Exam AES1340

Reservoir Engineering

Examination 15 April 2016
13:30-16:30

Name (In Capitals):

Student number:

Use separate sheets to write your answers and clear derivation with name and student number indicated at the top of each sheet. Also present them in the logical order from answer 1 to last. Do not write answers on question sheets. Number the sheets and indicate nr of sheets handed in (e.g. 2 of 4). Hand in the original question sheets together with your answers.

Q1

Water is being injected into a layered reservoir under a constant pressure differential. The layers are separated by impermeable non-reservoir strata. The layer properties:

#	Permeability mD	Height ft	Porosity %	Connate water %	Residual Oil %
1	500	10	20	20	25
2	600	3	30	16	20
3	250	5	25	20	25

The oil viscosity is 2 cP and the Oil Formation Volume Factor (B_o) is 1.5 vol/vol, and assume B_w = 1 vol/vol.

After 2 years water breaks through whereafter the water cut appears to stabilize.

Assume piston-like displacement and unit mobility ratio (M = 1):

a) What is the water-cut level after breakthrough?
b) How long will the period with constant water-cut last?
c) If M > 1, would you then expect the time-span b) to be different? Adduce arguments in support of your answer.

Q2

You are the manager of an oil field. After two more appraisal wells it was estimated that 250 MMstb can be recovered. On that basis your company approved your team's development proposal. Currently all twelve development wells have been drilled and the surface facilities are nearing completion.

The company is listed at the New York Stock Exchange and has to submit proven reserve estimates to the SEC. Your reservoir engineer proposes to file 250 MMstb since all new wells indicated reservoir properties that were as, or even better, than prognosed. Do you agree? Provide arguments.

Q3

You are about to open a well that is perforated on an oil column that has bottom water. The lowest point of the perforated interval is 10 m above the OWC.

The oil is undersaturated and the following fluid data pertain:

Oil surface density	800 kg/m^3
Gas specific gravity (air=1)	0.8
Gas-Oil-Ratio	150 m^3/m^3
Water gravity	1.03
Oil viscosity (in-situ)	5 cP
Water viscosity (in-situ)	1 cP
Oil Formation Volume Factor (B_o)	1.8 vol/vol
Water Formation Volume Factor (B_w)	1.03 vol/vol

Well testing has shown that the Productivity Index is 25 $sm^3/d/bar$.

What is the critical rate? (The maximum oil rate at which water free production can be maintained)

Recall:
- Gravity constant is about 9.8 m/s^2
- Air density is 1.20 kg/m^3
- 1 bar = 10^5 Pa

Q4

A reservoir contains $10 * 10^9$ sm^3 of gas. Other fluid/reservoir data:

Initial Pressure	250 bar
Connate Water	15 %
Residual Gas Saturation	20 %
Pore Compressibility	$72 * 10^{-6}$ 1/bar
Water Compressibility	$44 * 10^{-6}$ 1/bar

a) It is often taken for granted that water and pore compressibility can be ignored in analyses of gas reservoirs. Do you agree in this case? Motivate.
b) The abandonment pressure is 60 bar. What is the Recovery Factor in case of an ideal gas and no water influx?
c) If the gas were not ideal (see table below), what would the RF be?
d) However, during production it was found that a fairly strong aquifer caused significant water invasion, such that the reservoir pressure cannot be lower than 100 bar. What is then the maximum attainable Recovery Factor?

Pressure (bar)	Z-factor
50	0.946
60	0.937
100	0.908
150	0.893
200	0.902
250	0.929
300	0.968

Q5

A build-up test was executed after about 100 hours of flow, during which period 80 sm^3 of oil was produced. The stabilized rate prior to shut-in was 20 m^3/d. Other fluid and reservoir data:

Reservoir thickness	6 m
Well bore radius	0.1 m
Oil viscosity	1 cP
Oil formation volume factor	1.5 rm^3/sm^3
Total compressibility	3E-4 1/bar

The pressure record of the build-up:

Time since shut-in (hours)	Pressure (bar)
0	310.8
0.5	322.4
0.67	324.5
1	326.4
1.5	327.6
2	328.1
2.5	328.3
3	328.5
4	328.7
6	329.0
8	329.2
10	329.3
12	329.4

a) The well drained the whole section; what is the effective permeability to oil?
b) What was the initial pressure? Assume the test was executed under transient conditions.

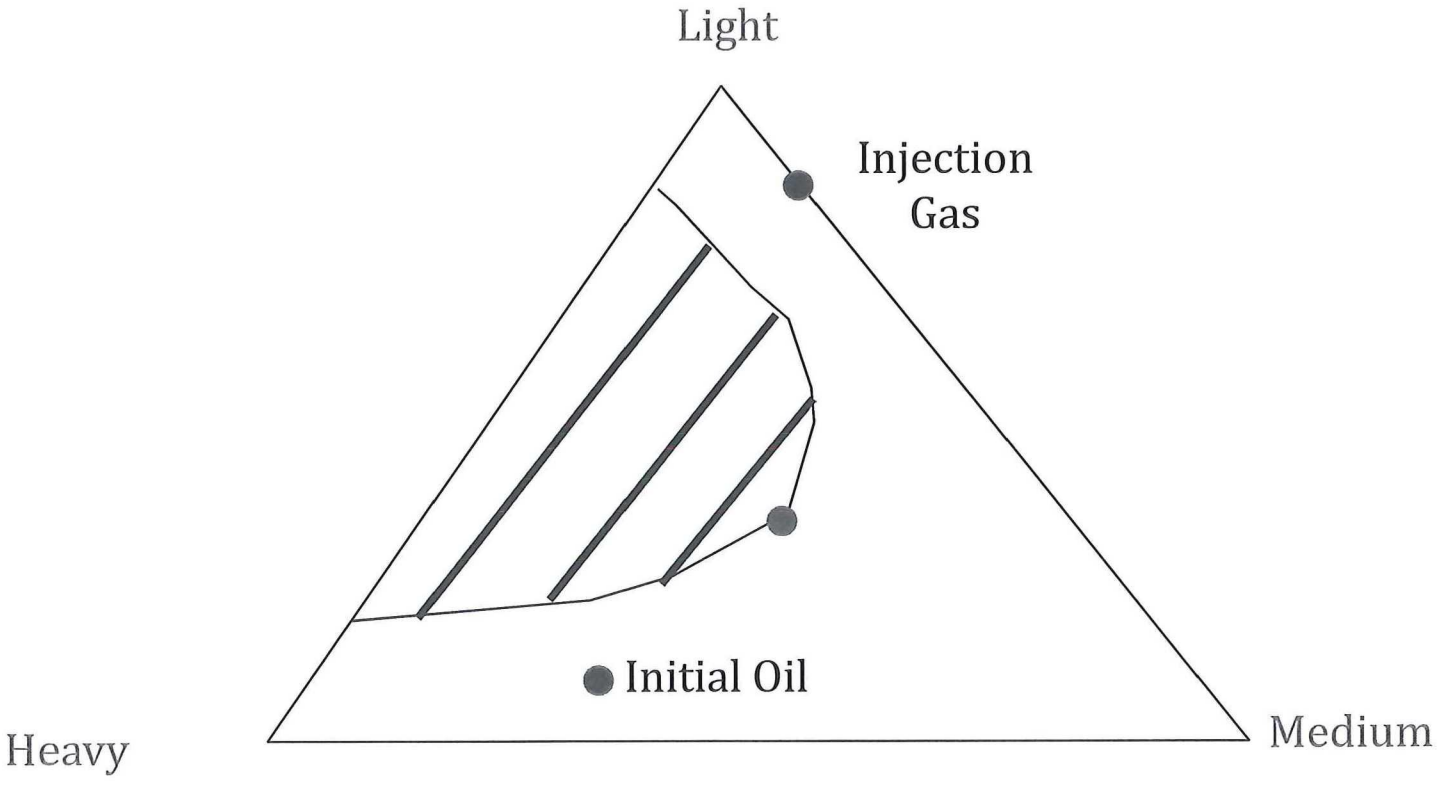
Conversion factors

1 bar	10^5 Pa
1 cP	1E-3 Pa.s
1 mD	0.987 E-15 m^2

Q6

A gas injection project is being considered and the phase behavior is approximated as shown in the ternary diagram below.

a) Do you expect that a miscible condition will develop upon continued injection? Why?
b) By how much "Medium" will the Injection Gas have to be enriched to achieve *first contact miscibility*? (A first guess of the minimum fraction of "Medium" in the injection mixture suffices).
c) If you cannot afford to add that much "Medium", what other strategy may result in first contact miscibility?



Q7

One is not satisfied with the (projected) waterflood recovery of subject reservoirs. What Enhanced-Oil-Recovery process(es) would you consider for the following reservoir conditions?

#	Pressure (bar)	Temperature (deg C)	Oil Viscosity (cP)
1	60	30	1000
2	180	60	5
3	60	25	75
4	90	35	2
5	300	90	8
6	120	45	200
7	180	60	800

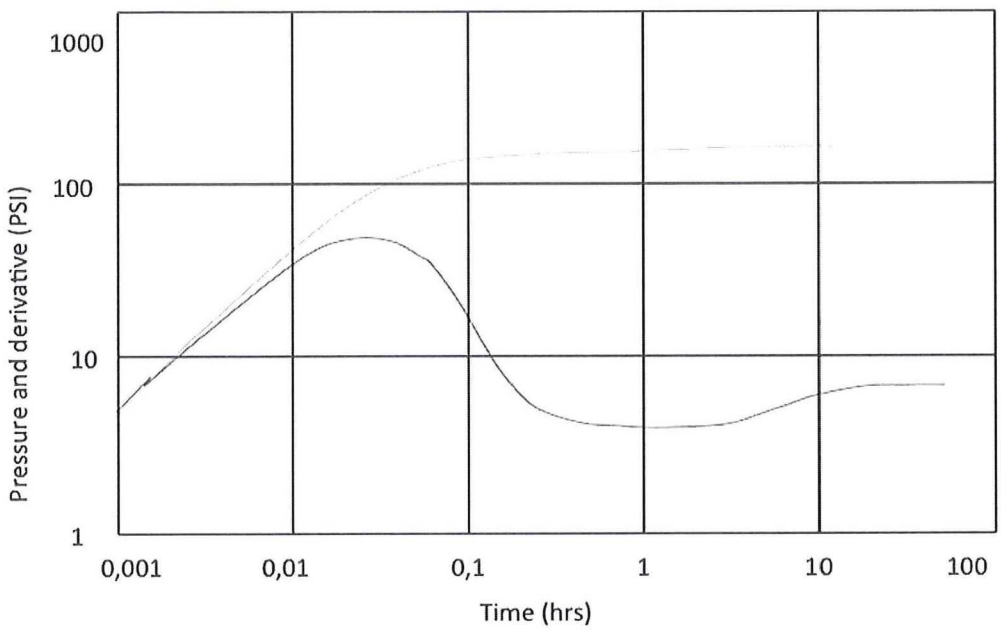
Q8

a) What is the main difference between a "II-" and a "II+" system. Support your answer with a sketch of a ternary diagram with oil, water and surfactant as the three (pseudo-) components.
b) Which parameter predominantly controls the nature of the system (II- vs. II+)

Q9

See the type curve below.

a) Which flow regimes do you distinguish?
b) Information from which time interval(s) may be used to estimate reservoir properties?
c) What is the implication of the final 30 hours on the derivative plot?


1000
100
10
1
Pressure and derivative (PSI)
0,001
0,01
0,1
1
10
100
Time (hrs)