CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY –
MARINE ENGINEER OFFICER

EXAMINATIONS ADMINISTERED BY THE
SCOTTISH QUALIFICATIONS AUTHORITY
ON BEHALF OF THE
MARITIME AND COASTGUARD AGENCY

STCW 78 as amended CHIEF ENGINEER REG. III/2 (UNLIMITED)

041-32 – APPLIED HEAT

MONDAY, 12 DECEMBER 2016

1315 - 1615 hrs

Examination paper inserts:

Worksheet Q4 - Specific Enthalpy–Specific Entropy Chart for Steam

Notes for the guidance of candidates:

1. Non-programmable calculators may be used.
2. All formulae used must be stated and the method of working and ALL intermediate steps must be made clear in the answer.

Materials to be supplied by examination centres:

Candidate's examination workbook
Graph paper
'Thermodynamic and Transport Properties of Fluids' by Mayhew & Rogers (5^{th} edition)

APPLIED HEAT

Attempt SIX questions only.

All questions carry equal marks.

Marks for each part question are shown in brackets.

1. The initial pressure, volume and temperature of air in a cylinder are 1.0 bar, 0.2 m^3 and 25°C respectively. It is heated at constant volume to a temperature of 600°C and then reversibly expanded to the original pressure according to the law $pV^{1.35}$= constant.

(a) Calculate EACH of the following:

(i) the work done; (4)

(ii) the change in internal energy in the expansion process; (4)

(iii) the heat transferred in the expansion process; (2)

(iv) the overall change in entropy. (2)

(b) Sketch the processes on Pressure-Volume and Temperature-specific entropy diagrams. (4)

Note: for air c_v = 0.718 kJ/kgK and R = 0.287 kJ/kgK

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2. In an open gas turbine cycle, 4.5 kg/s of air is induced into a rotary compressor at a pressure and temperature of 1 bar and 18°C respectively.
It is compressed through a pressure ratio of 5:1 with an isentropic efficiency of 0.85.

The hot gases leave the combustion chamber and enter the turbine at a temperature of 810°C, expanding to the initial pressure with an isentroic efficiency 0.88.

The mass flow rate of fuel may be ignored.

(a) Sketch the cycle on a Temperature-specific entropy diagram. (4)

(b) Calculate EACH of the following:

(i) the net power output of the cycle; (6)

(ii) the work ratio; (2)

(iii) the thermal efficiency. (4)

Note: for air and the hot gas $\gamma = 1.4$ *and* $c_p = 1.006$ *kJ/kgK*

3. A fuel has a mass analysis of 80% carbon, 15% hydrogen, 1.5% sulphur and 2% water. The remainder being ash.

The fuel is completely burned in 10% excess air.

Calculate EACH of the following:

(a) the stoichiometric air fuel ratio by mass; (6)

(b) the mass of oxygen required to convert the SO_2 in the combustion products to soluble SO_3; (4)

(c) the volumetric analysis of the dry combustion products after the formation of the SO_3. (6)

Note: Relative Atomic masses: C=12, H=1, O=16 N=14, S=32.
Air contains 23% oxygen by mass

4. In a regenerative steam power plant, steam enters the turbine at a pressure and temperature of 60 bar and 540°C respectively and expands to a condenser pressure of 0.05 bar.
The specific entropy at exit is 10% greater than that at inlet.
Steam is bled from the turbine at a pressure of 2 bar and supplied to a surface feed heater, from which the drain is throttled to the main condenser.
There is no under cooling in the condenser and the feed water leaves the heater at the saturation temperature of the bled steam.
The feed pump work cannot be ignored.

(a) Using Worksheet Q4 plot the straight line expansion process. (2)

(b) Determine EACH of the following:

(i) the condition of the bled steam at entry to the feed heater; (2)

(ii) the mass of bled steam per kg of steam flow; (4)

(iii) the thermal efficiency of the cycle. (4)

(c) Sketch the cycle on a Temperature-specific entropy diagram. (4)

5. The blades of a particular stage in a 50% reaction turbine develop a power of 400 kW when the steam is dry saturated at pressure of 3 bar.
The speed of rotation is 5500 rev/min.
The mean blade ring diameter is 700 mm and the blade height is 50 mm.
The absolute velocity of the steam at the stage exit is in the axial direction.

(a) Sketch the velocity vector diagram for the stage and identify ALL velocities. (3)

(b) Calculate EACH of the following:

(i) the absolute velocity of the steam at exit; (6)

(ii) the fixed and moving blade angle; (2)

(iii) the absolute velocity of the steam at inlet; (2)

(iv) the specific enthalpy drop of the steam in the moving blades. (3)

6. In a vapour compression plant 0.452 tonne/hour of refrigerant R134a, leaves the evaporator at a pressure of 2.006 bar and temperature of 0°C. It is then compressed with an isentropic efficiency of 0.825 to a pressure of 8.8672 bar.

The refrigerant leaves the condenser with 5 K of sub-cooling.

(a) Sketch the cycle on EACH of the following:

(i) a Pressure-specific enthalpy diagram indicating the refrigeration effect, compressor work and condenser heat rejection; (2)

(ii) a Temperature-specific entropy diagram, indicating superheat and sub-cooling. (2)

(b) Determine EACH of the following:

(i) the cooling load; (5)

(ii) the compressor power required; (3)

(iii) the heat rejection in the condenser; (2)

(iv) the coefficient of performance when operating as a heat pump. (2)

7. Dry saturated steam at 10 bar enters a steam pipe 50 m in length with an inner diameter of 100 mm and wall thickness of 3 mm.

The pipe insulation limits the condensation of the steam to 6%, when the mass flow rate of steam in the pipe is 7200 kg/hr and the air temperature surrounding the pipe is 20° C.

Calculate EACH of the following:

(a) the thickness of the insulation surrounding the pipe; (8)

(b) the percentage reduction in condensation when the thickness of the insulation is doubled. (8)

Note: *inner heat transfer coefficient of the pipe = 545 W/m^{2}K*
thermal conductivity of steel = 50 W/mK
thermal conductivity of the insulation = 0.5 W/mK
the outer heat transfer coefficient of the pipe may be ignored

8. A two-stage, single acting, water cooled, reciprocating air compressor is designed for minimum work and fitted with an after cooler.

It delivers air at the rate of 17 m^3/min at free air conditions of 1.01325 bar 0° C.

The air is compressed from a pressure and temperature of 1 bar 33°C to a pressure of 30 bar and the air leaves the after cooler at a temperature of 45°C. The law for all expansion and compression processes is $pV^{1.3}$= constant.

(a) Sketch the cycle on a Pressure–Volume diagram. (2)

(b) Calculate EACH of the following:

(i) the stage power; (4)

(ii) the enthalpy rise of the air in each stage; (4)

(iii) the total heat removed by the cooling water. (6)

Note: for air R = 0.287 kJ/kgK, c_p=1.005 kJ/kgK

9. A rigid vessel contains 6 kg of oxygen and 9 kg of nitrogen at a pressure and temperature of 3 bar and 27° C respectively.

Calculate EACH of the following:

(a) the mole fraction of the oxygen and nitrogen; (2)

(b) the partial volumes of the oxygen and nitrogen; (4)

(c) the partial pressures of the oxygen and nitrogen; (4)

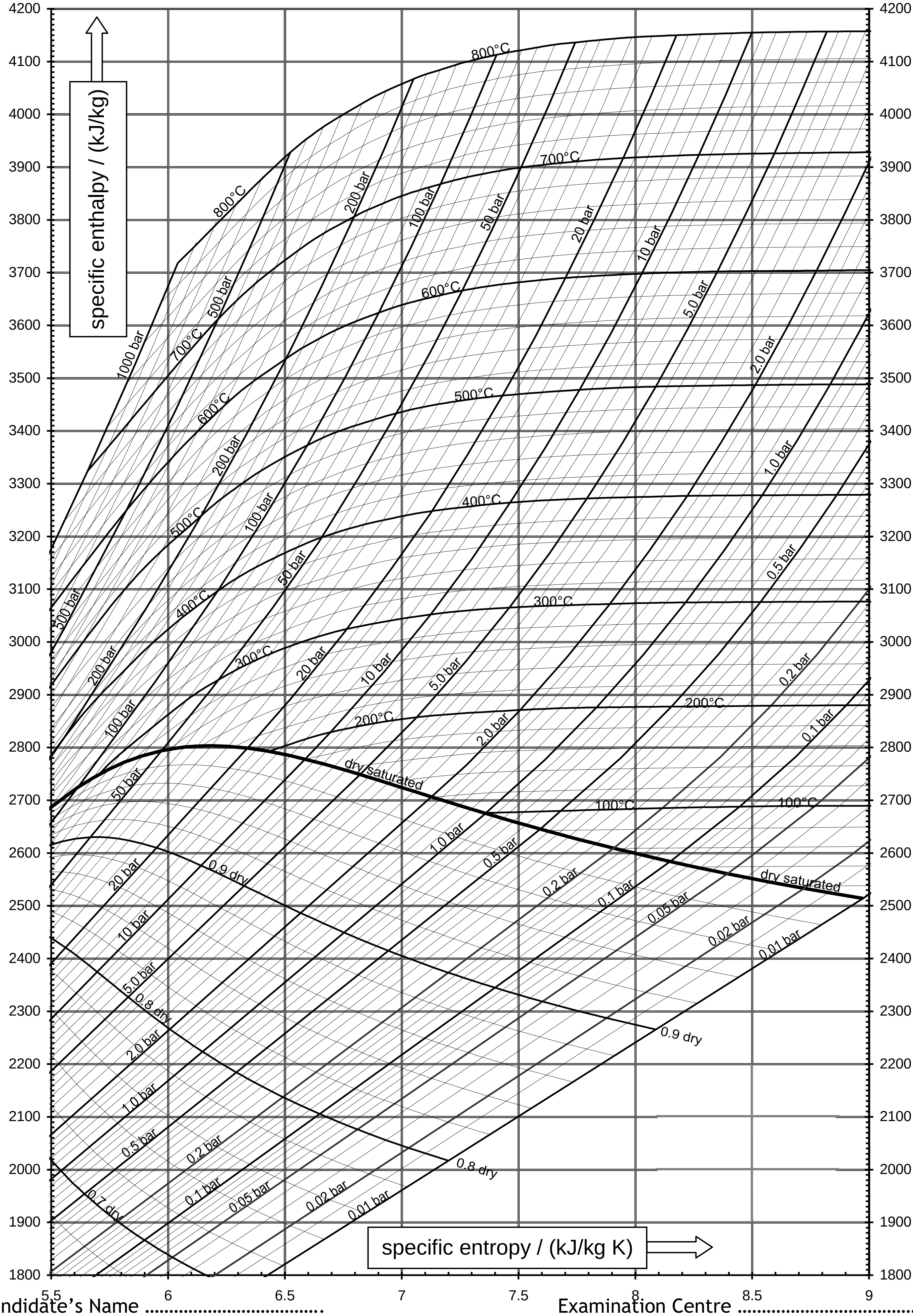
(d) the adiabatic index when the gasses are mixed. (6)

Note:
Atomic mass relationships: N = 14, O = 16.
the universal gas constant = 8.3145 kJ/kmolK.
the values of c_p at 300 K are: oxygen = 0.918 kJ/kgK, nitrogen = 1.040 kJ/kgK .

(This worksheet must be returned with your answer book)

Enthalpy Entropy Chart for Steam

(prepared at Glasgow College of Nautical Studies using data from NEL Steam Tables 1964 and other formulations: for exercises only)



Candidate's Name .... Examination Centre ....