Roll No.													

PRESIDENCY UNIVERSITY
BENGALURU

SCHOOL OF ENGINEERING

TEST 1

Sem & AY: Odd Sem. & 2019-20 | **Date**: 27.09.2019

Course Code: PET 317 | **Time**: 11:00AM to 12:00PM

Course Name: ADVANCED DRILLING ENGINEERING | **Max Marks**: 40

Program & Sem: B.Tech (PET) & V DE | **Weightage**: 20%

Instructions:

(i) Read the question properly and answer accordingly.

(ii) Question paper consists of 3 parts.

(iii) Scientific and Non-programmable calculators are permitted.

Part A [Memory Recall Questions]

Answer all the Questions. Each Question carries four marks. (4Qx4M=16M)

1. Define MD and Declination Angle. (C.O.NO. 1) [Knowledge]

2. Determine the azimuth with respect to true north of the following wells.

(C.O.NO.1) [Knowledge]

Well	Observed bearing w.r.t to magnetic north	Declination
1	N 60° E	5° west
2	S 90° W	1° east

3. Describe Type III profile? (C.O.NO.2) [Knowledge]

4. Write the requirements for jetting. (C.O.NO.1) [Knowledge]

Part B [Thought Provoking Questions]

Answer all the Questions. Each Question carries seven marks. (2Qx7M=14M)

5. List the general considerations for directional well planning and explain any three of them. (C.O.NO.2) [Comprehension]

6. Define directional drilling and explain any three applications.

(C.O.NO.1) [Comprehension]

Part C [Problem Solving Questions]

Answer the Question. The Question carries ten marks. (1Qx10M=10M)

7. Using the following information, calculate the coordinates of a Type 1 well profile.

(C.O.NO.2) [Comprehension]

Slot Coordinates	25.1 ft N; 7.2 ft E
Target Coordinates	2250 ft N; 5100 ft E
TVD of target	12000 ft
KOP	1500 ft
Build up rat e	1.8° per 100 ft

Roll No.													

PRESIDENCY UNIVERSITY
BENGALURU

SCHOOL OF ENGINEERING

TEST –I

Semester: 5th
Course Code: PET 317
Course Name: Advanced Drilling Engineering
Program & Sem: B.Tech Petroleum Engineering- V Sem

Date: 27/09/2019
Time: 1 hr
Max Marks: 40
Weightage: 20%

Instructions:

(i) *Read the question properly and answer accordingly.*
(ii) *Question paper consists of 3 parts.*
(iii) Scientific and Non-programmable calculators are permitted.

Part A

Answer all the Questions. **(4Qx4M=16)**

Q.NO.1 Define UTM and Lambert projection systems. [4M] (C.O.1) [Knowledge level]

Q.NO.2 Determine the azimuth with respect to true north of the following wells [4M] (C.O.1) [Knowledge level]

Well	Observed bearing w.r.t to magnetic north	Declination
1	N 60° E	3° west
2	S 90° W	3° east

Q.NO.3 Describe the motor section of PDM. [4M] (C.O.1) [Knowledge level]

Q.NO.4 Describe standard removable whipstock? [4M] (C.O.1) [Knowledge level]

Part B

Answer all the Questions. Each question carries Seven marks. **(2Qx7M=14)**

Q.NO.5. List the general considerations for directional well planning and explain any three of them. [7M] (C.O.2) [Comprehension level]

Q.NO.6. Describe different type of well profiles with neat diagrams [7M] (C.O.1) [Comprehension level]

Part C

Answer all the Questions. Each question carries Ten marks. **(1Qx10M=10)**

Q.NO.7. A directional well is to be drilled from an offshore platform to intersect a target whose horizontal displacement is 4200 ft at a true vertical depth of 10,500 ft. A Type 1 profile is to be used with a KOP= 1600 ft and build up rate of 1.5° per 100 ft. Calculate the coordinates of the build and hold profile.

SCHOOL OF ENGINEERING

Semester: 5th

Course Code: PET 317

Course Name: Advanced Drilling Engineering

Date: 27/09/2019

Time: 1 hr

Max Marks: 40

Weightage: 20%

Extract of question distribution [outcome wise & level wise]

Q.NO.	C.O.NO	Unit/Module Number/Unit /Module Title	Memory recall type [Marks allotted] Bloom's Levels			Thought provoking type [Marks allotted] Bloom's Levels			Problem Solving type [Marks allotted]			Total Marks
			K			C			A			
1	1	Unit 1	4									4
2	1	Unit 1							4			4
3	2	Unit 2	1			3						4
4	1	Unit 1	4									4
5	2	Unit 2				7						7
6	2	Unit 2				7						7
7	2	Unit 2							10			10
	Total Marks		9			17			14			40

K =Knowledge Level C = Comprehension Level, A = Application Level

Note: While setting all types of questions the general guideline is that about 60%

Of the questions must be such that even a below average students must be able to attempt, About 20% of the questions must be such that only above average students must be able to attempt and finally 20% of the questions must be such that only the bright students must be able to attempt.

I here certify that All the questions are set as per the above lines Dr Geetanjali]

Annexure- II: Format of Answer Scheme

SCHOOL OF ENGINEERING

SOLUTION

Semester: 5th

Course Code: PET 317

Course Name: Advanced Drilling

Date: 27/09/2019

Time: 1 hr

Max Marks: 40

Weightage: 20%

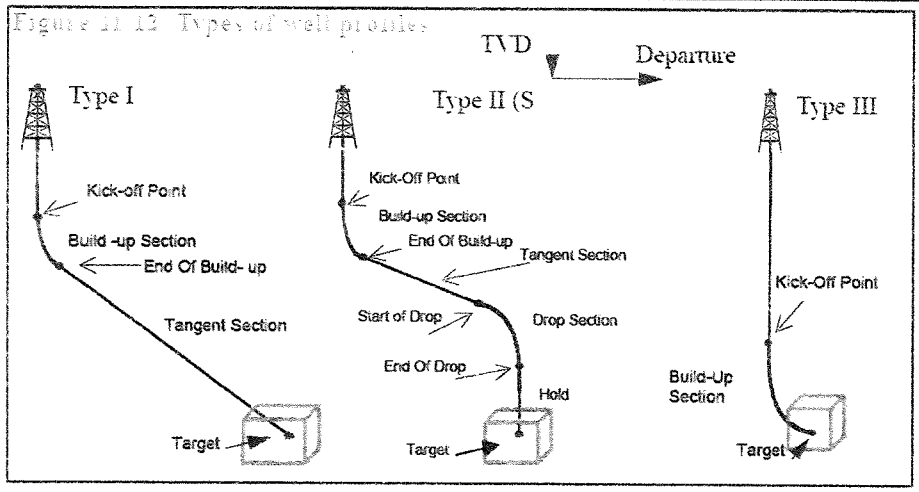
Part A (4Q x 4M = 16Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
1	The Lambert conical projection is used in the USA as it is most suited to areas where there is a greater extent of east- west and lesser extent of north-south. The Lambert system produces a projection that has meridians as convergent lines and parallels as arcs of circles. The UTM projection is the most commonly used projection worldwide and it uses a horizontal cylinder for projection with the earth inside the horizontal cylinder and touches the spheroid along a chosen meridian	2 marks for each definition	5 mins
2	1) Azimuth for well 1 is 57° 2) Azimuth for well 2 is 273°	2 marks for each	5 mins
3	The positive displacement motor consists of two basic components. (a) The rotor is a steel shaft which is shaped in the form of a spiral or helix. For a single-lobe motor the cross-section of the shaft is circular. It is free at the top but attached to the universal joint at the bottom. (b) The stator is a moulded rubber sleeve that forms a spiral passageway to accommodate the rotor. The rubber sleeve is fixed to the steel body of the motor.	2 marks for rotor and 2 marks for stator	5 mins

	When the rotor is fitted inside the stator, the difference in geometry between the two components creates a series of cavities. When the drilling fluid is pumped through the motor, it seeks a path between the rotor and stator. In doing so the mud displaces the shaft, forcing it to rotate clockwise as the mud continues to flow through the passageways. Positive displacement motors will operate with either gas or liquid as the drilling fluid.		
4	A "removable whipstock" can be used to initiate deflection in open hole, or straighten vertical wells that have become crooked. The whipstock consists of a steel wedge with a chisel-shaped point at the bottom to prevent movement once drilling begins. The tapered concave section has hard facing to reduce wear. At the top of the whipstock is a collar that is used to withdraw the tool after the first section of hole has been drilled. The whipstock is attached to the drill string by means of a shear pin. Having run into the hole, the drill string is rotated until the toolface of the whipstock is correctly positioned. By applying weight from .surface, the chisel point is set firmly into the formation or cement plug. The retaining pin is sheared off and drilling can begin. A small-diameter pilot hole is drilled to a depth of about 15 ft below the toe of the whipstock. After this rathole has been surveyed, the bit and whipstock are tripped out. A hole opener is then run to ream out the rathole to full size. Once the deflected section of hole has been started, a rotary building assembly can be run to continue the sidetrack.	4 marks for the answer	5 mins

Part B (2Q x 7M = 14 Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
5	Careful planning before the well is spudded can lead to substantial savings in the cost of drilling a directional well. Many factors influence the trajectory of the borehole which can reduce the amount of bit walk that may occur in certain formations). The experience gained from drilling previous directional wells in the same area is therefore very useful and should be incorporated at the planning stage of the next well. The general considerations for well planning are: 1. Reference points and coordinates 2. Target Zone 3. Formation Characteristics 4. Deflection tool available 5. Location of adjacent wells 6. Choice of build up rate Explanation:	2 marks for consideration 1.5 marks for each explaination	10 mins

	(a) In selecting the kick-off point (KOP) the hardness of the formation is important. Hard formations may give a poor response to the deflecting tool, so that the kick-off may take a long time and require several bits. (b) Certain formations exhibit a tendency to deflect the bit either to the left or to the right. The directional driller can compensate for this effect by allowing some "lead angle" when orienting the deflecting tool. (4) The capabilities of the deflecting tools available and the techniques that are applicable in a particular situation will influence the shape of the wellpath. If jet deflection is to be used, the KOP must be at a relatively shallow depth in a fairly soft formation. (5) On offshore platforms there is only a small distance (7-12 ft) between adjacent conductors. Under these conditions precise control is required and great care must be taken to avoid collisions directly beneath the platform. For this reason the KOPs for adjacent wells are chosen at varying depths to give some separation. When choosing slots it is better to allocate an outer slot to a target which requires large horizontal displacement. This will result in a shallower KOP to allow a smaller inclination. Slots closer to the centre of the platform should be allocated to targets requiring smaller inclinations and deeper KOPs. This will help to avoid the problem of wells running across each other.		
6	 **Type I: Build and hold trajectory.** • Most common and the simplest profile for a directional well. • The hole is drilled vertically down to the KOP, where the well is deviated to the required inclination. • This inclination is maintained over the tangential section to intersect the target. • Generally, a shallow KOP is selected since this reduces the size of the inclination angle necessary to hit the target. • This type of profile is often applied when a large horizontal displacement is required at relatively shallow target depths. • Since there are no major changes in inclination or azimuth after the build-up section is complete, there are fewer directional problems with this profile.	2 marks for each profile 1 marks for diagram	10 min

- Under normal conditions the inclination should be *15-55°*, although greater inclinations have been drilled.

Type II: Build Hold and Drop (S –Shape) trajectory

- This profile is similar to the Type I down to the lower part of the tangential section.
- Here the profile enters a drop-off section where the inclination is reduced, and in some cases becomes vertical as it reaches the target.
- This is a more difficult profile to drill than the Type **I**, owing to the problems of controlling the drop-off section just above the target.
- Extra torque and drag can also be expected owing to the additional bend.
- This type of profile is used when the target is deep but the horizontal displacement is relatively small.
- It also has applications when completing a well that intersects multiple producing zones, or in relief well drilling.

Type III: Deep Kick off and Build trajectory

- This profile is only used in particular situations such as salt dome drilling or sidetracking.
- A deep KOP has certain disadvantages.

(a) Formations will probably be harder and less responsive to deflection.
(b) More tripping time is to change out BHAs while deflecting.
(c) Build up rate is more difficult to control.

Part C (1Q x 10M = 10Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
7	The final profile for Type 1 profile: R= 3819.71 ft α= 25.39°	2 marks each for correct coordinates for points A, B, C, T 2 marks for table and figure	15 min

Point	TVD (ft)	Horizontal Displacement (ft)	MD (ft)
A	0	0	0
B	1600	0	1600
C	3383.23	441.8	3455.33
T	10500	4200	11502.91

Roll No.													

PRESIDENCY UNIVERSITY
BENGALURU

SCHOOL OF ENGINEERING

TEST – 2

Sem & AY: Odd Sem 2019-20	**Date:** 16.11.2019
Course Code: PET 317	**Time:** 11:00 AM to 12:00 PM
Course Name: ADVANCED DRILLING ENGINEERING	**Max Marks:** 40
Program & Sem: B.Tech (PET) & V	**Weightage:** 20%

Instructions:

(i) *Read the question properly and answer accordingly.*
(ii) *Question paper consists of 3 parts.*
(iii) Scientific and Non-programmable calculators are permitted.

Part A (Memory Recall Questions)

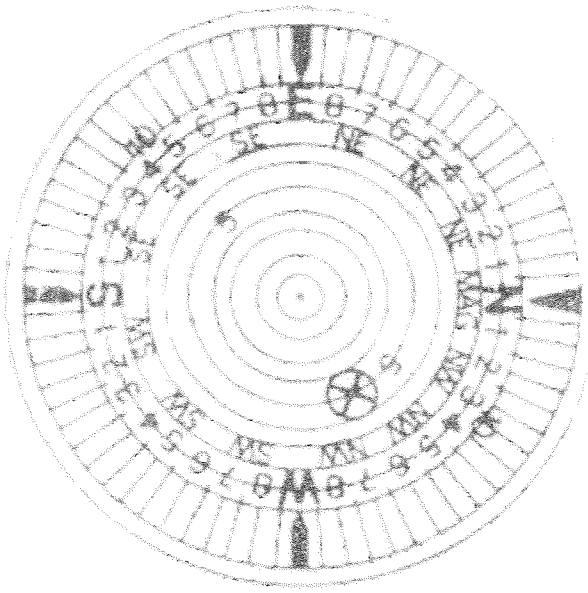
Answer all the Questions. Each Question carries five marks. (4Qx5M=20M)

1. What are Magnetometers and Accelerometer? (C.O.NO.3) [Knowledge]
2. What kind of information can be gathered by MWD tool? (C.O.NO.3) [Knowledge]
3. Describe Dropping Assembly using adjustable stabilizers with neat diagram. (C.O.NO.1) [Comprehension]
4. What is the oldest survey tool? Describe it. (C.O.NO.3) [Comprehension]

Part B (Thought Provoking Questions)

Answer both the Questions. Each Question carries five marks. (2Qx5M=10M)

5. The diagram below shows the result of magnetic single shot survey. Write the results. (C.O.NO.3) [Application]



Correct the bearing by applying the magnetic declination in the following areas:
(i) Bombay High, declination = 9° East.

6. What is Monel? Why MWD tool has to be run inside monel?

(C.O.NO.1) [Knowledge]

Part C [Problem Solving Questions)

Answer the Question. The Question carry ten marks. (1Qx10M=10M)

7.

a) A directional well with a Measured depth of 12000 ft has to be drilled at an inclination and bearing of 40° and N 30° W respectively. You as a directional driller working for Jindal Drilling suggest most efficient and cost-effective survey tool to the company with your reasons.

[4M] (C.O.NO.3) [Application]

b) Explain the major component of the tool which you suggested.

[6 M] (C.O.NO.3) [Comprehension]

SCHOOL OFENGINEERING

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

Semester: 5th
Course Code: PET 317
Course Name: **Advanced Drilling Engineering**

Date:16/11/2019
Time: 1 hr
Max Marks:40
Weightage: 20%

Extract of question distribution [outcome wise & level wise]

Q.NO	C.O.NO	Unit/Module Number/Unit /Module Title	Memory recall type [Marks allotted] Bloom's Levels			Thought provoking type [Marks allotted] Bloom's Levels			Problem Solving type [Marks allotted]			Total Marks
			K			C			A			
1	3	Unit 3	5									5
2	3	Unit 3	5									5
3	1	Unit 1	5									5
4	3	Unit 3	5									5
5	3	Unit 3				5						5
6	1	Unit 1				5						5
7	3	Unit 3							10			10
	Total Marks		20			10			10			40

K =Knowledge Level C = Comprehension Level, A = Application Level

Note: While setting all types of questions the general guideline is that about 60%

Of the questions must be such that even a below average students must be able to attempt, About 20% of the questions must be such that only above average students must be able to attempt and finally 20% of the questions must be such that only the bright students must be able to attempt.

Annexure- II: Format of Answer Scheme

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

SCHOOL OFENGINEERING

SOLUTION

Semester: 5th

Course Code: PET 317

Course Name:Advanced Drilling Engineering

Date:16/11/2019

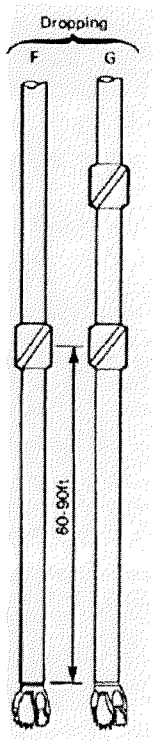
Time: 1 hr

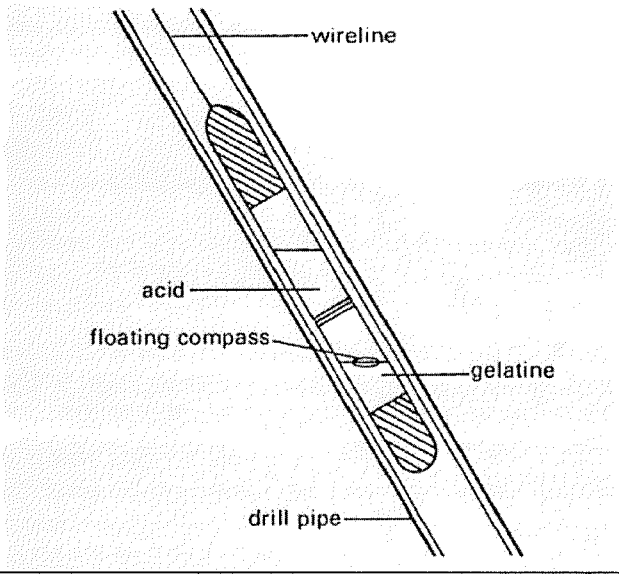
Max Marks:40

Weightage: 20%

Part A (4Q x 5M = 20Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
1	To survey the borehole continuously while drilling requires the use of rugged, solid state accelerometers and magnetometers. A magnetometer is a sensor that detects and measures the strength of the Earth's magnetic field along a fixed axis. A accelerometer is a sensor that measures the Earth's acceleration along a fixed axis.	2.5 marks for each definition	5 mins
2	The type of information may be: (a) directional data (inclination, azimuth, toolface) (b) formation characteristics (gamma-ray, resistivity logs) (c) drilling parameters (downhole WOB, torque, rpm)	2.5 marks for each	5 mins
3	The principle- the force of gravity can be used to deflect the hole back to vertical. The force of gravity is related to the length of drillcollars between the drill bit and the first point of tangency between the drillcollars and hole (the active length of drillcollars). The **pendulum effect** is produced by removing the stabilizer just above the bit while retaining the upper ones. While the remaining stabilizers hold the bottom drill collar away from the low side of the wall, gravity acts on the bit and the bottom drill collar and tends to pull them to the low side of the hole, thus decreasing the hole angle.	3 marks for writeup 2 marks for figure	8 mins

			
4	The earliest form of surveying tool used in the oil industry was the "acid bottle". The technique had been used in the mining industry from about 1870. It is based on the simple principle that the free surface of a liquid always remains horizontal regardless of how its container is positioned. In this particular instrument the container is a glass cylinder and the liquid is hydrofluoric acid. If the instrument is allowed to rest in an inclined position for a certain period of time the acid will react with the glass and leave a mark on the side of the cylinder indicating the horizontal surface. The distance between the mark and the acid's original position when the cylinder was level can be used to calculate the inclination angle (Fig. 7.1). The strength of the acid must be chosen carefully to etch a sharp distinct line on the glass within a reasonable length of time. The instrument was lowered down the drill string on wireline until it rested on top of the bit or on a baffle plate at some point above the bit. The acid bottle was left in this position for about 30 minutes to allow the reaction to take place. The motion of the acid during running in and pulling out prevented any other lines being etched on the glass. The glass was inspected back at the surface and the angle of inclination was determined. To measure the hole direction, an additional compartment was required containing gelatine and a magnetic compass needle. The compass needle was free-floating and aligned itself with Magnetic North. It was held in this position by the gelatine. The direction of the deviated well could therefore be referenced to Magnetic North.	4 marks for each write up 1 marks for figure	8 mins

	The major disadvantage of the acid bottle technique was that the acid did not always leave a distinct line to show the interface. In reading the mark some allowance had also to be made for capillary effects.  		

Part B (2Q x 5M = 10 Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
5	Inclination is 5.5 degree Direction N 65 W or Azimuth is 295 (i) 1n Mumbai High, true bearing is N 54°W or 304°	1 marks for inclination 2 marks for direction for part A and B each	5 min
6	a) Monel is a nonmagnetic drill collar. The steel drill collars, casings or drilling bit may become magnetized, creating "poles" especially near connections. To isolate the magnetic compass from possible distortion, the instrument must be contained within a non-magnetic environment. They are made of alloys containing copper, nickel, chromium and other metals. The physical properties of the monels are slightly different from regular steel collars. Monel collars should be handled carefully to prevent damage, because of their additional cost. b) MWD tool should should be placed within monel as it has magnetometer sensor to measure the earth's gravitation field and its results can be affected in the normal drill collar.	3 marks for part a 2 marks for part b	8 min

Part C (1Q x 10M = 10Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
7	The survey tool suggested should be MWD i.e. Measurement while drilling. The major benefits of MWD in directional drilling are that: (a) Valuable rig time is saved when taking surveys, owing to the elimination of conventional wire line techniques. (b) Orientation of toolface for steering runs is made much easier, as is monitoring of toolface while drilling with no wire line problems. (c) Less time is spent with the drill string in a stationary position, thereby reducing the risk of stuck pipe. (d) Closer density of surveys is possible without a great loss of rig time; therefore there is better monitoring of the wellpath. (e) The effects that changing drilling parameters or formation changes may have on the well path can be detected very much quicker, reducing the risk of severe dog-legs and the need to make correction runs. The downhole components are all housed in a nonmagnetic drill collar. This is a special collar supplied by the MWD company. The major components are: (a) a power source to operate the tool (b) sensors to measure the required information; (c) a transmitter to send the data to surface in the form of a code (d) a microprocessor or control system to coordinate the various functions of the tool The surface equipment consists of: (a) a standpipe pressure transducer to detect variations in pressure and convert these to electrical signals (b) an electronic filtering device to reduce or eliminate any interference from rig pumps or downhole motors that may also cause pressure variations (c) a surface computer to interpret the results (d) a rig-floor display to communicate the results to the driller, or plotting devices to produce continuous logs	A) 1 marks for the tool 3 marks for advantages of the tool B) 3 marks for surface and downhole components each	15 min

Roll No												

PRESIDENCY UNIVERSITY
BENGALURU

SCHOOL OF ENGINEERING

END TERM FINAL EXAMINATION

Semester: Odd Semester: 2019 - 20
Course Code: PET 317
Course Name: ADVANCED DRILLING ENGINEERING
Program & Sem: B.Tech (PET)-V Sem (DE–I)

Date: 20 December 2019
Time: 9:30 AM to 12:30 PM
Max Marks: 80
Weightage: 40%

Instructions:

(i) Read the question properly and answer accordingly.
(ii) Question paper consists of 3 parts.
(iii) Scientific and Non-programmable calculators are permitted.

Part A [Memory Recall Questions]

Answer all the Questions. Each Question carries 4 marks. (5Qx4M=20M)

1. What is the function of the followings in Mud motor? 1) Dump Valve 2) Universal Joint. (C.O.No.1) [Knowledge]
2. List the data required for Type 1 profile geometrical planning. (C.O.No.2) [Knowledge]
3. Define Dogleg. How can it be detected? How can it be quantified? (C.O.No.4) [Knowledge]
4. Write the assumptions, equations and limitations of tangential method of survey calculations (C.O.No.3) [Knowledge]
5. Draw dropping BHA assembly. (C.O.No.2) [Knowledge]

Part B [Thought Provoking Questions]

Answer all the Questions. Each Question carries 4 marks. (3Qx10M=30M)

6. Explain any four main applications of horizontal drilling. (C.O.No.4) [Comprehension]
7. The drill string becomes struck while drilling a directional well. The driller reports that he can still circulate, but cannot rotate or reciprocate the pipe.
   (i) What is the most likely cause of the stuck pipe? (C.O.No.4) [Comprehension]
   (ii) Describe the cause. (C.O.No.4) [Comprehension]
   (iii) What can be done by the driller to free the pipe? (C.O.No.4) [Comprehension]
8. Describe the formation evaluation sensors used in MWD tool. Justify their usage in terms of cost effectiveness. (C.O.No.3) [Comprehension]

Part C [Problem Solving Questions]

Answer both the Questions. Each Question carries 15 marks. (2Qx15M=30M)

9.a) The following extract is taken from a survey report. The target bearing is 95°. Calculate the coordinates of the last three survey station using the average angle method. Calculate the dog leg severity of the last three survey stations. (C.O.No.4) [Comprehension]

No	MD (ft)	Inclination (degree)	Azimuth (degree)	Northing (ft)	Easting (ft)	TVD (ft)	DLS
15	6000	20	87	10	800	5900	
16	6093	22	91				
17	6186	23.5	96				
18	6279	26	111				

10.a) Express the formula for maximum permissible dogleg severity for drill pipe with proper nomenclature and units. (C.O.No.4) [Comprehension]

b) A dogleg is expected at a depth of 6500ft. A string of 5in OD and 4.125 in OD, 19.7 lb/ft, grade E drill pipe is being used. If the tensile load below this point is 235,000 lb and Modulus of Elasticity is 30×10^6 psi, Calculate the maximum dog-leg that can be allowed. (C.O.No.4) [Application]

c) In a directional well, the maximum dog leg severity is 4° per 100ft. For a tensile load of 100,000 lb, what is the maximum side force that can be tolerated to prevent tool joint failure? (C.O.No.4) [Application]

SCHOOL OF ENGINEERING

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

END TERM FINAL EXAMINATION

Extract of question distribution [outcome wise & level wise]

Q.NO.	C.O.NO (% age of CO)	Unit/Module Number/Unit /Module Title	Memory recall type [Marks allotted] Bloom's Levels	Thought provoking type [Marks allotted] Bloom's Levels	Problem Solving type [Marks allotted]	Total Marks
			K	C	A	
1	1	1	4			4
2	2	2	4			4
3	3	3	4			4
4	4	3	4			4
5	2	2	4			4
6	4	4		10		10
7	4	4		10		10
8	3	3		10		10
9	4	4			15	15
10	4	4			15	15
	Total Marks		20	30	30	80

K =Knowledge Level C = Comprehension Level, A = Application Level

Note: While setting all types of questions the general guideline is that about 60%

Of the questions must be such that even a below average students must be able to attempt, About 20% of the questions must be such that only above average students must be able to attempt and finally 20% of the questions must be such that only the bright students must be able to attempt.

I hereby certify that all the questions are set as per the above guidelines.

Faculty Signature:

Reviewer Commend:

Format of Answer Scheme

SCHOOL OF ENGINEERING

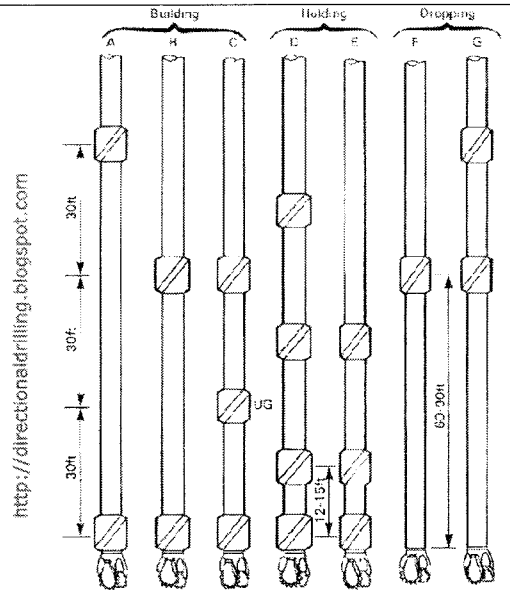
SOLUTION

Semester: Odd Sem. 2019-20
Course Code: PET 317
Course Name: Advanced Drilling Engineering
Program & Sem: B.Tech Petroleum Engineering-V Sem

Date: 20.12.2019
Time: 3 HRS
Max Marks: 80
Weightage: 40%

Part A (5Q x 4M = 20Marks)

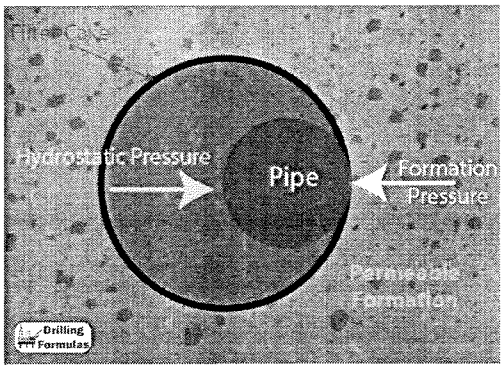
Q No	Solution	Scheme of Marking	Max. Time required for each Question
1	1) Dump Valve To prevent the motor rotating while running into the hole or pulling out of the hole, a by-pass valve or dump valve is installed at the upper end of the motor. This valve has radial ports that allow communication between the drill string and the annulus. During a trip when the pumps are shut off, these ports are open to allow the drill string to drain while pulling out or fill when running in. The ports must be closed off during drilling to allow normal flow through the motor. 2) Universal Joint Since the shaft is rotating eccentrically, the lower end must be connected to a universal joint. This joint converts the eccentric motion to concentric motion, which is then transmitted to the bit. Various types of flexible joints can be used, but the simplest design is a ball joint lubricated by grease. A rubber sleeve around the joint prevents contamination by mud. The universal joint is then connected to the drive shaft, which rotates within the bearing assembly.	2 marks for each function	10 mins
2	The following information is required: (a) surface (slot) coordinates; (b) target coordinates; (c) true vertical depth of target; (d) true vertical depth to KOP; (e) build-up rate.	1 mark for each point	5 mins
3	a) Dog-leg is the abrupt turn, bend or change of direction in a survey line, a wellbore, or a piece of equipment. It can be detected by increased torque and drag on the drill string.	2 marks for A 1 mark for B	5 mins

	b) Dog-legs can be described in terms of their length and severity and quantified in degrees or degrees per unit of distance. c) The severity of the dog-leg is expressed as the change in angle per 100 ft drilled, i.e. DLS = 100 (Φ/L) where DLS = dog-leg severity (degrees/100 ft) Φ = dog-leg angle L = course length between stations.	1 mark for C	
4	In this model the wellpath is assumed to be a straight line defined by the inclination and azimuth at the lower survey station. Notice that the angles measured at the upper station are not used in the analysis. This method clearly gives large errors in wellbore position when the trajectory is changing significantly between stations. In a directional well, where even over relatively short intervals there can be significant changes in azimuth and inclination, this method of calculation is not recommended. $\Delta N = L\left[\sin I_2 \bullet \cos A_2\right]$ $\Delta E = L\left[\sin I_2 \bullet \sin A_2\right]$ $\Delta V = L\left[\cos I_2\right]$	2 marks for assumptions 2 marks for equations	8 mins
5		4 marks	8 min

Part B (3Q x 10M = 30 Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
6	**1. Intersection of Vertical Fractures** Many reservoirs contain fractures that are vertical or near-vertical at depths greater than 2000-3000 ft. Although the matrix of the rock may be fairly impermeable, the oil may still be able to flow along the fractures. It has been found that in some reservoirs (e.g. fractured limestone) the most efficient way of producing the oil is to drill highly deviated or horizontal wells to intersect as many fractures as possible. If the orientation	2.5 marks for each	15 ins

	of the fractures is known, a horizontal well can be planned to intersect the fractures at right-angles. **2. Enhanced Oil Recovery** Large deposits of highly viscous oil occur in many parts of the world. Since these reservoirs cannot be exploited by conventional means, special techniques have had to be applied, such as the injection of steam or polymers to improve the mobility of the oil. At Cold Lake, in Western Canada, one such project is aimed at recovering oil from a large bitumen deposit. **3.Reducing the Number of Wells and Platforms Required to Develop an Offshore Field** The increased productivity of horizontal wells may result in fewer wells having to be drilled to develop an offshore field. Although the cost of an individual well might be more expensive, owing to the higher inclination, the overall economics of the project could be improved. In shallow reservoirs that cover a wide area the extended reach of horizontal wells may also mean that fewer platforms are necessary. Horizontal drilling may therefore allow the development of a field that would otherwise be considered uneconomic. In offshore fields where there are large distances between bottom hole locations, horizontal wells may be drilled as an alternative to infill drilling, thus further reducing the number of wells to be drilled. **4.Increased Production from a Single Well** The increased productivity of horizontal wells may result in fewer wells having to be drilled to develop an offshore field. Although the cost of an individual well might be more expensive, owing to the higher inclination, the overall economics of the project could be improved. In shallow reservoirs that cover a wide area the extended reach of horizontal wells may also mean that fewer platforms are necessary. Horizontal drilling may therefore allow the development of a field that would otherwise be considered uneconomic. In offshore fields where there are large distances between bottom hole locations, horizontal wells may be drilled as an alternative to infill drilling, thus further reducing the number of wells to be drilled.		

7	i) Differential Seating ii) Differential sticking is a problem frequently encountered in directional wells, since the drill collars will tend to sag on the Low Side of the hole and become stuck against the filter cake. In a permeable zone, a natural filtration process will take place whereby the fluid content of the mud will invade the formation while the solids will build up on the wall of the borehole to form a filter cake. If the filter cake becomes thick, the drill collars may come into contact with it and become embedded. If the positive pressure differential is large (about 1000 psi), it may be difficult to free the pipe The risk of differential sticking is increased if the pipe is allowed to stay static for a period of time.  iii) For differential sticking, a special soaking fluid can be pumped down the drill string and displaced into the annulus adjacent to the stuck zone and time is allowed for the fluid to soak into the interface between the collars and the borehole.	a) 2 marks b) 5 marks c) 3 marks	15 ins
8	Gamma rays are emitted by radioactive elements such as isotopes of potassium, thorium and uranium. By measuring the gamma-ray emission from a sequence of rocks it is therefore possible to identify shale zones. For practical reasons, the distance between the bit and the gamma-ray sensor is about 6 ft. Only a small percentage of the gamma-rays being emitted will actually be detected, owing to attenuation in the mud and the drill collar. There are two types of sensor used: 1. GEIGER-MULLER TUBE 2. SCINTALLATION SENSOR The GM is not as accurate as the scintillation counter, since it can only detect a much smaller percentage of the total rays emitted. However GM is more rugged and reliable and being cheaper than the scintillation counter. **Resistivity Sensor:** Resistivity is a measure of the formation's resistance to the flow of electric current. The response from the formation will depend on the fluid content of the pore space (oil and gas act as insulators, while brine is a conductor). The resistivity sensor on an MWD tool has been adapted from the equivalent wire line logging tool (16-in. normal device). Two electrodes are	a) 6 marks b) 4 marks	15 mins

	mounted on an insulating rubber sleeve on the outside of the MWD tool. The electric current emitted by the upper electrode passes through the formation and is detected by the lower electrode. The actual response is also affected by borehole dimensions, mud invasion and bed thickness. Certain correction factors must be applied to compensate for these effects. This type of sensor will not be effective in boreholes in which oil-based mud is being used. An induction type sensor has been developed for oil-based muds and can be incorporated in an MWD tool. **Justification for cost-effectiveness** Logging-while-drilling with gamma-ray and resistivity sensors is becoming more popular, but it is much more difficult to justify in strict economic terms. This is because the operator will probably wish to run a complete suite of wire line logs in any case. The incremental benefits of having logging data as the well is being drilled must be investigated. Some of these benefits are listed as follows: (a) Selection of casing points using gamma ray log to identify shale zones. (b) Picking the top of the reservoir to begin coring operations. (c) Correlation with other neighbouring wells as drilling proceeds. (d) Identification of troublesome zones. (e) Ability to run logs in high-angled wells where wireline methods may not be suitable. (f) At least some formation data is available if the hole is lost before wire line logs are run. (g) Resistivity logs can detect the presence of shallow gas zones. (h) Formation pressures can be evaluated		

Part C (2Q x 15M = 30Marks)

Q No	Solution								Scheme of Marking	Max. requi for ea Quest
9		**No**	**MD (ft)**	**Inclination (degree)**	**Azimuth (degree)**	**Northing (ft)**	**Easting (ft)**	**TVD (ft)**	**DLS**	5 marks for each station	30 m
		15	6000	20	87	10	800	5900			
		16	6093	22	91	10.58	833.32	5986.82	2.45		
		17	6186	23.5	96	8.38	869.22	6072.58	2.445		
		18	6279	26	111	-0.71	907.08	6157.04	6.738		

10	To limit the bending stresses on the pipe, a maximum permissible dog-leg severity C can be calculated as follows: $$C = \frac{432{,}000\sigma_b \tanh(KL)}{\pi EDKL} \quad \text{where} \quad K = \left(\frac{T}{EI}\right)^{1/2}$$ where C = maximum dog-leg severity (degrees/100 ft) σ_b = maximum permissible bending stress (psi) E = modulus of elasticity (psi) D = outside diameter of drill pipe (in.) L = half distance between tool joints (L = 180 in. for range 2 pipe) T = tension loading below the dog-leg (lb) I = moment of inertia (in.^{4}); for circular pipe, $I = (\pi/64)(D^4 - d^4)$ d = inside diameter of drill pipe (in.). b) C=3.24°/100 ft c) 2094.59 lb	5 marks for (a) 5 marks for (b) 5 marks for (c)	30 m