25/18

University of Stavanger

FACULTY OF SCIENCE AND TECHNOLOGY

SUBJECT: PET 535: MODERN WELL DESIGN

DATE: MAY 19 , 2016

TIME: 0900 - 1300

AID: CALCULATOR

THE EXAM CONSISTS OF 5 PROBLEMS AND 6 PAGES

REMARKS: PLEASE STATE ASSUMPTIONS

Problem 1. Hydraulics

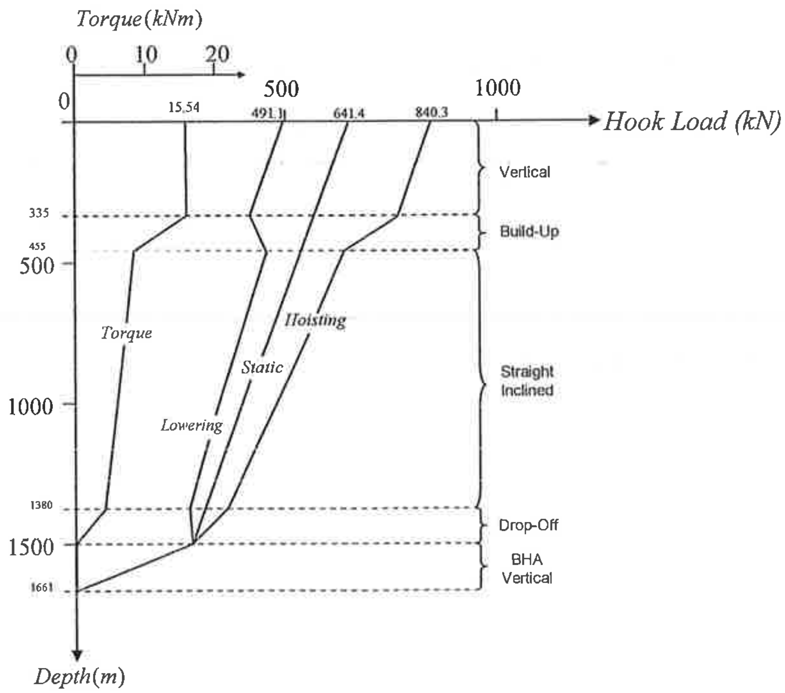
Please define the most correct answer.

	A	B	C
1. Reynolds number defines:	Inertial/viscous forces	Viscous/inertial forces	None
2. Bernoullis equation is a conservation of:	Mass	Momentum	Energy
3. Pipe friction factor applies for:	Laminar flow	Turbulent flow	Both
4. Viscous effects applies for	Laminar flow	Turbulent flow	Both
5. Drillstring hydraulics is mostly:	Laminar	Turbulent	None
6. Flow through bit nozzles is:	Laminar	Turbulent	Both
7. Flow through the marine riser is:	Laminar	Turbulent	Both
8. Increased flow rate gives	Less nozzle press.	More nozzle press.	I don't know

Problem 2: Wellbore friction

The enclosed figure shows hookload data for a deviated well.

a) By inspection of the force plot, suggest the type of well geometry for each of the four distinct intervals.
b) In a long deviated well titanium drillpipe will be used for half of the well length. Would you use the titanium pipe in the top or in the bottom part of the well. Why?
c) The oil industry uses a stuck pipe model that does not include friction. Will the depth to the stuck point be too shallow or too deep using this model?
d) Static pipe weight without friction is defined by "the projected height principle". Prepare a figure of an inclined pipe element, show the forces and derive this principle.



Problem 3: Design of liner and tieback string

An HPHT well is drilled. The formation evaluation is positive and recommends flow testing of the well. A tieback string is therefore installed in the well. Other data are:

Liner interval:	4650 m-5100 m (well bottom)
Tie-back interval:	4650 m- 0
Top cement:	4650 m
Depth of test packer:	4950 m
Mud weight:	2.2. s.g.
Pore pressure:	2.11 s.g. at 5000 m
Density of reservoir fluid:	0.547 s.g.

Data for the liner and tie-back string:
7-5/8 in. SMC 110

Weight in air:	625 N/m
Burst resistance:	1005 bar
Collapse resistance:	959 bar
Tensile strength:	6816 kN

Yield factor reduction due to temperature: 0.91

a) Prepare a figure and write all assumptions.

b) Define a realistic collapse scenario for the liner. Derate strength to 88% level because of high temperature. Determine the design factor.

c) Define two burst criteria. Determine the design factor for burst, and correct for temperature.

d) Define a criterion for tension design. Determine the design factor, including the temperature derating.

Problem 4. Rock Mechanics

Below is a wellbore stress state

$$\begin{bmatrix} \sigma_r & 0 & 0 \\ 0 & \sigma_\theta & \tau_{\theta z} \\ 0 & \tau_{\theta z} & \sigma_z \end{bmatrix}$$

a. Explain the physics behind the elements that are zero in the matrix
b. Show the 3 principal stress equations
c. Rank the principal stresses for fracturing
d. Rank the principal stresses for wellbore collapse

Problem 5: Casing strength

The following casing types are available:

Size(in):	Grade, weight(lb/ft):	Outer diam.(mm):	Inner diam.(mm)
20	P110, 133	508	475,7
13-3/8	K55,88.2	346.1	314.3
10-3/4	N80, 60.7	273	245.4
7	L80, 20	177.8	164

a) Compute the burst strength of each casing. List the casings from strongest to weakest in burst.

b) Are these casings suitable for use in the same well? Explain which of the casings could be replaced, and indicate if it should be stronger or weaker.

c) A closed pipe is pressurized from the inside. Define two failure modes, and show which failure mode is dominating.

Some Formulas

$P(bar) = 0.098 \times d(s.g.) \times D(m)$

$P_3 = Cq^m$

$P_2 = \rho q^2/2A^2 0.95^2$

Index:	Equation:	Criterion:	Fraction parasitic pressure loss:	Flow rate:
1	qP_2	Max. HP	1/(m+1)	$P_1/C(m+1)$
2	$q\sqrt{P_2}$	Max. jet impact	2/(m+2)	$2P_1/C(m+2)$
3	$q3/2\sqrt{P_2}$	New A	3/(m+3)	$3P_1/C(m+3)$
4	$q^2\sqrt{P_2}$	New B	4/(m+4)	$4P_1/C(m+4)$
5	$q^{5/2}\sqrt{P_2}$	New C	5/(m+5)	$5P_1/C(m+5)$

$A = q\{\rho/2P_2\}^{1/2}/0.95$

Using the units of: density(kg/l), flowrate (l/min) and pressure (bar), the nozzle area in in^2 can be obtained by dividing the equation above with 122.4.

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

$LOT = 2\sigma_a - P_o$

$P_{wf}(\gamma) = P_{wf}(0) + {}^1/_3\,(P_o - P_o^*)\sin^2\gamma$

$P_{wf}(0) = \{P_{wf}(\gamma) + (\sigma_o - 1/2P_o)\sin^2\gamma\}/\{1 + 1/2\sin^2\gamma\}$

$\Delta\sigma_a = \Delta P_o(1-2\nu)/(1-\nu)$

$\Delta P_{wf} = \Delta P_o(1-3\nu)/(1-\nu)$

$P_{burst} = 2\sigma_{tensile}\, t/D_o$

$P_{collapse} = \{2CE/1 - \nu^2\}\{1/(D_o/t - 1)^2 D_o/t\}$

$(\sigma_t/\sigma_{yield}) = 1/2(\sigma_a/\sigma_{yield}) \;+/-\{1 - 3/4(\sigma_a/\sigma_{yield})^2\}^{1/2}$

$\rho = (d_p D - 1.03h_w)/(D - h_f - h_w)$

$$d_{wf2} = d_{wf1}\frac{D_1}{D_2} + d_{sw}\frac{D_{w2} - D_{w1}}{D_2}$$

$$D_2 = D_1 + (D_{w2} - D_{w1}) + (D_{f2} - D_{f1})$$

$$D_2 = D_1 + (D_{w2} - D_{w1}) + (D_{f2} - D_{f1}) + \left(\frac{d_{ob1}}{d_{ob2}} - 1\right)(D_1 - D_{w1} - D_{f1})$$

$$\frac{\Delta V}{V} = \frac{1}{2}\alpha \Delta T$$

$$\Delta P = \left(\frac{-1}{c}\right)\frac{\Delta V}{V}$$

Units

1 bar = 14.5 psi = 10^5 Pa
1 ft = 0.3048 m = 12 in
1 lb_f = 0.454 kp = 4.45 N