GATE 2022 Petroleum Engineering (PE)

GATE 2022 General Aptitude

Q.1 – Q.5 Carry ONE mark each.

Q.1	After playing _____ hours of tennis, I am feeling _____ tired to walk back.
(A)	too / too
(B)	too / two
(C)	two / two
(D)	two / too

Q.2	The average of the monthly salaries of M, N and S is ₹ 4000. The average of the monthly salaries of N, S and P is ₹ 5000. The monthly salary of P is ₹ 6000. What is the monthly salary of M as a percentage of the monthly salary of P?
(A)	50%
(B)	75%
(C)	100%
(D)	125%

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Q.3	A person travelled 80 km in 6 hours. If the person travelled the first part with a uniform speed of 10 kmph and the remaining part with a uniform speed of 18 kmph. What percentage of the total distance is travelled at a uniform speed of 10 kmph?
(A)	28.25
(B)	37.25
(C)	43.75
(D)	50.00

Q.4	Four girls P, Q, R and S are studying languages in a University. P is learning French and Dutch. Q is learning Chinese and Japanese. R is learning Spanish and French. S is learning Dutch and Japanese. Given that: French is easier than Dutch; Chinese is harder than Japanese; Dutch is easier than Japanese, and Spanish is easier than French. Based on the above information, which girl is learning the most difficult pair of languages?
(A)	P
(B)	Q
(C)	R
(D)	S

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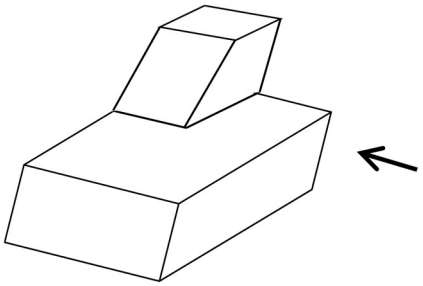
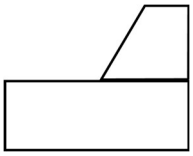
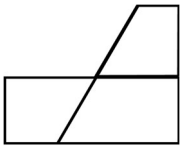
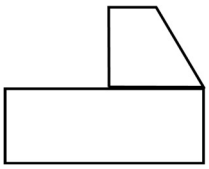
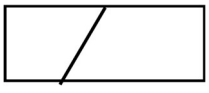
Q.5	 A block with a trapezoidal cross-section is placed over a block with rectangular cross section as shown above. Which one of the following is the correct drawing of the view of the 3D object as viewed in the direction indicated by an arrow in the above figure?
(A)	
(B)	
(C)	
(D)	

Q. 6 – Q. 10 Carry TWO marks each.

Q.6	Humans are naturally compassionate and honest. In a study using strategically placed wallets that appear "lost", it was found that wallets with money are more likely to be returned than wallets without money. Similarly, wallets that had a key and money are more likely to be returned than wallets with the same amount of money alone. This suggests that the primary reason for this behavior is compassion and empathy. Which one of the following is the CORRECT logical inference based on the information in the above passage?
(A)	Wallets with a key are more likely to be returned because people do not care about money
(B)	Wallets with a key are more likely to be returned because people relate to suffering of others
(C)	Wallets used in experiments are more likely to be returned than wallets that are really lost
(D)	Money is always more important than keys

Q.7	A rhombus is formed by joining the midpoints of the sides of a unit square. What is the diameter of the largest circle that can be inscribed within the rhombus?
(A)	$\frac{1}{\sqrt{2}}$
(B)	$\frac{1}{2\sqrt{2}}$
(C)	$\sqrt{2}$
(D)	$2\sqrt{2}$

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Q.8	An equilateral triangle, a square and a circle have equal areas. What is the ratio of the perimeters of the equilateral triangle to square to circle?
(A)	$3\sqrt{3} : 2 : \sqrt{\pi}$
(B)	$\sqrt{(3\sqrt{3})} : 2 : \sqrt{\pi}$
(C)	$\sqrt{(3\sqrt{3})} : 4 : 2\sqrt{\pi}$
(D)	$\sqrt{(3\sqrt{3})} : 2 : 2\sqrt{\pi}$

Q.9	Given below are three conclusions drawn based on the following three statements. Statement 1: All teachers are professors. Statement 2: No professor is a male. Statement 3: Some males are engineers. Conclusion I: No engineer is a professor. Conclusion II: Some engineers are professors. Conclusion III: No male is a teacher. Which one of the following options can be logically inferred?
(A)	Only conclusion III is correct
(B)	Only conclusion I and conclusion II are correct
(C)	Only conclusion II and conclusion III are correct
(D)	Only conclusion I and conclusion III are correct

Q.10	In a 12-hour clock that runs correctly, how many times do the second, minute, and hour hands of the clock coincide, in a 12-hour duration from 3 PM in a day to 3 AM the next day?
(A)	11
(B)	12
(C)	144
(D)	2

GATE 2022 Petroleum Engineering (PE)
Q.11 – Q.35 Carry ONE mark Each

Q.11	The value of $\lim_{x\to 0}\left[\frac{1}{x}\ln(1+x)\right]$ is
(A)	e
(B)	1
(C)	0
(D)	$\frac{1}{e}$
Q.12	The following second order ordinary differential equation has the boundary conditions: $y(0) = 0$, and $y(1) = 1$. $$\frac{d^2y}{dx^2} + \frac{dy}{dx} = 5y$$ The type of above boundary conditions is
(A)	Neumann
(B)	Dirichlet
(C)	Cauchy
(D)	Robin

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Q.13	Let $\vec{F}(x,y)=e^{x}\sin x\hat{i}+x\hat{j}$ for $(x,y)\in\mathbb{R}^2$. If C is the circle $x^2+y^2=4$ oriented in the anticlockwise direction then $\int_C \vec{F}\cdot d\vec{R}$ equals
(A)	4π
(B)	6π
(C)	7π
(D)	8π

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Q.14 The general equation for the production rate decline can be expressed as

$$\frac{1}{q}\frac{dq}{dt} = -bq^{d}$$

where, b and d are empirical constants, and q is the production rate.

Match the value of d (Group 1) with the appropriate decline curves (Group 2).

Group 1	Group 2
I. $d = 0$	P. Harmonic decline
II. $d = 1$	Q. Exponential decline
III. $0 < d < 1$	R. Hyperbolic decline

(A) I – P; II – Q; III – R

(B) I – P; II – R; III – Q

(C) I – Q; II – R; III – P

(D) I – Q; II– P; III– R

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Q.15	The production optimization is evaluated on the basis of discounted revenue to be generated by the projects. The net present value (*NPV*) for calculating the discounted revenue is defined by $$NPV = NPV_R - \text{cost}$$ where, NPV_R = present value of cash flow discounted at a given rate *i*. If ΔR_n is the annual incremental revenue after optimization for n^{th} year, and *m* is the remaining life of the project at the end of n^{th} year, then which ONE of the following options for NPV_R is **CORRECT**?
(A)	$NPV_R = \sum_{n=1}^{m} \frac{(1+i)^n}{\Delta R_n}$
(B)	$NPV_R = \sum_{n=1}^{m} \frac{\Delta R_n}{(1+i)^{n-1}}$
(C)	$NPV_R = \sum_{n=1}^{m} \left[\frac{\Delta R_n}{(1+i)}\right]^n$
(D)	$NPV_R = \sum_{n=1}^{m} \frac{\Delta R_n}{(1+i)^n}$

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Q.16	The formation volume factors of oil and water are B_o and B_w, respectively. The **CORRECT** relationship between the fractional water cut at the surface condition (f_{ws}) and the fractional water cut at the reservoir condition (f_w) is
(A)	$f_{ws} = \dfrac{B_o f_w}{B_w + B_o}$
(B)	$f_{ws} = \dfrac{B_o f_w}{B_w + B_o f_w}$
(C)	$f_{ws} = \dfrac{B_w}{B_o\left(\dfrac{1}{f_w} - 1\right) + B_w}$
(D)	$f_{ws} = \dfrac{B_o}{B_w\left(\dfrac{1}{f_w} - 1\right) + B_o}$
Q.17	Which ONE of the following is used to support the packer against the casing while expanding the rubber sealing element?
(A)	Blast joints
(B)	Slips
(C)	Landing nipples
(D)	Side pocket mandrels

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Q.18	‘Cupola’ offshore storage tank is an example of
(A)	floating storage type.
(B)	above-water storage type.
(C)	submerged storage type.
(D)	platform storage type.

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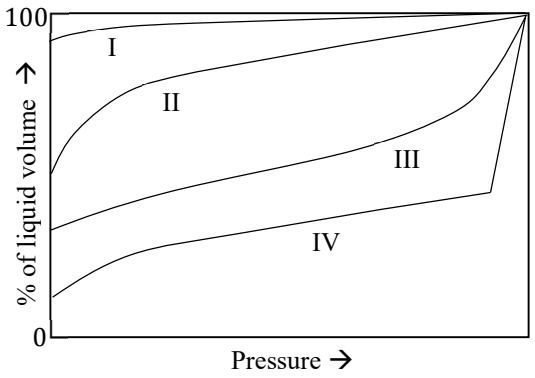
Q.19	The liquid shrinkage curves for different types of crude oil are shown in the following figure.  Which curve represents the Black Oil?
(A)	I
(B)	II
(C)	III
(D)	IV

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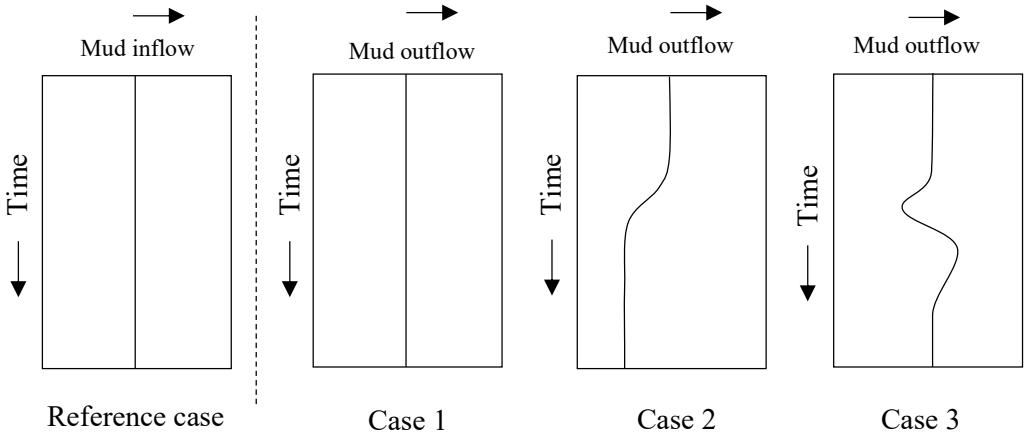
Q.20	The dynamic mud inflow rate and mud outflow rate profiles are shown in the following figure.  Identify the "Hole ballooning" and the "Lost circulation" phenomena.
(A)	Case 1 – Hole ballooning; Case 3 – Lost circulation
(B)	Case 2 – Lost circulation; Case 3 – Hole ballooning
(C)	Case 1 – Lost circulation; Case 2 – Hole ballooning
(D)	Case 2 – Hole ballooning; Case 3 – Lost circulation

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Q.21	What is the maximum permissible limit of 'oil and grease' in discharged wastewater from a petroleum industry as per the guidelines of Central Pollution Control Board (CPCB), India?
(A)	5 ppm
(B)	10 ppm
(C)	30 ppm
(D)	50 ppm
Q.22	The *Timur* chart for estimating the permeability is the plot between
(A)	Porosity and Water Saturation
(B)	True Resistivity and Water Saturation
(C)	Porosity and Irreducible Water Saturation
(D)	Porosity and True Resistivity

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Q.23	The logging tool(s) preferred for the measurement of formation resistivity in a well drilled with oil-based mud is/are
(A)	Dual Laterolog
(B)	Compensated Neutron Log
(C)	Compensated Density Log
(D)	Induction Log
Q.24	Which of the following properties of Matrix $\mathbf{A} = \begin{bmatrix} 1 & 0.5 & 0 \\ 0.5 & 1 & 0.5 \\ 0 & 0.5 & 1 \end{bmatrix}$ are **CORRECT**?
(A)	Singular
(B)	Positive definite
(C)	Symmetric
(D)	Diagonal

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Q.25	Simpson's one-third rule will give the exact value of the integral, $I = \int_a^b \left[b_0 + b_1 x + b_2 x^2 + \cdots + b_n x^n \right] dx$ (where $a, b, b_0, b_1, b_2, \cdots, b_n$ are numeric constants), if the values of n are
(A)	1
(B)	2
(C)	3
(D)	4
Q.26	Which of the following are **NOT CORRECT** during the operating cycle of a 'sucker rod pump'?
(A)	Standing valve is open during the upward stroke.
(B)	Standing valve is closed during the upward stroke.
(C)	Travelling valve is closed during the upward stroke.
(D)	Travelling valve is open during the upward stroke.

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Q.27	Which of the following statements related to the 'enriched gas drive' are **CORRECT**?
(A)	The enriching components are transferred from the oil to the gas.
(B)	The enriched gas drive is an example of immiscible enhanced oil recovery.
(C)	A miscible zone is formed between the injected gas and the reservoir oil.
(D)	In enriched gas drive, the viscous fingering results in poor sweep efficiency.
Q.28	Select the **CORRECT** statements for the injection-production well pattern.
(A)	Inverted 5-spot drive includes four injectors at the corners and the producer at the centre.
(B)	Regular 7-spot drive includes six injectors at the corners and the producer at the centre.
(C)	Staggered-line drive involves staggered injectors and producers.
(D)	Crestal injection involves positioning of the wells along the periphery of the reservoir.

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Q.29	The flammable gas detector works on which of the following phenomena?
(A)	Catalytic
(B)	Paramagnetic
(C)	Electrochemical
(D)	Photoionisation
Q.30	A drilling mud with high gel strength is undesirable because it
(A)	retards the separation of cuttings and entrained gas at the surface.
(B)	leads to the lost circulation.
(C)	creates swabbing action beneath the bit while pulling the string.
(D)	leads to the hole ballooning.

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Q.31	Which of the following Logging tool combinations are required to estimate the Hydrocarbon Initial in Place (HCIP)?
(A)	Resistivity Log, Neutron Log and Gamma Ray Log
(B)	Sonic Log, Neutron Log and Gamma Ray Log
(C)	Resistivity Log, Density Log and Gamma Ray Log
(D)	Neutron Log, Density Log and Sonic Log
Q.32	A homogeneous sandstone reservoir is under a radial steady state flow. The wellbore radius is 0.1 m. The formation near the wellbore is damaged up to 0.9 m from the sand face. The permeability impairment results in $k/k_s = 5$, where k is the permeability in the undamaged region and k_s is that of the damaged region. The value of skin factor is _____ (*rounded off to two decimal places*).

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Q.33	A reservoir is producing oil at 7000 stb/day with a producing gas to oil ratio (GOR) of 2000 scf/stb. At a certain point of time, the reservoir pressure is monitored and decided to be maintained at a constant pressure of 2500 psi using water injection. The PVT properties estimated at 2500 psi are: • Bubble point pressure = 3000 psi • Oil formation volume factor = 1.2 rb/stb • Water formation volume factor = 1.0 rb/stb • Gas formation volume factor = 0.0012 rb/scf • Solution GOR = 300 scf/stb The initial water injection rate (stb/day) required to maintain oil production at 7000 stb/day is _____ (*rounded off to the nearest integer*).
Q.34	An oil well is drilled using an 8.5-inch drill bit at a penetration rate of 30 ft/hr. The rotary speed is 20 rpm and the weight on the bit is 3500 lb. The value of the '*d*' exponent for the drilled section is _____ (*rounded off to two decimal places*).
Q.35	A vertical wellbore is drilled with a 12.25-inch drill bit. While drilling, the bit could drill a total rock volume of 385 ft^3 in 6.5 hr. After drilling, the hole diameter throughout the depth is found to be 12.49 inch. The average rate of penetration is _____ ft/hr (*rounded off to two decimal places*).

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Q.36 – Q.65 Carry TWO marks Each

Q.36	A real gas is produced from a gas reservoir at a constant temperature of 30°C. The compressibility factor (Z) is observed to change with pressure (P) at a rate of $\left(\frac{\partial Z}{\partial P}\right)_T = Z^2$. The difference in the compressibility of the real gas from the ideal gas at a given pressure (P) and temperature (T) is
(A)	Z
(B)	Z^2
(C)	$\sqrt{Z}$
(D)	$\frac{1}{Z^2}$

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Q.37	A brine solution is being injected at a velocity (u) downward through a tubing of diameter (d) inclined at an angle of θ from vertical with gravitational acceleration g. Which ONE of the following options is **CORRECT** for the velocity (u) and the angle (θ) such that the ratio of frictional pressure drop to the gravitational pressure drop is four times the Fanning friction factor?
(A)	$u = (2gd)^{1/2}; \theta = 30^{\circ}$
(B)	$u = gd; \theta = 30^{\circ}$
(C)	$u = (gd)^{1/2}; \theta = 60^{\circ}$
(D)	$u = gd^{1/2}; \theta = 30^{\circ}$

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Q. 38	Which ONE of the following options is the **CORRECT** match of contaminants and their effluent treatment techniques? I. Suspended solids — P. Ion exchange II. Biodegradable organics — Q. Filtration III. Heavy metals — R. Trickling filters IV. Suspended oil and grease — S. Flocculation
(A)	I – P ; II – Q ; III – R ; IV – S
(B)	I – Q ; II – R ; III – P ; IV – S
(C)	I – Q ; II – S ; III – P ; IV – R
(D)	I – R ; II – S ; III – Q ; IV – P

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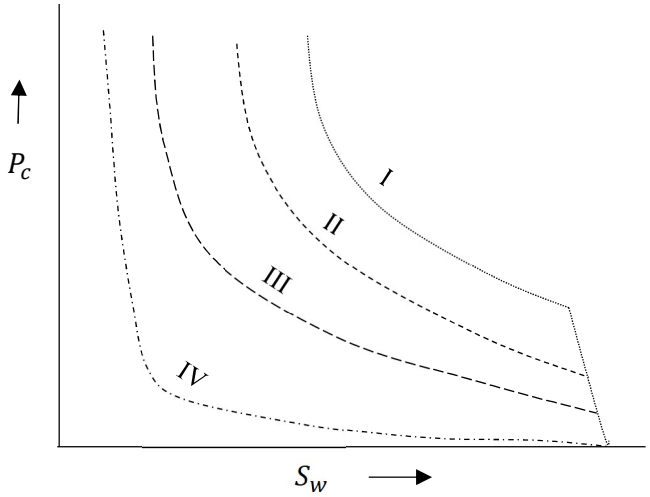
Q.39	Capillary pressure (P_c) vs water saturation (S_w) curves for different sandstone reservoirs (I, II, III and IV) are given in the following figure.  Which reservoir has the most uniform pore size distribution?
(A)	I
(B)	II
(C)	III
(D)	IV

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Q.40 Flow tests are conducted for oil well in reservoirs P, Q, R and S having different parameters as given in the following table. In all the four cases the wells are tested at 1200 stb/day.

Reservoir	Permeability (mD)	Porosity (%)	Oil Viscosity (cP)	Total Compressibility ($\times 10^{-6}$ psi^{-1})	Wellbore Radius (ft)	Pay Zone Thickness (ft)
P	100	23	0.8	75	0.5	10
Q	50	21	1.1	70	0.4	12
R	150	25	0.9	80	0.3	15
S	170	28	1.0	90	0.6	20

Identify the reservoir in which the pressure transient reaches earliest at a point 2000 ft away from the wellbore.

(A) P

(B) Q

(C) R

(D) S

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Q.41 Identify the **CORRRECT** match for the flow regimes (Group 1) with the corresponding slopes of the pressure derivative (Group 2) used in the type curve analysis.

Flow Regime (Group 1)	**Pressure Derivative Slope (Group 2)**
I. Spherical flow	P. 1
II. Linear flow	Q. $\frac{1}{4}$
III. Bilinear flow	R. $-\frac{1}{2}$
IV. Boundary dominated flow	S. $\frac{1}{2}$

(A) I – P; II – Q; III – R; IV – S

(B) I – Q; II – S; III – R; IV – P

(C) I – R; II – S; III – Q; IV – P

(D) I – S; II – P; III – Q; IV – R

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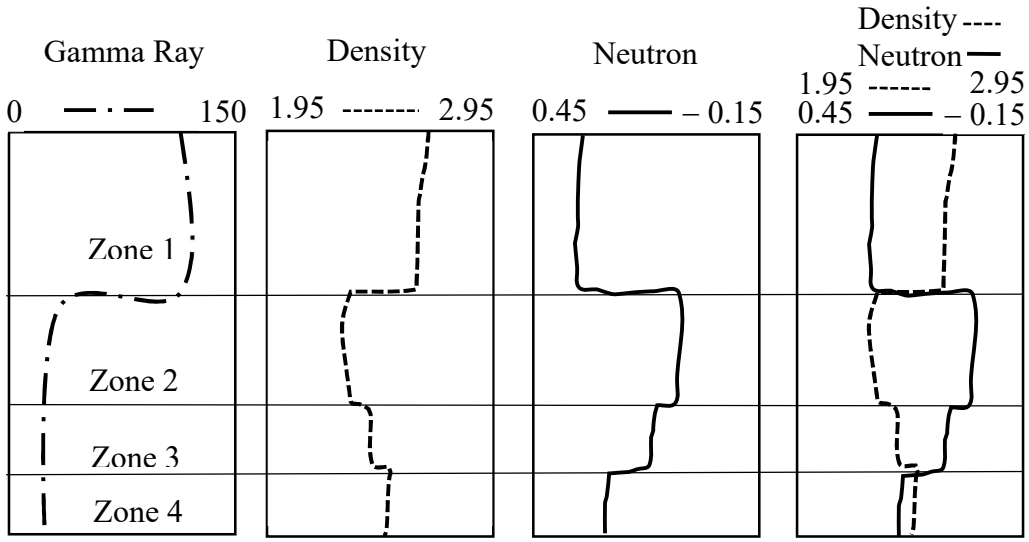
Q.42	The log data obtained for a particular well section are shown in the following figures. Identify the **CORRECT** interpretations for different zones. 
(A)	Zone 1 – shale Zone 2 – clean sand with oil Zone 3 – clean sand with gas Zone 4 – clean sand with water
(B)	Zone 1 – clean sand with gas Zone 2 – clean sand with oil Zone 3 – clean sand with water Zone 4 – shale
(C)	Zone 1 – shale Zone 2 – clean sand with gas Zone 3 – clean sand with oil Zone 4 – clean sand with water
(D)	Zone 1 – clean sand with water Zone 2 – clean sand with oil Zone 3 – clean sand with gas Zone 4 – shale

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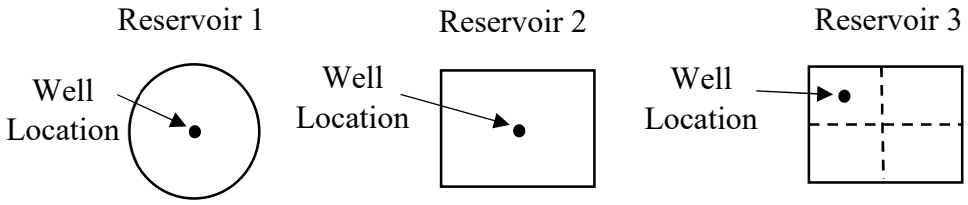
Q.43	Well testing is to be conducted on the bounded sandstone reservoirs as shown in the following figures. All the reservoirs have the same drainage area, rock and fluid properties, and well bore conditions.  Which of the following statements are **CORRECT** for the given reservoirs?
(A)	Pseudo steady flow regime will develop first in Reservoir 1.
(B)	Infinite acting behavior will stop first in Reservoir 2.
(C)	Infinite acting behavior will sustain the longest in Reservoir 1.
(D)	Pressure depletion will be the fastest in Reservoir 3.

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<table>
<tr><td>Q.44</td><td>An exploratory well is planned to be drilled in a basin that extends up to a depth of 5000 m. The surface temperature is 30°C. The geothermal gradient of the basin is 0.025°C/m. Select the possible range(s) of depth at which the potential oil bearing zones can be encountered.</td></tr>
<tr><td></td><td></td></tr>
<tr><td>(A)</td><td>800 m to 950 m</td></tr>
<tr><td>(B)</td><td>1500 m to 1650 m</td></tr>
<tr><td>(C)</td><td>3100 m to 3150 m</td></tr>
<tr><td>(D)</td><td>4550 m to 4600 m</td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td>Q.45</td><td>The following data are given for an oil well scheduled for a drawdown test.
<table><tr><td>Total compressibility = 20×10^{-6} psi^{-1}</td><td>Porosity = 15%</td></tr><tr><td>Oil compressibility = 100×10^{-6} psi^{-1}</td><td>Wellbore radius = 0.25 ft</td></tr><tr><td>Volume of fluid in the wellbore = 180 rb</td><td>Oil viscosity = 2 cP</td></tr><tr><td>Average oil density in the wellbore = 45 lb/ft^3</td><td>Pay zone thickness = 50 ft</td></tr><tr><td>Tubing outer diameter = 2 inch</td><td>Skin factor = 0</td></tr><tr><td>Casing inner diameter = 7.675 inch</td><td>Permeability = 30 mD</td></tr></table>If the well is tested at a constant rate, the ‘Wellbore Storage Effect’ would sustain for _____ hours (rounded off to two decimal places).</td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
</table>

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Q. 46

During the core analysis, the following data are measured at laboratory and reservoir conditions.

Property	Laboratory condition	Reservoir condition
Interfacial tension (dynes/cm)	35	25
Porosity (%)	30	25
Permeability (mD)	100	80
Pore radius (μm)	22	18

The capillary pressure at the laboratory condition is 50 psi. The calculated capillary pressure using the Leverett J-function at the reservoir condition is _____ psi (*rounded off to two decimal places*).

Q.47

The total oil production rate (measured at the bottom hole conditions) from a volumetric reservoir is 200 bbl/day (1 bbl = 5.615 ft^3) at the flowing bottom hole pressure (FBHP) of 3000 psi. The reservoir has the following properties:

Pay zone thickness = 10 ft	Porosity = 18%
Total compressibility = 50×10^{-6} psi^{-1}	Permeability = 35 mD
Wellbore radius = 0.25 ft	Skin factor = 0
Drainage radius = 1000 ft	

Considering a radial flow under pseudo steady state, the bottom hole pressure after 180 days is _____ psi (*rounded off to two decimal places*).

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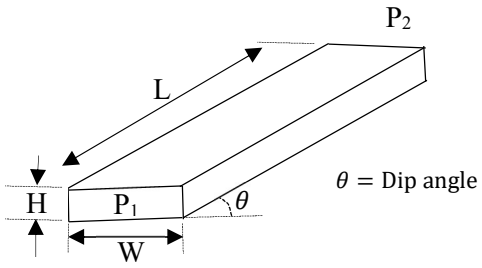
Q. 48

An incompressible fluid (density = 40 lb/ft^3) flows at a steady state through a linear porous media with the following properties:

Length (L) = 1500 ft	Permeability = 150 mD
Height (H) = 15 ft	Viscosity = 1.5 cP
Width (W) = 30 ft	Inlet pressure (P_1) = 1600 psi
Porosity = 18%	Outlet pressure (P_2) = 1590 psi



The absolute value of the difference between the actual fluid velocity (ft/day) at $\theta = 0^o$ and $\theta = 10^o$ is _____ (*rounded off to three decimal places*).

Q. 49

An oil well (wellbore radius = 0.5 inch) in a heavy oil reservoir (drainage radius = 745 ft, oil viscosity = 500 cP) is being operated at 200 rb/day and 150 psi under the radial steady state flow regime. A huff and puff steam injection is planned to reduce the oil viscosity to 35 cP. The steam soaks into the reservoir up to a distance of 65 ft from the centre of the wellbore. The new production rate at the downhole condition after the steam stimulation is _____ rb/day (*rounded off to two decimal places*).

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Q.50	If Z is the standard normal variable having mean 0 and standard deviation 1, then the probability of occurrence of Z in the range of -3 to 3 is _____ (*rounded off to three decimal places*). Given: $\text{erf}(z) \approx \tanh\left(\frac{167z}{148} + \frac{11z^3}{109}\right)$
Q.51	In a three dimensional xyz -space, if $\vec{v} = 3z\,\hat{i} + 2z\,\hat{j} + z\,\hat{k}$, and $\textbf{curl}(\vec{v}) = a\,\hat{i} + b\,\hat{j} + c\hat{k}$, then the value of $(a+b+c)$ is _____(*in integer*).
Q.52	The local minimum value of the real function $f(x) = 2x^3 - 21x^2 + 36x - 20$ is _____ (*in integer*).
Q.53	Consider the following ordinary differential equation $$\frac{dy}{dx} = x^2 y$$ The initial value is $y(0) = 1$ and the step-size is 0.1. Solving this differential equation by Euler's first-order method, the value of $y(0.2)$ is _____ (*rounded off to three decimal places*).

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Q.54 In a horizontal circular pipe, liquid and gas are flowing concurrently at the same superficial velocity. However, the average velocity of the gas is greater than the average velocity of liquid. If the slip velocity is equal to the superficial velocity of each of the phases, the fractional liquid holdup is _____ (*rounded off to two decimal places*).

Q. 55 A 1 kg-mol bottled gas consists of the following composition at 30°C.

Component	**n-Butane**	**Propane**	**Ethane**
Composition (mol %)	50	45	5
Vapour pressure (bar)	3	10	40

The equilibrium vapour composition of n-Butane in mol % is _____ (*rounded off to two decimal places*).

Q. 56 A crude oil with a flowrate of 1000 kg/hr is to be cooled using water in a double-pipe counter-flow heat exchanger from a temperature of 80°C to 40°C. The water enters the exchanger at 20°C and leaves at 40°C. The specific heat capacities of the oil and the water at constant pressure are 2 kJ kg^{-1} K^{-1} and 4.2 kJ kg^{-1} K^{-1}, respectively. The overall heat transfer coefficient is 0.25 kW m^{-2} K^{-1}. Neglecting the heat loss and using the log mean temperature difference (LMTD) method, the minimum heat exchanger area (m^2) required for the operation is _____ (*rounded off to two decimal places*).

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Q. 57	In an oil reservoir undergoing water flooding, the areal and vertical sweep efficiencies are 0.75 and 0.85, respectively. The average water saturation behind the flood front is 0.63 at breakthrough, and the initial water saturation is 0.17. If the initial volume of in-situ oil at the start of water flooding is 3200 rb, the amount of oil produced during the water flooding is _____ rb (*rounded off to two decimal places*).
Q.58	The initial water saturation in an oil reservoir with a free gas cap is 30%. The initial gas saturation is 40%. At the end of water flooding, all the free gases are dissolved due to the elevated pressure and the oil formation volume factor reaches a value of 1.20 rb/stb. The final water saturation at the end of water flooding is 50%. If the two-phase formation volume factor at the initiation of the water flood is 2.3 rb/stb, the pore-to-pore displacement efficiency under the current reservoir condition is _____ % (*rounded off to one decimal place*).

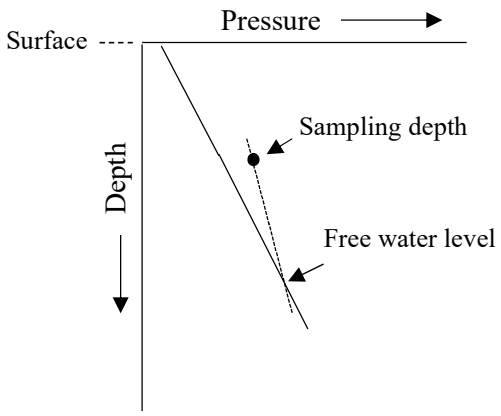
Q.59 The station survey data during the directional drilling at two locations are given below.

Survey location	Depth (m)	Inclination (α) (degree)	Azimuth (β) (degree)
A	4499	14.8	N19E
B	4530	13.5	N10E

$$\text{Dogleg angle} = \cos^{-1}[\cos\alpha_A \cos\alpha_B + \sin\alpha_A \sin\alpha_B \cos(\beta_A - \beta_B)]$$

The calculated dogleg severity (dogleg angle per 100 m of drilled section) is _____ (*rounded off to one decimal place*).

Q.60 A sandstone reservoir has the formation top at a depth of 3421 ft from the surface as shown in the following figure. The reservoir is logged with a modular dynamic tester (MDT). At a depth of 3425 ft, the formation pressure is recorded as 1560 psi and the sampled crude has a density of 35°API.



Considering a normal hydrostatic pressure gradient (brine density of 1.04 g/cc) and a capillary displacement pressure of 1.2 psi, the oil water contact (OWC) is found at a depth of _____ ft from the surface (*rounded off to two decimal places*).

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Q.61

The drill pipes and drill collars with a combined length of 2500 m are held on the hook without rotation and mud flow. The specific gravity of the mud in the annulus is 1.5 and that inside the drill string is 1.4. The material density of the drill pipe and drill collar is 7850 kg/m^3. The specifications of drill pipes and drill collars are given below.

Specification	**Drill pipe**	**Drill collar**
Length (m)	2000	500
Inside diameter (m)	0.106	0.127
Outside diameter (m)	0.156	0.406
Mass per unit length (kg/m)	30	870

The overall weight acting on the hook is _____ kN (*rounded off to two decimal places*).

Q.62

A drilling rig is designed with 12 lines strung between the crown block and the traveling block. The hoisting system has an output power of 650 HP (1 HP = 33000 lb-ft/min). When the drill string is pulled up with a speed of 52.5 ft/min, the tension in the fast line reads 46180 lb. Assume that the rig utilizes all the available output power of drawworks and the drill string is pulled at a constant system efficiency. If the drill string is pulled at the same output power and the tension in the fast line is 35690 lb, then the pullout speed of the drill string is _____ ft/min (*rounded off to one decimal place*).

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Q.63

In a sandstone reservoir, the density log reads 2.11 g/cc and sonic log reads 90 µs/ft. The other parameters are given below:

Matrix density (ρ_{ma}) = 2.68 g/cc
Fluid density (ρ_{fl}) = 1.0 g/cc
Compressional wave travel time in matrix (Δt_{ma}) = 54 µs/ft
Compressional wave travel time in fluid (Δt_{fl}) = 189 µs/ft

The calculated secondary porosity of the reservoir is _____ % (*rounded off to the nearest integer*).

Q. 64

The *Waxman–Smits* equation to estimate water saturation for shaly sands is given as,

$$C_t = \emptyset^{m^*} S_w^{n^*} \left(C_w + \frac{BQ_v}{S_w} \right)$$

where, B is cation mobility (m Ω^{-1} meq^{-1} ml^{-1}), and Q_v is cation exchange capacity per pore volume (meq ml^{-1}). The values of other parameters are:

Porosity ($\emptyset$) = 0.25
BQ_v = 17.0 m Ω^{-1}
Cementation factor (m^*) = Saturation exponent (n^*) = 2.0
Resistivity of water (R_w) = 0.05 Ω m
True resistivity of formation in the oil zone (R_t) = 12 Ω m

As per the given dataset, the calculated water saturation (s_w) in oil zone is _____ % (*rounded off to the nearest integer*).

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Q. 65	The hydrogen index (HI) of a potential source rock is 500. If 400 g of the same rock produces 6000 mg of hydrocarbons during a thermal pyrolysis at the maximum temperature, the calculated total organic content (TOC) of the rock is _____ weight % (*rounded off to one decimal place*).