Name: .... Student ID. ....

Seat NO

King Mongkut's University of Technology Thonburi

Final-term Examination Semester 2/2014
MEE 224 Thermal Engineering Credits 3
Department of Automation Engineering and Electrical Engineering
11 May 2015 13:00 – 16:00

Note: 1. You are not allowed to bring lecture notes and any other texts to the examination room.
2. Calculators are permitted.
3. Answer all six questions.
4. If you have any doubt that the given information does not clarify, you may assume.
5. Tables of thermodynamic properties and charts are provided.
Total marks 20 × 6 =120

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Basic Principle Formulations

Simple Compressible Closed System:

Conservation of mass: $m_1 = m_2$

Conservation of energy: $Q = U_2 - U_1 + W$

Mechanical work of simple compressible system: $W = \int p\, d\forall$

Open system, Steady Flow: one inlet, one outlet

Conservation of mass: $\dot{m}_i = \dot{m}_e = \rho_i A_i \bar{v}_i = \rho_e A_e \bar{v}_e$

Conservation of energy: $q - w = h_e - h_i + \left(\dfrac{\bar{v}_e^2 - \bar{v}_i^2}{2}\right) + g(z_e - z_i)$

Properties of pure substances:

Specific heats: $c_v = \left(\dfrac{\partial u}{\partial T}\right)_v$ and $c_p = \left(\dfrac{\partial h}{\partial T}\right)_p$

The specific volume of the mixture (liquid and vapor): $v = v_f + x\,(v_g - v_f)$

An ideal gas equation of state: $\dfrac{p_1 v_1}{T_1} = \dfrac{p_2 v_2}{T_2}$

Enthalpy $h = u + p\,v$

$du = c_v\, dT$, $dh = c_p\, dT$

Gas Law $p\,v = R\,T$

The isentropic relations of ideal gases with constant specific heats

$$\left(\frac{T_2}{T_1}\right) = \left(\frac{P_2}{P_1}\right)^{\frac{(k-1)}{k}} = \left(\frac{v_1}{v_2}\right)^{k-1}$$

Air at room temperature are $c_p = 1.005$ kJ/kg·K, $c_v = 0.718$ kJ/kg·K, $R = 0.287$ kJ/kg·K, and $k = 1.4$

Clausius inequality $\oint\left(\dfrac{dQ}{T}\right) \le 0$

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Entropy	$dS = \left(\dfrac{dQ}{T}\right)_{int\,rev}$
T ds relation	$T\,ds = du + p\,dv$ $T\,ds = dh - v\,dp$
Compression ratio	$r = \dfrac{V_{max}}{V_{min}} = \dfrac{V_{BDC}}{V_{TDC}}$
MEP	$MEP = \dfrac{w_{net}}{v_{max} - v_{min}}$

1. Determine the work input required to compress steam isentropically from 100 kPa to 1 MPa, assuming that the steam exists as (*a*) saturated liquid and (*b*) saturated vapor at the inlet state. Compare the result from (a) and (b).

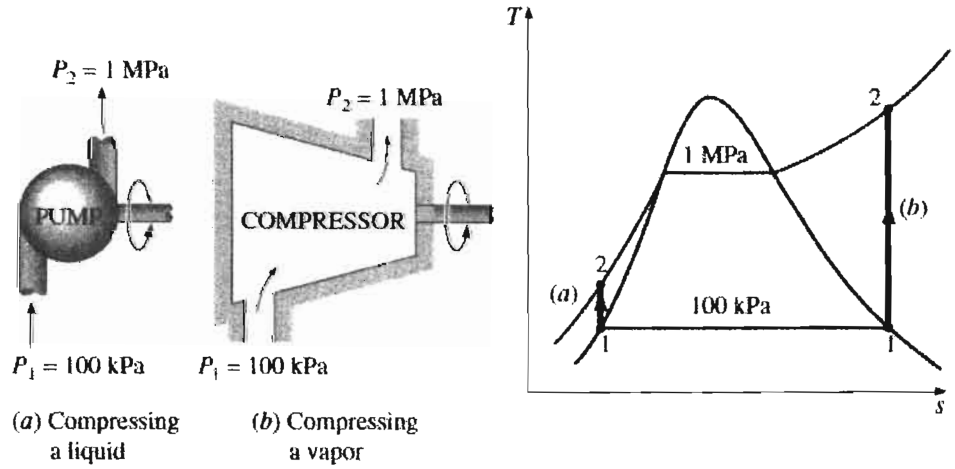

Fig. 1. Schematic and T-s diagram for Question 1.

Solution

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2. Show that an ideal air standard Otto cycle has a thermal efficiency as in the following:

$$\eta_T = 1 - \frac{T_1}{T_2} = 1 - \left(\frac{v_2}{v_1}\right)^{k-1} = 1 - \frac{1}{r^{k-1}}$$

where r = compression ratio = v_1/v_2
k = specific heat ratio = c_p/c_v
subscripts 1 and 2 are the initial and final sates of an isentropic compression.

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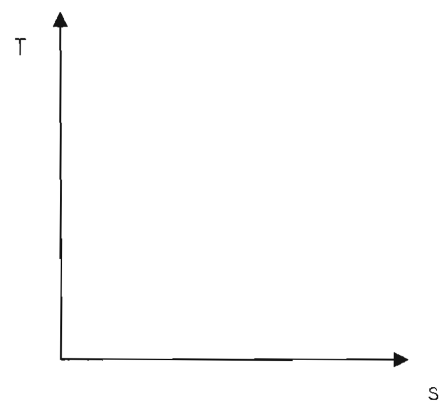
3. A steam power plant operates on a simple ideal Rankine cycle between the pressure limits of 3 MPa and 50 kPa. The temperature of the steam at the turbine inlet is 700°C, and the mass flow rate of steam through the cycle is 35 kg/s. Show the cycle on a *T-s* diagram with respect to saturation lines, and determine (*a*) the thermal efficiency of the cycle and (*b*) the net power output of the power plant.



Answer: η_{th} = ...%

Wnet = ...MW

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4. Given data: Refrigerant 134a (properties refer to p-h diagram)
Average temperature at the evaporator coil = -20 °C
Average temperature at the condenser coil = 40 °C
The compressor power = 2.90 kW

Assumption: An ideal vapor-compression refrigeration cycle operates at steady state

Find: Draw the operating cycle on given diagram & complete the table below.
The mass flow rate of refrigerant in kg/s
The refrigerating capacity, in tons (1 ton of refrigeration = 3.516 kW)
The coefficient of performance

From the R-134a chart at T_{sat} = -20 °C, P = ... MPa
T_{sat} = 40 °C, P = ... MPa

State	T (°C)	P (MPa)	h (kJ/kg)	s (kJ/kg-K)	Phase description
1					
2					
3					
4					

The mass flow rate of refrigerant = ... kg/s
The refrigerating capacity = ... tons
COP. =

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5. Complete the following table for air at atmospheric pressure:

T_{db} (°C)	T_{wb} (°C)	T_{dp} (°C)	ω (g H_2O/kg dry air)	RH (%)	h (kJ/kg)
30	30				
	29			70	
40					99
			25	80	
23	25				

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6. Use your knowledge of Thermodynamics to explain how to save energy in heat engines such as car engines and heat pumps such as refrigerators.

Hint: use Carnot principle to adjust temperatures or heat transfer of such devices in order to improve their performance.

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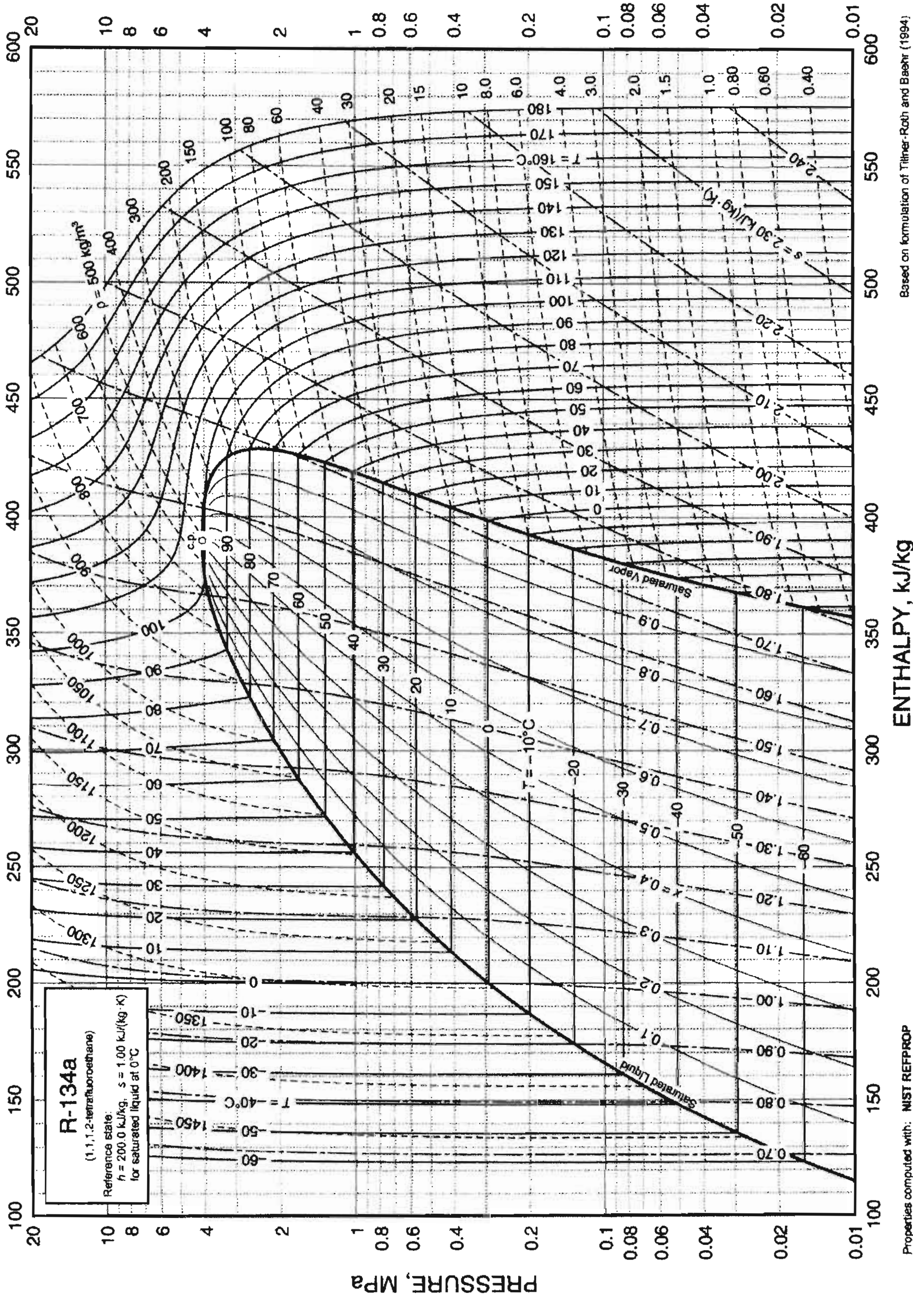

Fig. 8 Pressure-Enthalpy Diagram for Refrigerant 134a

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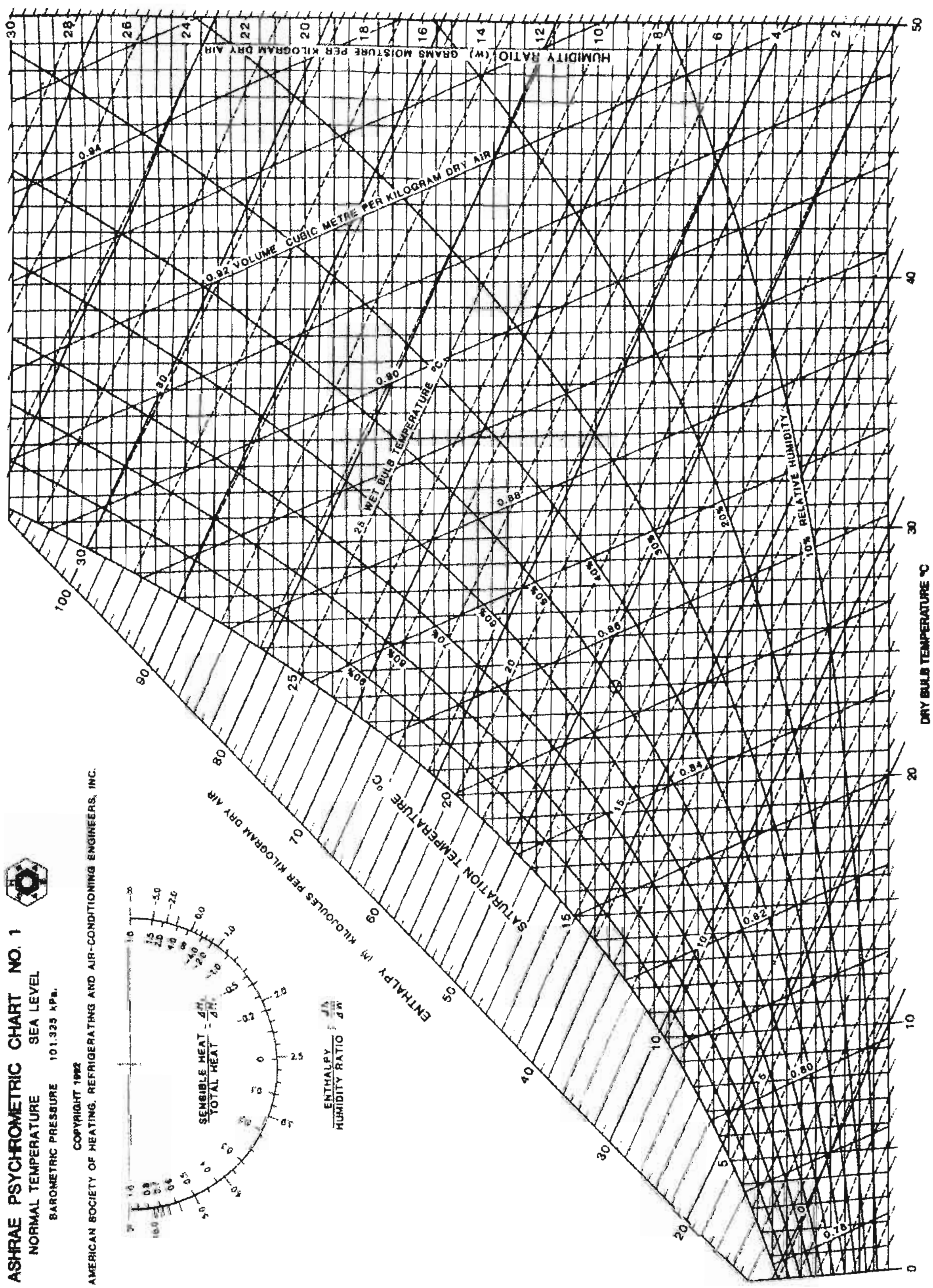

Fig. 1 ASHRAE Psychrometric Chart No. 1