FACULTY OF SCIENCE AND TECHNOLOGY

Subject:	**PET100 DRILLING**
Date:	**09.12.2019**
Time:	**09:00 – 13:00 (4 HOURS)**
Allowed aid:	**Approved calculator**

Universitetet i Stavanger

NOTE: All 4 tasks are equally standing for 25% each. Read quickly all tasks before starting the calculation and make sure that you understand the questions. Plan the time allocation to each task so that you have enough time to answer the questions for each task.

Task 1 Axial load

A vertical well is being drilled from a fixed platform to a depth of 2400 m. The drillpipe used is 4.5", 16.60 lb/ft, premium grad G105, with NC50(IF) joints. A 80 m long drillcollar, 8", 218.8 kg/m is used. The mud density is 1180 kg/m^3 and the viscosity is 16 cP.

a) **1.** Calculate the maximum axial load on the drill string, before circulation and drilling starts.
2. Calculate the safety factor against yield.

b) Assuming nozzle forces of 8 kN:
1. Calculate the WOB (the force pushing on the formation) assuming that 1/3 of the drillcollar in under tension.
2. Why do we want to have 1/3 of the drillcollar under tension and why is the WOB independent of the well depth?

c) **1.** Calculating with a torque of 15 kNm and a nozzle force of 5 kN, what will be the maximum allowable mud pressure at the top of the drillstring when the safety factor is not allowed to be lower than 1.5?

d) The traveling block has 6 sheaves (n = 12), the friction factor is $k_T = 1.044$, and the hoisting equipment is 3100 kg.
1. Calculate the maximum force in the fast line, while tripping the drillstring from 2400m depth?
We want to lift one stand (three drillpipes, each 10 meter) from the well within a minute.
2. What is the motor effect (kW) needed when the efficiency from motor to cable is 0.71?

Multiple choice Axial load

1. Where is the optimum position of the neutral point?
   a) 2/3 h_{dc} from the top of the drillpipe
   b) 2/3 h_{dc} from the bottom of the well
   c) 2/3 h_{dc} from top of the drillcollar
   d) 1/3 h_{dc} from the bottom of the well

2. What is the function of *slips*?
   a) To suspend pipe in the rotary table when making or breaking connection
   b) To slip pipe into the well during drilling
   c) To transfer rotation from the rotary table to the drillpipe during drilling
   d) To unscrew or make connections between drillpipe stands

3. What is the main advantage of using heavy weight drillpipe (HWDP)?
   a) Increased wall thickness
   b) Longer tool joints
   c) Uses more hard facing
   d) All of the above

4. What happens when the pressure in the open section of the well becomes higher than the fracturing pressure of the formation?
   a) Surging
   b) Lost circulation
   c) Swabbing
   d) Reduction in mud weight

5. Which components can usually be found in the BHA (bottom hole assembly)
   a) Monkey board, Drilling hook, shrunk-on tool-joints, conductor
   b) Drill collars, Stabilizers, Reamers, Jars
   c) Kelly hose, Reamers, Monel collars, drillpipe
   d) Liners, generator, Kelly cock, gooseneck

Task 2 Mud pump dimensioning

For drilling the well in task 1, a mud flowrate of 2600 liter/min will be used. The pressure drop from the pump to the inlet of the drillstring and in the annulus sums up to 5.1 bar.

a) Calculate the pressure drop in the drill string (from inlet to the nozzles) using the DDH tables. (use same mud data as in task 1)

b) There are three nozzles in the drillbit, each with a diameter of 11 mm. The nozzle constant $C_D = 0.97$.
   1. How much is the pressure drop over the nozzles for the given mud flow rate?
   2. Is this an optimal value? Explain.
   3. Show that the pressure build up to be delivered by the mud pump is about 280 bar.

c) How much is the nozzle force?

Based on the results of the part b) it is required that the mud pump delivers at minimum a mud pressure of 210 barg. A triplex pump is available with the following data:

Stroke:	12"	Volumetric efficiency:	0.97
Motor effect:	1280 kW	Mechanical efficiency:	0.83
Max. speed:	140 rev/min	Transmission efficiency:	0.84
Bushing/Liner diameter:	4.5,5, 5.5, 6, 6.5 and 7"		

Efficiency of the electric motor: 0.92

d) Which bushing/liner diameter should be used to deliver the minimum pressure required?

e) 1. Calculate the maximum flow rate from the pump.
2. Calculate the maximum pump pressure.
3. How many mud pumps are required?

Multiple choice Mud pump:

1. Which statement is NOT correct?
   a) The main disadvantage of using water based muds is that the water in these muds causes instability in shales.
   b) Oil based muds do contain free water that can react with the clays in the shale
   c) Water based mud is the most common used mud world-wide
   d) Oil based muds are more expensive and require more careful handling (pollution control) than water based muds.

2. What would happen if a larger bushing/liner diameter is used in the pump?
   a) The pump pressure increases, while the volume flow also increases
   b) The pump pressure decreases, while the volume flow increases
   c) The pump pressure increases, while the volume flow decreases
   d) The pump pressure decreases, while the volume flow also decreases

3. What would happen if the nozzle diameter is reduced (while everything else is unchanged)?
   a) Friction pressure loss in the annulus will increase
   b) Friction pressure loss in the annulus will decrease
   c) Friction pressure loss in the nozzle will decrease
   d) Minimum pump pressure required will increase

4. What happens if the bushing/liner diameter is reduced by 50%?
   a) The pump pressure doubles, while the volume flow reduces by 50%
   b) The pump pressure reduces by 50%, while the volume flow increases in square
   c) The pump pressure increases by factor 4, while the volume flow is reduced by factor 4
   d) The pump pressure increases by factor 4, while the volume flow is reduced by 50%

5. Which one of these parameters the frictional pressure drop in the drillstring does NOT depend on?
   a) The rheological properties of the drilling fluid
   b) The length of the different drillstring sections
   c) The pressure drop in the annulus
   d) The inner and outer diameter of the drillcollar

Task 3 Casing design

When the depth of 2400m is reached, casing of 9.625" will be run into the well. The fracturing pressure at this depth is estimated to 550 barg. For drilling of the next section of the well a mud density of 1215 kg/m³ will be used. It is assumed that in case of loss of mud to fractured low pressure formation 40% of the mud in the well would be lost. For the casing design following safety factors will be used: 1.8 against axial load (tear off), 1.5 against burst and 1.2 against collapse. The density of gas, in case of gas kick, is estimated to 280 kg/m³. The density of degraded mud drops to 1030 kg/m³.

a) 1. Calculate the maximum pressure caused by possible gas kick.
   2. At which depth the maximum load occurs?

b) 1. Calculate the maximum pressure caused by loss of mud to low-pressure fractured formation.

c) 2. At which depth the maximum load occurs?

For cementing operation a slurry with density of 1940 kg/m³ is prepared. The displacement liquid have a density of 1215 kg/m³. The cementing job is aimed to cement the casing 300 m above the bottom of the previous casing which is reaching down to 1640 m. Assuming the "worst case scenario" because of caving, it is decided to fill the current casing up to the top with the cement slurry.

d) 1. Calculate the maximum burst and collapse pressure during cementing.
   2. At which depth the burst and collapse pressure reach their maximum value?

e) 1. What are the dimensioning burst and collapse pressure?
   2. Select the lightest casing that fulfills the safety factors
   3. Calculate the safety factors for the selected casing

f) Calculate the maximum axial force and calculate the safety factor (tear off) for both degenerated mud and for cement. Which one of these two cases is the dimensioning case?

Multiple choice Casing

1. which one of the following statements is a reason for setting a casing:
   a) To "fish" lost equipment
   b) To be able to perforate the formation
   c) To be able to cement the well
   d) To prevent caving into the well

2. What is the main function of the conductor casing?
   a. Protect the well against Blowout
   b. To transport the formation fluids to the platform
   c. To cement the well
   d. To function as fundament for the well head and the BOP

3. Which statement is NOT correct?
   a) Cement is used primarily as an impermeable seal material in oil and gas well drilling
   b) Cement is used to protect the casing from corrosive fluids in the formations
   c) The production casing is manufactured with relatively low burst and collapse tolerance
   d) The temperature and the pressures can be extreme in the reservoir sections, and since the production casing is used to secure the reservoir section, it must have the strength of withstanding harsh conditions

4. Which statement about cementing is NOT correct?
   a. Casing cement will prohibit caving of the formation into the well
   b. Casing cement will prohibit fluids from flowing from one formation to another
   c. Casing cement will support the casing
   d. Casing cement will protect the casing from corroding fluids in the formation

5. Which one of the following statements is NOT among the casing's function?
   a. Stabilizing downhole conditions
   b. Controlling the pressure of the well
   c. Preventing fracturing and collapse of the formation around the borehole
   d. Preventing blowouts from the well.

Task 4 Kick calculations

In a vertically drilled well to 2900m depth the level of the mud in the mud pit starts to rise. The mud flowrate is 2600 l/min, mud density is 1215 kg/ m^3, and the viscosity is 16 cP. After 132 seconds the drilling is stopped, mud pumps turned off and the BOP is closed. The excess mud volume is measured to be 6.8 m^3. When the pressure levels have stabilized, the pressure at the top of the drillstring is measured to 15 barg and at the top of the annulus, below the BOP the pressure is measured to 20.5 barg.

The length of the drillcollar is:	80 m
The inner volume of the drillstring is:	16.9 m^3
Cross sectional area outside the drillcollar is:	0.0528 m^2
Cross sectional area outside the drillpipe is:	0.0754 m^2

a) 1. Calculate the pressure at the bottom of the well
   2. Calculate the height of the inflow in the well

b) 1. Calculate the density of the inflow
   2. A kill mud is to be prepared, giving a 5 bar margin in the bottom of the well. What density should the kill mud have to manage this?

c) ~~1~~. Calculate the time needed to circulate the drill string and the time needed to circulate the whole well?
   For circulating the well, a mud flowrate of 500 liter/min is used.
   2. List three indicators showing that the well has been circulated fully?

The "wait and weigh" method is used to circulate the well. The kill mud has a viscosity of 24 cP. The nozzle pressure and frictional pressure loss with kill mud (flowrate 500 l/min.) and the original mud (density 1215 kg/m^3) are 5.4 bar and 7.3 bar respectively.

NOZZL Friction

d) **1. What is the reason for the quick pressure rise at top of the drillsting when circulating the well starts?**
2. What value should be used to regulate the pressure at top of the drillstring when the mud pumps are started to circulate the well?

e) **1. Calculate necessary parameter values to make a drawing/sketch that shows the process of well circulation.**

Multiple choice Kick:

1. Which statement is NOT correct?
   a) The kill line is a high pressure pipeline between the side outlet (opposite the choke line outlet) on the BOP stack and the mud pumps, which provides means of pumping fluids downhole when the normal method of circulating down the drillstring is not possible
   b) The BOP equipment is the equipment which is used to shut in a well and circulate out an influx
   c) There is only one basic type of BOP used for closing in a well. This BOP type is called "Annular preventer"
   d) The opening and closing of the BOP's is controlled from the rig floor

2. For circulating the kick which one of the following method will require longest time:
   a) Weight-and-weight method
   b) Drillers method
   c) Engineers method
   d) All require same time

3. Which one of the statements below is correct?
   a) BOP works as storage unit for drillpipe during harsh weather conditions.
   b) The Blowout preventer prevents kicks from occurring.
   c) The hydraulic power package produces the main pump pressure during kick circulation.
   d) The kill line provides means of pumping fluids downhole when the drillstring is absent.

4. Which one of the following is NOT an indicator for a kick?
   a) Reduced height of the mud column
   b) Drilling break
   c) Return mud flowrate increase
   d) Gas cut mud

5. What is the MAASP?
   a. Major annular anticipated spontaneous pressure
   b. Minimum annular angle side projection
   c. Maximum allowable annular surface pressure
   d. Minor annular artificial sliding packer

EQUATIONS GIVEN ON THE EXAM:

0,0254 m = 1"

g = 9,81 m/s^2

ρ_s = 7850 kg/m^3

- ***Tension in the fastline (deadline):*** $F_F = F_d = \frac{k_T - 1}{1 - k_T^{-n}} \cdot W$
- ***Frictional pressure drop in a circular pipe:*** $\Delta P_F = \frac{Q^{1,8} \cdot \rho^{0,8} \cdot \mu_p^{0,2}}{90163 \cdot D^{4,8}} \cdot \Delta L$
- ***Frictional pressure drop in an annular space:*** $\Delta P_F = \frac{Q^{1,8} \cdot \rho^{0,8} \cdot \mu_p^{0,2}}{70696 \cdot (D+d)^{4,8} \cdot (D-d)^3} \cdot \Delta L$

Units for ΔP_F [bar]: Q[Liter/min], ΔL [m], D & d [inch], density and viscosity relative to water

- ***Nozzle formulas:*** $v = C_D \sqrt{\frac{2 \cdot \Delta P_D}{\rho}}$ $(C_D = 0,95)$ /// $F_D = \dot{m} \cdot v = \rho \cdot Q \cdot v = \frac{\rho \cdot Q^2}{A_D}$
- ***Relative drillstring frictional pressure drop:*** $\Delta P_{F2} = \frac{Q_2^{1,8} \cdot \rho_2^{0,8} \cdot \mu_2^{0,2}}{Q_1^{1,8} \cdot \rho_1^{0,8} \cdot \mu_1^{0,2}} \cdot \Delta P_{F1}$
- ***Relative nozzle pressure drop:*** $\Delta P_{D2} = \frac{Q_2^2 \cdot \rho_2}{Q_1^2 \cdot \rho_1} \cdot \Delta P_{D1}$
- ***Initial drillstring pressure loss with kill rate:*** $P_{c1} = \Delta P_{F,m,2} + \Delta P_{D,m,2} + \Delta P_s$
- ***Final drillstring pressure loss with kill rate:*** $P_{c2} = \Delta P_{F,km} + \Delta P_{D,km}$
- ***Length of kick 1 ($V_k > V_{ann,dc}$):*** $L_K = L_{dc} + \frac{V_i + Q_m \Delta t - A_{ann,dc} L_{dc}}{A_{ann,dp}}$
- ***Length of kick 2 ($V_k \leq V_{ann,dc}$):*** $L_K = \frac{V_i + Q_m \Delta t}{A_{ann,dc}}$
- ***Height of kick:*** $h_k = \frac{P_{ann} - P_{dp}}{g(\rho_m - \rho_{kick})} \cdot \left[1 + \frac{Q_m \cdot \Delta t}{\Delta V_i}\right]$
- ***Density of inflow:*** $\rho_{kick} = \rho_m - \frac{P_{ann} - P_{dp}}{g \cdot h_k} \cdot \left[1 + \frac{Q_m \cdot \Delta t}{\Delta V_i}\right]$
- ***Mass balance:*** $\rho_1 \cdot V_1 + \rho_2 \cdot V_2 = \rho_m \cdot V_m$
- ***Combined safety factor during drilling:*** $\frac{1}{SF} = \sqrt{\left(\frac{P_i - P_o}{P_Y}\right)^2 + \left(\frac{F_E}{F_Y}\right)^2 + \left(\frac{M_R + M_F}{M_Y}\right)^2}$

- ***Safety factor under tension:*** $SF = \frac{F_Y}{F_A}$

GEOMETRIC CHARACTERISTICS OF DRILL PIPES
(New pipe bodies and tool joints) (continued)

Nominal diameter	Nominal weight	Wall thickness	ID		Cross-section	Polar moment of inertia	Polar modulus	Upset and grade		Type of tool joint	Tool joint OD	Tool joint ID	Approximate weight including tool joint	
(in)	(lb/ft)	(mm)	(in)	(mm)	(mm²)	(mm⁴)	(mm³)				(mm)	(mm)	(kg/m)	(lb/ft)
4 (101.60 mm)	14.00	8.38	3.340	84.84	2 454	5 374 730	105 802	**EU**	**G**	**NC46 (IF)**	**152.4**	**82.6**	**24.10**	**16.19**
								IU	**G**	**NC40(FH)**	**139.7**	**61.9**	**23.59**	**15.85**
								IU	G	H90	139.7	71.4	23.22	15.60
								EU	**S**	**NC46 (IF)**	**152.4**	**76.2**	**24.44**	**16.42**
								IU	**S**	**NC40(FH)**	**139.7**	**50.8**	**24.00**	**16.13**
								IU	S	H90	139.7	71.4	23.22	15.60
4 1/2 (114.30 mm)	13.75	6.88	3.958	100.54	2 322	6 725 300	117 678	**EU**	**E**	**NC50 (IF)**	**161.9**	**95.3**	**22.91**	**15.39**
								EU	E	NC50 (WO)	155.6	98.4	22.03	14.80
								EU	E	OH	146.1	100.8	20.98	14.10
								IU	E	H90	152.4	82.6	22.62	15.20
	16.60	8.56	3.826	97.18	2 844	8 000 523	139 992	**EU**	**E**	**NC50 (IF)**	**161.9**	**95.3**	**26.78**	**18.00**
								EU	E	NC50 (IF)	168.3	95.3	27.49	18.47
								EU	E	OH	149.2	95.3	25.45	17.10
								IEU	**E**	**NC46 (XH)**	**158.8**	**82.6**	**27.34**	**18.37**
								IEU	E	FH	152.4	76.2	27.00	18.14
								IEU	E	H90	152.4	82.6	26.64	17.90
								IEU	E	NC38 (SH)	127.0	68.3	25.00	16.80
								EU	**X**	**NC50 (IF)**	**161.9**	**95.3**	**27.33**	**18.36**
								EU	X	NC50 (IF)	168.3	95.3	28.05	18.85
								IEU	X	NC46 (XH)	158.8	76.2	27.71	18.62
								IEU	X	FH	152.4	76.2	27.02	18.16
								IEU	X	H90	152.4	82.6	26.79	18.00
								EU	**G**	**NC50 (IF)**	**161.9**	**95.3**	**27.33**	**18.36**
								EU	G	NC50 (IF)	168.3	95.3	28.05	18.85
								IEU	G	NC46 (XH)	158.8	76.2	27.71	18.62
								IEU	G	FH	152.4	76.2	27.02	18.16
								IEU	G	H90	152.4	82.6	26.79	18.00
								EU	**S**	**NC50 (IF)**	**161.9**	**88.9**	**27.72**	**18.63**
								EU	S	NC50 (IF)	168.3	88.9	28.44	19.11
								IEU	S	NC46 (XH)	158.8	69.9	28.02	18.83
								IEU	S	FH	158.8	63.5	28.31	19.02
								IEU	S	H90	152.4	76.2	27.02	18.16

mm × 0.0394 = in $mm^2 \times 0.00155 = in^2$ $mm^3 \times 6.10\ 10^{-5} = in^3$ $mm^4 \times 2.40\ 10^{-6} = in^4$

NEW (N), PREMIUM CLASS (P) AND CLASS 2 (2) DRILL PIPE, TORSIONAL AND TENSILE DATA (continued)
(API RP 7G, 16th edition, August 1998)

Size OD	Nominal weight	Class	Torsional yield strength[1]								Tensile yield strength							
			E		95		105		135		E		95		105		135	
(in)	(lb/ft)		(ft.lb)	(daN.m)	(ft.lb)	(daN.m)	(ft.lb)	(daN.m)	(ft.lb)	(daN.m)	(lb)	(10^3 daN)	(lb)	(10^3 daN)	(lb)	(10^3 daN)	(lb)	(10^3 daN)
4	11.85	N	19 474	2 639	24 668	3 343	27 264	3 694	35 054	4 750	230 755	102.6	292 290	129.9	323 057	143.6	415 360	184.8
		P	15 310	2 075	19 392	2 628	21 433	2 904	27 557	3 734	182 016	80.9	230 554	102.5	254 823	113.3	327 630	145.6
		2	13 281	1 800	16 823	2 280	18 594	2 520	23 907	3 239	158 132	70.3	200 301	89.0	221 385	98.4	284 638	126.5
	14.00	N	23 288	3 156	29 498	3 997	32 603	4 418	41 918	5 680	285 359	126.8	361 454	160.6	399 502	177.6	513 646	228.3
		P	18 196	2 466	23 048	3 123	25 474	3 452	32 752	4 438	224 182	99.6	283 963	126.2	313 854	139.5	403 527	179.3
		2	15 738	2 133	19 935	2 701	22 034	2 986	28 329	3 839	194 363	86.4	246 193	109.4	272 108	120.9	349 852	155.5
	15.70	N	25 810	3 497	32 692	4 430	36 134	4 896	46 458	6 295	324 118	144.1	410 550	182.5	453 765	201.7	583 413	259.3
		P	20 067	2 719	25 418	3 444	28 094	3 807	36 120	4 894	253 851	112.8	321 544	142.9	355 391	158.0	456 931	203.1
		2	17 315	2 346	21 932	2 972	24 241	3 285	31 166	4 223	219 738	97.7	278 335	123.7	307 633	136.7	395 528	175.8
4 1/2	13.75	N	25 907	3 510	32 816	4 447	36 270	4 915	46 633	6 319	270 034	120.0	342 043	152.0	378 047	168.0	486 061	216.0
		P	20 403	2 765	25 844	3 502	28 564	3 870	36 725	4 976	213 258	94.8	270 127	120.1	298 561	132.7	383 864	170.6
		2	17 715	2 400	22 439	3 041	24 801	3 361	31 887	4 321	185 389	82.4	234 827	104.4	259 545	115.4	333 701	148.3
	16.60	N	30 807	4 174	39 022	5 288	43 130	5 844	55 453	7 514	330 558	146.9	418 707	186.1	462 781	205.7	595 004	264.4
		P	24 139	3 271	30 576	4 143	33 795	4 579	43 450	5 888	260 165	115.6	329 542	146.5	364 231	161.9	468 297	208.1
		2	20 908	2 833	26 483	3 588	29 271	3 966	37 634	5 099	225 771	100.3	285 977	127.1	316 080	140.5	406 388	180.6
	20.00	N	36 901	5 000	46 741	6 333	51 661	7 000	66 421	9 000	412 358	183.3	522 320	232.1	577 301	256.6	742 244	329.9
		P	28 683	3 887	36 332	4 923	40 157	5 441	51 630	6 996	322 916	143.5	409 026	181.8	452 082	200.9	581 248	258.3
		2	24 747	3 353	31 346	4 247	34 645	4 694	44 544	6 036	279 502	124.2	354 035	157.3	391 302	173.9	503 103	223.6
	22.82	N	40 912	5 544	51 821	7 022	57 276	7 761	73 641	9 978	471 239	209.4	596 903	265.3	659 734	293.2	848 230	377.0
		P	31 587	4 280	40 010	5 421	44 222	5 992	56 856	7 704	367 566	163.4	465 584	206.9	514 593	228.7	661 620	294.1
		2	27 161	3 680	34 404	4 662	38 026	5 153	48 890	6 625	317 497	141.1	402 163	178.7	444 496	197.6	571 495	254.0

(1) See note B 13.

NEW (N), PREMIUM CLASS (P) AND CLASS 2 (2) DRILL PIPE, COLLAPSE AND BURST PRESSURE DATA (continued) (API RP 7G, 16th edition, August 1998)

Size OD	Nominal weight	Class	Collapse pressure								Burst pressure							
			E		95		105		135		E		95		105		135	
(in)	(lb/ft)		(psi)	(MPa)	(psi)	(MPa)	(psi)	(MPa)	(psi)	(MPa)	(psi)	(MPa)	(psi)	(MPa)	(psi)	(MPa)	(psi)	(MPa)
4	11.85	N	8 381	57.8	9 978	68.8	10 708	73.8	12 618	87.0	8 597	59.3	10 889	75.1	12 036	83.0	15 474	106.7
		P	5 704	39.3	6 508	44.9	6 827	47.1	7 445	51.3	7 860	54.2	9 956	68.6	11 004	75.9	14 148	97.5
		2	4 311	29.7	4 702	32.4	4 876	33.6	5 436	37.5	6 878	47.4	8 712	60.1	9 629	66.4	12 380	85.4
	14.00	N	11 354	78.3	14 382	99.2	15 896	109.6	20 141	138.9	10 828	74.7	13 716	94.6	15 159	104.5	19 491	134.4
		P	9 012	62.1	10 795	74.4	11 622	80.1	13 836	95.4	9 900	68.3	12 540	86.5	13 860	95.6	17 820	122.9
		2	7 295	50.3	8 570	59.1	9 134	63.0	10 520	72.5	8 663	59.7	10 973	75.7	12 128	83.6	15 593	107.5
	15.70	N	12 896	88.9	16 335	112.6	18 055	124.5	23 213	160.0	12 469	86.0	15 794	108.9	17 456	120.4	22 444	154.7
		P	10 914	75.2	13 825	95.3	15 190	104.7	18 593	128.2	11 400	78.6	14 440	99.6	15 960	110.0	20 520	141.5
		2	9 531	65.7	11 468	79.1	12 374	85.3	14 840	102.3	9 975	68.8	12 635	87.1	13 965	96.3	17 955	123.8
4 1/2	13.75	N	7 173	49.5	8 412	58.0	8 956	61.7	10 283	70.9	7 904	54.5	10 012	69.0	11 066	76.3	14 228	98.1
		P	4 686	32.3	5 190	35.8	5 352	36.9	5 908	40.7	7 227	49.8	9 154	63.1	10 117	69.8	13 008	89.7
		2	3 397	23.4	3 845	26.5	4 016	27.7	4 287	29.6	6 323	43.6	8 010	55.2	8 853	61.0	11 382	78.5
	16.60	N	10 392	71.7	12 765	88.0	13 825	95.3	16 773	115.6	9 829	67.8	12 450	85.8	13 761	94.9	17 693	122.0
		P	7 525	51.9	8 868	61.1	9 467	65.3	10 964	75.6	8 987	62.0	11 383	78.5	12 581	86.7	16 176	111.5
		2	5 951	41.0	6 828	47.1	7 185	49.5	7 923	54.6	7 863	54.2	9 960	68.7	11 009	75.9	14 154	97.6
	20.00	N	12 964	89.4	16 421	113.2	18 149	125.1	23 335	160.9	12 542	86.5	15 886	109.5	17 558	121.1	22 575	155.6
		P	10 975	75.7	13 901	95.8	15 350	105.8	18 806	129.7	11 467	79.1	14 524	100.1	16 053	110.7	20 640	142.3
		2	9 631	66.4	11 598	80.0	12 520	86.3	15 033	103.6	10 033	69.2	12 709	87.6	14 047	96.9	18 060	124.5
	22.82	N	14 815	102.1	18 765	129.4	20 741	143.0	26 667	183.9	14 583	100.5	18 472	127.4	20 417	140.8	26 250	181.0
		P	12 655	87.3	16 030	110.5	17 718	122.2	22 780	157.1	13 333	91.9	16 889	116.4	18 667	128.7	24 000	165.5
		2	11 458	79.0	14 514	100.1	16 042	110.6	20 510	141.4	11 667	80.4	14 779	101.9	16 333	112.6	21 000	144.8

See note B 16.

WEIGHT OF DRILL COLLARS (kg/m)

OD		Inside diameter (in and mm)														
		1	1 1/4	1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	2 4/5	2 7/8	3	3 1/4	3 1/2	3 3/4	4
(in)	(mm)	25.40	31 75	38.10	44.45	50.80	57.15	63.50	69.85	71.44	73.03	76.20	82.55	88.90	95.25	101.60
2 7/8	73.03	28.90	26.66	23.93												
3	76.20	31.82	29.58	26.85												
3 1/8	79.38	34.87	32.63	29.89												
3 1/4	82.55	38.04	35.80	33.06												
3 1/2	88.90	44.75	42.51	39.78												
3 3/4	95.25	51.96	49.72	46.99	43.75											
4	101.60	59.66	57.43	54.69	51.46	47.73	43.51									
4 1/8	104.78	63.70	61.47	58.73	55.50	51.77	47.55									
4 1/4	107.95	67.87	65.63	62.90	59.66	55.94	51.71									
4 1/2	114.30	76.57	74.33	71.60	68.37	64.64	60.41									
4 3/4	120.65	85.77	83.53	80.80	77.56	73.84	69.61	64.89								
5	127.00	96.46		90.49	87.28	83.53	79.30	74.58	69.36							
5 1/4	133.35	105.66		100.68	97.45	93.72	89.50	84.77	79.55	78.17	76.76	73.84				
5 1/2	139.70	116.35		111.37	108 14	104 41	100.19	95.46	90.24	88.86	87.45	84.53				
5 3/4	146.05	127.53		122.56	119.33	115.60	111.37	106.65	101.43	100.05	98.63	95.71	89.50			
6	152.40	139.22		134.25	131.01	127.28	123.06	118.34	113.11	111.73	110.32	107.40	101.18	94.47	87.26	
6 1/4	158.75	151.40		146.43	143.20	139.47	135.24	130.52	125.30	123.91	122.50	119.58	113.36	106.65	99.44	
6 3/8	161.93	157.68		152 70	149.47	145 74	141 52	136.79	131 57	130.19	128.78	125.86	119.64	112.93	105.72	
6 1/2	165 10	164.08		159 11	155.87	152 15	147.92	143.20	137 97	136.59	135.18	132.26	126.04	119.33	112.12	
6 5/8	168.28	170.60		165.63	162.40	158.67	154.44	149.72	144.50	143.12	141.70	138.78	132.67	125.86	118.65	
6 3/4	171.45	177.25		172 28	169.05	165.32	161.09	156.37	151.15	149.77	148.35	145.43	139.22	132.51	125.30	117.59
7	177.80	190.93		185.96	182.72	178.99	174.77	170.04	164.82	163.44	162.03	159.11	152.89	146.18	138.97	131.26
7 1/4	184 15	206.10		200 13	196.89	193.16	188.94	184.22	178.99	177.61	176.20	173.28	167.06	160.35	153.14	145.43
7 1/2	190.50	219 77		214.79	211.56	207.63	203.61	198.88	193.66	192.28	190.87	187.94	181.73	175.02	167.81	160.10
7 3/4	196.85	234.93		229.96	226 73	223.00	218.77	214.05	208.83	207.44	206.03	203.11	196.89	190.18	182.97	175.27
8	203.20	250.59		245.62	242.39	238.66	234.43	229.71	224.49	223.11	221.69	218.77	212.56	205.84	198.63	190.93
8 1/4	209.55	266.75		261.78	258.55	254.82	250.59	245.87	240.65	239.27	237.85	234.93	228.72	222.00	214.79	207.09
8 1/2	215.90	283.41		278.44	275.20	271.47	267.25	262.53	257.30	255.92	254.51	251.59	245.37	238.66	231.45	223.74
8 3/4	222.25	300.56		295.59	292.36	288.63	284.40	279.68	274.46	273.08	271.66	268.74	262.53	255.81	248.60	240.90
9 1/4	234.95	336.36			328.16	324.43	320.20	315.48	310.26	308.87	307.46	304.54	298.32	291.61	284.40	276.70
9 1/2	241.30	355.01			346.80	343.07	338.85	334.12	328.90	327.52	326.11	323.18	316.97	310.26	303.05	295.34
9 3/4	247.65	374.15			365.94	362.22	357.99	353.27	348.04	346.66	345.25	342.33	336.11	329.40	322.19	314.48
10	254.00	393.79				381.85	377.63	372.91	367.68	366.30	364.89	361.97	355.75	349.04	341.83	334.12
10 1/2	266.70	434.56				422.63	418.40	413.68	408.46	407.07	405.66	402.74	396.52	389.81	382.60	374.89
10 3/4	273.05	455.69				443.76	439.53	434.81	429.59	428.20	426.79	423.87	417.65	410.94	403.73	396.03
11	279.40	477.32						456.44	451.22	449.83	448.42	445.50	439.28	432.57	425.36	417.65
11 1/4	285.75	499.44						478.56	473.34	471.96	470.54	467.62	461.41	454.70	447.49	439.78
12	304.80	568.80						547.92	542.70	541.32	539.90	536.98	530.77	524.06	516.85	509.14
14	355.60	775.64							749.54	748.16	746.74	743.82	737.61	730.89	723.68	715.98

Pipe body	1	Nominal size (OD)
	2	Nominal weight
	3	Wall thickness
	4	Inside diameter
	5	Steel cross-section
	6	Capacity
	7	Displacement (1)
	8	Grade
	9	Collapse resistance (MPa)
	10	Internal yield pressure (MPa)
	11	Pipe body yield strength (1000 daN)
Tensile strength (10^3 daN)	12	Buttress Standard
	13	Buttress Special Clearance
	14	API STC
	15	API LTC
Connection efficiency	16	Grant Prideco TCII
	17	Grant Prideco STL
	18	Hydril LX
	19	Hydril 563
	20	Hydril 511
	21	Hydril 521
	22	Vallourec & Mannesmann New VAM
	23	Vallourec & Mannesmann VAM ACE
	24	Vallourec & Mannesmann VAM PRO
	25	Vallourec & Mannesmann VAM TOP
	26	Vallourec & Mannesmann FJL
Connection characteristics	27	Buttress Standard
	28	Buttress Special Clearance
	29	API STC
	30	API LTC
	31	Grant Prideco TCII
	32	Grant Prideco STL
	33	Hydril LX
	34	Hydril 563
	35	Hydril 511
	36	Hydril 521
	37	Vallourec & Mannesmann New VAM
	38	Vallourec & Mannesmann VAM ACE
	39	Vallourec & Mannesmann VAM PRO
	40	Vallourec & Mannesmann VAM TOP
	41	Vallourec & Mannesmann FJL

(1) The closed-end displacement does not account for couplings.

GEOMETRICAL CHARACTERISTICS AND MECHANICAL PROPERTIES OF CASING (continued)

1	**9.625** in			244.5 mm				**9.625** in			244.5 mm			
2	**36.00** lb/ft			52.5 daN/m				**40.00** lb/ft			58.4 daN/m			
3	0.352 in			8.9 mm				0.395 in			10.0 mm			
4	8.921 in			226.6 mm				8.835 in			224.4 mm			
5	10.25 in²			6616 mm²				11.45 in²			7390 mm²			
6	3.25 gal/ft			40.33 l/m				3.18 gal/ft			39.55 l/m			
7	3.78 gal/ft			46.94 l/m				3.78 gal/ft			46.94 l/m			
8	K55	L80	N80	C90	RT95	CP110	Q125	K55	L80	N80	C90	RT95	CP110	Q125
9	14.0	16.4	16.4	16.9	17.0	17.1	17.1	17.7	21.3	21.3	22.4	22.9	24.0	24.3
10	24.3	35.3	35.3	39.7	41.9	48.5	55.2	27.2	39.6	39.6	44.6	47.0	54.5	61.9
11	251	365	365	411	433	502	570	280	408	408	459	484	560	637
12	336	377	390	407	428	504	555	375	421	436	454	478	563	620
13	336	377	390	407	428	504	555	375	416	436	437	459	547	591
14	188	245	249	271	286	334	374	216	282	285	312	328	383	430
15	218	282	286	312	328	383	430	250	323	328	358	377	440	493
16				100.0							100.0			
17				59.9							60.0			
18				100.0							100.0			
19				100.0							100.0			
20											59.6			
21				66.7							70.0			
22											100.0			
23				100.0							100.0			
24														
25														
26														
	Make-up torque (daN.m)							Make-up torque (daN.m)						
	55ksi	75-80ksi	90-95ksi	110ksi	125ksi	OD (mm)	ID (mm)	Drift API (mm)	55ksi	75-80ksi	90-95ksi	110ksi	125ksi	OD (mm)	ID (mm)	Drift API (mm)
27						269.9		222.6						269.9		220.4
28						257.2		222.6						257.2		220.4
29	574					269.9		222.6	659					269.9		220.4
30	663					269.9		222.6	761	992	1148			269.9		220.4
31		1593	1593	1593	1593	258.1	225.8	222.6		1708	1708	1708	1708	260.0	224.4	220.4
32	624	814	814	814	814	244.5	225.4	222.6	692	881	881	881	881	244.5	223.4	220.4
33	1658	1879	1961	2076	2175	269.9	225.3	222.6	1885	2148	2248	2389	2510	269.9	223.0	220.4
34	1626	1626	1626	1626	1626	269.9	225.3	222.6	1762	1762	1762	1762	1762	269.9	224.4	220.4
35									1233	1233	1233	1233	1233	244.5	223.4	220.4
36	1491	1491	1491	1491	1491	251.0	224.7	222.6	1707	1707	1707	1707	1707	252.9	223.5	220.4
37										3570	3710	3970	4220	262.1	224.7	220.4
38	1080	1270	1370	1570	1670	258.8	228.5	222.6	1080	1270	1370	1570	1670	260.7	226.7	220.4
39																
40																
41																

MPa × 145 = psi daN × 2.25 = lb daN.m × 7.38 = lb.ft mm × 0.0394 = in

GEOMETRICAL CHARACTERISTICS AND MECHANICAL PROPERTIES OF CASING (continued

1		9.625 in			244.5 mm					9.625 in			244.5 mm
2		43.50 lb/ft			63.5 daN/m					47.00 lb/ft			68.6 daN/m
3		0.435 in			11.0 mm					0.472 in			12.0 mm
4		8.755 in			222.4 mm					8.681 in			220.5 mm
5		12.56 in²			8103 mm²					13.57 in²			8756 mm²
6		3.13 gal/ft			38.84 l/m					3.07 gal/ft			38.19 l/m
7		3.78 gal/ft			46.94 l/m					3.78 gal/ft			46.94 l/m
8	K55	L80	N80	C90	RT95	CP110	Q125	K55	L80	N80	C90	RT95	CP110
9	22.4	26.3	26.3	27.6	28.4	30.5	31.9	26.8	32.8	32.8	34.4	35.1	36.5
10	30.0	43.6	43.6	49.1	51.8	60.0	68.2	32.5	47.3	47.3	53.3	56.2	65.1
11	307	447	447	503	531	615	698	332	483	483	543	574	664
12	411	462	478	498	524	617	679	445	499	516	538	566	667
13	411	416	437	437	459	547	591	416	416	437	437	459	547
14	242	315	319	348	367	428	481	265	346	350	382	403	470
15	279	362	367	400	422	492	552	306	397	403	439	463	540
16				100.0							100.0		
17				66.6							66.0		
18				100.0							100.0		
19				100.0							100.0		
20				62.5							61.2		
21				72.3							74.1		
22				100.0							100.0		
23				100.0							100.0		
24													
25													
26				69.4							71.9		

	Make-up torque (daN.m)					OD (mm)	ID (mm)	Drift API (mm)	Make-up torque (daN.m)					OD (mm)	ID (mm)
	55ksi	75-80ksi	90-95ksi	110ksi	125ksi				55ksi	75-80ksi	90-95ksi	110ksi	125ksi		
27						269.9		218.4						269.9	
28						257.2		218.4						257.2	
29															
30		1110	1285	1498		269.9		218.4		1219	1410	1645	1844	269.9	
31		2054	2054	2054	2054	261.7	222.4	218.4		2373	2373	2373	2373	263.3	[illegible]
32	868	1098	1098	1098	1098	244.5	220.5	218.4	908	1234	1234	1234	1234	244.5	[illegible]
33	2126	2436	2558	2728	2874	269.9	221.3	218.4	2328	2679	2818	3014	3181	269.9	[illegible]
34	1938	1938	1938	1938	1938	269.9	222.4	218.4	2141	1790	1790	1790	1790	269.9	[illegible]
35	1369	1369	1369	1369	1369	244.5	220.2	218.4	1694	1694	1694	1694	1694	244.5	[illegible]
36	1897	1897	1897	1897	1897	254.6	220.5	218.4	2087	2087	2087	2087	2087	256.2	[illegible]
37		4050	4180	4440	4700	263.0	222.7	218.4		4700	4880	5220	5530	264.6	[illegible]
38	1470	1770	1960	2160	2350	262.5	225.0	218.4	1770	2160	2350	2750	2940	264.1	[illegible]
39															
40															
41		2020	2180	2330	2490	247.6	220.0	218.4		2280	2460	2640	2830	248.3	218.4

MPa × 145 = psi   daN × 2.25 = lb   daN.m × 7.38 = lb.ft   mm × 0.0394 = in

TABLE OF COEFFICIENTS N_2 (continued)
Calculation of pressure losses in drill pipes $p_{int} = N_2 B$ (kPa/100 m)

Nominal pipe size (in)	4 1/2										
Nominal weight (lb/ft)	16.6							20			
Pipe inside diameter (in)	3.826							3.64			
Tool joint inside diameter (in)	3 3/4	3 1/2	3 1/4	3	2 3/4	2 11/16	2 1/2	3 5/8	3 1/2	3 1/4	3
Flow rate Q (l/min)											
1 500	93	95	100	106	116	120	133	117	119	123	129
1 550	98	101	106	112	123	127	142	124	126	130	137
1 600	104	107	112	119	130	134	150	132	133	138	145
1 650	110	113	118	126	138	142	158	139	141	146	153
1 700	116	120	125	133	145	150	167	147	149	154	162
1 750	123	126	131	140	153	158	176	155	157	162	170
1 800	129	133	138	147	161	166	185	163	165	170	179
1 850	135	139	145	154	169	174	195	171	173	179	188
1 900	142	146	152	162	178	183	204	179	182	188	198
1 950	149	153	160	170	186	192	214	188	190	197	207
2 000	156	160	167	178	195	201	224	197	199	206	217
2 050	163	168	175	186	204	210	234	206	208	215	226
2 100	170	175	182	194	213	219	245	215	218	225	237
2 150	177	183	190	202	222	229	255	224	227	235	247
2 200	185	190	198	211	231	238	266	234	237	245	257
2 250	193	198	206	220	241	248	277	243	246	255	268
2 300	200	206	215	228	250	258	288	253	256	265	279
2 350	208	214	223	237	260	268	299	263	266	275	290
2 400	216	223	232	247	270	279	311	273	277	286	301
2 450	224	231	241	256	281	289	323	284	287	297	312
2 500	233	239	250	265	291	300	335	294	298	308	324
2 550	241	248	259	275	302	311	347	305	309	319	335
2 600	250	257	268	285	312	322	359	316	320	330	347
2 650	259	266	277	295	323	333	372	327	331	342	360
2 700	267	275	287	305	334	344	384	338	342	354	372
2 750	276	284	296	315	346	356	397	349	354	366	384
2 800	285	294	306	325	357	368	410	361	365	378	397
2 850	295	303	316	336	368	380	424	372	377	390	410

l/min × 0.264 = gal/min

TABLE OF COEFFICIENTS N_3 (continued)

Calculation of pressure losses in drill collars $p_{int} = N_3 B$ (kPa/100 m)

Drill collar ID	(in)	1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	2 13/16	3	3 1/4	3 1/2
	(mm)	38.10	44.45	50.80	57.15	63.50	69.85	71.44	76.20	82.55	88.90
Flow rate Q (l/min)	**2 150**	15 781	7 530	3 967	2 254	1 359	860	772	566	386	270
	2 200	16 447	7 848	4 134	2 349	1 417	896	805	590	402	282
	2 250	17 126	8 172	4 305	2 446	1 475	933	838	615	419	293
	2 300	17 817	8 502	4 479	2 545	1 535	971	872	640	436	305
	2 350	18 521	8 837	4 655	2 645	1 595	1 009	906	665	453	317
	2 400	19 236	9 178	4 835	2 747	1 657	1 048	941	691	470	329
	2 450	19 963	9 526	5 018	2 851	1 719	1 088	977	717	488	342
	2 500	20 703	9 878	5 204	2 957	1 783	1 128	1 013	743	506	355
	2 550	21 454	10 237	5 393	3 064	1 848	1 169	1 050	770	524	367
	2 600	22 217	10 601	5 584	3 173	1 913	1 211	1 087	798	543	381
	2 650	22 992	10 971	5 779	3 284	1 980	1 253	1 125	825	562	394
	2 700	23 779	11 346	5 977	3 396	2 048	1 296	1 164	854	581	407
	2 750	24 577	11 727	6 178	3 510	2 117	1 340	1 203	882	601	421
	2 800	25 387	12 114	6 381	3 626	2 186	1 384	1 242	911	621	435
	2 850	26 209	12 506	6 588	3 743	2 257	1 429	1 282	941	641	449
	2 900	27 043	12 903	6 797	3 862	2 329	1 474	1 323	971	661	463
	2 950	27 888	13 307	7 010	3 983	2 402	1 520	1 365	1 001	682	478
	3 000	28 744	13 715	7 225	4 105	2 476	1 567	1 407	1 032	703	492
	3 050	29 612	14 130	7 443	4 229	2 550	1 614	1 449	1 063	724	507
	3 100	30 492	14 549	7 664	4 355	2 626	1 662	1 492	1 095	745	522
	3 150	31 383	14 974	7 888	4 482	2 703	1 711	1 536	1 127	767	538
	3 200	32 285	15 405	8 115	4 611	2 781	1 760	1 580	1 159	789	553
	3 250	33 199	15 841	8 345	4 741	2 859	1 810	1 624	1 192	812	569
	3 300	34 124	16 282	8 577	4 873	2 939	1 860	1 670	1 225	834	584
	3 350	35 060	16 729	8 813	5 007	3 020	1 911	1 716	1 259	857	601
	3 400	36 008	17 181	9 051	5 142	3 101	1 963	1 762	1 293	880	617
	3 450	36 966	17 639	9 292	5 279	3 184	2 015	1 809	1 327	904	633
	3 500	37 936	18 101	9 536	5 418	3 267	2 068	1 856	1 362	927	650
	3 550	38 917	18 569	9 782	5 558	3 352	2 121	1 904	1 397	951	667
	3 600	39 910	19 043	10 032	5 700	3 437	2 175	1 953	1 433	976	684
	3 650	40 913	19 522	10 284	5 843	3 524	2 230	2 002	1 469	1 000	701
	3 700	41 927	20 006	10 539	5 988	3 611	2 285	2 052	1 505	1 025	718
	3 750	42 953	20 495	10 797	6 134	3 699	2 341	2 102	1 542	1 050	736
	3 800	43 989	20 989	11 057	6 282	3 789	2 398	2 152	1 579	1 075	753
	3 850	45 036	21 489	11 320	6 432	3 879	2 455	2 204	1 617	1 101	771
	3 900	46 095	21 994	11 586	6 583	3 970	2 512	2 256	1 655	1 127	790
	3 950	47 164	22 504	11 855	6 736	4 062	2 571	2 308	1 693	1 153	808
	4 000	48 244	23 020	12 127	6 890	4 155	2 630	2 361	1 732	1 179	826
	4 050	49 335	23 540	12 401	7 046	4 249	2 689	2 414	1 771	1 206	845
	4 100	50 436	24 066	12 678	7 203	4 344	2 749	2 468	1 811	1 233	864
	4 150	51 549	24 597	12 957	7 362	4 440	2 810	2 522	1 850	1 260	883

l/min × 0.264 = gal/min

PET100 DRILING

Multiple choice answers

Hand in as part of the exam result

Select the correct answer A, B, C or D. **Only one correct answer for each question.**

CANDIDATE NUMBER: ________________ DATE: _________

Multiple choice 1

	A	B	C	D
Question 1.	☐	☐	☐	☐
Question 2.	☐	☐	☐	☐
Question 3.	☐	☐	☐	☐
Question 4.	☐	☐	☐	☐
Question 5.	☐	☐	☐	☐

Multiple choice 2

	A	B	C	D
Question 1.	☐	☐	☐	☐
Question 2.	☐	☐	☐	☐
Question 3.	☐	☐	☐	☐
Question 4.	☐	☐	☐	☐
Question 5.	☐	☐	☐	☐

Multiple choice 3

	A	B	C	D
Question 1.	☐	☐	☐	☐
Question 2.	☐	☐	☐	☐
Question 3.	☐	☐	☐	☐
Question 4.	☐	☐	☐	☐
Question 5.	☐	☐	☐	☐

Multiple choice 4

	A	B	C	D
Question 1.	☐	☐	☐	☐
Question 2.	☐	☐	☐	☐
Question 3.	☐	☐	☐	☐
Question 4.	☐	☐	☐	☐
Question 5.	☐	☐	☐	☐