\,0.19576$

$= 0.0425128\ m^3/kg$

$v_i = v_{f\,25°C} = 0.000829\ m^3/kg$.

$\therefore \dot{V} = \dot{m} v$.

$$\therefore \frac{\dot{V}_e}{\dot{V}_i} = \frac{\cancel{\dot{m}}\, v_e}{\cancel{\dot{m}}\, v_i} = \frac{0.0425128}{0.000829} = \underline{\underline{51.28}}.$$

$\therefore$ Increase is 5128%

(6M)

5. $\dot{m}_1 = \dot{m}_2$ | $\dot{m}h_1 + \dot{Q}_H = \dot{m}h_2$ (energy eqn).

$h_1 = 535.34$ kJ/kg | $h_2 = 2716.89$ kJ/kg

$T_L = 16 + 273.15 = \underline{289.15K}$; $T_H = T_{Sat} = 127.43 + 273.15 = \overline{400.58}$ (1M)

$$\dot{Q}_H = \frac{h_2 - h_1}{\underset{\hookrightarrow hr \to sec.}{60}} = \frac{1}{60}[2716.89 - 535.34] = \underline{\underline{36.36\,kW}}.\quad (2M)$$

Carnot pump; $\beta' = \frac{\dot{Q}_H}{W} \equiv \frac{T_H}{T_H - T_L} = \underline{\underline{3.59}}$

$$\dot{W} = \frac{\dot{Q}_H}{\beta'} = \frac{36.36}{3.59} = \underline{\underline{10.13\,kW}} \quad (4M)$$

---

6. (i) Thermal efficiency: $T_H = 550 + 273.15 = 823.15$ K

(10kpa T_{Sat}) $T_L = 45.81 + 273.15 = 318.96$ K

$$\eta = 1 - \frac{T_L}{T_H} = \underline{\underline{0.62}} \quad (2M)$$

(ii) Exchaust from powerplant 10kPa Satd. Vapor.

$h = \underline{\underline{2584.63}}$ kJ/kg ⇒ heat not converted into work. ($\dot{Q}_L$) (2M)

(iii) Heat taken by the cooling water $= \dot{m}\, C_p \Delta T$.

Heat lost by Satd Vap. in the Condenser $= h_2 - h_1$

$= (191.81 - 2584.63) = -2392.82$ kJ

10kPa, liquid ↓10kPa Vapor (5M)

$\dot{m}\, C_p \Delta T = +2392.82$

$$\Delta T = \frac{+2392.82}{80 \times 4.18} = \underline{\underline{7.15\,K}}$$

BITS, PILANI DUBAI CAMPUS

DUBAI INTERNATIONAL ACADEMIC CITY

SECOND SEMESTER 2012-13

COURSE: BITS F111 Thermodynamics

Test I (Closed Book)

Max. Marks: 50 **Date: 24.03.2013**

Weightage : 25% **Time: 50 min**

Note: Answer all the Questions and Assume suitable value if required

1. A $1 m^3$ container is filled with 300 kg of bricks, 400 kg of coal, 0.2 m^3 of liquid water and the rest of the volume is air. Find the average specific volume and density. **(8)**
2. Two cylinders are filled with liquid water and connected by a line with a closed valve (Fig 1). A has 200 kg and B has 600 kg of water, their cross sectional areas are $A_A = 0.2\ m^2$ and $A_B = 0.5\ m^2$ and the height h is 2m. Find the pressure on each side of the valve. The valve is opened and water flows to an equilibrium. Find the final pressure. **(8)**
3. To what pressure saturated liquid H_2O at 80°C is to be compressed to reduce its volume by 2% through a constant temperature process? Plot the process in a Tv diagram. **(6)**
4. A sealed rigid vessel of 1 m^3 contains saturated mixture of R-134a at 10°C. At 60°C it is converted into a single phase of saturated vapor. Calculate the final pressure and the initial mass of the liquid. Plot the process in a Tv diagram. **(6)**
5. Saturated mixture of NH_3 at 10°C and mass 15 kg in a piston/cylinder with a volume of 1 m^3 is heated to 50°C (at constant pressure). Find the final volume. Plot the process in a Pv diagram. **(6)**
6. A piston –cylinder device contains 0.1 m^3 of liquid water and 0.9 m^3 of water vapor in equilibrium at 800kPa. Heat is transferred at constant pressure until the temp reaches 350°C.

a. Determine the initial temp of water

b. Determine the total mass of water

c. Find the final volume

d. Find the work done during the process,

e. Also represent the process in a P-v diagram. **(10)**

7. Name the different modes of heat transfer and give the relationship between the heat transfer and temperature for all the three modes of heat transfer. **(6)**

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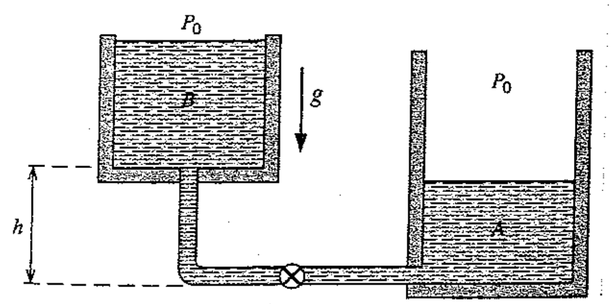


FIGURE. 1

BITS PILANI, DUBAI CAMPUS.

II SEM. - 2012-'13.

BITS F111. THERMODYNAMICS.

Date: 24/3/13. TEST - I. Max. Marks: 50.

ANSWER KEY.

1) $V_{bricks} = m/\rho = 300/1800 = 0.1667\ m^3.$

$V_{coal} = 400/1200 = 0.3333\ m^3.$

$V_{water} = 0.2\ m^3.$

$\therefore V_{air} = V_{TOT.} - (V_{brick} + V_{coal} + V_{water})$

$= 1 - (0.1667 + 0.3333 + 0.2)$

$\therefore V_{air} = 0.3\ m^3.$

$m_{air} = V/v = V\rho = 0.3 \times 1.169 = 0.3507\ kg$

$m_{water} = V\rho = 0.2 \times 997 = 199.4\ kg.$

$\therefore m_{TOT} = 300 + 400 + 199.4 + 0.3507$

$= 899.75\ kg.$

$\therefore v = V_{TOT.}/m_{TOT.} = 1/899.75 = \underline{0.00111\ m^3/kg}$

$\rho = 1/v = 899.75/1 = \underline{899.75\ kg/m^3}$

(8M)

2) $V_A = m_A/\rho = 0.2 = A_A h_A$

$\therefore h_A = \frac{0.2}{0.2} = \underline{1m}.$

$V_B = m_B/\rho = 0.6.$

$\therefore h_B = \frac{0.6}{0.5} = \underline{\underline{1.2m.}}$

$P_{VB} = P_0 + \rho g (h_B + H)$

$= 101000 + 997 \times 9.8 \times 2.2$

$\therefore P_{VB} = \underline{\underline{122495 \text{ Pa}}}.$

$P_{VA} = P_0 + \rho g h_A$

$= 101000 + 997 \times 9.8 \times 1$

$= \underline{\underline{110770 \text{ Pa}}}.$

$V_{TOT.} = V_A + V_B.$

$V_{TOT.} = h_2 A_A + (h_2 - H) A_B$

$\therefore h_2 = \frac{h_A A_A + (h_B + H) A_B}{A_A + A_B}.$

$\therefore h_2 = \frac{0.2 + (2.2) \times 0.5}{0.7} = \underline{\underline{1.857m.}}$

$\therefore P_2 = P_0 + \rho g h_2$

$= 101 + (997 \times 9.8 \times 1.857)/1000.$

$= \underline{\underline{119.1 \text{ kPa}}}.$ (8M).

3. $T_1 = 80^\circ C$; $v_f = 0.001029$ (Tab. B.1.1) $\underline{H_2O}$

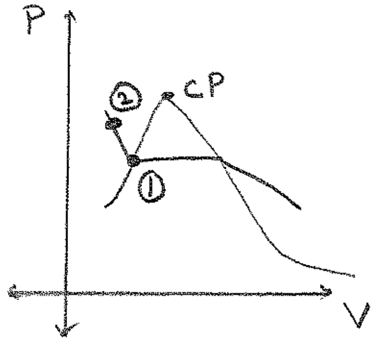
$T_2 = 80^\circ C$; $v_{f(2)} = \frac{98}{100} \times v_{f(1)} = 0.001008 \ m^3/kg$ (6 M)

Tab. B.1.4 ; interpolate for $80^\circ C$ at pressures 30 & 50 MPa,

$$P_2 = 30 + 20\left[\frac{0.001008 - 0.001016}{0.001007 - 0.001016}\right] = \underline{\underline{47.77 \ MPa}}$$

'P' to be compressed is

$\underline{\underline{47.77 \ MPa}}$



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4. $V = \text{Constant}$; $V_1 = V_2$ $\underline{R\text{-}134a}$

State ① $10^\circ C$; $v_1 = 0.01146 (v_2)$

State ② $60^\circ C$ Satd. Vap.

$P_2 = P_{sat} = \underline{\underline{1681.8 \ kPa}}$

$v_2 = 0.01146 \ m^3/kg$

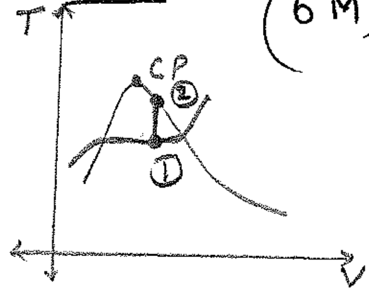
$x_1 = \frac{v_1 - v_{fx}}{v_{fg}} = \frac{0.01146 - 0.000794}{0.04866}$

$\underline{\underline{x_1 = 0.219}}$

(6 M)

$m = \frac{V}{v_1} = \frac{1}{0.01146} = 87.26 \ kg$

$m_{liq} = (1 - x_1) m = \underline{\underline{68.15 \ kg}}$



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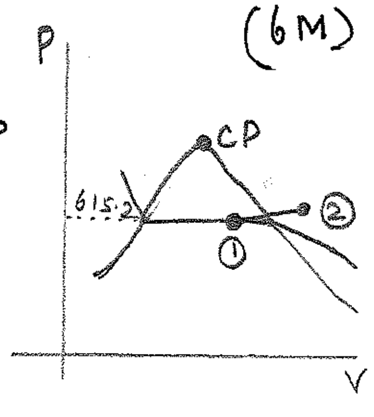
5. ① $P_1 = P_2$; $10^\circ C$ – $P_1 = P_{satd} = 615.2 \ kPa$ (6M)

$\underline{NH_3}$ $m_1 = m_2 = 15 \ kg$; $v_1 = \frac{V}{m} = \frac{1}{15} = 0.0666$

$x_1 = \frac{v - v_f}{v_{fg}} = \frac{0.0666 - 0.001600}{0.20381} = \underline{\underline{0.319}}$



② $50^\circ C$; $P_2 = 615.2 \ kPa$ Super heated Vap.

Interpolation between 600 & 800°C

$$\frac{v_2 - 0.25059}{0.18465 - 0.25059} = \frac{615.2 - 600}{800 - 600} \Rightarrow v_2 = \underline{\underline{0.2455}} \ m^3/kg$$

or $V_{2(t)} = 3.68 \ m^3$

6) ① $800\,kPa \longrightarrow$ ② $800\,kPa$, $350^\circ C$.

ⓐ $T_{sat} = 170.43^\circ C$. (2)

$v_f = 0.001115\ m^3/kg$

$V_f = 0.1\,m^3$

$m_f = \dfrac{0.1}{0.001115} = 89.69\,kg$

$V_g = 0.9\,m^3$

$v_g = 0.24043\ m^3/kg$

$m_g = \dfrac{0.9}{0.24043} = 3.74\,kg$

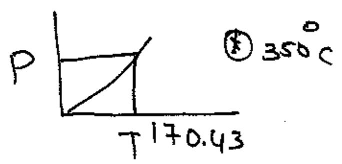
ⓑ $m_{tot} = m_f + m_g$

$= 89.69 + 3.74$

$= 93.43\,kg$ (2)

ⓒ $P_2 = 800\,kPa$; $T_2 = 350^\circ C$

$\Rightarrow$ Super heated Vapour

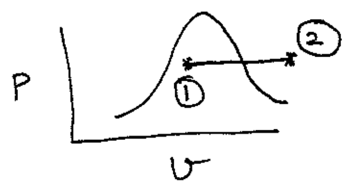


$v_2 = 0.35439\ m^3/kg$ (from B.1.3) $\therefore V_2 = 0.35439 \times 93.43$

$= 33.11\,m^3$. (2)

ⓓ $_1W_2 = P(V_2 - V_1) = 800\,kPa\,(33.11 - 1) = 25688\ kJ$. (2)

ⓔ



(2)

7) Modes of Heat Transfer

① Conduction $\dot{Q} = kA\,dT/dx$

② Convection $\dot{Q} = \dot{Q} = Ah\,\Delta T$

③ Radiation $\dot{Q} = \varepsilon \sigma A T_s^4$

(6).

BITS, PILANI DUBAI CAMPUS

DUBAI INTERNATIONAL ACADEMIC CITY

SECOND SEMESTER 2012-13

COURSE: BITS F111 Thermodynamics

Test I (Closed Book)

Max. Marks: 50 **Date: 24.03.2013**

Weightage : 25% **Time: 50 min**

Note: Answer all the Questions and Assume suitable value if required

1. A $1 m^3$ container is filled with 300 kg of bricks, 400 kg of coal, 0.2 m^3 of liquid water and the rest of the volume is air. Find the average specific volume and density. **(8)**
2. Two cylinders are filled with liquid water and connected by a line with a closed valve (Fig 1). A has 200 kg and B has 600 kg of water, their cross sectional areas are $A_A = 0.2\ m^2$ and $A_B = 0.5\ m^2$ and the height h is 2m. Find the pressure on each side of the valve. The valve is opened and water flows to an equilibrium. Find the final pressure. **(8)**
3. To what pressure saturated liquid H_2O at 80°C is to be compressed to reduce its volume by 2% through a constant temperature process? Plot the process in a Tv diagram. **(6)**
4. A sealed rigid vessel of 1 m^3 contains saturated mixture of R-134a at 10°C. At 60°C it is converted into a single phase of saturated vapor. Calculate the final pressure and the initial mass of the liquid. Plot the process in a Tv diagram. **(6)**
5. Saturated mixture of NH_3 at 10°C and mass 15 kg in a piston/cylinder with a volume of 1 m^3 is heated to 50°C (at constant pressure). Find the final volume. Plot the process in a Pv diagram. **(6)**
6. A piston –cylinder device contains 0.1 m^3 of liquid water and 0.9 m^3 of water vapor in equilibrium at 800kPa. Heat is transferred at constant pressure until the temp reaches 350°C.

a. Determine the initial temp of water

b. Determine the total mass of water

c. Find the final volume

d. Find the work done during the process,

e. Also represent the process in a P-v diagram. **(10)**

7. Name the different modes of heat transfer and give the relationship between the heat transfer and temperature for all the three modes of heat transfer. **(6)**

========

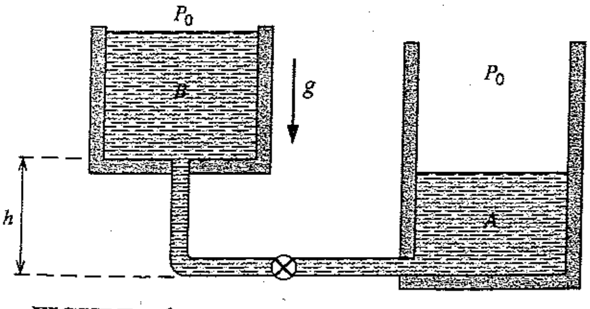


FIGURE. 1

BITS, PILANI – DUBAI CAMPUS
SECOND SEMESTER 2012 – 2013

First Year Sections 1, 2 & 3

Quiz 2 **A**

Course Code: BITS F111	Date: 22. 05 .13	**Name:**------------------------------
Course Title: THERMODYNAMICS	Max Marks: 14	**ID.No:**------------------------------
Duration: 20minutes	Weightage: 7%	**Sec.:** ------------------------------

Instructions: 1. Attempt all questions 2.Assume suitable value if required

$C_p(CO_2)$ = 0.842 kJ/kg-K, $R(CO_2)$ =0.1889kJ/kg-K, C_p (H_2O) = 4.187 kJ/kg-K, C_p (Steam) = 1.872 kJ/kg-K

1.Carbon dioxide is heated from 400 K to 1200 K and during this process the pressure is dropped from 300 kPa to 100 kPa. Calculate the change in entropy. **(2)**

2. 3Kg of water at 70^0 C is mixed adiabatically with 5 kg of water at 30^0C in a constant pressure process of 1 atmosphere where the final temperature is 50^0 C. Find the increase in the entropy of the total mass of water due to the mixing process. **(2)**

3. Find the polytropic exponent when CO_2 gas is expanded from 300 kPa, 100^0C to 100^0C, 100kPa. (2)

4. Comment on the temperature change in an adiabatic compression of a liquid. (2)

5. $\oint_1^2 \delta Q/T$ for all the reversible process between the state 1 and 2 is same, Why? (2)

6. Steam at 100^0C and 200kPa is compressed to 600kPa in a reversible adiabatic process. Calculate the final temperature. (2)

7. Will there be an entropy change when a bomb explodes? Justify. (2)

****

BITS PILANI, DUBAI CAMPUS, ACADEMIC CITY, DUBAI

SECOND SEMESTER, 2012-2013

Quiz-2 (Closed Book)

Course Title	: Thermodynamics		Course No : BITS F111
Date	**: 22.05.2013**		**MAX. MARKS : 14**
Time	**: 20 min**	**ANSWERING SCHEME**	**Weightage : 7%**

$C_p(CO_2) = 0.842$ kJ/kg-K, $R(CO_2) = 0.1889$ kJ/kg-K, $C_p\ (H_2O) = 4.187$ kJ/kg-K, C_p (Steam) = 1.872 kJ/kg-K

1. Carbon dioxide is heated from 400 K to 1200 K and during this process the pressure is dropped from 300 kPa to 100 kPa. Calculate the change in entropy. **(2)**

$$s_2 - s_1 = c_p \ln \frac{T_2}{T_1} - R \ln \frac{P_2}{P_1}$$

$$= 0.842 \ln \frac{1200}{400} - 0.1889 \ln \frac{100}{300}$$

$$= 1.1326 \text{ kJ/kg-K}$$

2. 3Kg of water at 70^0 C is mixed adiabatically with 5 kg of water at 30^0C in a constant pressure process of 1 atmosphere where the final temperature is 50^0 C. Find the increase in the entropy of the total mass of water due to the mixing process. **(2)**

$$(\Delta S)_{\text{Total mass}} = \Delta S_A + \Delta S_B$$

$$= m_A c_p \ln \frac{T_f}{T_A} + m_B c_p \ln \frac{T_f}{T_B}$$

$$= 3 \times 4.187 \ln \frac{323}{343} + 5 \times 4.187 \ln \frac{323}{303}$$

$$= 0.5813 \text{ kJ/K}$$

3. Find the polytropic exponent when CO_2 gas is expanded from 300 kPa, 100^0C to 100^0C, 100kPa. **(2)**

$n = 1$ [Isothermal process].

4. Comment on the temperature change in an adiabatic compression of a liquid. **(2)**

Temperature will increase.

5. $\oint_1^2 \delta Q/T$ for all the reversible process between the state 1 and 2 is same, Why? **(2)**

For all reversi[illegible] process, $\oint_1^2 \delta Q/_T = \Delta S$

as entropy is a state property $\int_1^2 \delta Q/_T$

will be same as long as the states are Same.

6. Steam at 100^0C and 200kPa is compressed to 600kPa in a reversible adiabatic process. Calculate the final temperature. **(2)**

$\Delta S = 0 \quad \therefore \quad C_{p0} \ln T_2/_{T_1} = R \ln P_2/_{P_1}$

$\ln T_2/_{T_1} = \frac{0.4615}{1.872} \ln 600/_{200} \quad \therefore T_2 = 489\text{ k}.$

7. Will there be an entropy change when a bomb explodes? Justify. **(2)**

ΔS will be positive for all irreversible process.

****

BITS, PILANI – DUBAI CAMPUS
SECOND SEMESTER 2012 – 2013

First Year Sections 1, 2 & 3

Quiz 1 **A**

Course Code: BITS F111	Date: 10. 04 .13	**Name:**------------------------------
Course Title: THERMODYNAMICS	Max Marks: 16	**ID.No:**----------------------------
Duration: 20minutes	Weightage: 8%	**Sec.:** --------------------------------

***Instructions:*. Attempt all questions.**

R_{air} = 0.287 kJ /kg-K ; R_{O_2} = 0.2598 kJ /kg-K; $C_{p\,H_2O}$=4.18kJ/kg.K; $C_{v\,O_2}$ = 0.66 kJ /kg-K.

---

1. A 6 pack canned drink is to be cooled from 25°C to 3°C. The mass of each canned drink is 0.33kg.The drinks can be treated as water and the energy stored in the can itself is negligible. Calculate the amount of heat transfer from the 6 canned drinks. **(3)**

2. During a boundary work, a saturated liquid is converted into super heated vapour at constant pressure. Show the work done during the process in a P-v diagram.**(2)**

3. A piston cylinder contains 0.2 kg air at 400 K and 200 kPa. The air is now slowly compressed in an isothermal process to a final pressure of 600 kPa. Find the work done in the process **(3)**

4. A piston motion moves a 20 kg hammerhead vertically down 2 m from rest to a velocity of 60 m/s in a stamping machine. What is the change in total energy of the hammerhead? **(2)**

5. 3000 m^3 of water is flowing out of a reservoir per hour. Find the mass flow rate if v_f= 0.001002 m^3/kg **(2)**

6. The enthalpy of oxygen molecule is 1540 kJ/kg at 1500 K. If its enthalpy is 275 kJ/kg, what would be the temperature? **(3)**

7. When this equation will be true? $dh \approx Cp\ dT \approx CvdT \approx du$. **(1)**

ANSWER KEY.

BITS, PILANI – DUBAI CAMPUS
SECOND SEMESTER 2012 – 2013
First Year Sections 1, 2 & 3

Quiz 1 **A**

Course Code: BITS F111 Date: 10. 04 .13 Name:--------------------------------

Course Title: THERMODYNAMICS Max Marks: 16 ID.No:--------------------------------

Duration: 20minutes Weightage: 8% Sec.: --------------------------------

Instructions: ***. Attempt all questions.***

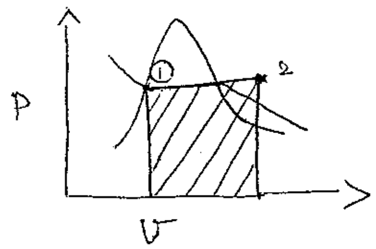
R_{air} = 0.287 kJ /kg-K ; R_{O_2} = 0.2598 kJ /kg-K; $C_{p\,H_2O}$ =4.18kJ/kg.K; $C_{v\,O_2}$ = 0.66 kJ /kg-K.

---

1. A 6 pack canned drink is to be cooled from 25°C to 3°C. The mass of each canned drink is 0.33kg.The drinks can be treated as water and the energy stored in the can itself is negligible. Calculate the amount of heat transfer from the 6 canned drinks. **(3)**

$$ {}_1Q_2 = 6 \times 0.33 \times 4.18\,(3-25) $$
$$ = -182 \text{ kJ} $$

2. During a boundary work, a saturated liquid is converted into super heated vapour at constant pressure. Show the work done during the process in a P-v diagram.**(2)**



3.A piston cylinder contains 0.2 kg air at 400 K and 200 kPa. The air is now slowly compressed in an isothermal process to a final pressure of 600 kPa. Find the work done in the process **(3)**

$$ {}_1W_2 = mRT \ln \frac{P_1}{P_2} $$
$$ = 0.2 \times 0.287 \times 400 \ln \frac{200}{600} $$
$$ = -25.2 \text{ kJ} $$

4. A piston motion moves a 20 kg hammerhead vertically down 2 m from rest to a velocity of 60 m/s in a stamping machine. What is the change in total energy of the hammerhead? **(2)**

$$E_2 - E_1 = m(u_2 - u_1) + m\left[\frac{1}{2}V_2^2 - 0\right] + mg(h_2 - 0).$$

$$= 0 + 20 \times \left[\frac{1}{2} \times 60^2\right] + 20 \times 9.81 \times (-2)$$

$$= \underline{35.6\ kJ}$$

5. 3000 m^3 of water is flowing out of a reservoir per hour. Find the mass flow rate if $v_f = 0.001002\ m^3/kg$ **(2)**

$$\text{mass flow rate, } \dot{m} = \frac{\dot{V}}{v_f} = \frac{3000}{0.001002} \times \frac{1}{3600} \qquad (2M)$$

$$= \underline{831.66\ kg/s}$$

(or) $\underline{2.99 \times 10^6\ kg/hr}$

6. The enthalpy of oxygen molecule is 1540 kJ/kg at 1500 K. If its enthalpy is 275 kJ/kg, what would be the temperature? **(3)**

$$C_p - C_v = R; \quad C_p = 0.2598 + 0.66 = 0.9198 \qquad (1M)$$

$$h_2 - h_1 = C_p(T_2 - T_1); \quad T_1 = T_2 - \left(\frac{h_2 - h_1}{C_p}\right)$$

(2M)

$$\underline{T_1 \simeq 125\ K}$$

7. When this equation will be true? $dh \approx C_p\, dT \approx C_v dT \approx du$. **(1)**

For Constant Volume processes.

(or)

Solids and incompressible liquids