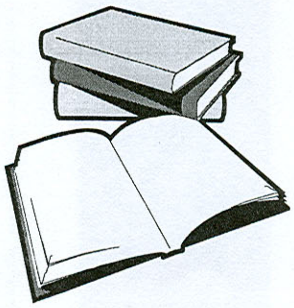
EXAMINATION: AES1330 Drilling & Production Engineering

4th April 2005

- Write your name and personal student number ***clearly*** at the top of ***each*** page.
- Decimal points and comma's in this examination paper are used in the *English* manner,
- thus, for example 100,000 is hundred thousand, not 100 with three decimals !
- It is important to supplement all your answers with your personal calculation sheets, as points are also awarded for the actual method being applied.
- Use sketches and drawings freely if this will facilitate your calculations and / or make it easier to understand the actual situation in the exercise. (Note this also assists the examiner in judging the level of understanding in the event of an incorrect arithmetical answer)
- You may consult all your study books and notes. With this exercise, a simple and quick to use handout with ***tables*** has been given to you to speed up the search for the required capacities, buoyancy's, weights, etc.



Marks allocation

	a	*b*	*c*	*d*	*e*	*f*	*Total*
Question 1	3	3	3	3			12
Question 2	2	3	2	3	2		12
Question 3	3	3	3	3			12
Question 4	2	3	3	2	2		12
Question5.1	2						2
Question 5.2	2						2
Question 5.3	2						2
Question 5.4	1	1					2
Question 5.5	2						2
Question5.6	2						2
Question 5.7	2						2
Question 5.8	2						2
Question 5.9	2						2
Question 5.10	2						2

Total *: 68 marks*

1. Drill string

A driller is instructed to run a bottom hole assembly with the possibility of applying 250kN weight on bit whilst drilling. He has 15 drill collars available, each 9.8 m long, and many joints of heavy weight drill pipe, each of 9.5 m length, which can also be used to apply weight on bit, in addition to the drill collars.

Further information:-

- -Drill collars:- 6-1/2" (165.1 mm) OD, 2 13/16" (71.4 mm) ID; with a weight of 135.4 kg/m
- -HWDP:- 5" (127 mm) OD by 3" (76.2 mm) ID, with a weight of 73.4 kg/m;
- -Mud gradient:- 10.4 kPa/m
- -The "Neutral point" in the BHA to lie at 90% of the total BHA buoyant weight.

1a. Calculate the minimum number of HWDPs that the driller must run in order to achieve the criteria of 250kN weight on bit. (Assume all 15 drill collars are run)

1b. Whilst drilling ahead, a sudden weight loss of 115 kN is observed, accompanied by a large pressure loss at the pump. It is concluded that the drill string has broken. Calculate the number of drill collars (and HWDPs?) that have been lost down hole.

1c. Recalculate the number of HWDPs to achieve 250 kN weight on bottom in the event that the hole is deviated by 20 degrees inclination.

1d. We now have to insert and place ***stabilisers*** to hold the well deviation at 20 degrees. We do not have a mud-motor, so the directional control will need to be accomplished by placing the stabilisers in the right place.

How many stabilisers would you propose to run, and where would you place these?

What do we call such a *Bottom Hole Assembly ?*

2. Pressure Control

Whilst drilling ahead in a vertical well at a depth of 2,710 meter a ***'kick'*** is experienced. The Driller closes in the well, and it is observed that an influx of volume **3.2 m³** has been taken. The driller collects and records all the data associated with the kick as follows:-

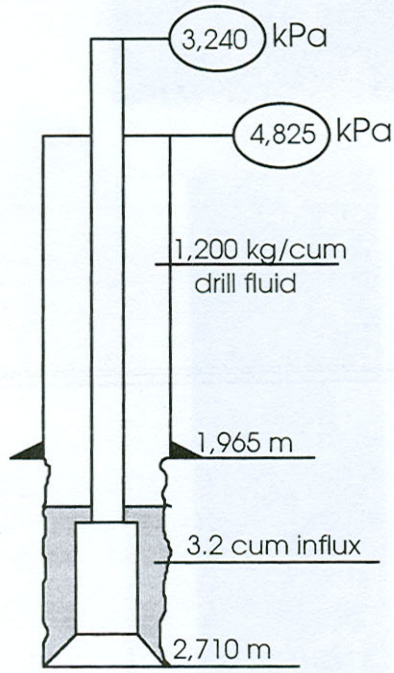
- Data (in Metric Units)

The following data is available:

Parameter	Value	Unit
Hole Depth of vertical well (all depths are TVD)	2,710	m
Hole Size	244.5	mm
Last Casing, 273.05 mm, 60.27 kg/m, K55, shoe at:	1,965	m
Formation Strength Gradient at shoe	15.38	kPa/m
Drilling fluid density	1,200	kg/m^3
Bottom Hole Assembly: - 192 m of 190.5 mm OD x 71.44 mm ID Drill Collars - 2518 m of 127 mm, 29.02 kg/m nom. wt, Grade 'E' Drill Pipe with NC50 connections		
Pump Output (each pump) - double acting duplex -	26.23	l/stroke
Slow Circulation Rate (SCR) Pressure at 30 SPM	3,585	kPa

Stabilised Build-up Pressure on Drill Pipe (Pdp)	3,240	kPa
Stabilised Build-up Pressure on Annulus (Pann)	4,825	kPa
Pit level increase after shutting in the well	3.2	m^3

Capacity 190.5 mm x 71.44 mm Drill Collar = 0.0040 m^3/m
Capacity 127 mm, 29.02 kg/m Drill Pipe = 0.0093 m^3/m
Capacity Drill Collar / Open Hole = 0.0185 m^3/m
Capacity Drill Pipe / Open Hole = 0.0343 m^3/m
Capacity Drill Pipe / Casing = 0.0382 m^3/m



- Exercise (in S.I. Units)

  Calculate:

2a. The Bottom Hole Pressure (BHP) before and just after the kick took place.

2b. Gradient and type of influx (gas, oil, water or combination of these).

2c. The required drilling fluid ***density*** to kill this well. *Round off the value in kPa/m and convert back to kg/m³ !*

2d. The Standpipe Pressure (P_{st}) at the start of killing this well

2e. Why is the formation strength gradient so important during the shutting in and killing of a well? Explain your answer with good reasoning and think about MAASP.

3. Artificial Lift

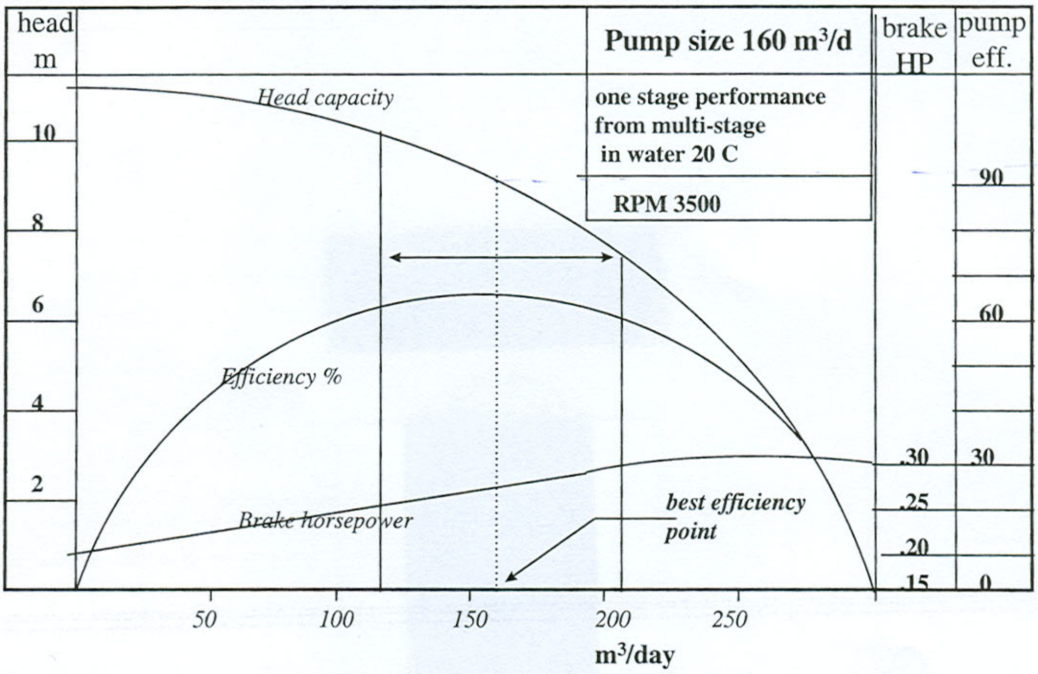
3a. It is planned to install either gas lift or an ESP in the following well, to achieve a production rate of 1000 bbl/day.

Depth	10000 ft
Watercut	0%
Reservoir pressure	2400 psi
Productivity Index PI	2 bbl/day/psi

What are the advantages and disadvantages of these two methods of artificial lift?

3b. If an ESP is installed at the bottom of the well, the required pressure at the outlet of the ESP is 2300 psi, in order to achieve the required tubing head pressure. Calculate the pressure difference that must be supplied by the pump at the planned production rate (1000 bbl/day).

3c How many stages should the ESP have, based on the following performance curve (1 psi = 6.89 kPa, 1 bbl = 0.159 m^3)



3d If instead gas lift is installed, the gas injection pressure on surface is 1000 psi. The tubing head pressure of the well is 500 psi. The fluid gradient is 0.4 psi/ft, the gas gradient 0.04 psi/ft and the flowing well gradient approximately 0.25 psi/ft. Determine the deepest point at which gas can be injected (i) without gaslift valves and (ii) with gaslift valves.

3e The gaslift valves are adjusted to operate at a pressure 100 psi above the flowing well gradient. Estimate from a graph the setting depths and setting pressures of the first two valves.

4. Stimulation

4a Explain the roles of the pre-flush, the main flush and the post-flush in matrix acidising of sandstone formations.

4b In a sandstone acidising treatment, the mud-acid is an HF/HCl acid blend, formed of 1.5% by wt HF and 13.5% HCl. One of the minerals present is kaolinite $Al_4Si_4O_{10}(OH)_8$. Calculate the Volumetric Dissolving Power for HF for the primary reaction given by

$$Al_4Si_4O_{10}(OH)_8 + 24\ HF + 4H^+ \leftrightarrow 4AlF_2^+ + 4SiF_4 + 18H_2O$$

The molecular mass of kaolinite is 516.4 and of HF 20. The density of the acid blend is 1070 kg/m^3 and of kaolonite 2800 kg/m^3.

4c The wellbore has <u>diameter</u> 20 cm. The interval to be treated is 50m in height. The sandstone has porosity 0.25 and it contains 2% of kaolonite. A volume of 60 m^3 of mud-acid is pumped into this interval. Assume homogeneous penetration. Calculate the depth from the wellbore for which all the mud-acid will react with all kaolinite.

4d What are the potential problems in pumping acid into such a long openhole interval. How can you try to avoid these?

4e What are thought to be the reasons for failure in using mud-acid with high HF concentrations?

5. Short calculation questions / General knowledge:

5.1 What is a "bent sub" and what is a "bent housing" and for what purpose is it used?

5.2 A deviated land well is being planned. The following data are given:

Surface Co-ordinates	North 1375 m and East 625 m
Target Co-ordinates	South 850 m and West 450 m

Calculate the **Target Displacement** and **Azimuth.**

5.3 A well has to be closed in after observing clear signs that a formation has been penetrated with a high pore pressure. Which two 'observations' do we make, or tools do we have, to notify the driller that the well is kicking?

5.4 A *drill string* can get stuck, once and a while:-

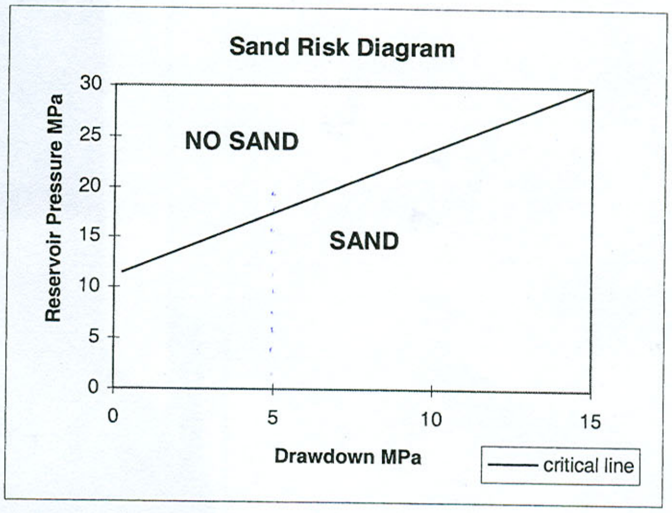
5.4a Name two major categories of *stuck pipe*;

5.4b Name an important kind of tool which is part of the *drill string*, with which we attempt to free ourselves from the stuck point;

5.5 When we perform a casing cementation, it is of utmost importance to optimise the ***displacement efficiency*** as much as practically possible, so that we can expect to obtain a perfect sealing of the *annulus*. Name **three** ways to increase this *displacement efficiency*.

5.6 What is the design collapse pressure for a casing at depth 7000 ft if the mud has specific gravity 1.25 (the pressure gradient for water is 0.4335 psi/ft)?

5.7 What are the available types of sand control. The initial pressure in a reservoir is 20 MPa. The initial production rate from a well is planned at 450 m^3/day, and the PI is 90 m^3/day/MPa. The sand risk diagram is given here. Do you anticipate sand production?



5.8 Name three types of deposition that can occur in a well as a result of phase changes. Describe how to prevent one of these types of deposition.

5.9 A hydraulic fracture is created in a vertical well. The minimum horizontal principal stress is oriented North-South. In which direction do you expect the fracture to propagate?

5.10 Describe the advantages and disadvantages of J-lay over S-lay for offshore pipelines.