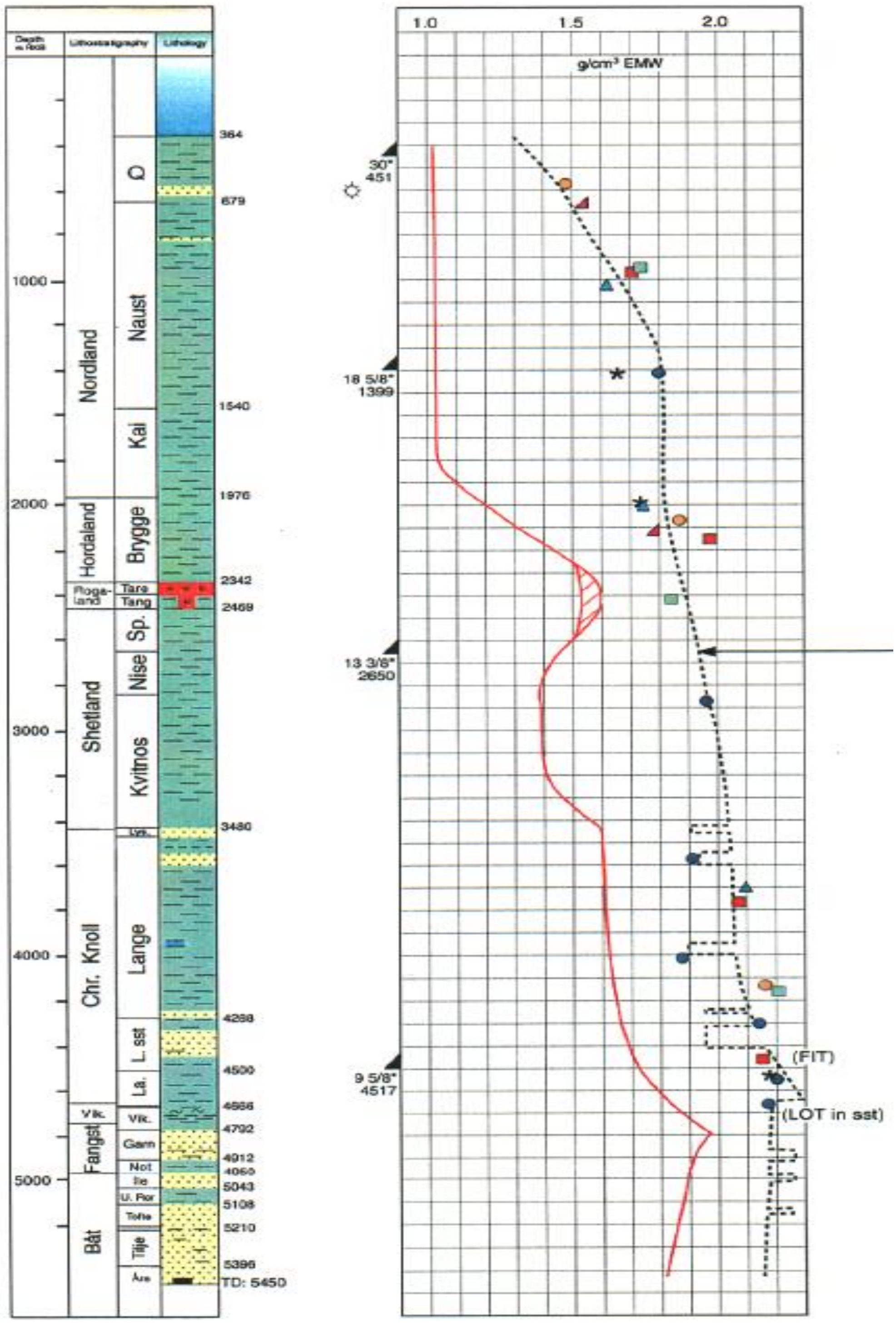
PART I - Directional Drilling

This part constitutes 50 % of the exam. Formulas can be found in the Appendix just after Part I.

1) How would you plan the mudweight selection for the following casing program?



2) Explain shortly what a kick tolerance is and how it affects the casing shoe depth selection. Also explain why they chose to set the 9 5/8” shoe below the weak fracture pressure zone.

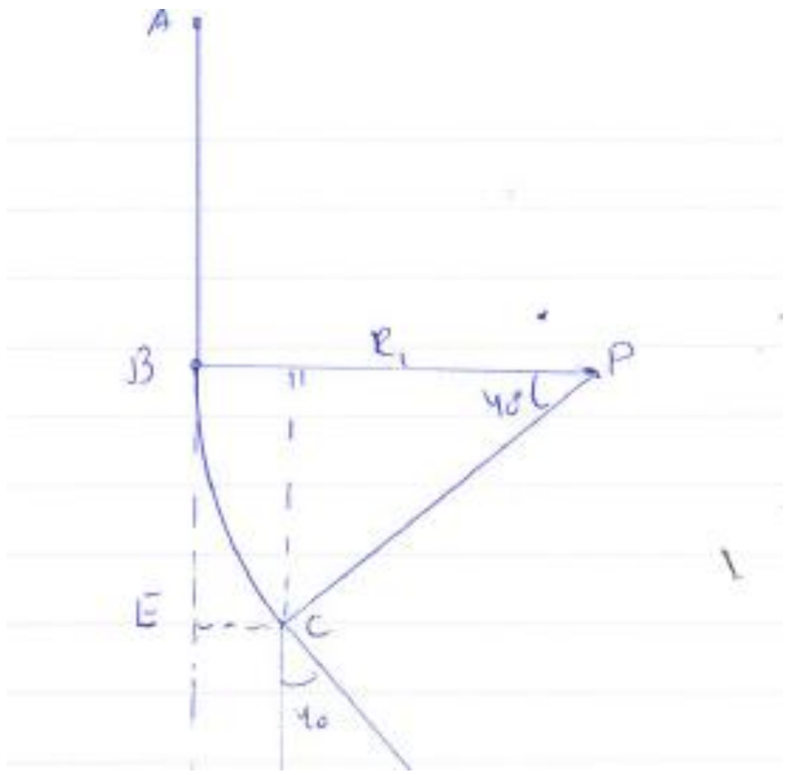
3) Explain how gas lift works and what additional barrier element is required in this case ?

4) Give some examples of typical directional well profiles

5) Explain the difference between a mud motor and a rotary steerable assembly !

6) Azimuthal resistivity measurements are used in the geosteering process. Why do we perform measurements with different frequencies and different depth of investigation (what can we obtain by this ?)

7) The following figure illustrates the build up section of a well.



We are given the following exact data:

Point	Exact Measured depth MD (m)	Inclination I	Azimuth A	Exact TVD
B	884,3	0	90	884,3
C	1284,3	40	90	1252,7

The exact value of EC is 134,1 m. BE is 368,4 m.

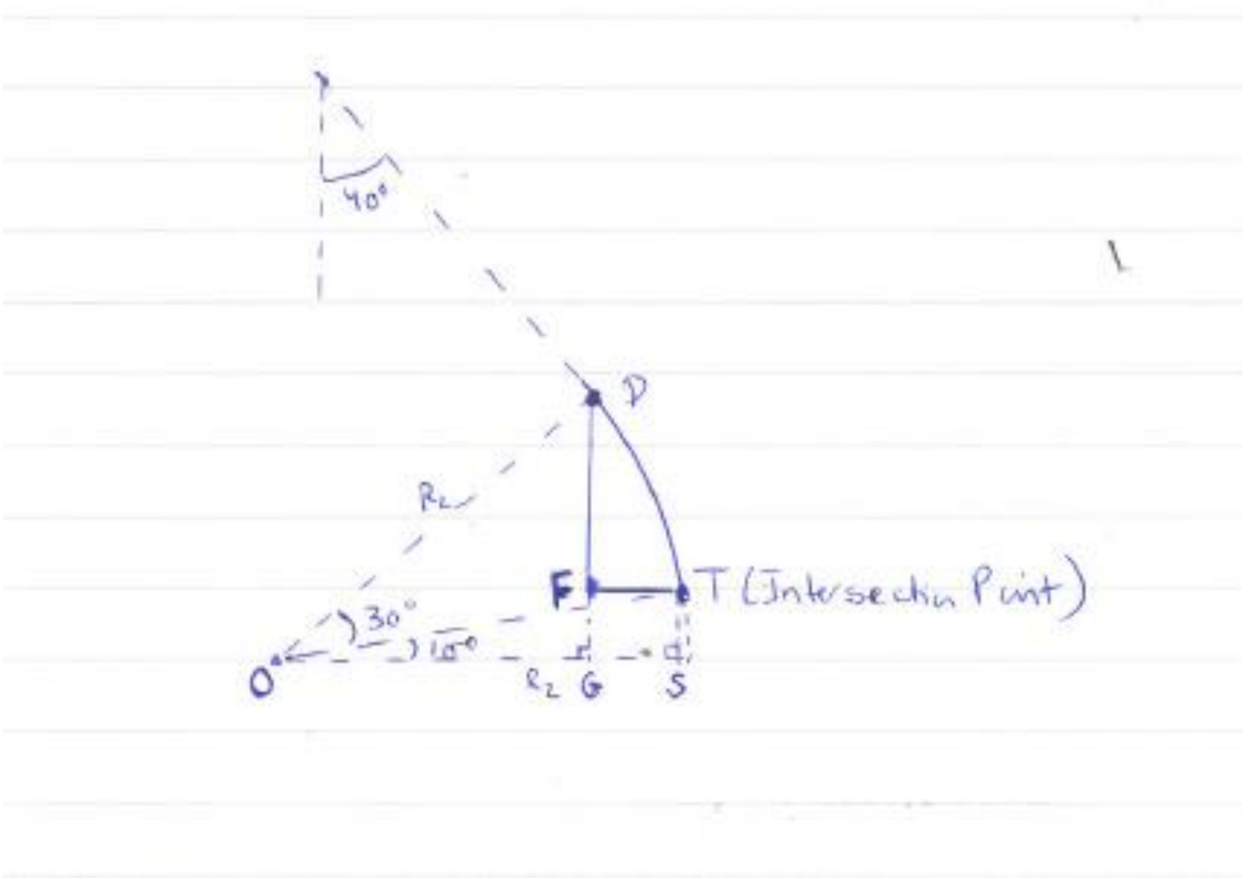
We are now going to use both the minimum curvature method and the balanced tangential method to calculate the changes in ΔN, ΔE and ΔV and compare this with the exact values.

a) What is the dogleg and dogleg severity (in unit deg/30 meters)?
b) Explain why ΔE should be equal to EC , why ΔN should be zero and why ΔV should be equal to BE!

c) Set up tables and calculate ΔN, ΔE and ΔV using both balanced tangential and the minimum curvature method! Comment the results in light of the exact values given above (what method gives best results and why)

8) A blowout is taking place in the Barents Sea. We will try to intersect the blowing well with an S shaped relief well at the last casing shoe in the blowing well which is set at 3000 meters TVD. The horizontal displacement is 1500 meters. After the build up, we shall have a hold section that has an inclination of 40°.
We will intersect at the shoe with an inclination of 10° just after finishing the drop section.

The build up and drop off rates are both $\frac{3^0}{30m}$. Considering the following help figure, we are given that the horizontal displacement FT is 125,4 meter and the vertical displacement DF is 268,9 meter in the drop section.



a) The prevailing wind direction in the Barents Sea is from SouthWest, Where do you want to place your relief well ? (give a suggestion for Azimuth of the target)

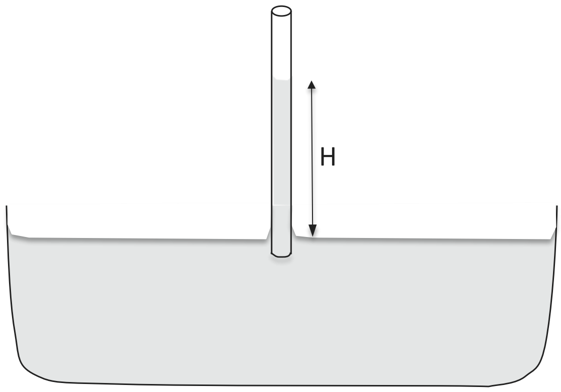
b) Show that the depth of the Kick off point is 884,3 meters. (Hint: Maybe you can use some of the information given in Exercise 7)

c) What is the measured depth of the well when reaching target (intersection with blowing well)

d) Show by calculation why the horizontal displacement FT is 125,4 meter and the vertical displacement DF is 268,9 meter in the drop section.

MULTIPHASE PROBLEM 1.

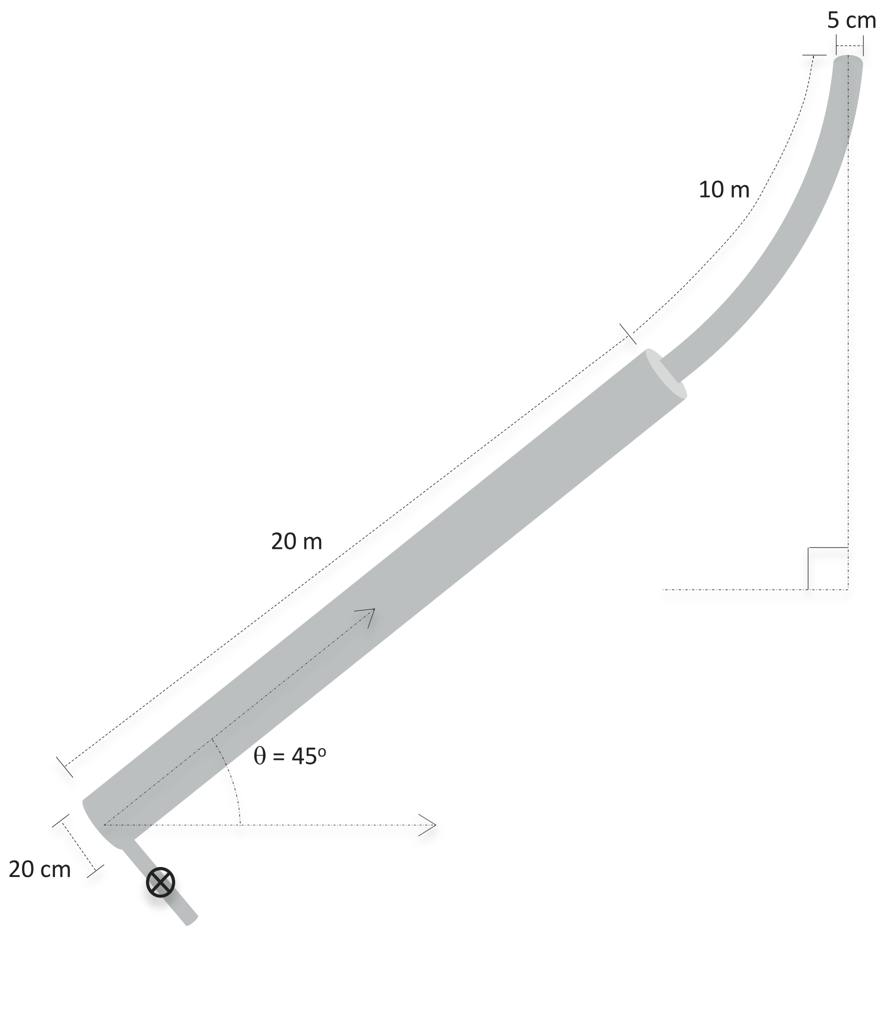
a) Prove the distributive rule for averages for spacial averaging
b) Express mass dryness fraction as a function of the gas fraction for slip and no-slip.



MULTIPHASE PROBLEM 2.

A capillary tube with diameter 0.01mm is placed in a bath of water. The water temperature is 20ºC.

a) Estimate the height H of the liquid column in the capillary.
b) What is H with a water temperature of 90ºC?



MULTIPHASE PROBLEM 3

A pipe consists of two sections of different diameter. The lower section is straight, with inclination 45^o from vertical, length 20m, and 20cm diameter. The upper section is curved with constant curvature from 45^o inclination to vertical (0^o), length 10m, and 5cm diameter. The inner surface of the lower pipe section is smooth while the upper section is rough, with a relative wall roughness of 10^{-2}. Liquid is flowing through the pipe at a volumetric flowrate of 2 m^3 / h. Liquid density is 900 kg / m^3 and viscosity 3.0 cP.

a) What is the flow regime in the upper and lower pipe sections, and what are the relevant friction factors?
b) Estimate the maximum velocity of the cross-sectional velocity profile in the lower pipe section.
c) What is the pressure change solely due to acceleration from the large to the small pipe?
d) What is the frictional pressure loss gradient in the upper and lower pipe sections?
e) Calculate the pressure difference between top and bottom of the pipe. The frictional pressure losses across the pipe connection may be neglected.

MULTIPHASE PROBLEM 4

Consider the same setup as for problem 3. Connected to the bottom of the lower pipe is a valve through which gas may be injected into the flow. The gas is assumed ideal with density 1.2 kg/m^3 at atmospheric conditions. The gas viscosity is 0.2 cP. The volumetric flowrate of the liquid is increased to 8m^3/h. The gas valve is opened and a mass flowrate of 12kg/h of gas is injected until steady state. The inlet pressure at the bottom of the pipe is 100bar.

a) What kind of multiphase flow regime may be expected?
b) Calculate the gas fraction at the bottom of the pipe.
c) What is the pressure gradient at the bottom of the pipe?

Properties:

$\sigma_{Water/air}$ = 72mN/m at 20^oC

$$T_{C\,Water} = 374°C$$

$$\rho_{Water} = 1000\ kg/m^3$$

$$g = 9.81\ m/s^2$$

Surface tension temperature dependence:

$$\sigma_1 = \sigma_2 \left[\frac{1-T_{r1}}{1-T_{r2}}\right]^{1.2}, \quad T < T_C$$

Mixture viscosity relations:

Cichitti: $\mu_m = x\mu_G + (1-x)\mu_L$

McAdams: $\dfrac{1}{\mu_m} = \dfrac{x}{\mu_G} + \dfrac{1-x}{\mu_L}$

Dukler: $\mu_m = \varepsilon_G \mu_G + (1-\varepsilon_G)\mu_L$

Small gas fraction corresponds to $\varepsilon_G \le 0.1$

Turbulent friction factors:

Blasius form: $f = C \cdot \mathrm{Re}^{-n}$

Dukler: $C = 0.046,\ n = 0.2$

Drew, Koo and McAdams: $f = 0.0056 + 0.5C \cdot \mathrm{Re}^{-0,32}$

Nikuradse: $\dfrac{1}{\sqrt{f}} = 1.74 - 2\log_{10}\left(\dfrac{2\varepsilon}{D}\right)$

Steady state velocity profile in pipe:

Turbulent: $u(r) = u_{\max}\left(1 - \dfrac{r}{R}\right)^n,\ \dfrac{1}{5} \le n \le \dfrac{1}{7}$

Laminar: $u(r) = u_{\max}\left(1 - \left(\dfrac{r}{R}\right)^2\right)$