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

Seat NO

King Mongkut's University of Technology Thonburi

Final-term Examination — Semester 2/2013
MEE 224 Thermal Engineering — Credits 3
Department of Control system and Instrumentation Engineering
6 May 2014 — 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

Dr. Wanchai Asvapoositkul

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 $dS = \left(\frac{dQ}{T}\right)_{int\,rev}$

T ds relation $T\,ds = du + p\,dv$

$T\,ds = dh - v\,dp$

Compression ratio $r = \frac{V_{max}}{V_{min}} = \frac{V_{BDC}}{V_{TDC}}$

MEP $MEP = \frac{w_{net}}{v_{max} - v_{min}}$

1.1 What is a thermal energy reservoir? Give some examples.

Ans:

1.2 Is it possible for a heat engine to operate without rejecting any waste heat to a low-temperature reservoir?

Ans:

1.3 What is an isentropic process?

Ans:

1.4 What is a compression process of gas between the same pressure limits that requires the minimum work?

Ans:

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1.5 How does the thermal efficiency of an ideal cycle, in general, compare to that of a Carnot cycle operating between the same temperature limits?

Ans.

1.6 How do gas power cycles differ from vapor power cycles?

Ans:

1.7 How does a diesel engine differ from a gasoline engine?

Ans:

1.8 Define the coefficient of performance of a heat pump in words. Can it be greater than unity?

Ans.

1.9 Define specific humidity and relative humidity of air-conditioning in words.

Ans.

1.10 What is the difference between a refrigerator and an air conditioner?

Ans.

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2 An ideal air standard Otto cycle has a compression ratio of 8. At the beginning of the compression process, air is at 100 kPa and 27°C, and 750 kJ/kg of heat is transferred to air during the constant-volume heat-addition process. Determine

(a) the pressure and temperature at the end of the heat addition process, (*b*) the net work output, (*c*) the thermal efficiency, and (*d*) the mean effective pressure for the cycle. Assumed Air is an ideal gas with constant specific heats. [c_p = 1.005 kJ/kg·K, c_v = 0.718 kJ/kg·K, R = 0.287 kJ/kg·K, and k = 1.4]

Answer: $P_{max.}$ = ...kPa

$T_{max.}$ = ...°C

Q_{out} = ...kJ/kg

W_{netout} = ...kJ/kg

MEP = ... kPa

Thermal efficiency = ...%

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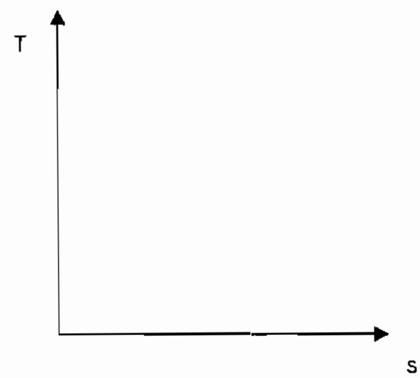
3. A steam power plant operates on a simple ideal Rankine cycle between the pressure limits of 3 MPa and 50 kPa. The temperature of the steam at the turbine inlet is 700°C, and the mass flow rate of steam through the cycle is 35 kg/s. Show the cycle on a *T-s* diagram with respect to saturation lines,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



Answer: η_{th} = ...%

W_{net} = ...MW

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4. Subject: refrigerator (20 marks)

Given data: Refrigerant 134a (properties refer to p-h diagram)
Average temperature at the evaporator coil = -10 °C
Average temperature at the condenser coil = 40 °C
The compressor power = 3.0 kW

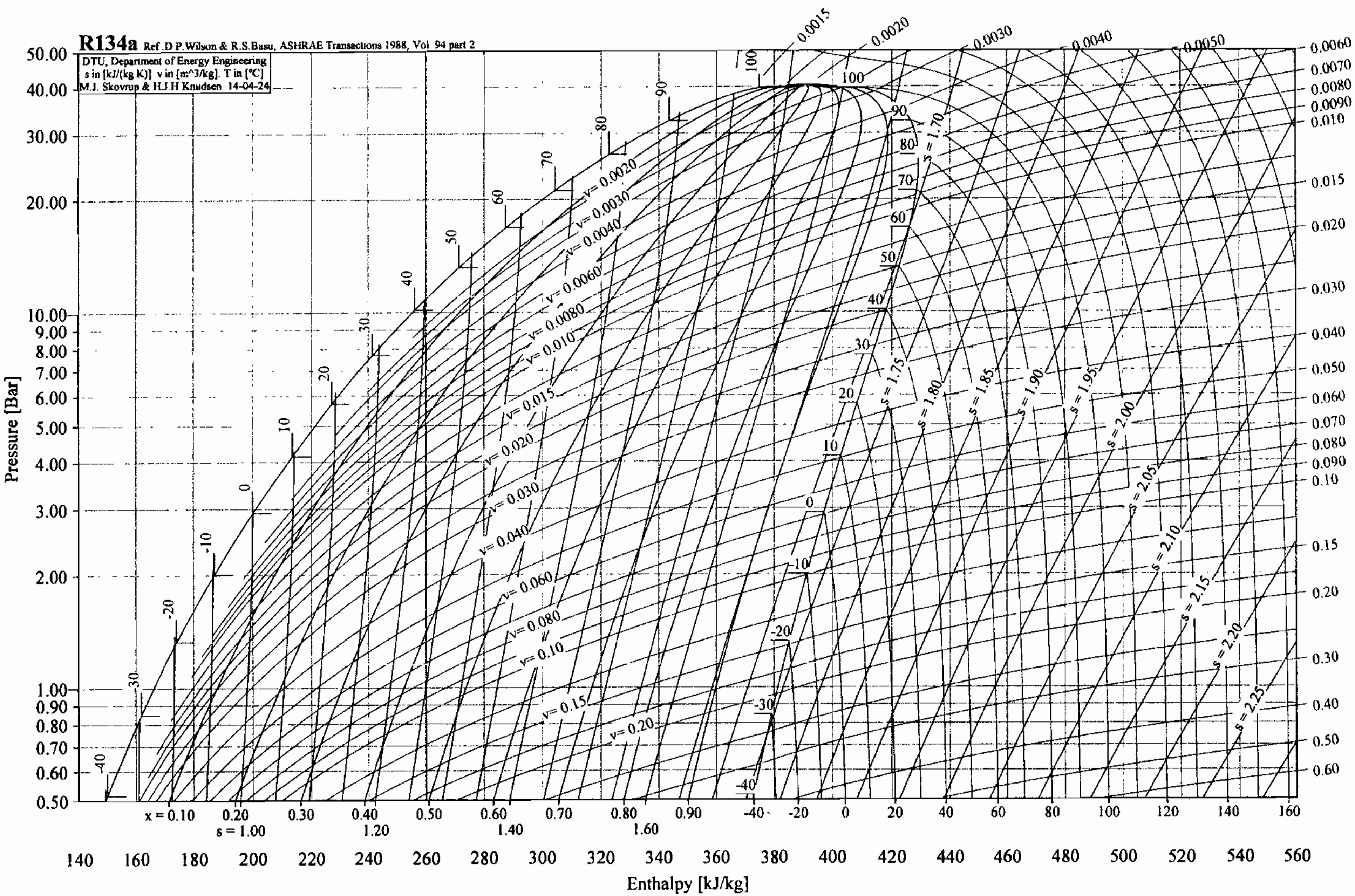
Assumption: An ideal vapor-compression refrigeration cycle operates at steady state

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} = -10 °C, P = ... Bar
T_{sat} = 40 °C, P = ... Bar

State	T (°C)	P (Bar)	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. =


R134a Ref. D.P.Wilson & R.S.Basu, ASHRAE Transactions 1988, Vol 94 part 2
DTU, Department of Energy Engineering
s in [kJ/(kg K)] v in [m^3/kg]. T in [°C]
M.J. Skovrup & H.J.H Knudsen 14-04-24
Pressure [Bar]
Enthalpy [kJ/kg]
x = 0.10
s = 1.00
v= 0.0020
v= 0.0030
v= 0.0040
v= 0.0060
v= 0.0080
v= 0.010
v= 0.015
v= 0.020
v= 0.030
v= 0.040
v= 0.060
v= 0.080
v= 0.10
v= 0.15
v= 0.20
s = 1.70
s = 1.75
s = 1.80
s = 1.85
s = 1.90
s = 1.95
s = 2.00
s = 2.05
s = 2.10
s = 2.15
s = 2.20
s = 2.25

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5. Subject: Air-conditioning unite (20 marks)

A flow of moist air initially has a flow rate of 10 m^3/s, a dry-bulb temperature of 30°C and 70% RH.

(a) Determine the dew point temperature and initial specific humidity ω of the air.

(b) The air is then cooled to a dry-bulb temperature of 15°C and a wet-bulb temperature of 10°C. Determine the rate of removal of water in kg/s.

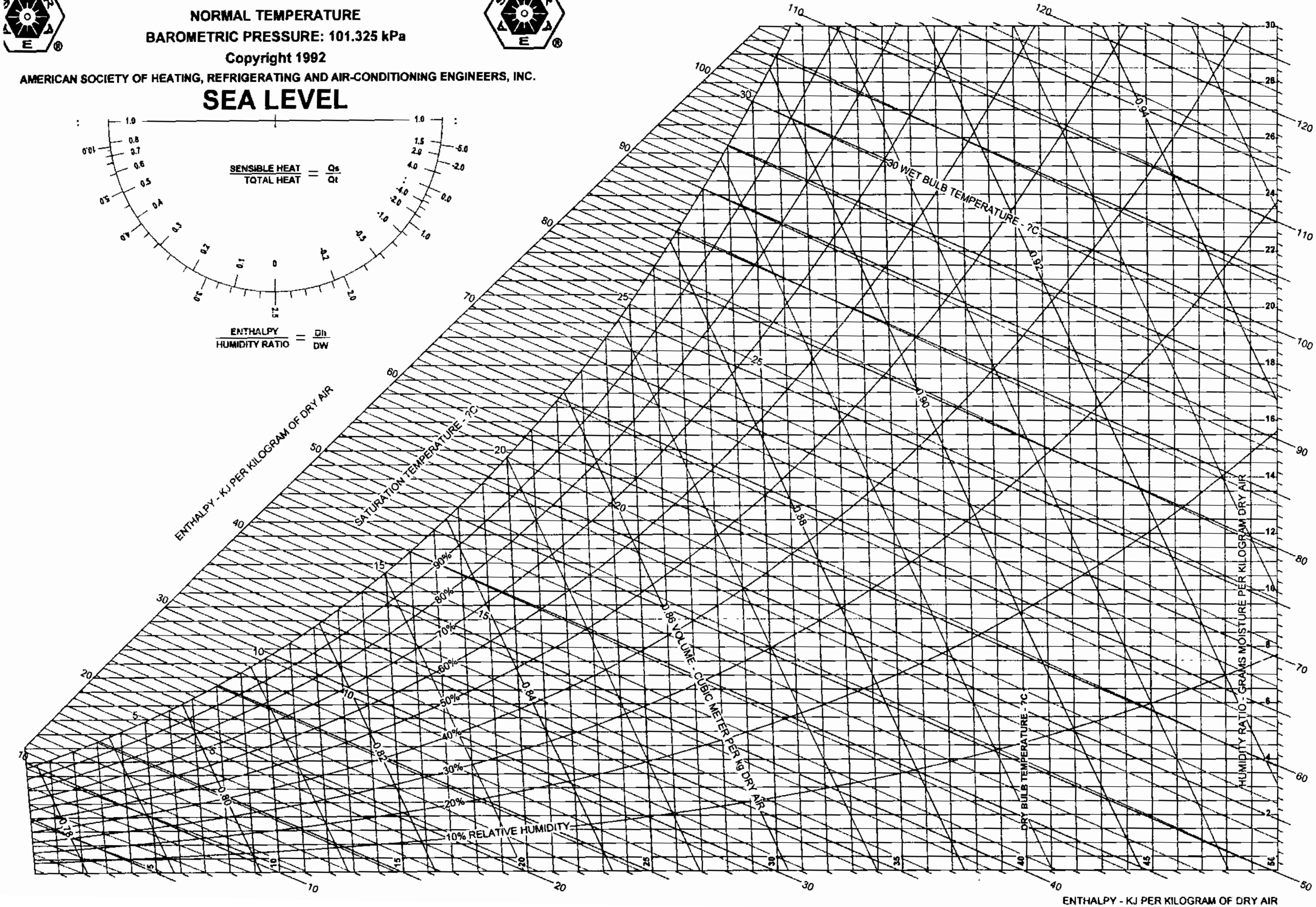
ASHRAE PSYCHROMETRIC CHART NO.1

NORMAL TEMPERATURE

BAROMETRIC PRESSURE: 101.325 kPa

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.

SEA LEVEL



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6. Use your knowledge of Thermodynamics to explain how to improve motor efficiency.
Hint: use 1st and 2nd laws principle to improve its performance.