Mansoura University	**Faculty of Engineering**
(BME) Program	**Mid Term Exam**
Full Semester 2013 / 2014	**Time: 90 minutes**
Course Title: Thermodynamics	**Date: May 2014**
Course Code:	

Solve the Following Problems:

Question No.1: (*13 Marks*)

(a) Prove that for an ideal gas, the specific heat at constant pressure equals the summation of specific heat at constant volume and the gas constant. ***(2 Marks)***

(b) 0.2 m3 of air at 4 bar and 130°C is contained in a system. A reversible adiabatic expansion takes place till the pressure falls to 1.02 bar. The gas is then heated at constant pressure till enthalpy increases by 72.5 kJ. Calculate : (i) The work done ; (ii) The index of expansion, if the above processes are replaced by a single reversible polytropic process giving the same work between the same initial and final states. Take *cp* = 1.005 kJ/kg K, *cv* = 0.714 kJ/kg K. ***(8 Marks)***

Question No.2: (12 Marks)

(a) Steam is supplied to a Turbine of *1100 kW* full power at *15 bar* with an internal energy of *2935 kJ/kg* and specific volume of *0.16 m^3/kg* and velocity of *110 m/sec*. Exhaust takes place at *0.05 bar* with internal energy of *1885 kJ/kg* and specific volume equal to *26m^3/kg* and velocity of *300 m/sec*. Heat loss from the turbine casing to surroundings is *21kJ/kg*. Potential energy change is negligible. Determine : (i) work output per *kg* of steam, (ii) steam flow rate in *kg/hr*. ***(5 Marks)***

(b) An inventor claims that his engine has the following specifications : Temperature limits 750°C and 25°C, Power developed 75 kW , Fuel burned per hour 3.9 kg , Heating value of the fuel 74500 kJ/kg. State whether his claim is valid or not. ***(5 Marks)***

Good Luck Dr. 3mad Elnegiry

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① ⓐ $\delta Q = du + \delta W$

$m c_p dT = m c_v dT + m p dv$, $p dv + v \cancel{dp} = R dT$ ($\cancel{dp} = 0$)

$c_p \cancel{dT} = c_v \cancel{dT} + R \cancel{dT}$

$c_p = c_v + R$

ⓑ $PV = mRT$ $\therefore 4\times10^5 \times 0.2 = m \times 289 (130+273)$

$\therefore m = 0.687$ kg.

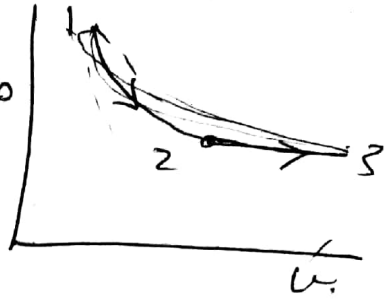
$P_2 = 1.02$ bar $= P_3$

$m(h_3 - h_2) = 72.5$ kJ

$m c_p (T_3 - T_2) = 72.5$

$\therefore 0.687 \times 1.005 (T_3 - 272.74) = 72.5$

$\therefore T_3 = 377.75$ K



$\therefore \frac{T_1}{T_2} = \left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}}$ $\therefore \frac{403}{T_2} = \left(\frac{4}{1.02}\right)^{\frac{0.4}{1.4}} \longrightarrow T_2 = 272.74$ K

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$W_{tot} = W_{1-2} + W_{2-3} = \frac{P_1V_1 - P_2V_2}{\gamma - 1} + P_2(V_3 - V_2)$

$= \frac{mR(T_1 - T_2)}{\gamma - 1} + mR(T_3 - T_2)$

$= \frac{0.687 \times 0.289 (403 - 272.74)}{0.4} + 0.687 \times 0.289 (377.75 - 272.74)$

$= \cancel{137.16}$ 84.5 kJ

if the process is polytropic for the same work from 1 to 3

$W_{1-3} = \frac{P_1V_1 - P_3V_3}{n-1} = \frac{mR(T_1 - T_3)}{n-1} = \frac{0.687 \times 0.289 (403 - 377.75)}{n-1}$ $= \cancel{137.16}$ 84.5

$\therefore n = 1.06$

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2ⓐ $\dot{Q} + \dot{m}\left(h_1 + \frac{c_1^2}{2} + gz_1\right) = \dot{m}\left(h_2 + \frac{c_2^2}{2} + gz_2\right) + \dot{W}$

for ① kg/s

$-21 \left(2935 + 15\times10^2 \times 0.16 + \frac{110^2}{2000}\right) = \left(0.05\times10^2 \times 26 + 1885 + \frac{300^2}{2000}\right) + w$

$\therefore w = 1100$ kJ/kg $\longrightarrow \dot{W} = \dot{m} w$ $\therefore 1100 = \dot{m}(1100)$

$\dot{m} = 1$ kg/s $= 3600$ kg/hr.

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ⓑ $\dot{Q}_{add} = \frac{3.9 \times 74500}{3600} = 80.71$ kJ/s (kW)

Power = 75 kW $\eta_{Carnot} = 1 - \frac{T_2}{T_1} = 1 - \frac{298}{1023} = 70.87\%$

$\eta_{inventor} = \frac{\text{Power}}{\dot{Q}_{add}} = \frac{75}{80.71} = 92.92\%$

the inventor claim is not valid since $\eta_{inv} > \eta_{Carnot}$.

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