UNIVERSITI TEKNOLOGI PETRONAS

FINAL EXAMINATION

MAY 2024 SEMESTER

COURSE : DCM5073:Advanced Well Design and Operation

DATE : XXXXXXXXX

TIME : XXXXXXXX

INSTRUCTIONS TO CANDIDATES

1. 1Answer **ALL** questions in the Answer Booklet.
2. Indicate clearly answers that are cancelled, if any.
3. Where applicable, show clearly steps taken in arriving at the solutions and indicate **ALL** assumptions, if any.
4. Do not open this Question Booklet until instructed.

Note :

1. There are FOURTEEN **(14)** pages in this Question Booklet, including the cover page.

1. a. Well ERD-6 was planned to be drilled in offshore Asia on 2024. 4 hole sections were planned on this well:

- Kick off was perform at 26" hole section
- 17-1/2" hole section
- 12-1/4" x 13-1/2" hole section (with RSS & under reamer)
- 8-1/2" x 9-1/2" hole section (with RSS & under reamer) with well TD at 1600m TVD at horizontal section of 4700m.

With reference to **FIGURE Q1a**, answer the following questions:

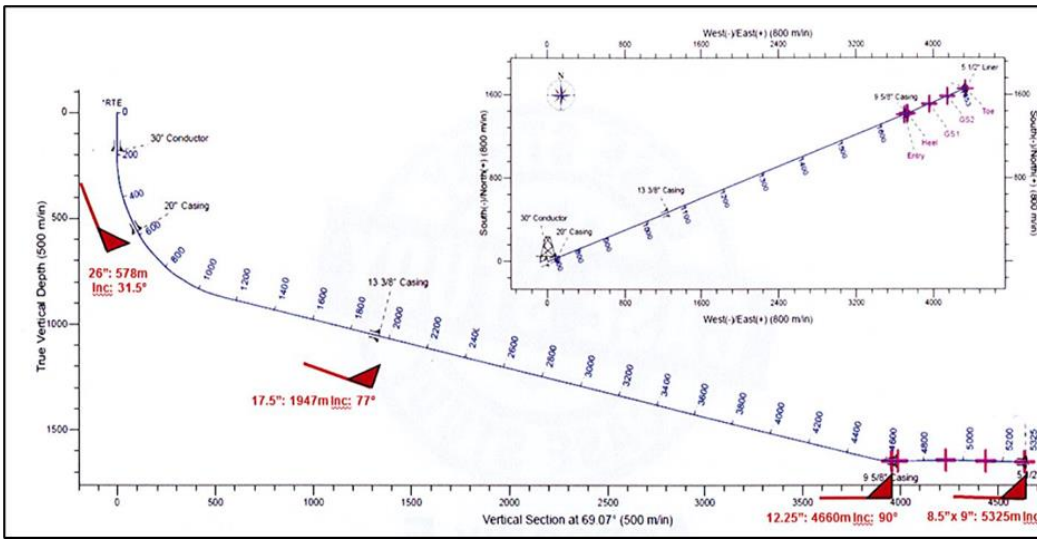

FIGURE Q1a

i. Determine the ERD ratio for this well.

[2 marks]

ii. During a simulation run of drilling 8-1/2" hole section at WellPlan software, the hydraulics simulation report shows that the ECD is exceeding the formation fracture gradient. Simulation inputs are as follows:

- Hole angle: 85°
- Mud weight: 10.5 ppg
- Drill pipe size: 5-7/8"
- Pipe rotation: 130 rpm

- Mud flow rate: 350 gpm

Propose the parameters that you can manipulate to reduce the ECD.

[2 marks]

iii. For 17-1/2" hole section, propose whether ECD or hole cleaning is difficult to mange, with justification.

[3 marks]

iv. For 8-1/2" hole section, propose whether ECD or hole cleaning is difficult to mange, with justification.

[3 marks]

v. In hole cleaning for effective cutting transport/ removal, based on observation High speed RPM is the key to operation of the conveyor belt. For "big hole", explain at what rpm is the conveyor belt be switched "on".

[2 marks]

b. The road map in FIGURE Q2b clearly shows an increasing ECD trend up until 3977m with higher ESD than measured mud weight. Explain why does this happen.

[2 marks]

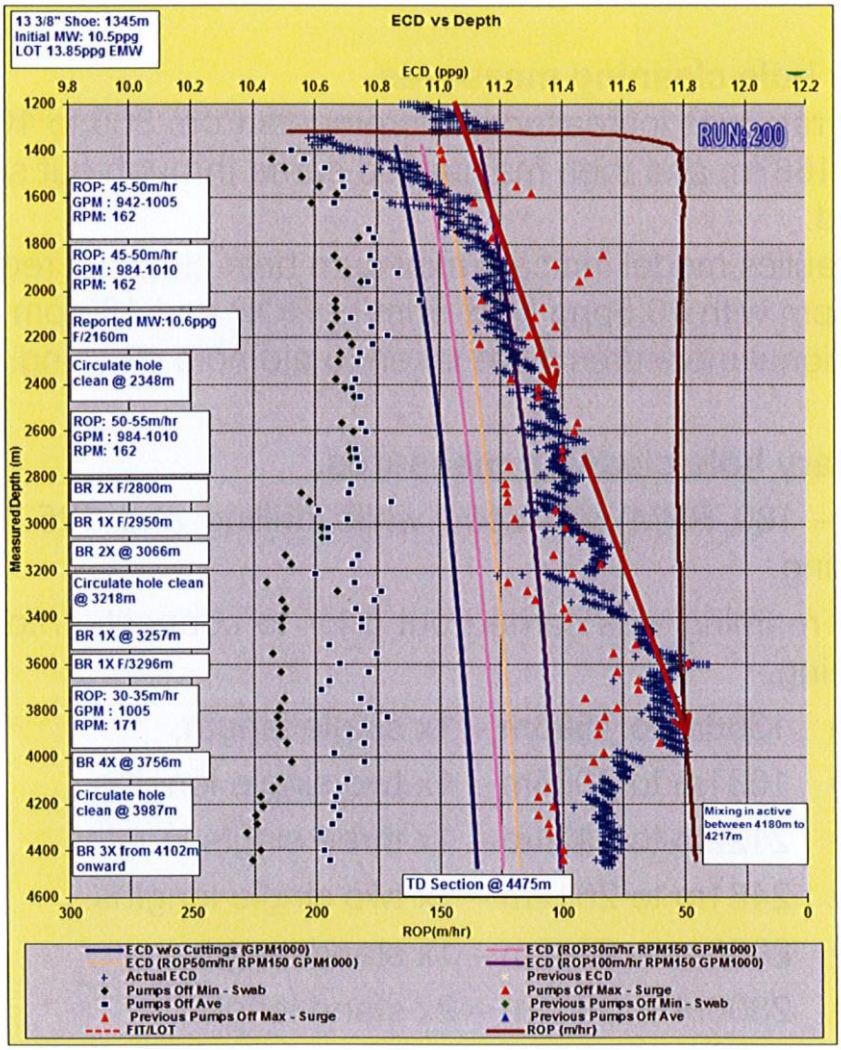

FIGURE Q1b: Well ERD-7 (12-1/4" hole section – ECD Roadmap

c. Refer to **FIGURE Q2c** and the data below:

- Hole section: 12-1/4" hole
- Lag depth: 3000m
- FG: 12.5 ppg
- Mud weight used: 11 ppg
- BHT (^{o}F): 297^{o}F

FIGURE Q1c(i)

i. Upon drilling the 12-1/4" hole section, the cuttings collected at surface are shown as in **FIGURE Q1c(ii)**. explain what does this indicate.

[2 marks]

FIGURE Q1c(ii).

ii. Upon reaching the 12-1/4" section TD and circulates bottoms up, the driller tried to pull the BHA out of the hole with elevator, however the driller observed an overpull due to tight hole. He performed backreaming for a few stands before circulating bottoms up. The cuttings collected at surface after the backreaming is shown as in **FIGURE Q1c(iii)**. Identify what type of caving does its indicate and explain why is this happened.

[2 marks]

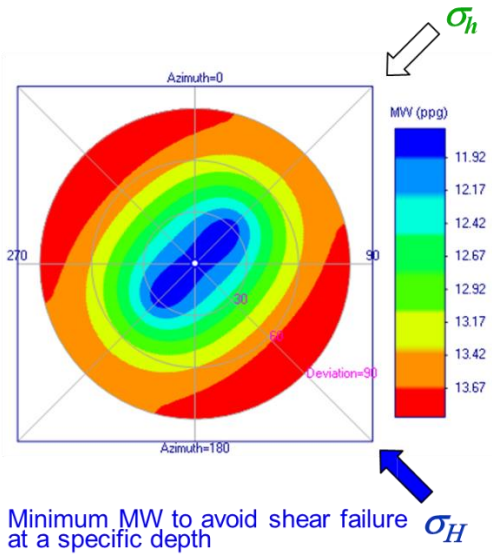

FIGURE Q1c(iii).

iii. Total Surface Torque = String + Bit + Mechanical + Dynamic Torque. Identify **TWO (2)** sources of mechanical torque.

[2 marks]

2. **TABLE Q2** shows the data of a vertical HPHT exploration well in Field Bravo using a jack up rig. The surface wellhead and BOP Well Control Equipment is rated at 15,000 psi. The rig is just performed LOT at 9 5/8" shoe to 18.8ppg EMW and now currently drilling 8 1/2" hole section gas reservoir with current mud weight of 18.0 ppg.

TABLE Q2: HPHT exploration well in Field Bravo

Casing Size / Depth- (mTVD / MD)	Casing Specification	Burst / Collapse Pressure (psi)	Drilling Mud Specification	Estimated Pore Pressure – Mid Case (ppg)	Planned Mud Weight (ppg)	Estimated Fracture Pressure – Mid Case (ppg)	Estimated Bottom Hole Static Temperature (deg C)
20" Conductor @ 1,000m	X56 167# Viper	B: 6,060 C: 3,297	Riserless Section Seawater	8.6	8.6ppg	9.0	107
16" Liner @ 1600m	P110 97# VAM BOLT	B: 6,920 C: 2,340	SBM	12.1	12.1 – 12.6	15.1	127
14" Casing @ 2600m	P110 116# VAM SLIJ-3	B: 11,280 C: 8,640	SBM	13.7	12.7 – 14.4	17.6	164
11 7/8" Liner @ 3200m	P-110 71.8# VAM SLIJ-3	B: 8,010 C: 3,610	SBM	16.6	14.5 – 17.0	18.5	187
9 5/8" Liner @ 3500m	P-110, 53.5# VAM SLIJ-3	B: 10,900 C: 7,950	SBM	17.0	17.2 – 18.2	18.8	195
8 ½" Open Hole TD @ 3800m	Open Hole	-	SBM	17.7	18.0 – 18.3	-	210

i. Determine the Maximum Anticipated Surface Pressure (MASP) assuming a gas gradient of 0.1 psi/ft. Evaluate, with justification, whether you can drill and reach the well TD safely.

[3 marks]

ii. Determine the Maximum Allowable Surface Pressure assuming a Safety Factor of 80% to equipment / casing rating.

[3 marks]

iii. Determine the Maximum Allowable Annular Surface Pressure (MAASP), with current mud weight.

[3 marks]

iv. Explain what will happen if the current mud weight is increased to 18.5 ppg. What will happen if there is well control and where is the weak point, if any?

[3 marks]

v. The Yield strength of steel material used in well construction will change due to the effects of high temperature. If the 9 5/8" casing is manufactured from material grade of P-110 with 110,000 Yield Strength, determine the approximate Yield Strength of this casing when exposed at 210 deg C.

[3 marks]

vi. There is a possibility that there is insufficient kick tolerance at 9 5/8" shoe while drilling 8 ½" hole to reach TD due to lower than anticipated LOT at previous shoe. Share at least five (5) mitigation and their principal behind.

[10 marks]

3. Well Burgundy-1 shown in **FIGURE Q3** is an exploration well which will drill the Cycle IV carbonate. Based on offset data, the total loss zone will be encountered when drilling in the Cycle IV Carbonate. The plan is to scratch the top of Carbonate and set the 9-5/8" casing at 1042m TVD. The 8 ½" hole is planned from 1042m TVD to well TD at 1800m TVD. Answer the questions **(Q3a – Q3c)** below based on the data in **TABLE Q3** and assuming drilling in 8-1/2".

TABLE Q3: Question Data

Flow rate (GPM)	500
Starting Mud weight before losses (ppg)	13
Planned Sacrificial Fluid Sea Water (ppg)	8.6
Gas gradient (psi per ft/ppg)	0.1/1.92
Speed (RPM)	140-160
WOB (klb)	10-15
Annular capacity of 8 ½" hole (bbl/ft)	0.0702
Annular capacity between 8 ½" hole & 5" DP/BHA (bbl/ft)	0.0459
Annular capacity of 5" DP/BHA (bbl/ft)	0.0243

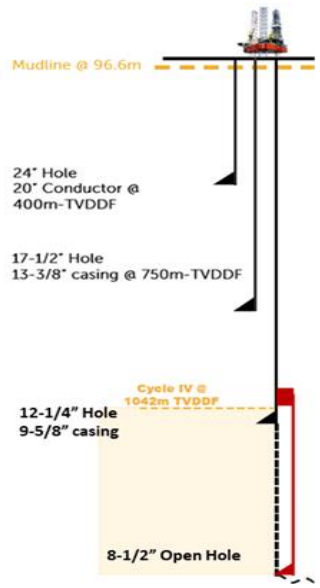

FIGURE Q4 – Well Schematic Diagram

a. Once drilling encountered total losses in the Carbonate, name the **EIGHT (8)** basic steps to convert to Pressurized Mud Cap Drilling (PMCD).

[4 marks]

b. The rig conducted the test shown in **FIGURE Q3b** to check the feasibility of converting to PMCD once they encountered total losses in the carbonate. What is the name of the test & is it possible to convert to PMCD on this well? Please explain your answer.

[2 marks]

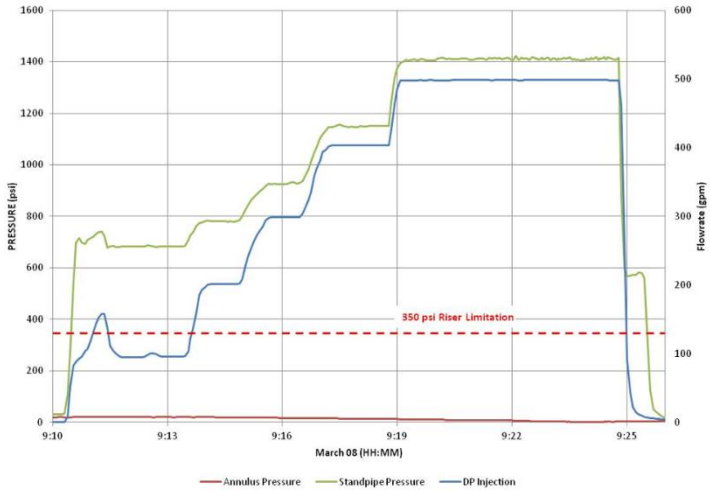

FIGURE Q3b – Test Prior To Converting to PMCD

c. While drilling the 8 ½" hole in the carbonate, the rig encountered total losses at 1060m TVD. Prior to converting to PMCD, the rig pumped Sea Water in the annulus to catch up with the losses. After pumping 250m equivalent height of seawater, the well balanced out. Answer the following questions:

i. Calculate the Equivalent Mud Weight (EMW) in ppg at the loss zone and calculate the planned Light Annular Mud (LAM) weight if we want to have 90 psi surface pressure when drilling with PMCD mode (gas free annulus pressure) zone (round up to 1 decimal point).

[4 marks]

ii. While drilling PMCD with the calculated LAM weight mud as per **Q3c(i)**, the surface pressure risen from 90 psi to 300 psi before the rig decided to bullhead the gas migration. Calculate the height of gas column (in meter) in the annulus.

[3 marks]

iii. The 8-½" hole section in the carbonate was drilled with BHA & 5" DP. The bullheading instruction is to pump 2 x influx volume to ensure only gas free LAM in annulus above the loss zone. Calculate the amount of 11.5 ppg LAM mud that need to be bullheaded in the annulus after reaching the gas column height in **Q3c(ii).**

[3 marks]

d. **FIGURE Q3d** below shows the Pore Pressure – Fracture Gradient (PPFG) plot for a shallow water vertical exploration well Bundalaga's 12 ¼" hole section (from 3825m TVD to section TD at 4060m TVD). In planning for MPD, the worst case PPFG scenario is taken into consideration. Answer the following questions:

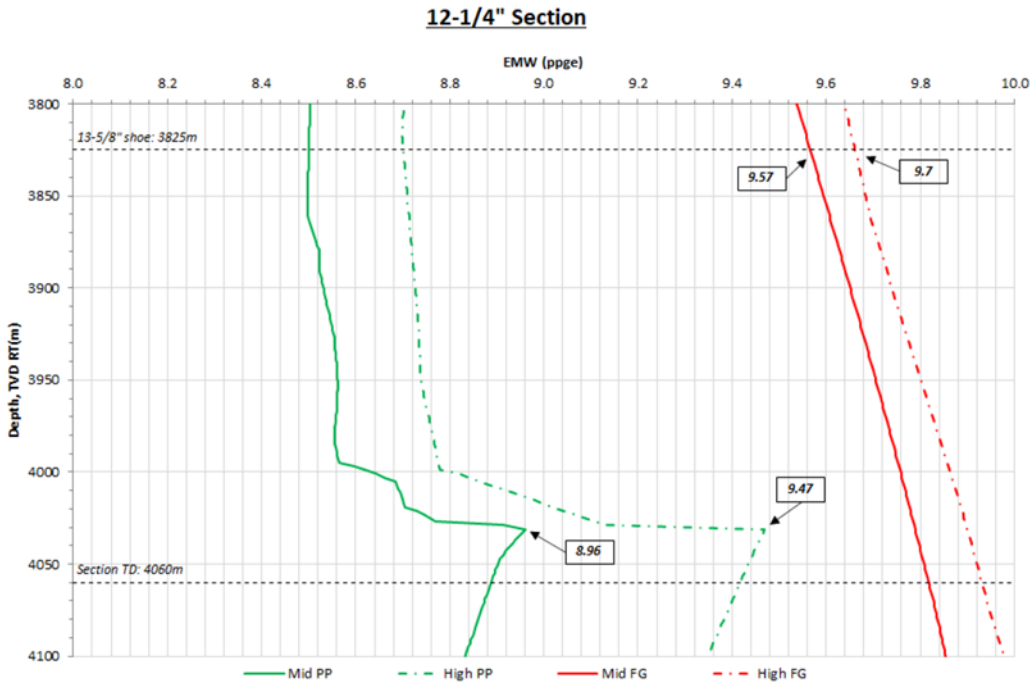

FIGURE Q3d – PPFG Plot

i. Identify the available EMW margin available to drill the 12 ¼" hole section under the worst case PPFG scenario as **FIGURE Q3d**.

[2 marks]

ii. If the annular friction pressure loss during drilling the 12 ¼" hole section is 0.3 ppg EMW, estimate the suitable starting mud weight to drill the 12 ¼" hole section while maintaining the ECD at 9.5 ppg.

[2 marks]

iii. Estimate the surface back pressure needed in **Q3d(ii)** above while making connection at TD.

[2 marks]

iv. If this is a deepwater application using a drillship with a surface line pressure drop of 140 psi, estimate the starting mud weight to drill the 12 ¼" hole section while maintaining the ECD at 9.5 ppg (at TD). The annular friction pressure lost during drilling the 12 ¼" hole section is 0.3 ppg EMW.

[3 marks]

3. Commodore Energy Company is planning to develop a newly awarded block across offshore Malaysia. **FIGURE Q4** shows the summary table of the well design and architecture for an upcoming horizontal well which is planned to be drilled after a subsurface study was conducted, complete with an offset wells analysis.

Bit size (inch)	Bit type	BHA type	Setting depth m TVDSS	Setting depth m MDDF	Interval (m)	Inclination (°)	Av. Offset UCS (K psi)	Remarks
20"	RC	Conductor clean out	158	205	205	2.5	n/a	For conductor cleanout so UCS is not an issue, more on hydraulics for jetting
8-1/2"	MT	Motor	623	706	706	37	2-5 kpsi	Formation : soft sticky clay Bit with center Jet to reduce bit balling and provide extra flow capability in soft formations
17-1/2" x 23"	HO or UR	TBC	623	706	706	37	2-5 kpsi	
17-1/2"	PDC	RSS	1,323	2,164	1,458	65	0-10kpsi Hard stringers of 15kpsi @ 2,020m & 2,180m MD	mostly shale interbedded with sandstone (soft type)
12-1/4"	PDC	RSS	2,016	3,926	1,762	90	10-15kpsi Hard stringers 20kpsi @2,750m MD and 30kpsi	Shale and sand interbedded formation Drill through out K5 sand at heel side
8-1/2"	PDC	RSS	2,016	4,629	703	90		Drill K5 sand horizontally

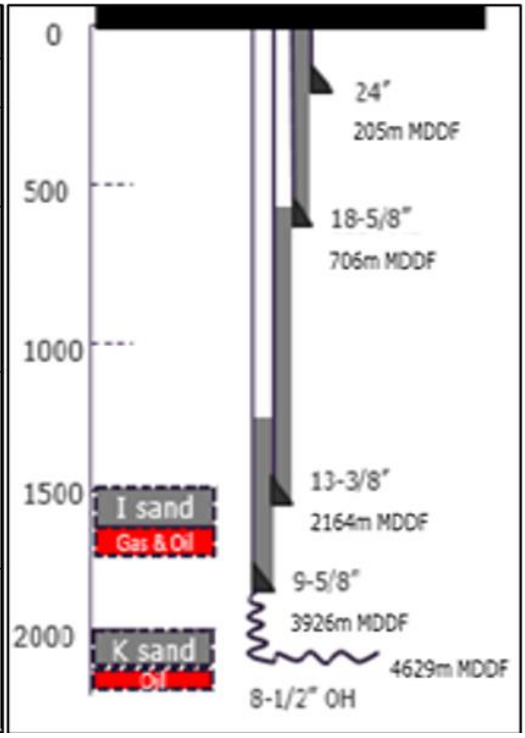

FIGURE Q4: Summary Table: Well Schematic and Proposed Hole Sections

The intermediate hole-sections are 17.5” and 12.25” hole-section, which will be drilled using Synthetic Based Mud (SBM). Based on the drilling program, the planned drilling flowrate for the 17.5” hole-section will be between 1000-1200 gal/min and for the 12.25” flowrate will be between 800-1000 gal/min.

The drilling rig that has been awarded to this project is a new jack-up rig with NOV Top Drive System TDS-4 that can provide continuous RPM of 180 at maximum continuous torque of 45,000 ft-lbs. The rig will be able to provide 5-7/8" OD Drill Pipe, S-135, XT-57 connection.

The team underwent a Cost Compression Initiative to consider changing the BHA Type & Design from Rotary Steerable System (RSS) to conventional Positive Displacement Motor (PDM), as the project will exhibit a 30% cost increase due to the cost of the RSS. If the new strategy is successful, then it will have a direct cost saving of 1.75 Million USD for the 3 x hole-sections combined.

Understanding the nature of drilling with PDM, it will require flowrate ranges between 600-1200 GPM for 9 5/8" OD Motor and 300-600 GPM for 6-3/4" OD Motor while having rotation of 40 RPM in the build-up section and 80 RPM in tangent section.

a. As the Stuck Pipe Prevention Expert, discuss this new strategy from the following **FOUR (4)** perspectives: Hydraulic Hole Cleaning, Torque & Drag, and Stuck Pipe Risk. State your recommendation whether this is good strategy to change from RSS to PDM.

[10 marks]

b. A 8.5in hole section will be drilled in horizontal section. The pore pressure and fracture gradient show a slim margin window, around 2 ppg, before either break the formation or inducing an influx. The formation is also overbalanced by more than 1500 psi. The section is planned to be drilled with 500-550 gpm and revolutions of 80-120 RPM. Discuss the risk expose for this hole section and provide recommendations on how to minimize the risks.

[5 marks]

c. The 8.5in BHA design has been changed to use 5in DP. The cross-sectional area of the DP is 5.2746 in^2. An over pull of 135,000 lbs gives a stretch of 6.5 ft. Calculate the approximate depth of the stuck point. Current bit depth was 10,000 ft and jar position is 850 ft away from the bit. Assess the possibility of firing the jar.

[5 marks]

d. Consider Bow-Tie Diagram shown in **FIGURE Q4d** for stuck-pipe as a top event. List 2 x control options (prevention measures) and 2 x de-escalation measures (mitigations) for each of the 3 x shown risks.

[5 marks]

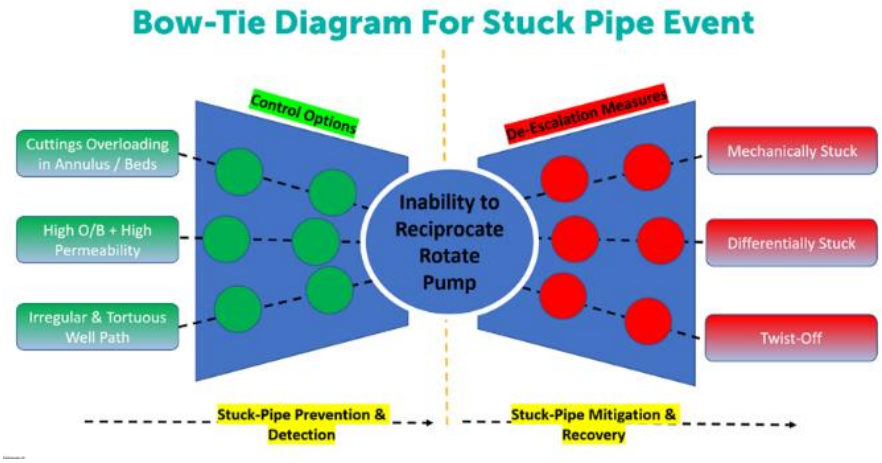

FIGURE Q4d

e. Propose some of the common fishing tools to retrieve Loose Junk. Define a fishing strategy and list some of the fishing tools that could be deployed if the string needs to be severed. Define a plan to sidetrack the well in the open-hole and list the major required tools.

[5 marks]

END OF PAPER