Problem 1.

a.
Scratch a block diagram to illustrate how the PVT-simulator works.
Describe shortly the content of each block.
- Specify the input data for each component, especially the pseudo components.
- Specify the parameters needed for each component, and how they are calculated from the input data for the pseudo components.

b.
The SRK-EOS is given by the formula:

$$P = \frac{RT}{V - b} - \frac{a(T)}{V(V + b)}$$

The following parameters are given for component i:

$$a_i(T) = a_{ci}\alpha_i(T)$$

$$a_{ci} = 0.42747 R^2 \frac{T_{ci}^{\,2}}{P_{ci}}$$

$$b_i = 0.08664 R \frac{T_{ci}}{P_{ci}}$$

1. Explain what the two terms in the SKR-EOS represent.
2. Explain what the two parameters: a(T) and b, represent.
3. Explain by figure and formula, without doing any calculations, how the parameters a_{ci} and b_i can be determined for the pure component i.

c.
By putting $V = \dfrac{ZRT}{P}$, the SRK-EOS can be written as a 3. order equation in Z:

$$Z^3 - Z^2 + (A\text{-}B\text{-}B^2)Z - AB = 0$$

where:

$$A = \frac{a(T)P}{R^2 T^2} \quad \text{and} \quad B = \frac{bP}{RT}$$

For a given value of P and T, a reservoir fluid with composition (mole fraction) z_i is in the 2-phase area, i. e. vapor and liquid in equilibrium. The cubic equation in Z is solved to give 2 real roots.

In order to do compositional calculations in the 2-phase region, K_i-values must be known.

Questions:
1. What is the physical meaning of the 2 real roots?
2. How is the K_i-value defined? What is the K_i -value depending on?
3. Describe in detail how the K_i –value is calculated by the means of the SRK-EOS. Use formulas as fare as possible.
4. How is the mole fraction of the vapor, V, and liquid phase, L, calculated? Use formulas.
5. How is the composition of the vapor, y_i, and liquids, x_i, phase calculated as mole fractions?

Problem 2.

The following reservoir data are given for an oil reservoir:

$P_i = 450$ bar
$P_b = 253.3$ bar
$T_{res} = 80\ ^oC$
$\Phi = 0.25$
$S_{wr} = 0.2$
Bulk reservoir volume: $V_{bulk} = 10^6\ m^3$

a.
A representative reservoir fluid sample is needed for PVT and compositional analysis. What is the most optimum sampling technique in this case? Give a short explanation.

A Constant Mass Expansion (CME) analysis of the reservoir fluid is performed at T_{res}, and the following data are given:

Pressure Bar	Rel. Vol. V/Vb	Compressibility 1/Bar	Y -Factor
500.0	0.9634	1.134E-04	
450.0	0.9693	1.240E-04	
400.0	0.9759	1.364E-04	
350.0	0.9832	1.510E-04	
300.0	0.9914	1.686E-04	
253.3	1.0000	1.884E-04	
250.0	1.0033		4.02
200.0	1.0725		3.68
150.0	1.2087		3.30
100.0	1.5271		2.91
50.0	2.6158		2.52

A separator test was simulated, and the following data were obtained:

Pressure Bar	Temp °C	GOR Sm³/Sm³	Gravity air=1	Oil Dens g/cm³	FVF m³/Sm³
253.3	80.0			0.732	1.340
100.0	60.0	73.7	0.682	0.796	1.155
30.0	40.0	31.1	0.710	0.834	1.070
1.0	15.0	21.3	1.048	0.865	1.000

b.
Verify that P_b is correctly determined from the CME-analysis.

c.
Calculate the production of STO (Sm^3) and gas (Sm^3) by a pressure depletion from P_i to P_b. It is assumed that the HCPV is constant during the pressure depletion, and that the fluid is produced through the given separator system.

d.
Calculate the density of the reservoir fluid at $P_i = 450$ bar, $(\rho_o)_i$ (kg/m^3).

Important formula/correlations in PVT-Analysis.

Temperature: $^oK = 273.15 + {}^oC$
$^oF = 1.8 \times {}^oC + 32$
$^oR = {}^oF + 459.69$

Pressure: $1 atm = 1013.250$ mBar $= 1.013250$ bar $= 101.3250$ kPa $= 0.1013250$ MPa $= 14.69595$ psia
psia $= 14.69595 +$ psig
1 atm $= 760.002$ mmHg at $0\,^oC$

Density: $1\ g/cm^3 = 62.43\ lb/ft^3 = 350.54\ lb/bbl$
$1\ lb/ft^3 = 16.0185\ kg/m^3$
$\rho_w = 0.999015\ g/cm^3$ $(60\,^oF, 1\ atm)$
$\rho_w = 0.9991\ g/cm^3$ $(15\,^oC, 1\ atm)$

Specific density: For liquids: Determined relative to water at sc.
For gases: Determined relative to air at sc.

$$\gamma_o = \frac{\rho_o}{\rho_w} = \frac{141.5}{131.5 + {}^oAPI}$$

$$^oAPI = \frac{141.5}{\gamma_o} - 131.5$$

Cragoe`s formula (empirical formula giving molecular weight of hydrocarbons):

$$M_o = \frac{6084}{{}^oAPI - 5.9}$$

$$\gamma_g = \frac{M_g}{M_{air}} = \frac{M_g}{28.96}$$

Volume: $1\ bbl = 5.615\ ft^3 = 0.15898\ m^3$
$1\ ft^3 = 0.0283\ m^3$
1 US Gallon $= 3.785$ litre
1 Imp. Gallon $= 4.546$ litre
Molar volume of gas at standard conditions:
$V_m = 379.51$ SCF/lb mole ($60\,^oF$ and 14.69595 psia)
$V_m = 23644.7\ cm^3/g$ mole $= 23.6447\ m^3/kg$ mole ($15\,^oC$ and 101.3250 kPa)

Air: $Z_{air} = 0.9959$ $(60\,^oF, 14.69595\ psia)$
$M_{air} = 28.96$

Gas constant: $R = 10.732$ (psia, ft^3, ^oR, lb mole)
$R = 0.082054$ (atm, litre, ^oK, g mole)
$R = 8.3145$ (kPa, m^3, ^oK, kg mole)