Total No. of Printed Pages – 7

AEUD

MECHANICAL ENGINEERING

PAPER – I

SUBJECT CODE : 10

Full Marks : 200 **Time : 3 Hours**

Instructions For Candidates :

Please read each of the following instructions carefully before attempting questions.

(1) *Answers must be written in **ENGLISH** only.*

(2) *The question paper contains a total of 8 questions in **TWO** Sections : Section-A and Section-B. (**FOUR** questions in each section)*

(3) *Question No. 1 of Section 'A' and Question No. 5 of Section 'B' are **compulsory**.*

(4) *Candidates have to attempt another **THREE** questions from remaining **SIX** questions choosing atleast **ONE** question from each section.*

(5) *Assume suitable data if found necessary.*

(6) *Wherever any assumption be made for answering a question, they must be clearly indicated.*

(7) *Marks carried by a question / section is indicated against it.*

(8) *Unless struck off, attempt of question shall be counted even if attempted partly.*

(9) *Any page or portion of the page left blank in the Answer Booklet must be clearly struck off.*

SECTION – A

Marks

1. (i) 2 kg of an ideal gas is compressed adiabatically from pressure 100 kPa and temperature 220 k to a final pressure of 400 kPa. Calculate (a) initial volume (b) final volume and temperature (c) work performed and (d) change in internal energy. Take $C_p = 1.0$ kJ/kgK and $C_N = 0.707$ kJ/kg K. **8**

(ii) In a gas turbine, the gases flow at a rate of 5 kg/s. The gases enter the turbine at a pressure of 7 bar with a velocity of 120 m/s and leaves at a pressure of 2 bar with a velocity of 250 m/s. The turbine is insulated. If the enthalpy of the gas at inlet is 900 kJ/kg and at the outlet is 600 kJ/kg, determine the capacity of the turbine. **8**

Marks

(iii) Establish the Inequality of Clausius. 8

(iv) Two fins of 0.01 m diameter and 0.1 m length are used to dissipate heat from a surface at 230 °C. The surroundings is at 30 °C. The thermal conductivity of the material is 20 W/mk. The convective coefficient is 30 W/m^{2}k. To check alternate arrangement; it is proposed to replace the fins by a single fin of the total area of the two fins with length and other conditions being the same as before. Compare the heat transferred and the tip temperatures. 8

(v) An air conditioning unit receives an air water vapor mixture at 101 kPA, 35 °C and 80% relative humidity. Determine the following : 8

(a) the dew point

(b) the humidity ratio

(c) the partial pressure of air

(d) the mass fraction of water vapour

2. (i) (a) In a steam power station steam flows steadily through a 0.2 m diameter pipe line from the boiler to the turbine. At the boiler end, the steam conditions are found to be p = 4 MPa, t = 400 °C, h = 3213.6 kJ/kg and V = 0.073 m^3/kg. At the turbine end, the conditions are found to be P = 3.5 MPa, t = 392 °C, h = 3202.6 kJ/kg and ~ = 0.084 m^3/kg. There is a heat loss of 8.5 kJ/kg from the pipe line. Calculate the steam flow rate. 8

(b) A reversible heat engine operates between two reservoirs at temperature of 600 °C and 40 °C. The engine draws a reversible refrigerator which operates between reservoirs at temperatures of 40 °C and –20 °C. The heat transfer to the heat engine is 2000 kJ and the net work output of the combined engine - refrigerator plant is 360 kJ. 12

(I) Evaluate the heat transfer to the refrigerant and the net heat transfer to the reservoir at 40 °C.

(II) Reconsider (a) given that the efficiency of the heat engine and the COP of the refrigerator are each 40% of their maximum possible values.

Marks

(ii) A spark ignition engine working on ideal Otto cycle has the compression ratio 6. The initial pressure and temperature in the cycle are 1 bar and 37 °C respectively. The maximum pressure in the cycle is 30 bar. For unit mass flow, calculate **10**

(a) p, v and T at various salient points of the cycle and

(b) the ratio of heat supplied to the heat rejected.

Assume $\gamma = 1.4$ and R = 8.314 kJ/K mol K.

(iii) With the help of neat sketches explain the stages of combustion in CI engines. **10**

3. (i) For an engine working on the ideal dual cycle, the compression ratio is 10 and the maximum pressure is limited to 70 bar. If the heat supplied is 1680 kJ/kg, find the pressures and temperatures at the various salient points of the cycle and cycle efficiency. The pressure and temperature of air at the commencement of compression ratio are 1 bar and 100 °C respectively. **12**

Assume $C_p = 1.004$ kJ/kg K and

$C_v = 0.717$ kJ/kg K for air.

(ii) A heat flux of 1500 W/m^2 is incident on the surface of a slab of 10 cm thick with thermal conductivity of 7.5 W/mK. The hot side is found to be at 120 °C. On the other side, the heat is passed on to the surroundings at 30 °C by convection and radiation. If radiation is ideal, determine the convective coefficient and also the share of heat flow between the two processes. **8**

(iii) (a) A metal plate of 10 mm thick at 30 °C is suddenly exposed on one face to a heat flux of 3000 W/m^2 and the other side is expose to convection to a fluid at 30 °C with a convective heat transfer coefficient of 50 W/mK. Determine the heat transfer coefficient of 50 W/m^2 K. **12**

Determine the temperature variation with time and also steady state temperatures and the time to reach 1 °C less than the steady state temperature on the hot face.

(b) Air at 200 °C flows over a plane at 120 °C. The air pressure is at 1.8 atm. The free stream velocity is 15 m/s. The plate measures 0.2 m & 0.4 m. The air flow was designed to be in the direction of 0.4 m side. Due to some misunderstanding the equipment was fabricated with flow in the 0.2 m direction. Determine the change in performance. **8**

Marks

4. (i) A steam condenser condensing at 70 °C has to have a capacity of 100 kW. Water at 20 °C is used and the outlet temperature is limited to 45 °C. If the overall heat transfer co-efficient has a value of 3100 W/m^2 K, determine the area required. If the inlet water temperature is increased to 30° C determine the increased flow rate of water for maintaining the same water outlet temperature. Also determine the flow rate for the same amount of heat transfer. 10

(ii) (a) The atmospheric air at a pressure of 1 bar and temperature –5 °C is drawn in the cylinder of a compressor of the Bell Coleman refrigerating machine. It is compressed isentropically to a pressure of 5 bar. In this cooler, the compressed air is cooled to a 15 °C, pressure remaining the same. It is then expanded to a pressure of 1 bar in an expansion cylinder, from where it is passed to the wed chamber.

Find (I) The work done per kg of air and (II) The COP of the plant. Assume law of expansion for air is $pV^{1.2}$ = constant, law for compression is $pV^{1.4}$ = constant. The specific heat of air is 1 kJ/kg K. 12

(b) Derive an expression for the coefficient of performance of a vapour compression refrigeration system with sub-cooling. Indicate the process in P-h and T-S diagrams. 8

(iii) A vapour compression refrigerator works between the pressure limits of 60 bar and 25 bar. The working fluid is dry and the end of compression there is no under cooling of the liquid before the expansion valve.

Determine (a) COP of the cycle and (b) Capacity of the refrigerator if the fluid flow is at the rate of 5 kg/min. 10

Pressure (bar)	Saturation temperature, K	Specific enthalpy, kJ/kg K		Specific entropy, kJ/kg K	
		Liquid	Vapour	Liquid	Vapour
60	295	61.9	208.1	0.197	0.703
25	261	–18.4	234.5	–0.075	0.896

Marks

SECTION – B

5. (i) A circular plate of diameter 1.2 metre is placed vertically in water in such a way that the centre of the plate is 2.5 m below the free surface of water. Determine the total pressure and the position of the centre of pressure. **8**

(ii) A 200 mm × 120 mm venturimeter is installed in a horizontal pipe carrying water. If the mercury differential manometer shows a reading of 200 mm, find the discharge through the pipe. Take co-efficient of discharge $C_d = 0.98$. **8**

(iii) The rate of flow of water through a horizontal pipe is 250 litre/s. The diameter of the pipe which is 200 mm is suddenly enlarged to 400 mm. The pressure intensity in the smaller pipe is 150 kPa. Find

(a) loss of head (b) pressure intensity in the larger pipe (c) loss of power. **8**

(iv) A supersonic nozzle is to be designed for air flow with Mach number 3 at the exit section which is 250 mm in diameter. The pressure and temperature of air at the nozzle exit are 8.5 kN/m^2 and 215 K. Make the calculation for (a) reservoir pressure and temperature and (b) throat area. **8**

(v) A three stage single acting reciprocating compressor has a perfect inter cooling. The pressure and temperature at the end of suction stroke in LP cylinder is 1.013 bar and 15 °C respectively. If 8.4 m^3 of free air is delivered by the compressor at 70 bar per minute and the work done is minimum, calculate; **8**

(a) LP and HP delivery pressures

(b) Ratio of cylinder volumes and

(c) Total indicated power - Neglect clearance and assume $n = 1.2$

6. (i) Derive Euler's equation of motion. **10**

(ii) Derive an expression for a discharge through a convergent - divergent nozzle. **10**

(iii) A 30 long pipeline connects two reservoirs, both of which are open to the atmosphere. The difference in their water level is 12 m. The pipe has three equal sections of 10 m each. The first and last sections are 60 mm in diameter and the intermediate section is 40 mm in diameter. The value 'f' for the pipes is 0.0054. Calculate the flow rate and draw the total energy and hydraulic grade lines. **10**

(iv) A trapezoidal channel has side slopes 3 horizontal to 4 vertical and slope of its bed is 1 in 1500. Determine the most economical dimensions of the channel, if it carries water at 10 m^3/s. Take $C = 60$. **10**

Marks

7. (i) Air flows through a convergent divergent nozzle. At some section in the nozzle pressure is 2 bar, Velocity 170 m/s and temperature 200 °C, and the cross sectional area is 1000 m^2. Assuming the isentropic conditions determine (a) Stagnation temperature and stagnation pressure (b) Sonic velocity and Mach number at this section (c) velocity, Mach number and flow rate at outlet section when pressure is 1.1 bar (d) pressure, temperature, velocity and flow area of throat of the nozzle. **15**

Take R = 287 J/kg K, Cp = 1000 J/kg K and $\gamma = 1.4$

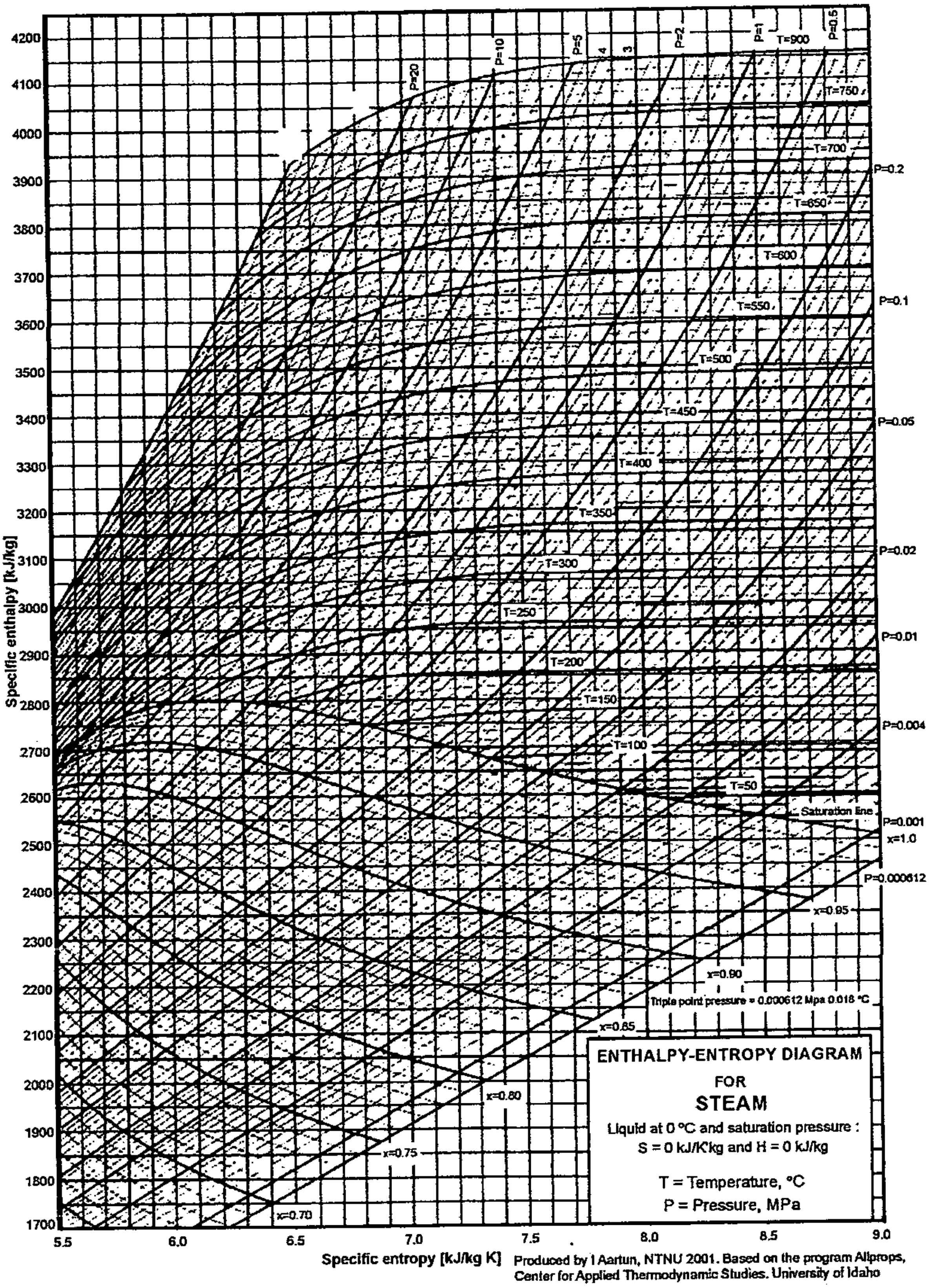
(ii) Define Fanno line and Raleigh line with required equations and plots. **10**

(iii) In a cartage of Impulse turbine, the nozzle angle is 20° with the plane of the wheel. The mean diameter of the blade ring is 2.8 metres. It develops 55 kW at 2400 rpm. Four nozzles each of 100 mm diameter expand isentropically from 15 bar and 250 °C to 0.5 bar. The axial thrust is 3.5 N. Calculate; (a) Blade angle at entrance and exit and, (ii) The power lost in blade friction. **15**

8. (i) A closed vessel of 0.2 m^3 contains steam at a pressure of 10 bar and a temperature of 250 °C. The vessel is cooled till the pressure of steam in the vessel falls to 3.5 bar. Find the final temperature, final dryness fraction, change in internal energy, heat transferred and change in entropy. **20**

(ii) In a gas turbine the air is compressed in a single stage compressor from 300 K. The same air is then heated to a temperature of 800 K and then expanded in the turbine. The air is then reheated to a temperature of 800 K and then expanded in the second turbine. Find the maximum power that can be obtained from the installation, if the mass of air is circulated per second. **10**

(iii) Define degree of reaction of axial flow compressor. Derive an expression for it. **10**


ENTHALPY-ENTROPY DIAGRAM
FOR
STEAM
Liquid at 0 °C and saturation pressure :
S = 0 kJ/K'kg and H = 0 kJ/kg
T = Temperature, °C
P = Pressure, MPa
Specific enthalpy [kJ/kg]
Specific entropy [kJ/kg K]
P=20
P=10
P=5
4
3
P=2
P=1
P=0.5
P=0.2
P=0.1
P=0.05
P=0.02
P=0.01
P=0.004
P=0.001
P=0.000612
T=900
T=750
T=700
T=650
T=600
T=550
T=500
T=450
T=400
T=350
T=300
T=250
T=200
T=150
T=100
T=50
Saturation line
x=1.0
x=0.95
x=0.90
x=0.85
x=0.80
x=0.75
x=0.70
Triple point pressure = 0.000612 Mpa 0.018 °C
Produced by I Aartun, NTNU 2001. Based on the program Allprops, Center for Applied Thermodynamic Studies. University of Idaho