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

King Mongkut's University of Technology Thonburi

Seat NO

Final-term Examination — Semester 1/2014
MEE 224 Thermal Engineering — Credits 3
Department of Control system and Instrumentation Engineering
26 November 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. The psychrometric chart and refrigerant R-134a chart 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: $q - w = h_e - h_i + \left(\frac{\bar{v}_e^2 - \bar{v}_i^2}{2}\right) + g(z_e - z_i)$

Properties of pure substances:

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

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

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

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 $\oint \left(\frac{dQ}{T}\right) \le 0$

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

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. What are the similarities and the differences between a pair of the following systems or devices? **(20 points)**

   1.1 Gasoline engines and diesel engines

Ans.

   1.2 Gas turbines (e.g. in Brayton cycle) and stream turbines (e.g. in Rankine Cycle)

Ans.

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1.3 Refrigerators and air conditioners

Ans.

1.4 Compressors and pumps

Ans.

1.5 Heat engines and heat pumps

Ans.

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2. In the following questions, underline the correct words in the bracket. (10 points)

2.1 Carnot heat engine can be *(more efficient than, less efficient than, the same efficient as)* a reversible heat engine which uses the same energy reservoirs.

2.2 A piston–cylinder device contains nitrogen gas. During a reversible, adiabatic process, the entropy of the nitrogen will (*never, sometimes, always*) increase.

2.3 Compressing steam in the vapor form would require (*more work than, the same work as, less work than*) compressing it in the liquid form between the same pressure limits.

2.4 The greater the entropy generation, the (*higher, same, lower*) the performance.

2.5 For saturated air, the dry-bulb temperature is (higher than, the same as, lower than) the wet-bulb temperature.

2.6 The state of the atmospheric air in the air-conditioning processes can be determined by using (psychrometric charts, Mollier diagram for air, refrigerant charts).

2.7 The human body responds to hot weather by (perspires more, cuts the blood circulation near the skin, sweats excessively).

2.8 The human body responds to hot and humid weather by (perspires more, cuts the blood circulation near the skin, sweats excessively).

2.9 The human body responds to cold weather by (perspires more, cuts the blood circulation near the skin, sweats excessively).

2.10 Consider a simple ideal Rankine cycle with fixed boiler and condenser pressures. What is the effect of super-heating the steam to a higher temperature on

Pump work input: (increases, decreases, remains the same).

Turbine work output: (increases, decreases, remains the same).

Heat supplied: (increases, decreases, remains the same).

Heat rejected: (increases, decreases, remains the same).

Cycle efficiency: (increases, decreases, remains the same).

Moisture content at turbine exit: (increases, decreases, remains the same).

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3.1 An automobile engine consumes fuel at a rate of 28 L/h and delivers 60 kW of power to the wheels. If the fuel has a heating value of 44,000 kJ/kg and a density of 0.8 g/cm^3, determine the efficiency of this engine. Compare your result with that of the Second Law efficiency (e.g. Carnot Heat engine) if the combustion raises the temperature to 1300°C from atmospheric pressure at the ambient temperature of 30°C. If an ideal Otto cycle with a compression ratio of 8.8 is assumed, find its air standard efficiency. **(15 points)**

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3.2 In order to save energy, what should be done in an air-conditioning room? **(15 points)**

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4. Subject: refrigerator (20 points)

Given data: Refrigerant 134a (properties refer to p-h diagram)
Average pressure at the evaporator coil = 0.15 MPa
Average pressure at the condenser coil = 1.00 MPa
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 P = 0.15 MPa, T_{sat} = ...°C,
P = 1.00 MPa, T_{sat} = ...°C,

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. =

7.2

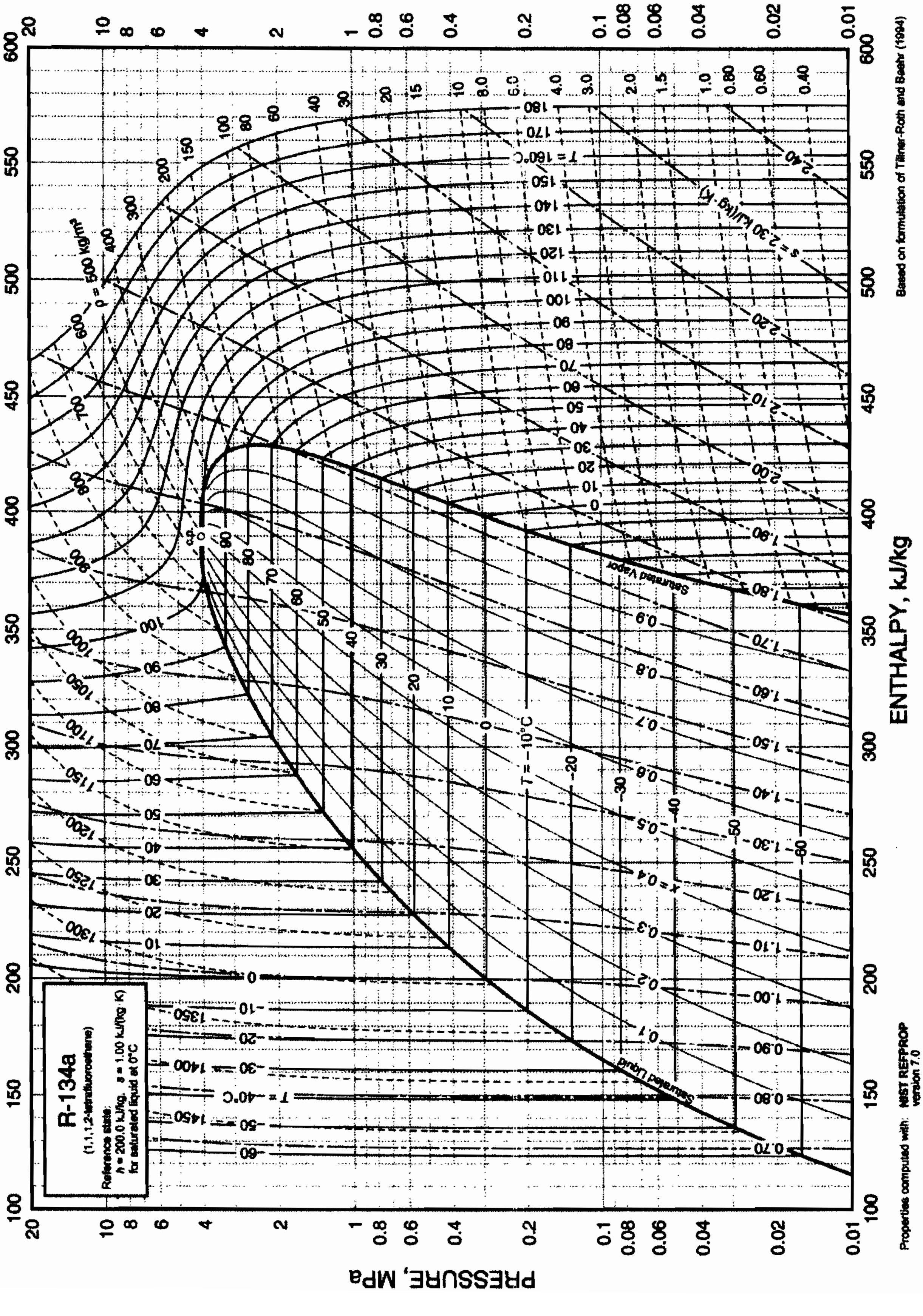

Fig. 8 Pressure-Enthalpy Diagram for Refrigerant 134a

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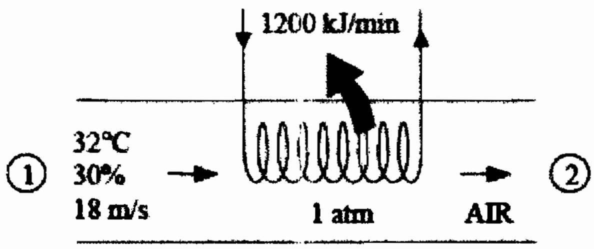
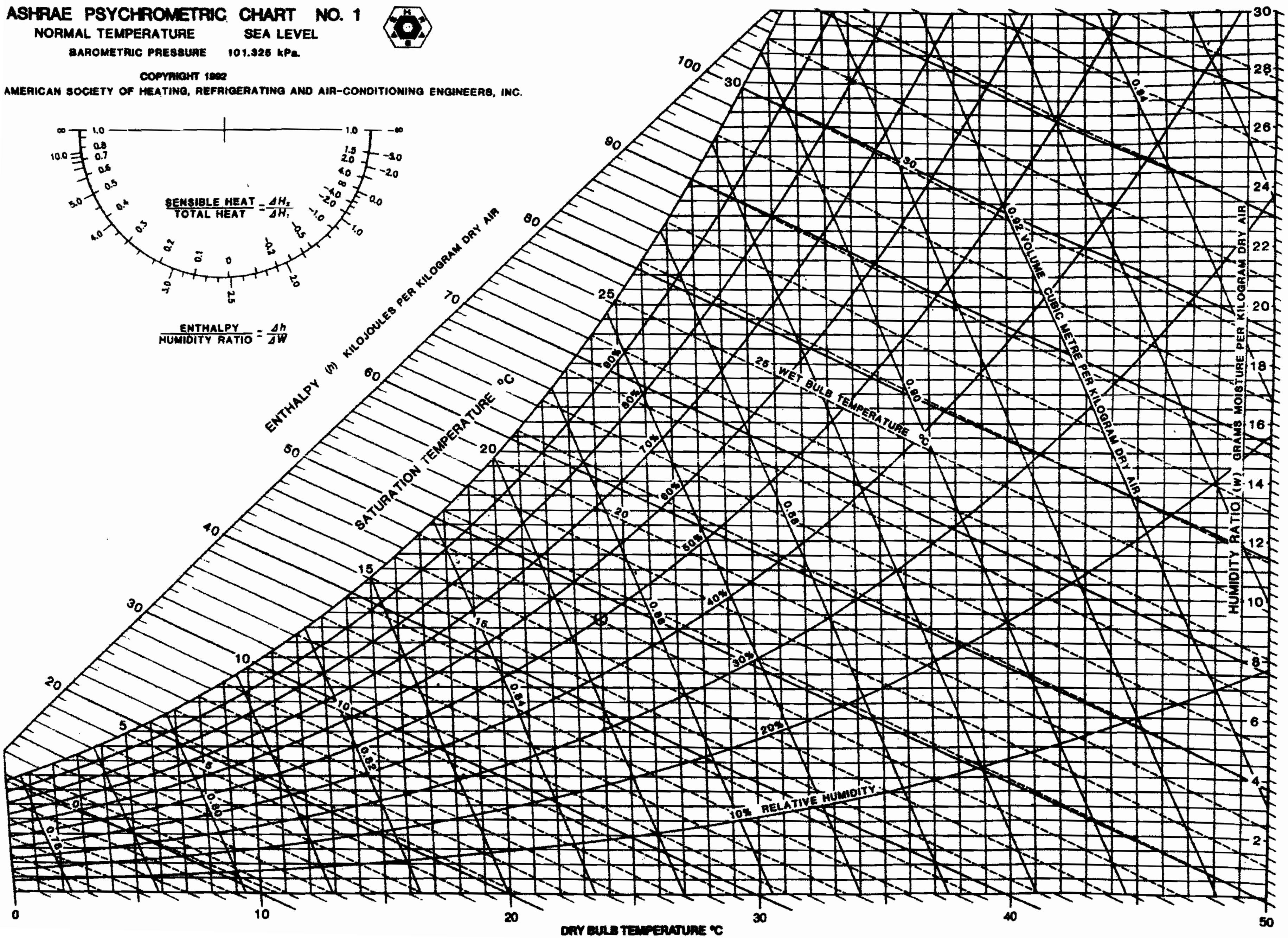
5. Subject: Air-conditioning unite (20 points)

Air enters a 40-cm-diameter cooling section at 1 atm, 32°C and 30% RH at 18 m/s. Heat is removed from the air at a rate of 1200 kJ/min. Determine (a) the exit temperature, (b) the exit relative humidity of the air, and (c) the exit velocity.

Note that there is no moisture removal from the air in this case.



8.2



ASHRAE PSYCHROMETRIC CHART NO. 1
NORMAL TEMPERATURE
SEA LEVEL
BAROMETRIC PRESSURE 101.325 kPa.
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AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.
SENSIBLE HEAT / TOTAL HEAT = ΔHs / ΔHt
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
ENTHALPY (h) KILOJOULES PER KILOGRAM DRY AIR
SATURATION TEMPERATURE °C
WET BULB TEMPERATURE °C
VOLUME CUBIC METRE PER KILOGRAM DRY AIR
RELATIVE HUMIDITY
HUMIDITY RATIO (W) GRAMS MOISTURE PER KILOGRAM DRY AIR
DRY BULB TEMPERATURE °C

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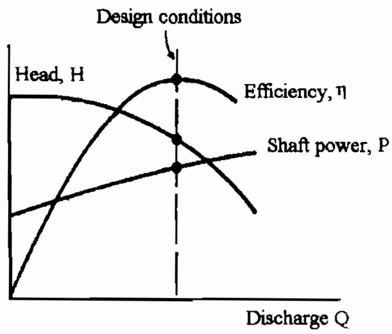
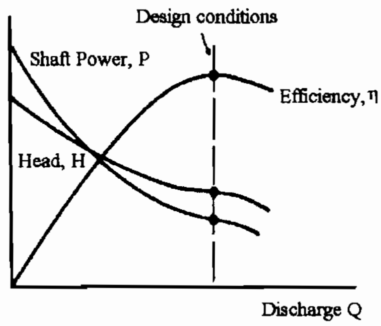
6. Use your knowledge of pumps to explain how to select pump type suitable for usage conditions.
And from the characteristic curves of the radial flow and axial flow pumps given below, describe how to start these pumps? (20 points)



Radial flow pump



Axial flow pump