UNIVERSITY OF JORDAN
CHEMICAL ENGINEERING DEPARTMENT

905322 – CHEMICAL ENGINEERING THERMODYNAMICS 1

الأسم	:
الرقم الجامعي	:
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الامتحان	: النهائي
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السؤال	العلامة الكاملة	العلامة
1	15	
2	20	
3	30	
4	20	
5	15	
المجموع	100	

وقع على القسَم التالي المتعلق بالغش الأكاديمي:

اقسم بالله أنني لم اغش في هذا الامتحان ولم أساعد أي شخص على الغش سواءً لمنفعتي الشخصية أو لمنفعة الآخرين، وعلى هذا أوقع.

التوقيع:

Student Name:

	(A)	(B)	(C)	(D)
⓿❶	○	○	○	○
⓿❷	○	○	○	○
⓿❸	○	○	○	○
⓿❹	○	○	○	○
⓿❺	○	○	○	○
⓿❻	○	○	○	○
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❶❶	○	○	○	○
❶❷	○	○	○	○
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❷❷	○	○	○	○
❷❸	○	○	○	○
❷❹	○	○	○	○
❷❺	○	○	○	○

Fill the circles completely.
Don’t fill more than one circle for each question. If there are more than one circles filled, you will get a zero for that question.
No answers on the questions sheet will be accepted.
Use a black/blue pen not a pencil.

Question 1 (15 points)

Select the most correct answer and circle it in the provided answers sheet. More than one answer may be correct, make your choices carefully and wisely.

1. A liquid at a temperature below its saturation temperature is called
   a) subcooled b) supercooled c) subcritical d) saturated

2. The standard reference state for chlorine would be defined as
   a) 25°C, 1 atm, Cl_2 vap. b) 25°C, 1 atm, Cl_2 liq. c) 25°C, 1 bar, Cl_2 vap. d) 25°C, 1 bar, Cl_2 liq.

3. Which of the following equations of state yield a three parameter corresponding states theory?
   a) PR b) Modified BWR c) RK d) a & b

4. The natural variables to yield a fundamental equation of state for $\underline{A}$ are
   a) T & P b) T & $\underline{V}$ c) $\underline{S}$ & $\underline{V}$ d) $\underline{S}$ & P

5. An incompressible fluid is defined as a fluid with
   a) $\kappa_T = 0$ b) $\alpha = 0$ c) a & b d) $\mu = 0$

6. The term $RT/(\underline{V} - b)$ in cubic equations of state stands for
   a) Repulsive forces b) Attractive forces c) Polar forces d) a & b

7. The critical compressibility factor (Z_c) predicted by the SRK EOS is
   a) 0.375 b) 0.3333 c) 0.3123 d) 0.3074

8. A thermal equation of state relates the internal energy ($\underline{U}$) to
   a) T & P b) T & $\underline{V}$ c) $\underline{S}$ & $\underline{V}$ d) $\underline{S}$ & P

9. The second virial coefficient at low temperatures is generally
   a) positive b) negative c) zero d) infinite

10. The main difference between the refrigeration Rankine cycle (RRC) and vapor compression cycle (VCC) is
    a) RRC uses a turbine while VCC uses a nozzle b) RRC uses a turbine while VCC uses an expansion valve c) RRC uses a nozzle while VCC uses an expansion valve d) RRC uses an expansion valve while VCC uses a turbine

11. If the Mach number of the shockwave accompanying a mechanical explosion is less than one; then the explosion is classified as?
    a) Explosion b) Detonation c) Deflagration d) Implosion

12. The effect of explosion of 5 kg of TNT at a radius of 14 m is to cause
    a) Total destruction b) Substantial damage c) Minor damage d) Shattered windows

13. Which of these is not an alternate energy source?
    a) Tidal waves b) Photovoltaic cells c) Biomass d) Tar sand

14. The power cycle that describes the gas-turbine engine is
    a) Rankine b) Brayton c) Carnot d) Otto

15. The heat addition step for an Otto cycle is carried out
    a) Isobarically b) Isochorically c) Isometrically d) b & c

Question 2 (20 points)

An intended plan to phase out the LPG cylinders used for heating in Jordan is to provide Amman with a natural gas network. The natural gas is to be imported from Egypt via the extension of Arabian pipeline in Aqaba. Natural gas is to be delivered from Amman central distribution system at 300 K and ≈1 bar. Base your calculations on the data below.

Population for Amman: 2,000,000 capita.
Electric consumption per capita per year: 2000 kW.h/yr/capita.
Municipal consumption out of the total consumption: 20%.
Assume the temperature of combustion products of methane to be 800 K.
The efficiency of utilizing the generated heat is estimated to be 85%.

The decision makers are in need of a good estimate for the flowrate of the imported natural gas per year. What is your recommended value for the imports per year?

Sketch
Assumptions
Summary & Comments

Question 3 (30 points)

A natural gas stream available at 1 bar and 180 K is to be used to produce liquefied methane. The compressed stream will be leaving the cooler at 180 K. The flash drum is adiabatic and operates at 1 bar, and each compressor stage can be assumed to operate reversibly and adiabatically. The compression ratio is the same in each compression stage and is equal to 5. Between each stage the gas is to be isobarically cooled to 180 K. (**Use the provided chart for methane**)

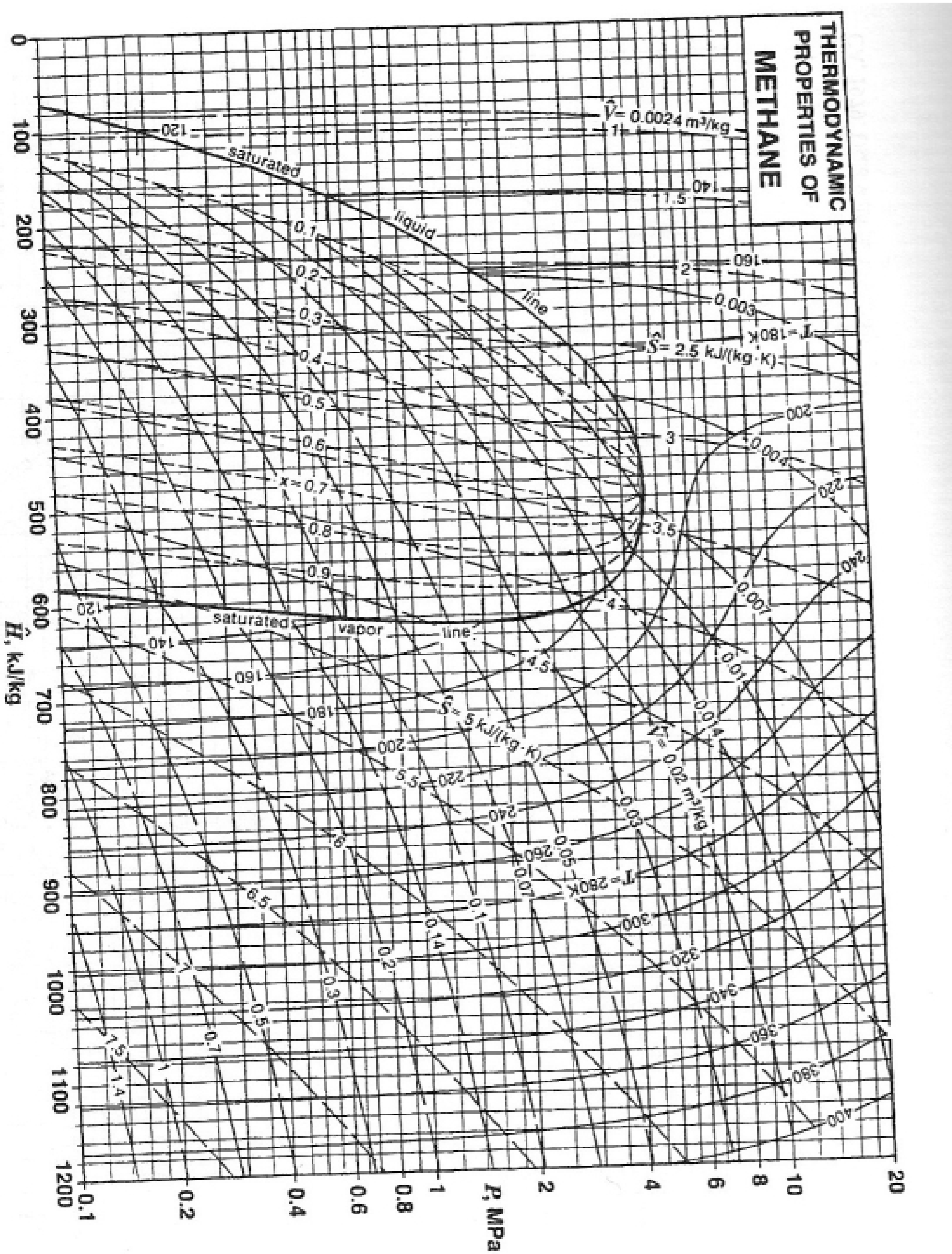
1. How many stages of compression are required for an outlet pressure from the cooler of 125 bars?
2. Calculate the amount of work required for each kilogram of methane that passes through the compressor in the simple liquefaction process.
3. Calculate the fractions of vapor and liquid leaving the flash drum in the simple liquefaction process and the amount of compressor work required for each kilogram of LNG produced.
4. What is the maximum permissible operating temperature out from the cooler?
5. Assuming that the recycled methane leaving the heat exchanger in the Linde process is at 1 bar and 180 K, calculate the amount of compressor work required per kilogram of LNG produced.

Assumptions

Summary & Comments

Process summary

1. Number o compression stages	
2. *W* (kJ/kg CH_4)	
3.a Liquid fraction (Simple)	
3.b *W* (kJ/kg LNG)	
4. Max operating *T* (K)	
5.a Liquid fraction (Linde)	
5.b *W* (kJ/kg LNG)	


THERMODYNAMIC PROPERTIES OF METHANE
$\hat{H}$, kJ/kg
P, MPa
saturated liquid line
saturated vapor line
$\hat{V}$ = 0.0024 m³/kg
$\hat{V}$ = 0.02 m³/kg
$\hat{S}$ = 2.5 kJ/(kg·K)
$\hat{S}$ = 5 kJ/(kg·K)
T = 180K
T = 280K
x = 0.7

Question 4 (20 points)

The "Quick Fill" bicycle tire filling system consists of a small cylinder filled with nitrogen to a pressure of 140 bar. **Use Departure Charts to solve this problem**.

You may assume the contents are initially at the ambient temperature of 298.15 K.
Cylinder dimensions: 2-cm-diameter and 6.5-cm-long.
You may use the ideal gas heat capacity of nitrogen up to the linear term i.e.; $C_p = A + BT$.

1. Estimate the explosive equivalent of the gas contained in the cylinder as grams of TNT.
2. What is the mass of nitrogen in the cylinder?

Sketch

Assumptions

Summary & Comments

Physical Properties Summary

T_c(K)	
P_c (MPa)	
$C_p = A + BT$	

Departure Calculations Summary

	Initial state	Final state
T_r		
P_r		
S^{IG} - S (kJ/kg.K)		
S (kJ/kg.K)		
H^{IG} - H (kJ/kg)		
H (kJ/kg)		

Results Summary

Final temperature (K)	
Work (kJ)	
TNT equivalent (kg)	
Mass (kg)	

Question 5 (15 points)

A LNG stream (may be assumed methane) at 20 bar and 140 K flows at a rate of 100 kg/s through a pipe of cross sectional area of 0.5 m^2. What is the volumetric flowrate and velocity for this stream? **Base your calculations on the Peng-Robinson EOS**.

Carry out three iterations starting with a reasonable initial guess then use $Z = 0.065$ for subsequent calculations.

Sketch

Assumptions

Summary & Comments

Equation of State Summary

T_c(K)		P_c (MPa)	
ω (-)			

A		α	
B		β	
A		γ	
B			
$Z_0 =$	$Z_1 =$	$Z_2 =$	$Z_3 =$

Results Summary

Volumetric flowrate (m^3/s)	
Density (kg/m^3)	
Velocity (m/s)	