Problem 1

H14

a) What are the two traditional hydraulic optimisation procedures?

- Maximum hydraulic horsepower
- Maximum impackt force

$$q^m = \frac{P_1}{C(m+1)} \quad \text{HP}$$

$$q^m = \frac{2P_1}{C(m+2)} \quad \text{Impackt force}$$

As fractions of total pump pressure

$$\left(\frac{P_3}{P_1}\right) = \frac{1}{m+1} = 0{,}65 \Rightarrow P_2 = 1 - 0{,}65 =$$

$$\frac{2}{m+2}$$

$$P_1 = P_2 + P_3$$

$$P_3 - P_1 = -P_2$$

Fraction of pressure loss through bit

$1 - \frac{P_3}{P_1} \Rightarrow$ Choose nozzle size to satisfy fractions

b) Pressure drop in Newtonian fluids depending on the flow regime

Laminar flow : Pressure drop proportional to viscosity and the flow rate

Turbulent flow : Pressure drop proportional to the density and the flow rate squared.

$$P \sim \mu q$$

$$P \sim \rho f q^2$$

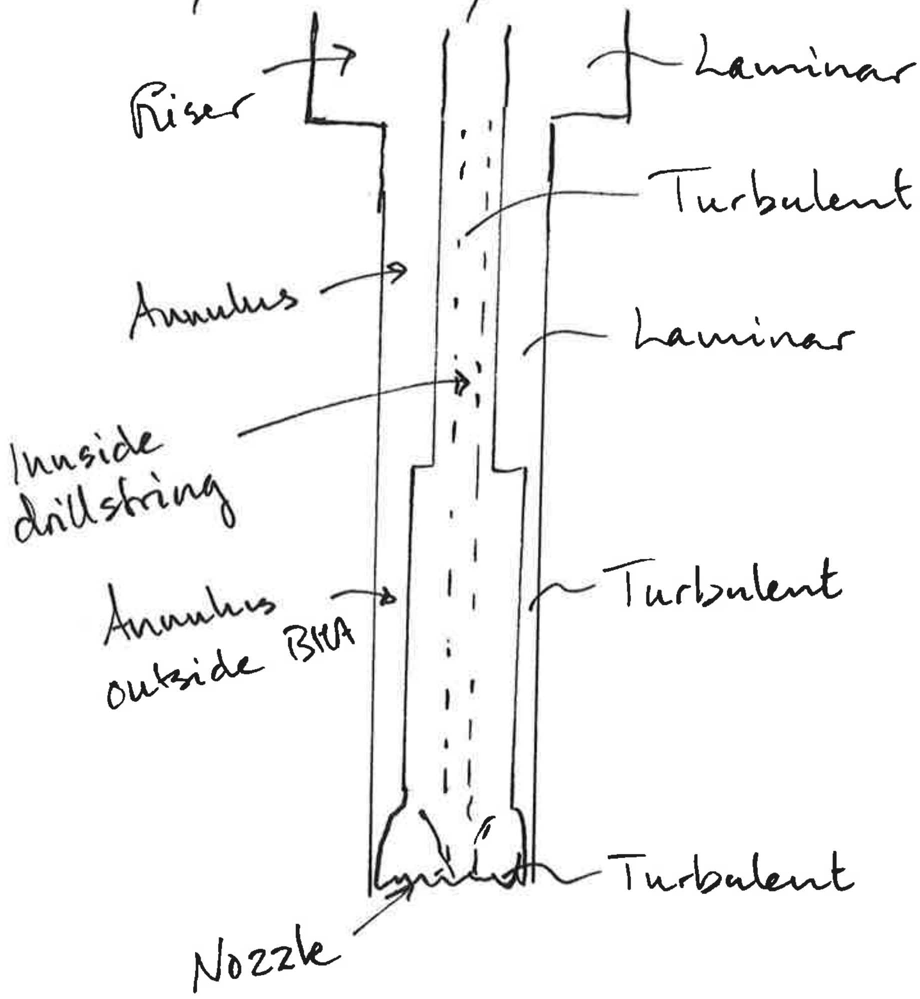
μ : viscosity

q : flowrate

ρ : density

f : friction factor

c) Describe the flow (regime) through the hydraulic system.

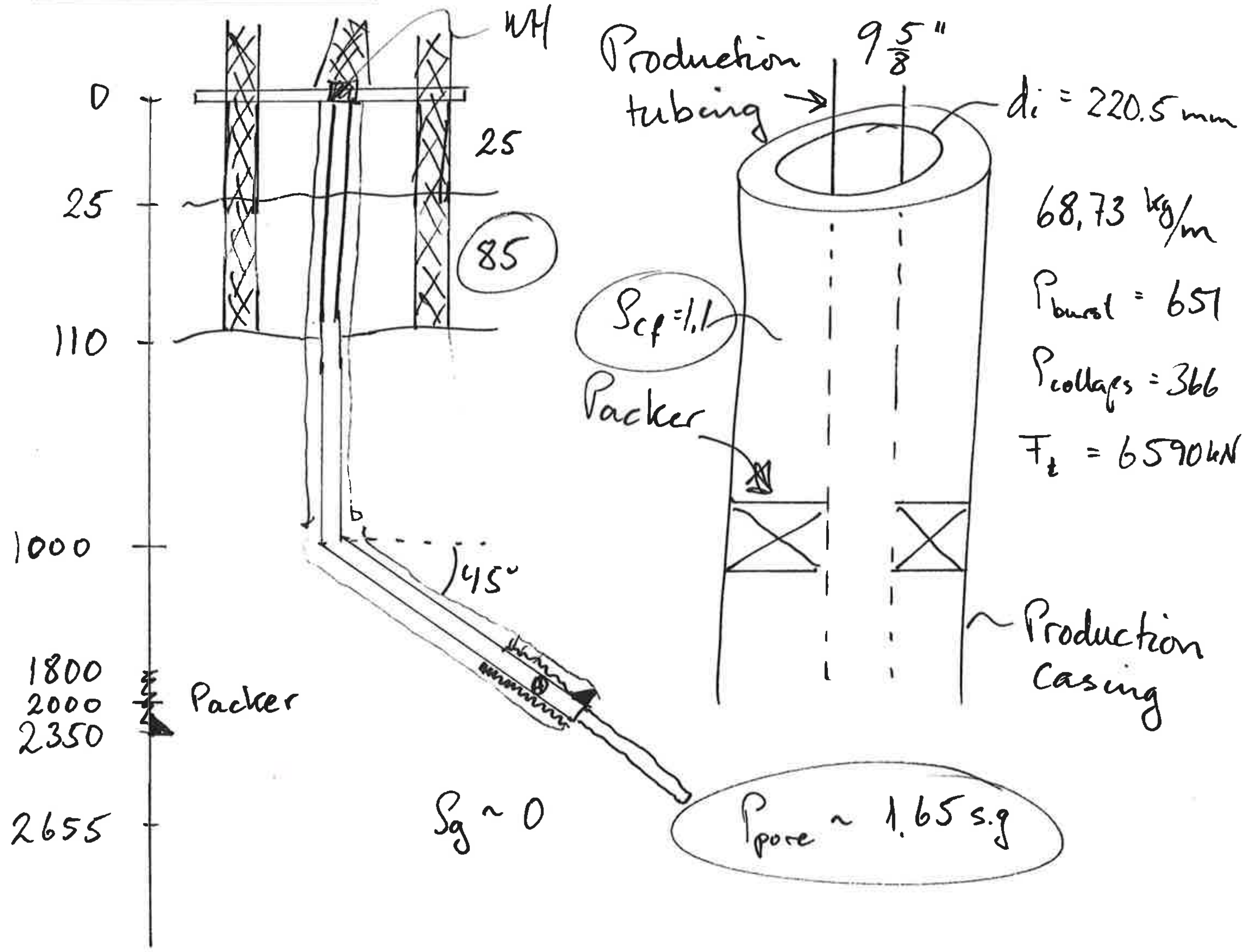


d) What is the most important shortcoming of the traditional hydraulic optimisation procedure?

- <u>Cutting transport</u> !

e) PDC vs. tri-cone

Problem 2



Production casing design

Burst

"Gas-filled casing"

At wellhead:

$P_o = 0$

$P_i = BHP - S_g g h_g$

$= 1,65 \cdot 0.0981 \cdot 2655 - 0$

$= \underline{429 \text{ bar}}$

$\Delta P = 429$ bar $\qquad DF = \frac{651}{429} = \underline{1,5}$ ok

"Leaking tubing"

Weak point is the productioncasing at the packer.

$$P_o = \rho_w g h_w$$

$$= 1.03 \cdot 0.0981 \cdot (2000 - 25)$$

$$P_o = 200 \text{ bar}$$

$$P_i = (BHP - \rho_g g h_g) + \rho_{cf} g h_{cf}$$

(gas filled case; completion fluid)

$$= 429 \text{ bar} + 1{,}1 \cdot 0.0981 \cdot 2000$$

$$= 429 + 215$$

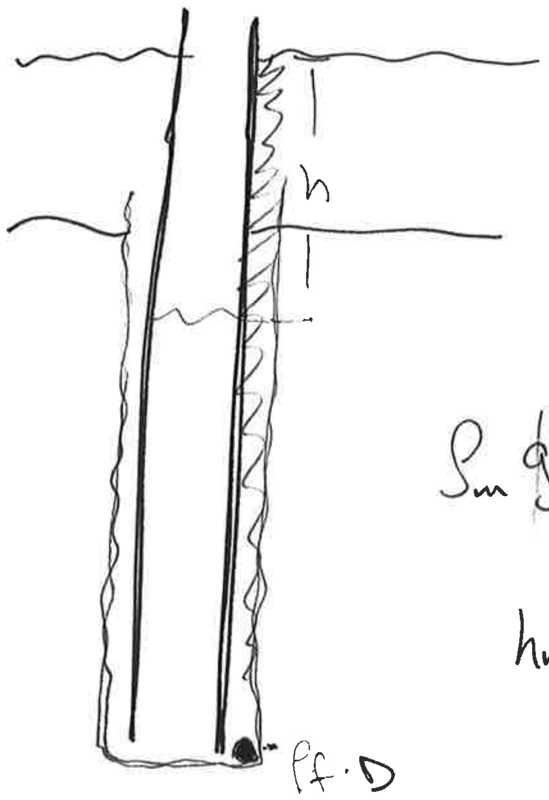
$$P_i = 644{,}8 \text{ bar}$$

$$\Delta P = 444 \text{ bar}$$

$$DF = \frac{651}{444} = 1{,}46$$ ok

b) Collapse

"Loss to thief zone"



$$\rho_m g h_m = \rho_w g h_w$$

$$h_m = \frac{\rho_w h_w}{\rho_m}$$

$$D \cdot P_f \cdot 0.0981 = P_m \cdot 0.0981 \cdot (D - h)$$

$$D \cdot P_f = P_m D - P_m \times h$$

$$(D - h) = \frac{D \cdot P_f}{P_m}$$

$$h = D - \frac{D P_f}{P_m}$$

$P_{o\_WH} = 0$

$P_{o\_h} = P_m \cdot (D - h)$

$P_{o\_TD} = P_m \cdot D$

$P_{i\_WH} = 0$

$P_{i\_h} = 0$

$P_{i\_CS} = 1.03 \times D$

$$D = \frac{P_c \times \%\ \text{DEFRATION}}{(P_{o\_h} - P_{i\_h})}$$

c) Tension

Weight in air

Length of casing 2909 m MD

$W = 68{,}73\ kg/m \cdot 2909 m \cdot 9.81 = 1961368 N$

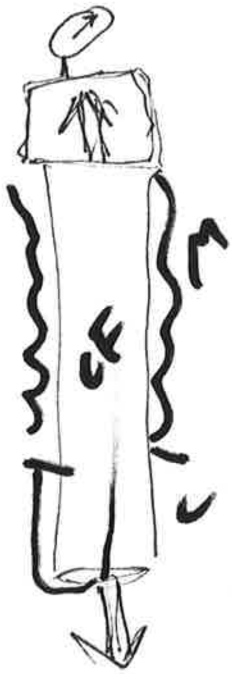
$W = 196 \cdot 10^3\ daN$

Bouyed weight

$\left(1 - \frac{1.6}{7.8}\right) \cdot 196 \cdot 10^3\ daN = 155 \cdot 10^3\ daN$

Pressure test

Assume wellhead can handle maximum 680 bar (10 000 psi)



$A = \frac{\pi}{4}(220.5 \cdot 10^{-3})^2 = 381\ cm^2$

$F = P \cdot A = 680 \cdot 381 = 259 \cdot 10^3\ daN$

Total tension $= 259 \cdot 10^3 + 155 \cdot 10^3$

$= 414 \cdot 10^3\ daN$

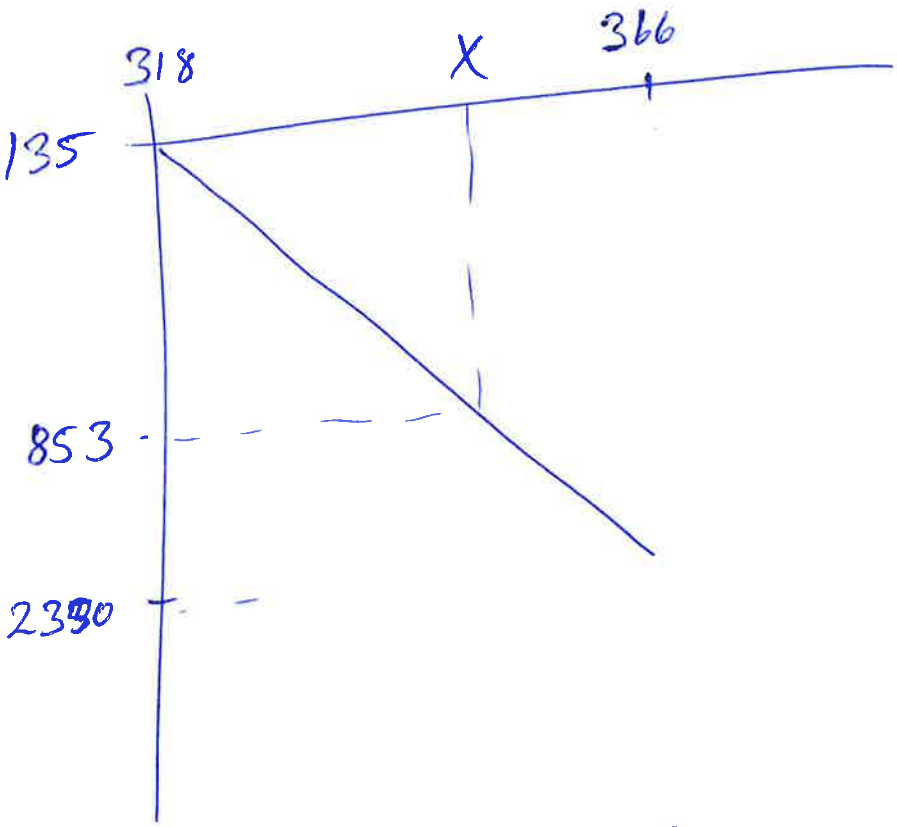
$DF = \frac{6590000 N}{4140000 N} = 1{,}6$ ok

biaxial calculations

$\% T = \frac{1561}{6590} \cdot 100\% = 23{,}6\%$

$\% C = 87\%$

$P_{collaps}$ at top $= 366 \cdot 0.87 = 318$



$$\frac{366 - 318}{2350 - 135} = \frac{x - 318}{853 - 135}$$

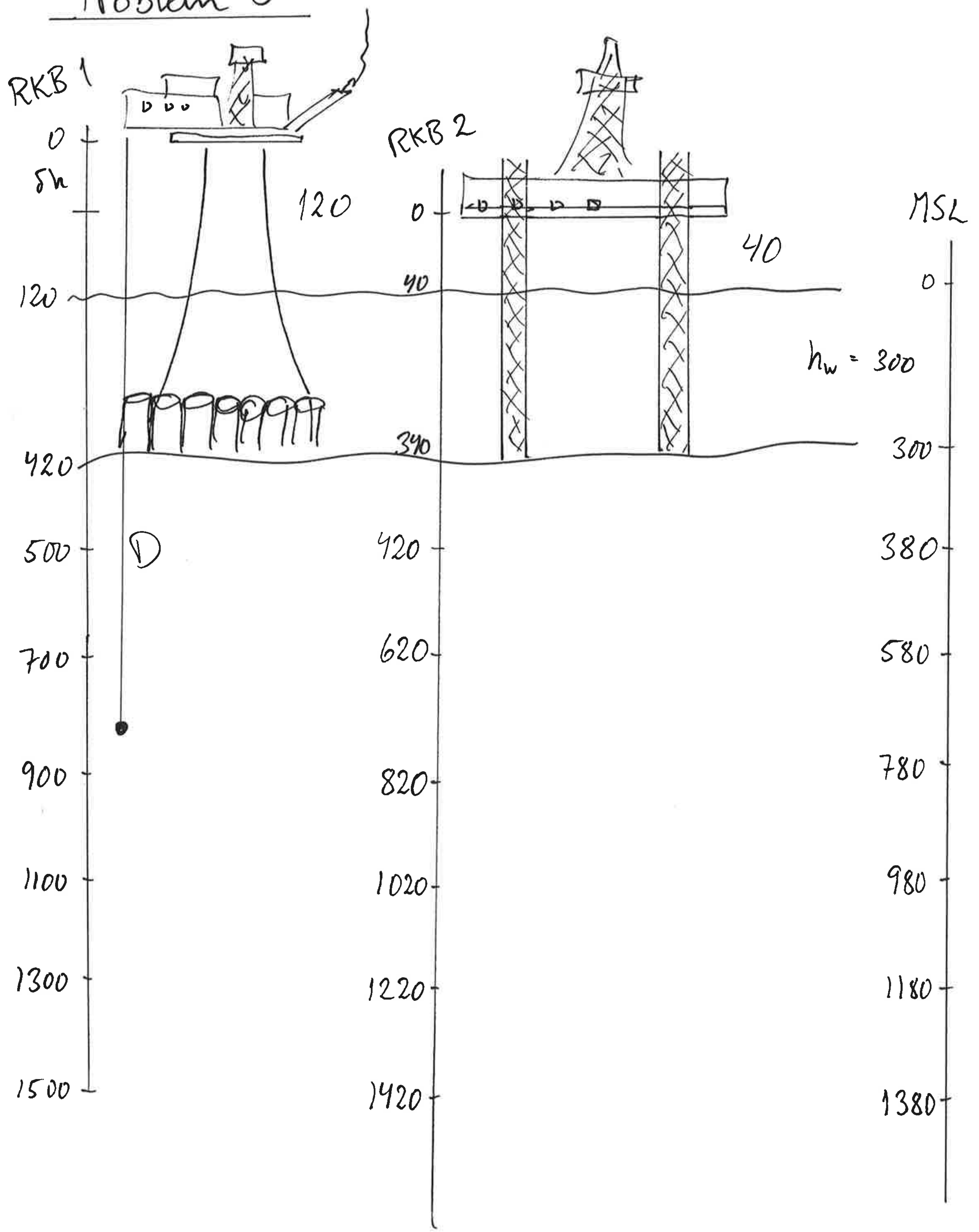
$$x = 318 + \frac{366 - 318}{2350 - 135}(853 - 135)$$

$x = 333$ bar

$$DF_{collapse} = \frac{333}{133} = 2{,}5$$

d) The reservoir has a vertical extent of 50m
Propose a drilled length below the reservoir
Explain why?

Problem 3


RKB 1
0
δh
120
120
420
500
D
700
900
1100
1300
1500
RKB 2
0
40
340
420
620
820
1020
1220
1420
40
MSL
0
h_w = 300
300
380
580
780
980
1180
1380

a) Considering a pressure at a given depth, this pressure remains the same regardless of the referance system.

$$\boxed{P = \rho g D}$$

$$P = \rho_{RKB1} g D$$

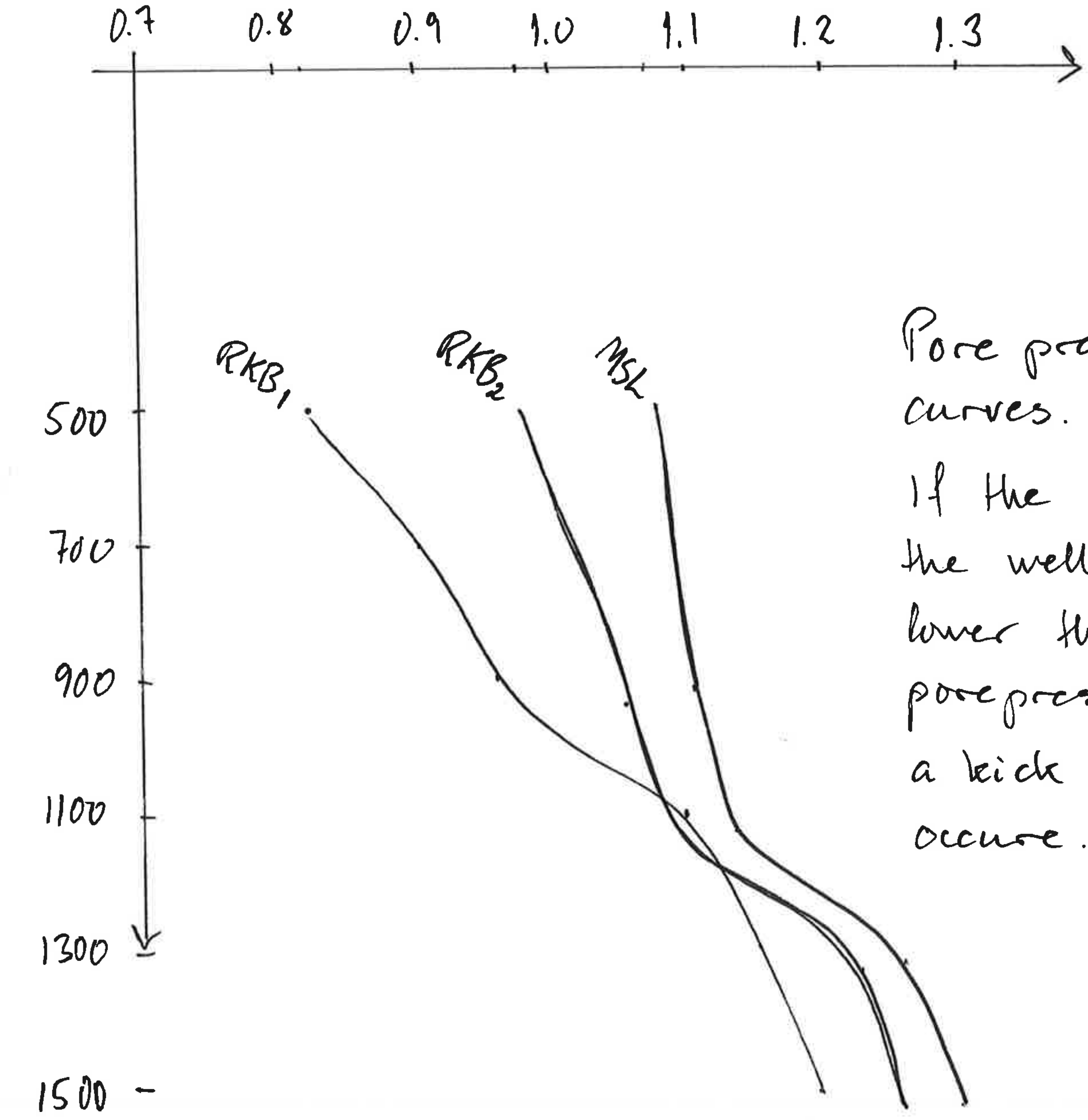
$$P = \rho_{RKB2} g (D - \delta h)$$

$$\rho_{RKB1} D = \rho_{RKB2} (D - \delta h)$$

$$\boxed{\rho_{RKB2} = \rho_{RKB1} \frac{D}{D - \delta h}}$$ Normalisation equation

$$\boxed{\rho_{MSL} = \rho_{RKB1} \frac{D}{D - h_f} \quad ; \; h_f = 120 \, m}$$

	ρ_{RKB1}	ρ_{RKB2}	ρ_{MSL}
500	0.82	0.976	1,07
700	0.90	1,016	1,086
900	0.95	1,043	1,096
1100	1.10	1,078	1,122
1300	1.15	1,225	1,267
1500	1.20	1,267	1,304



Pore pressure curves.

If the mud in the wellbore is lower than the porepressure, a kick situation occure.

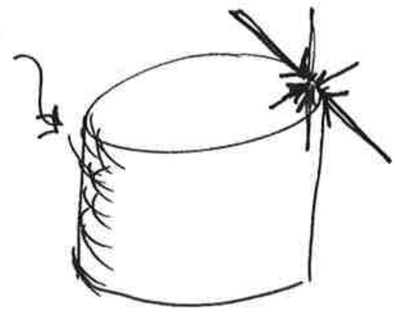
Problem 4

a) Two classical limits for the mud weight

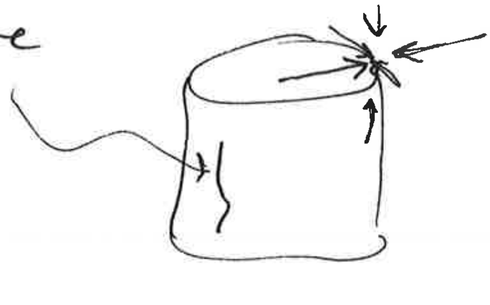
- Pore pressure / collapse pressure
- Fracturing pressure (LOT)

What are the failure mechanisms?

- Low borehole pressure
  ↳ Large difference between tangential stress and the radial stress
    ↳ collapse



- High borehole pressure
  ↳ tangential stress goes into tension
    ↳ Rock is weak in tension
      ↳ fracture



b) Using a simple fracturing equation, define the new optimization criterion presented in this course

$$\sigma_a = \frac{1}{2}(P_{wf} + P_o)$$

Find the mudweight such that it is between the pore pressure and fracturing.

This is called the median line principle