CentraleSupélec
Accelerated Engineering Degree Programme
Master's level

2018

CentraleSupélec Accelerated Engineering Degree Program

Mechanical Engineering track

Written exam

Pocket calculator may be used during this exam

The problems can be solved indepedently
Charts and tables are given at the end of the problems that can be usefull…

Problem A- Liquid-vapor mixture

In a rigid and closed tank, where initial pressure is p_1 = 500 kPa, water exists as part liquid and part vapor:

- 6 m^3 in vapor (gas) state
- 8 liters in liquid state

1- What is the mass of liquid water? The mass of vapor water? The quality of the mixture?
2- A physical change makes this system evolve to the final state defined by the pressure inside the tank: p_2 = 100 kPa.
   a. What is the mass of liquid water, the mass of vapor water? What is the final liquid water volume, the final vapor water volume, the quality of this new equilibrium?
   b. Explain how can be technically realised this physical change
   c. What is the enthalpy change between those two states?

Problem B- Refrigerating Steaks

In a meat processing plant, 1-cm-thick steaks initially at 25°C are to be cooled in a large refrigerator that is maintained at -15°C. The steaks are so close to each other so that there is no heat transfer edge effect. The entire steak is to be cooled below 5°C but its temperature is not to drop below 0°C at any point during refrigeration to avoid "frost-bite".
The convection heat transfer coefficient can be controled by varying the speed of a circulating fan.

1- Determine this heat transfer coefficient that will enable us to meet both temperature constraints while keeping the refrigeration time to a minimum.
The steak can be treated as a homogeneous layer having the properties:
density $\rho = 1190$ kg m^{-3}
thermal conductivity $k = 0.45$ W m^{-1} K^{-1}
specific heat capacity $c_p = 4$ kJ kg^{-1} K^{-1}
thermal diffusivity $\alpha = 9\ 10^{-8}$ m^2 s^{-1}
2- What is the necessary time for this value (minimum time)?

Problem C- Heat transfer: Multiple choice test

Some questions have only one correct answer, some questions may have 2, 3 or 4 correct answers. To get the point all correct answers must be selected.

1 Thermal resistance's unit is:
❒ W/K or W/°C
❒ K kg^{-1} m^{-3} s^{-2} or °C kg^{-1} m^{-3} s^{-2}
❒ K kg^{-1} m^{-2} s^{2} or °C kg^{-1} m^{-2} s^{2}
❒ K/W or °C/W

2 Convective heat transfer coefficient
❒ is greater in the air than in the water
❒ is greater in the water than in the air
❒ is greater in free convection than in forced convection
❒ does not depend on the velocity of the fluid

3 Thermal conductivity
❒ is isotropic
❒ of liquids always decreases with temperature
❒ of gases is generally lower than of liquids
❒ takes the value zero for thermal insulators

4 With thermal diffusivity α, and time t, the quantity $(\alpha\, t)^{1/2}$
❒ is the definition of a dimensionless time
❒ is the velocity of a thermal conduction wave
❒ is a nonsense quantity
❒ is a characteristic length of unsteady state heat conduction

5 With thermal conductivity of the fluid k_f, convective heat transfer coefficient h and characteristic size of a solid body L, the quantity $(L\, h / k_f)$
❒ is the Prandtl number
❒ is the Nusselt number
❒ is the Fourier number
❒ is the Biot number

6 With thermal conductivity of the solid k_s , convective heat transfer coefficient h and characteristic size of a solid body L, the quantity $(L\, h / k_s)$
❒ is the Prandtl number
❒ is the Nusselt number

❒ is the Fourier number
❒ is the Biot number

7 Fourier number Fo << 1 means
❒ the heat transfer diffusion is limited to a small volume close to the surface
❒ the solid is a thermal insulator
❒ the solution of the unsteady heat conduction problem depends on the error fucntion
❒ the solution of the problem is a steady heat conduction transfer

8 Exchange of radiation between gray surfaces (A_i area of the surface)
❒ on gray surfaces spectral emissivity and absorptivity do not depend of the angles (of incidence or of emission
❒ view factor calculation depend on the geometry of the bodies
❒ reciprocity relation between two view factors is: $A_iF_{ji} = A_jF_{ij}$
❒ in an enclosure of *N* bodies: $\sum_{i=1}^{N} A_i F_{ij} = 1$

9 Greenhouse effect
❒ greenhouse effect is caused by CO_2 molecules in the atmosphere
❒ geenhouse effect is caused by the disappearance of ozone molecules in the stratosphere
❒ geenhouse effect is caused by the appearance of pollution with ozone molecules in the troposphere
❒ geenhouse effect is caused by molecules that can absorb IR emission

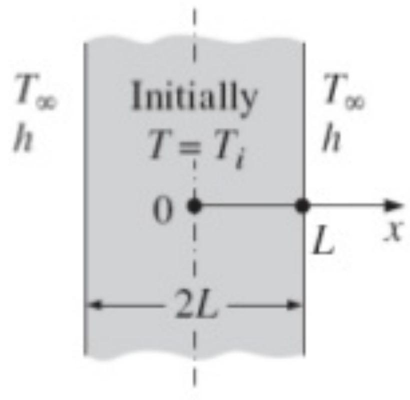
10 Free (or natural) convection
❒ free convection is caused by the wind (or any external natural fluid flow) over a heated plate (or any kind of geometry of a solid)
❒ free convection can be mixed with forced convection and its name is mixed convection
❒ free convection calculations can be done with Rayleigh number where $Ra = \frac{\rho g \beta \Delta T L^3}{\alpha \mu}$
❒ free convection can be stopped in some geometries

Problem D- Turbine

Steam expands in a turbine steadily at rate of 25,000 kh/h, entering at 8 MPa and 450°C and leaving at 50 kPa as saturated vapor. If the power generated by the turbine is 4 MW, determine :

1- if the process is reversible,
2- if not, what is the entropy generation during the process (result in kW/K),
3- if all the data are consistent.

Problem B: pages 4, 5 and 6



The plan wall

Initial temperature T_i = T_0, thickness 2*L*, convective heat transfer coefficient *h*, temperature of the fluid T_∞, thermal diffusivity α, time *t*, Fourier number *Fo*, thermal conductivity *k*, Biot number *Bi*.

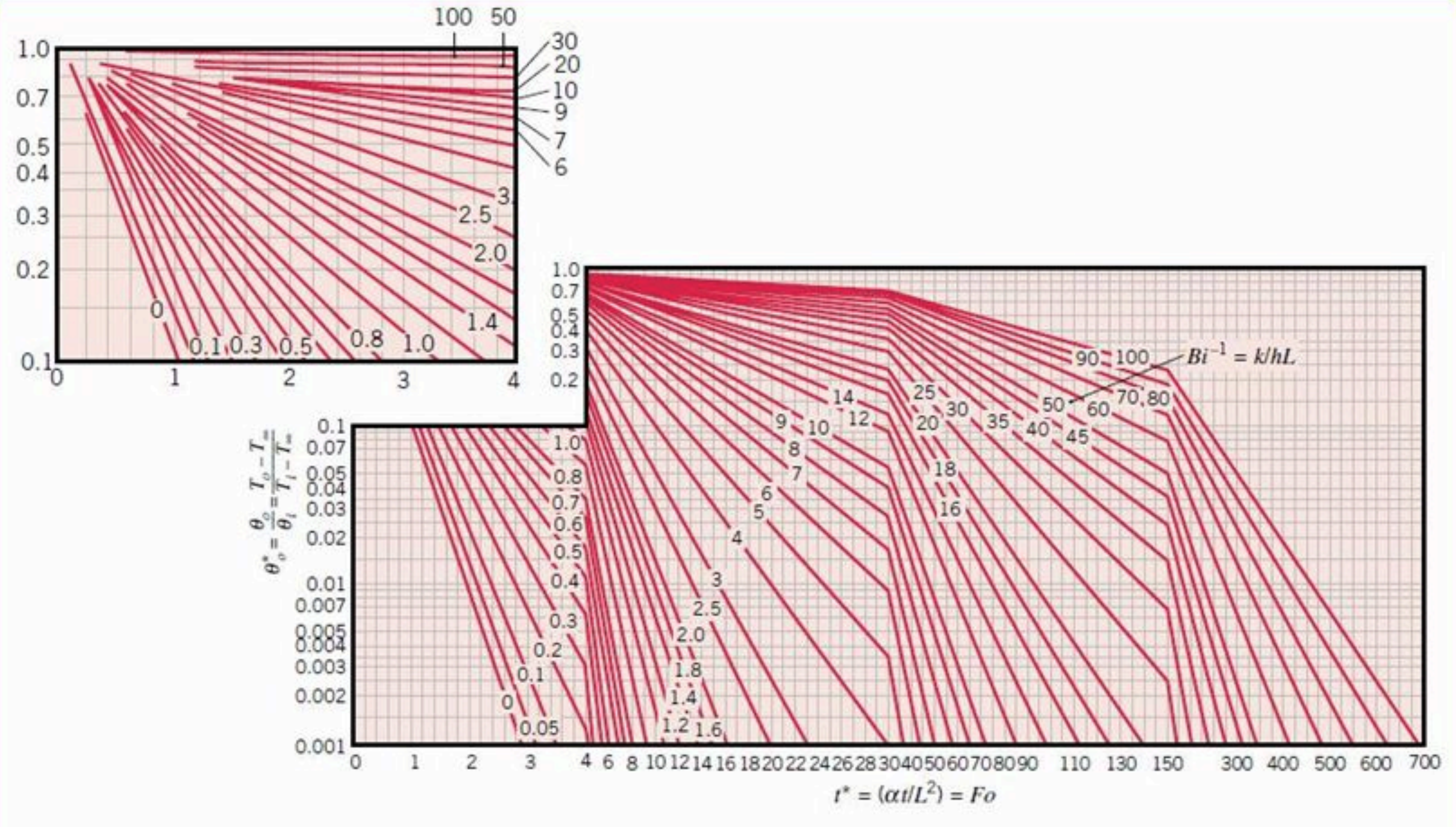


Fig 1- Midplane temperature for a plane wall of thickness 2*L*

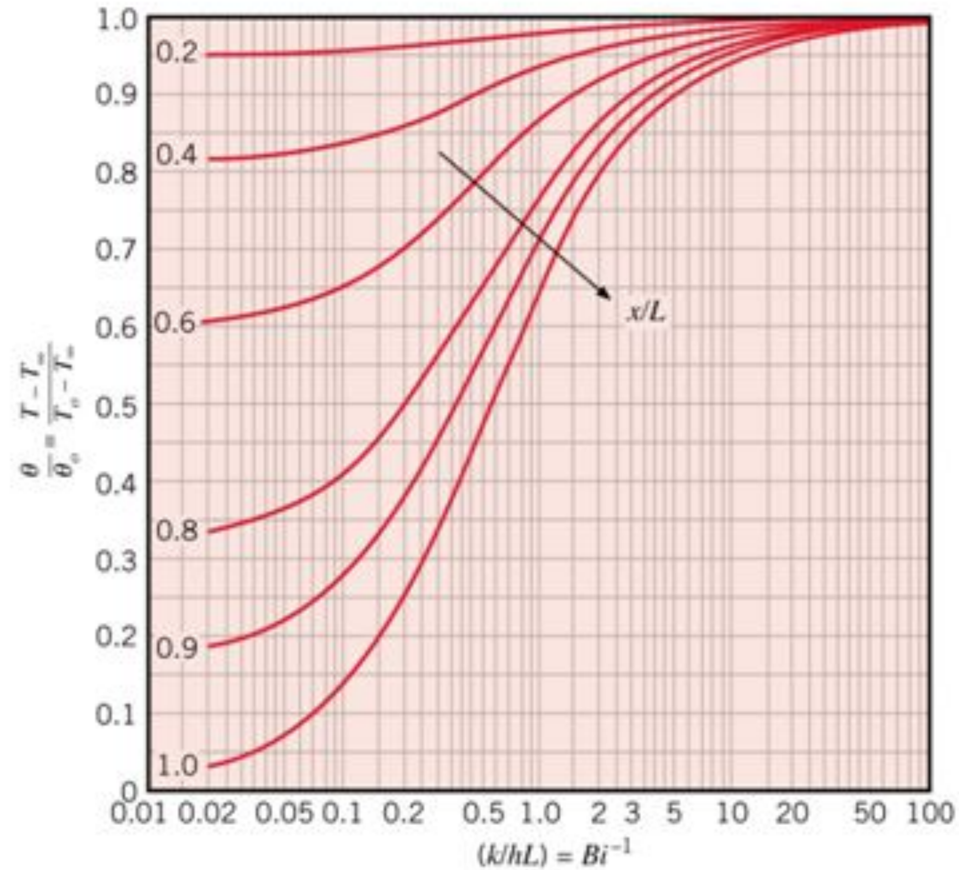


Fig 2- Temperature distribution for a plane wall of thickness 2*L*

Problem A: pages 7 and 8
Problem D: page 8

Saturated water – Pressure table

		Specific Volume m3/kg		Enthalpy kJ/kg			Entropy kJ/kgK	
Pressure *p* (MPa)	sat.temp. *T* (°C)	sat. liquid *vf*	sat. vapor *vg*	sat. liquid *hf*	Evap. *hfg*	sat. vapor *hg*	sat.liquid *sf*	sat. vapor *sg*
0.01	45.81	0.001010	14.67	191.83	2392.8	2584.7	0.6493	8.1502
0.05	81.33	0.001030	3.24	340.49	2305.4	2645.9	1.0910	7.5939
0.1	99.63	0.001043	1.6940	417.46	2258.0	2675.5	1.3026	7.3594
0.5	151.86	0.001093	0.3749	640.23	2108.5	2748.7	1.8607	6.8213
1	179.91	0.001127	0.19444	762.81	2015.3	2778.1	2.1387	6.5865
5	263.99	0.001286	0.03944	1154.23	1640.1	2794.3	2.9202	5.9734

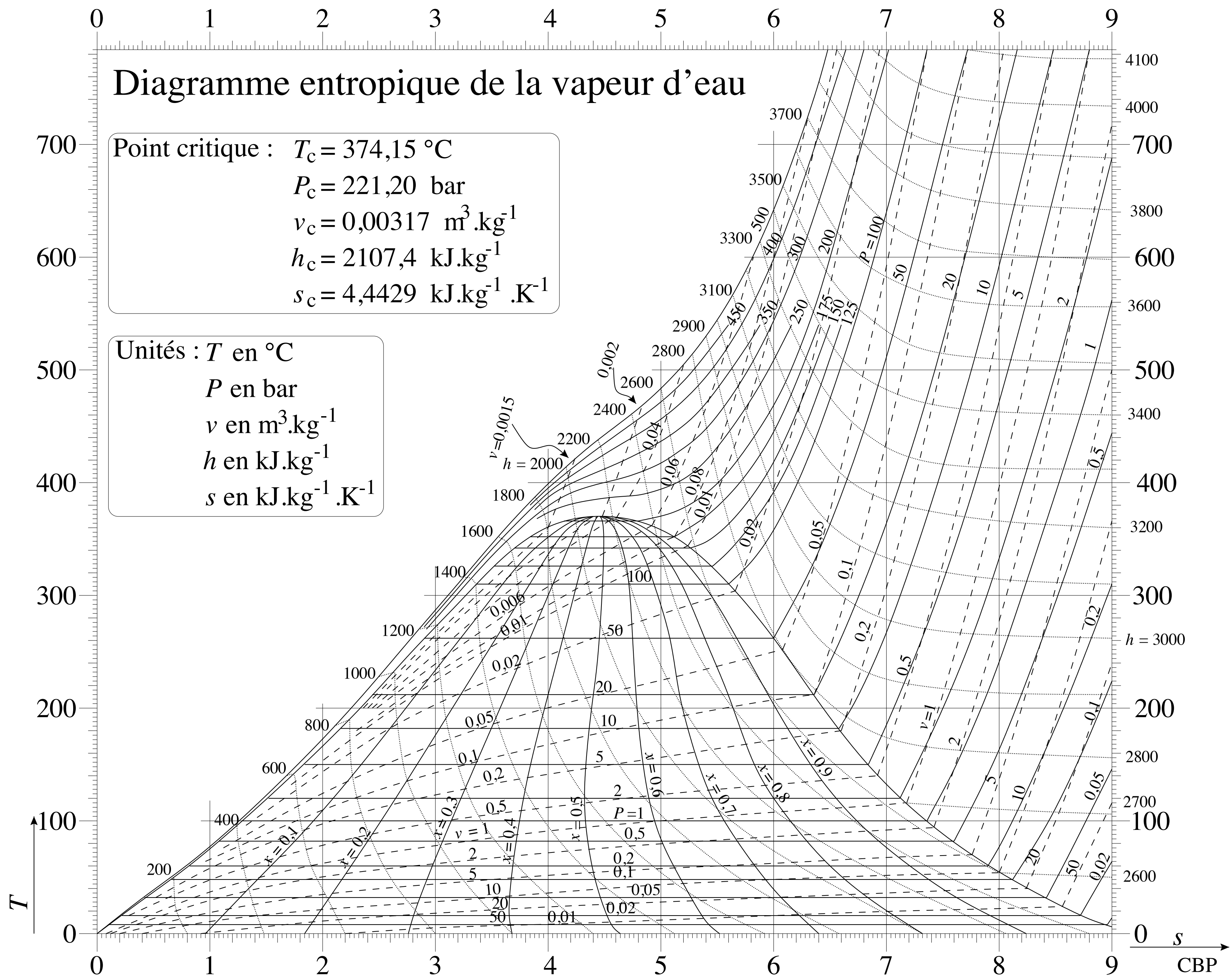


Diagramme entropique de la vapeur d'eau
Point critique : $T_c = 374,15$ °C
$P_c = 221,20$ bar
$v_c = 0,00317$ m^3.kg^{-1}
$h_c = 2107,4$ kJ.kg^{-1}
$s_c = 4,4429$ kJ.kg^{-1}.K^{-1}
Unités : T en °C
P en bar
v en m^3.kg^{-1}
h en kJ.kg^{-1}
s en kJ.kg^{-1}.K^{-1}
T
s
CBP
h = 2000
h = 3000
P = 100
P = 1
v = 1
v = 0,0015
x = 0,1
x = 0,2
x = 0,3
x = 0,4
x = 0,5
x = 0,6
x = 0,7
x = 0,8
x = 0,9