Roll No.											

PRESIDENCY UNIVERSITY

BENGALURU

End - Term Examinations – MAY 2025

Date: 31-05-2025 **Time:** 09:30 am – 12:30 pm

School: SOE	**Program:** B. Tech.-PET	
Course Code: PET3001	**Course Name:** Geomechanics for Wellbore Stability Analysis	
Semester: IV	**Max Marks**: 100	**Weightage**: 50%

CO - Levels	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Marks	06	08	42	22	22

Instructions:

1. *Read all questions thoroughly and answer them as directed.*
2. *Do not write anything on the question paper except your Roll Number, and only in the designated space.*

Part A

Answer ALL the Questions. Each question carries 2 Marks. **10Q x 2M=20M**

1.	Choose the correct answer: A geomechanical model consists of key components _____. a) Pore pressure, tectonic plates, and seismic waves b) In-situ stresses, rock properties, pore pressures, and failure criteria c) Gravity, density, and seismic velocity d) Mineral composition, porosity, and sedimentary structures	**2 Marks**	**L1**	**CO1**
2.	Choose the correct answer: _____ is a key application of geomechanical models in reservoirs. a) Measuring hydrocarbon reserves b) Predicting wellbore stability and hydraulic fracturing c) Identifying rock mineralogy d) Analyzing climate impact on rock formations	**2 Marks**	**L1**	**CO1**
3.	Fill in the blanks with one word: Geomechanics is the study of how ___________ materials behave under stress and ____________ in the subsurface environment.	**2 Marks**	**L1**	**CO1**
4.	Choose the correct answer: Pore pressure is __________. a) The pressure exerted by overlying rock layers	**2 Marks**	**L1**	**CO2**

	b) The pressure exerted by fluids within the pores of a rock c) The pressure due to tectonic forces d) The total stress in a rock formation			
5.	Identify the statement Ture or False: Overpressure in a formation can only be caused by fluid expansion due to temperature increase.	**2 Marks**	**L1**	**CO2**
6.	Define Overpressure Generation Mechanisms.	**2 Marks**	**L1**	**CO2**
7.	Identify the statement Ture or False: Poroelasticity accounts for the interaction between fluid pressure and rock deformation.	**2 Marks**	**L1**	**CO2**
8.	Choose the correct answer: _____ best describes shear failure in rocks. a) Opening of cracks due to low pressure b) Failure due to maximum principal stress only c) Sliding along planes when shear stress exceeds frictional resistance d) Breakage due to thermal expansion	**2 Marks**	**L1**	**CO3**
9.	Identify the statement Ture or False: Compressive failure in vertical wells occurs when the hoop stress exceeds the rock's compressive strength.	**2 Marks**	**L1**	**CO4**
10.	Fill in the blanks with one word: Mud penetration into the __________ may weaken the rock through ________ interactions.	**2 Marks**	**L1**	**CO5**

Part B

Answer the Questions. **Total Marks 80M**

11.	**a.**	Explain the role of faults and fractures in fluid flow within the subsurface.	**10 Marks**	**L2**	CO3
	b.	Discuss the representation of fault and fracture data using graphical methods.	**10 Marks**	**L2**	**CO3**
Or					
12.		Assume that you are associated with an Oil and Gas company as a Geomechanical Engineer. You have been assigned the task to estimate Unconfined Compressive Strength (UCS) for the formations encountered in a well drilled in Mumbai Offshore Basin. Refer to the geophysical log data shared in Table 1 and answer the following: (a) Name the geophysical log data required for the calculation of UCS, (b) Predict the UCS of the formation encountered at 5160.50 ft using density-porosity data directly, if possible, and (c) Predict the UCS of the formation encountered at 5168.50 ft using sonic travel time (Δt) data directly. Table 1.1 through Table 1.3 may be referred to for finding out the most suitable equation to calculate UCS. For enhanced clarity, these tables are also presented in the 'Charts and Plots' section at the end.	**20 Marks**	**L3**	**CO3**

Table 1: Geophysical Log data.

Depth (ft)	Density (g/cc)	Δt_comp. (μs/ft)	Δt_shear (μs/ft)	Formation Name	Formation Type
5160.00	2.5969	73.9180	134.3668	X	Sandstone
5160.50	2.7472	72.9881	134.6025		
5161.00	2.6879	70.6541	131.0170		
5161.50	2.6363	70.3154	126.5105		
5162.00	2.6322	68.2713	125.3421		
5162.50	2.6090	64.2715	118.7308		
5163.00	2.7408	57.9452	112.7404		
5163.50	2.5913	54.2315	106.4179		
5164.00	2.7339	49.3006	101.1393		
5164.50	2.7363	48.6093	98.2395		
5165.00	2.7862	46.7769	98.5376		
5165.50	2.7409	47.6919	95.0032		
5166.00	2.7210	47.0965	92.3078		
5166.50	2.7204	47.2167	95.9393		
5167.00	2.7264	46.8250	96.0021		
5167.50	2.7233	47.4132	94.2504	Y	Limestone
5168.00	2.7221	48.2833	94.1394		
5168.50	2.7153	47.7699	95.3368		
5169.00	2.7395	48.9384	93.4016		
5169.50	2.7152	48.2850	95.4636		
5170.00	2.7017	47.7034	95.4235		

Additional Information:
- Assume full saturation of 1.12 g/cc water in the pores.
- Use matrix density of 2.88 g/cc, which is a reasonable value for a matrix of quartz, feldspar, mica and clay.
- Assume hydrostatic pore pressure of 0.44 psi/ft
- Use 9.8 m/s² to approximate g, the acceleration due to gravity.

Table 1.1: Equations for estimating UCS of Sandstone.

Equation No.	UCS, MPa	Region where developed	General comments	Reference
1	$0.035\,V_p - 31.5$	Thuringia, Germany	–	(Freyburg 1972)
2	$1200\exp(-0.036\Delta t)$	Bowen Basin, Australia	Fine grained, both consolidated and unconsolidated sandstones with wide porosity range	(McNally 1987)
3	$1.4138\times10^{7}\,\Delta t^{-3}$	Gulf Coast	Weak and unconsolidated sandstones	Unpublished
4	$3.3\times10^{-20}\rho^2V_p^2[(1+\nu)/(1-\nu)]^2(1-2\nu)[1+0.78V_{clay}]$	Gulf Coast	Applicable to sandstones with UCS >30 MPa	(Fjaer, Holt *et al.* 1992)
5	$1.745\times10^{-9}\rho V_p^2 - 21$	Cook Inlet, Alaska	Coarse grained sands and conglomerates	(Moos, Zoback *et al.* 1999)
6	$42.1\exp(1.9\times10^{-11}\rho V_p^2)$	Australia	Consolidated sandstones with $0.05 < \phi < 0.12$ and UCS > 80MPa	Unpublished
7	$3.87\exp(1.14\times10^{-10}\rho V_p^2)$	Gulf of Mexico	–	Unpublished
8	$46.2\exp(0.000027E)$	–	–	Unpublished
9	$A(1-B\phi)^2$	Sedimentary basins worldwide	Very clean, well consolidated sandstones with $\phi < 0.30$	(Vernik, Bruno *et al.* 1993)
10	$277\exp(-10\phi)$	–	Sandstones with 2 < UCS < 360 MPa and $0.002 < \phi < 0.33$	Unpublished

Units used: V_p (m/s), Δt (μs/ft), ρ (kg/m³), V_{clay} (fraction), E (MPa), ϕ (fraction)

Table 1.2: Equations for estimating UCS of Shale.

	UCS, MPa	Region where developed	General comments	Reference
11	$0.77\,(304.8/\Delta t)^{2.93}$	North Sea	Mostly high porosity Tertiary shales	(Horsrud 2001)
12	$0.43\,(304.8/\Delta t)^{3.2}$	Gulf of Mexico	Pliocene and younger	Unpublished
13	$1.35\,(304.8/\Delta t)^{2.6}$	Globally	–	Unpublished
14	$0.5\,(304.8/\Delta t)^{3}$	Gulf of Mexico	–	Unpublished
15	$10\,(304.8/\Delta t - 1)$	North Sea	Mostly high porosity Tertiary shales	(Lal 1999)
16	$0.0528E^{0.712}$	–	Strong and compacted shales	Unpublished
17	$1.001\phi^{-1.143}$	–	Low porosity ($\phi < 0.1$), high strength shales	(Lashkaripour and Dusseault 1993)
18	$2.922\phi^{-0.96}$	North Sea	Mostly high porosity Tertiary shales	(Horsrud 2001)
19	$0.286\phi^{-1.762}$	–	High porosity ($\phi > 0.27$) shales	Unpublished

Units used: Δt (μs/ft), E (MPa), ϕ (fraction)

Table 1.3: Equations for estimating UCS of Carbonate.

	UCS, MPa	Region where developed	General comments	Reference
20	$(7682/\Delta t)^{1.82}\ /\ 145$	–	–	(Militzer 1973)
21	$10^{(2.44 + 109.14/(t)}\ /\ 145$	–	–	(Golubev and Rabinovich 1976)
22	$0.4067\ E^{0.51}$	–	Limestone with 10 < UCS < 300 MPa	Unpublished
23	$2.4\ E^{0.34}$	–	Dolomite with 60 < UCS < 100 MPa	Unpublished
24	$C\,(1-D\phi)^2$	Korobcheyev deposit, Russia	C is reference strength for zero porosity (250 < C < 300 MPa). D ranges between 2 and 5 depending on pore shape	(Rzhevsky and Novick 1971)
25	$143.8\ \exp(-6.95\phi)$	Middle East	Low to moderate porosity (0.05 < ϕ < 0.2) and high UCS (30 < UCS < 150 MPa)	Unpublished
26	$135.9\ \exp(-4.8\phi)$	–	Representing low to moderate porosity (0 < ϕ < 0.2) and high UCS (10 < UCS < 300 MPa)	Unpublished

Units used: Δt (μs/ft), E (MPa), ϕ (fraction)

13.	**a.**	Explain how compressive and tensile stresses develop around a vertical wellbore and influence wellbore stability.	**10 Marks**	**L2**	**CO4**
	b.	Describe the impact of stress concentration around a cylindrical wellbore on drilling efficiency and operational safety.	**10 Marks**	**L2**	**CO4**
		Or			

14.	The energy demand is continually increasing and with the decline of conventional reservoirs, the importance of understanding unconventional reservoirs is even greater. Within the last decade, the exploration and production of shale reservoirs has increased significantly, due to coupled horizontal drilling and hydraulic fracturing applications, along with other advancements in completion technologies. Estimation of the lower bound of the minimum horizontal stress, the upper bound of the maximum horizontal stress, and the range of possible magnitudes of the maximum horizontal stress given a magnitude of the minimum horizontal stress. Answer the following based on knowledge of the vertical stress, the pore pressure, and the coefficient of sliding friction. (a) Assuming a coefficient of sliding friction of 0.6, an overburden stress of 11500 psi, and a pore pressure of 4200 psi at 5500 ft depth, (i) identify the faulting regime with explanation, and (ii) predict the upper bound of the maximum horizontal stress. (b) Assuming a coefficient of sliding friction of 0.6, an overburden stress of 11500 psi, and a pore pressure of 4200 psi at 5500 ft depth, (i) identify the faulting regime with explanation, and (ii) identify the faulting regime and determine the lower bound of the maximum horizontal stress.	**20 Marks**	**L3**	**CO4**

15.	**a.**	Explain the mechanisms involved in preventing wellbore instability during drilling.	**10 Marks**	**L2**	**CO5**
	b.	Describe various approaches used to prevent sand production in unconsolidated formations.	**10 Marks**	**L2**	**CO5**
		Or			
16.		Natural fractures are identified from an image log data and the same has been presented in Table 1 along with other information gathered from the same image log. Interpret the data presented in Table 1 and answer the following: (a) _____ dip intervals contain the highest number of fractures. (i) 0° to 15° (ii) 15° to 30° (iii) 30° to 45° (iv) 45° to 60° (v) 60° to 75° (vi) 75° to 90° (b) _____ aperture intervals contain the highest number of fractures. (i) 0 mm to 4 mm (ii) 4 mm to 8 mm (iii) Greater than 8 mm	**20 Marks**	**L3**	**CO5**

(c) ______ depth intervals contain the highest number of fractures.

(i) Less than 5400 feet
(ii) 5400 feet to 5600 feet
(iii) 5600 feet to 5800 feet
(iv) 5800 feet to 6000 feet
(v) Greater than 6000 feet

(d) _____ aperture intervals contain the highest number of nearly north-south striking fractures of which the strike is either between 0° and 15°, or between 75° and 105°, or between 345° and 360°?

(i) 0 mm to 4 mm
(ii) 4 mm to 8 mm
(iii) Greater than 8 mm

Table 1:

Depth (ft)	Strike (degree)	Dip (degree)	Dip Direction (degree)	Aperture (millimeter)
5200.82	228.25	76.41	318.25	4.31
5200.97	207.80	86.11	297.80	5.87
5205.07	233.97	84.07	323.97	7.22
5208.82	206.68	82.67	296.68	5.52
5221.97	214.65	77.20	304.65	5.44
5232.42	211.99	79.37	301.99	9.95
5248.54	214.61	79.88	304.61	12.24
5252.68	226.41	84.78	316.41	10.21
5269.20	245.50	80.63	335.50	8.22
5280.63	238.08	81.70	328.08	2.67
5290.00	226.76	83.85	316.76	5.28
5298.56	212.76	82.34	302.76	2.28
5422.93	220.49	75.45	310.49	2.21
5480.59	235.58	78.23	325.58	2.79
5486.79	203.03	80.78	293.03	1.92
5541.47	228.51	78.70	318.51	0.25
5629.33	190.00	82.13	280.00	0.79
5654.14	162.75	18.04	252.75	9.69
5691.06	7.48	15.89	97.48	9.44
5715.48	162.80	7.92	252.80	2.69
5857.44	224.46	85.04	314.46	1.15
5878.72	219.11	86.63	309.11	3.08
6000.14	5.74	11.19	95.74	11.29
6020.27	0.37	40.44	90.37	11.04
6114.42	201.54	56.87	291.54	5.53
6142.56	208.40	59.07	298.40	4.22
6154.56	200.38	56.88	290.38	0.25
6164.20	351.60	5.34	81.60	16.72

17.	a.	Explain the concept of rock strength in compression and how it affects wellbore stability.	10 Marks	L2	CO3

	b.	Discuss how rock strength anisotropy influences drilling operations.	**10 Marks**	**L2**	**CO3**
Or					
18.	**a.**	Discuss the importance and techniques of wellbore imaging in understanding faults and fractures at depth.	**10 Marks**	**L2**	**CO3**
	b.	Discuss the concept of shear-enhanced compaction and its implications on reservoir performance.	**10 Marks**	**L2**	**CO3**

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