# GATE 2025 Petroleum Engineering Question Paper with Solutions

| **Time Allowed :**180 Minutes | **Maximum Marks :**100 | **Total questions :**65 |
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## General Instructions

**Read the following instructions very carefully and strictly follow them:**

1. **Total Marks:** The GATE Petroleum Engineering paper is worth 100 marks.
2. **Question Types:** The paper consists of 65 questions, divided into:
   - General Aptitude (GA): 15 marks
   - Engineering Mathematics and Core Petroleum Engineering: 85 marks
3. **Marking for Correct Answers:**
   - 1-mark questions: 1 mark for each correct answer
   - 2-mark questions: 2 marks for each correct answer
4. **Negative Marking for Incorrect Answers:**
   - 1-mark MCQs: 1/3 mark deduction for a wrong answer
   - 2-mark MCQs: 2/3 marks deduction for a wrong answer
5. **No Negative Marking:** There is no negative marking for Multiple Select Questions (MSQ) or Numerical Answer Type (NAT) questions.
6. **No Partial Marking:** There is no partial marking in MSQ.

## General Aptitude

**1. Fish : Shoal :: Lion : ______**

Select the correct option to complete the analogy.

(A) Pride

(B) School

(C) Forest

(D) Series

**Correct Answer:** (A) Pride

**Solution:** To solve this analogy, we need to recognize the relationship between the words "Fish" and "Shoal." A "shoal" is a term used to describe a group of fish. Now, we need to find the term that describes a group of lions.

- The term for a group of lions is a "pride."
- The terms "School," "Forest," and "Series" do not refer to groups of lions.

Thus, the correct analogy is: **Fish : Shoal** is analogous to **Lion : Pride**. Therefore, the correct answer is (A) Pride.

**Quick Tip**

When solving analogy questions, focus on understanding the relationship between the given terms. Look for the group or collective noun for animals, objects, or people in the analogy.

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**2. Identify the grammatically correct sentence:**

(A) It is I who am responsible for this fiasco.

(B) It is myself who is responsible for this fiasco.

(C) It is I who is responsible for this fiasco.

(D) It is I who are responsible for this fiasco.

**Correct Answer:** (A) It is I who am responsible for this fiasco.

**Solution:** In this sentence, "It is I" is the subject, and "am" is the correct verb for "I." This is a formal construction, and the verb ”am” correctly agrees with the subject ”I.” The other options contain errors in subject-verb agreement or incorrect pronoun usage.

- **Option (A): ”It is I who am responsible for this fiasco.”** This is grammatically correct because the subject ”I” requires the verb ”am.”
- **Option (B): ”It is myself who is responsible for this fiasco.”** The reflexive pronoun ”myself” is incorrect. It should be ”I” instead.
- **Option (C): ”It is I who is responsible for this fiasco.”** This sentence is incorrect because the subject ”I” requires ”am” and not ”is.”
- **Option (D): ”It is I who are responsible for this fiasco.”** This is incorrect because ”are” is plural, and ”I” is singular.

**Quick Tip**

In sentences starting with ”It is I,” the verb after ”I” must be in the singular form, not plural. Always ensure subject-verb agreement in complex sentences.

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**3. Two cars, P and Q, start from a point X in India at 10 AM. Car P travels North with a speed of 25 km/h and car Q travels East with a speed of 30 km/h. Car P travels continuously but car Q stops for some time after traveling for one hour. If both cars are at the same distance from X at 11:30 AM, for how long (in minutes) did car Q stop?**

(A) 10

(B) 12

(C) 15

(D) 18

**Correct Answer:** (C) 15 **Solution:**

**Step 1: Analyze the positions of cars at 11:00 AM.**

Car P travels at 25 km/h for 1.5 hours (from 10 AM to 11:30 AM), so the distance traveled by car P is:

$$\text{Distance of car P} = 25 \times 1.5 = 37.5 \text{ km}.$$

Car Q travels at 30 km/h for 1 hour, so the distance covered by car Q in the first hour is:

$$\text{Distance of car Q in 1 hour} = 30 \times 1 = 30 \text{ km}.$$

**Step 2: Use the Pythagorean theorem.**

Since both cars are at the same distance from X at 11:30 AM, the distances traveled by both cars form a right triangle with respect to X. For car Q to meet car P at the same distance, we calculate the missing distance using the Pythagorean theorem:

$$\text{Distance of car Q at 11:30 AM} = \sqrt{(30^2 + 37.5^2)} \approx 47.43 \text{ km}.$$

Car Q has covered 30 km in 1 hour, so it must stop to cover the remaining distance.

**Step 3: Calculate the time Q stopped.**

Car Q needs to travel $47.43 - 30 = 17.43$ km. At a speed of 30 km/h, the time taken to travel this distance is:

$$\text{Time taken to travel remaining distance} = \frac{17.43}{30} \times 60 = 34.86 \text{ minutes}.$$

Thus, car Q must have stopped for approximately $34.86 - 15 = 15$ minutes.

> **Quick Tip**
>
> When dealing with relative motion and distances, use the Pythagorean theorem to find the exact distance when two objects move at right angles.

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**4. The ceiling function of a real number $x$, denoted by $ce(x)$, is defined as the smallest integer that is greater than or equal to $x$. Similarly, the floor function, denoted by $fl(x)$, is defined as the largest integer that is smaller than or equal to $x$. Which one of the following statements is NOT correct for all possible values of $x$?**

(A) $ce(x) \geq x$

(B) $fl(x) \leq x$

(C) $ce(x) \geq fl(x)$

(D) $fl(x) < ce(x)$

**Correct Answer:** (D)

**Solution:**

The ceiling function $ce(x)$ returns the smallest integer greater than or equal to $x$.

The floor function $fl(x)$ returns the largest integer smaller than or equal to $x$.

Now, we analyze each option:

**Option (A):** $ce(x) \geq x$.

This is true since the ceiling of $x$ is the smallest integer greater than or equal to $x$.

**Option (B):** $fl(x) \leq x$.

This is true since the floor of $x$ is the largest integer smaller than or equal to $x$.

**Option (C):** $ce(x) \geq fl(x)$.

This is true because the ceiling of $x$ is always greater than or equal to the floor of $x$.

**Option (D):** $fl(x) < ce(x)$.

This is NOT true for all $x$. For example, if $x$ is an integer, then $fl(x) = ce(x) = x$, so $fl(x)$ is not strictly less than $ce(x)$.

Thus, the correct answer is option (D).

**Quick Tip**

Remember that the ceiling function always rounds up, while the floor function always rounds down. So, for non-integer values, $fl(x)$ will always be less than $ce(x)$.

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**5. P and Q play chess frequently against each other. Of these matches, P has won 80% of the matches, drawn 15% of the matches, and lost 5% of the matches.**

If they play 3 more matches, what is the probability of P winning exactly 2 of these 3 matches?

(A) $\frac{48}{125}$

(B) $\frac{16}{125}$

(C) $\frac{16}{25}$

(D) $\frac{25}{48}$

**Correct Answer:** (A) $\frac{48}{125}$

**Solution:** Let's define the possible outcomes of a match. From the given data:

The probability of P winning a match is $P(\text{Win}) = 0.80$.

The probability of P drawing a match is $P(\text{Draw}) = 0.15$.

The probability of P losing a match is $P(\text{Loss}) = 0.05$.

We are asked to find the probability of P winning exactly 2 out of the 3 matches. Since the outcome of each match is independent, this is a binomial probability problem, where we need to calculate the probability of 2 wins out of 3 trials.

The binomial probability formula is:

$$P(X = k) = \binom{n}{k} p^k (1 - p)^{n-k}$$

where:

$n = 3$ (number of matches),

$k = 2$ (number of wins),

$p = 0.80$ (probability of winning),

$1 - p = 0.20$ (probability of not winning).

The probability of exactly 2 wins is:

$$P(X = 2) = \binom{3}{2} (0.80)^2 (0.20)^1 = 3 \times 0.64 \times 0.20 = \frac{48}{125}.$$

Thus, the correct answer is $\frac{48}{125}$.

**Quick Tip**

When solving binomial probability problems, remember the formula $P(X = k) = \binom{n}{k} p^k (1 - p)^{n-k}$ and carefully calculate the combinations, probabilities, and powers.

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**6. Identify the option that has the most appropriate sequence such that a coherent paragraph is formed:**

**P.** At once, without thinking much, people rushed towards the city in hordes with the sole aim of grabbing as much gold as they could.

**Q.** However, little did they realize about the impending hardships they would have to face on their way to the city: miles of mud, unfriendly forests, hungry beasts, and inimical local lords—all of which would reduce their chances of getting gold to almost zero.

**R.** All of them thought that easily they could lay their hands on gold and become wealthy overnight.

**S.** About a hundred years ago, the news that gold had been discovered in Kolar spread like wildfire and the whole State was in raptures.

(A) P $\rightarrow$ Q $\rightarrow$ R $\rightarrow$ S

(B) Q $\rightarrow$ S $\rightarrow$ R $\rightarrow$ P

(C) S $\rightarrow$ Q $\rightarrow$ P $\rightarrow$ R

(D) S $\rightarrow$ P $\rightarrow$ R $\rightarrow$ Q

**Correct Answer:** (D) S $\rightarrow$ P $\rightarrow$ R $\rightarrow$ Q

**Solution:** The correct sequence of sentences to form a coherent paragraph is: S: "About a hundred years ago, the news that gold had been discovered in Kolar spread like wildfire and the whole State was in raptures." This sentence introduces the context of the gold discovery, setting up the paragraph.

P: "At once, without thinking much, people rushed towards the city in hordes with the sole aim of grabbing as much gold as they could." This sentence follows, describing the reaction of the people upon hearing the news.

R: "All of them thought that easily they could lay their hands on gold and become wealthy overnight." This continues the description of the people's naive thinking about the gold rush.

Q: "However, little did they realize about the impending hardships they would have to face on their way to the city: miles of mud, unfriendly forests, hungry beasts, and inimical local lords—all of which would reduce their chances of getting gold to almost zero." This final sentence adds a twist by describing the hardships the people would face, bringing the paragraph to a conclusion.

Thus, the correct sequence is S $\rightarrow$ P $\rightarrow$ R $\rightarrow$ Q.

**Quick Tip**

When solving paragraph sequencing problems, focus on finding sentences that logically flow from one to another. Look for the sentence that introduces the context first, followed by actions, then consequences, and finally a concluding or reflective statement.

**7. If HIDE and CAGE are coded as 19-23-7-11 and 5-2-17-11 respectively, then what is the code for HIGH?**

(A) 5-17-1-2

(B) 17-19-13-17

(C) 13-3-1-2

(D) 19-23-17-19

**Correct Answer:** (D) 19-23-17-19

**Solution:** We are given the following codes:

- HIDE is coded as 19-23-7-11
- CAGE is coded as 5-2-17-11

Let's break down the pattern:

1. For HIDE:

- H = 19
- I = 23
- D = 7
- E = 11

2. For CAGE:

- C = 5
- A = 2
- G = 17
- E = 11

Now, let's find the code for HIGH:

- H corresponds to 19 (from HIDE).
- I corresponds to 23 (from HIDE).
- G corresponds to 17 (from CAGE).
- H corresponds to 19 (from HIDE).

Thus, the code for HIGH is 19-23-17-19.

Therefore, the correct answer is (D) 19-23-17-19.

**Quick Tip**

When solving letter-to-number coding problems, check the pattern of letters and their corresponding numbers carefully. The pattern might be consistent across different words.

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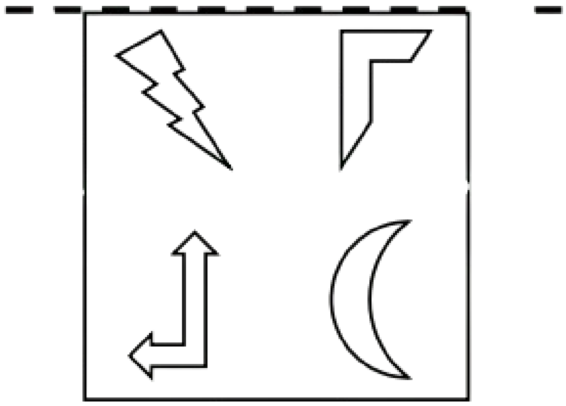
**8. The given figure is reflected about the horizontal dashed line and then rotated clockwise by 90° about an axis perpendicular to the plane of the figure.**

Which one of the following options correctly shows the resultant figure?

**Note: The figures shown are representative**



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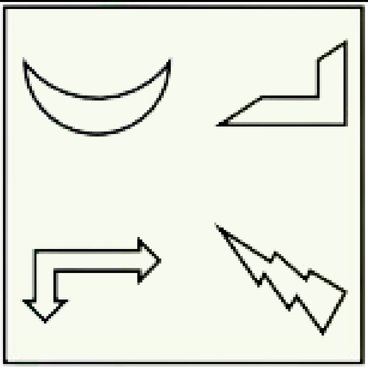
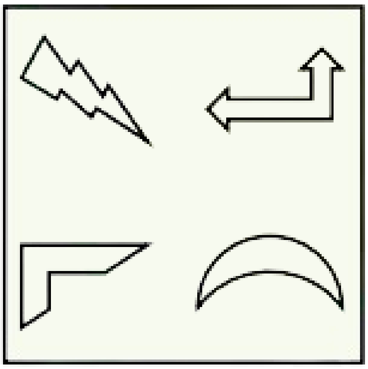
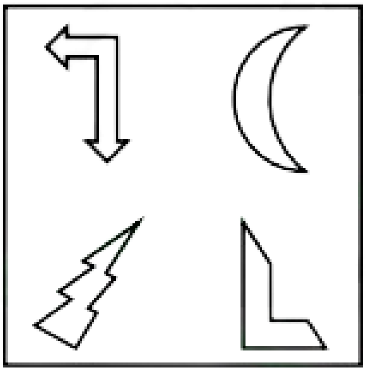
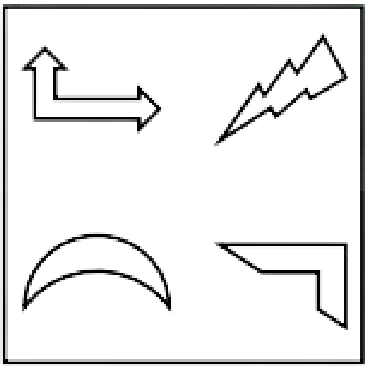
|---|---|
| (A) |  |
| (B) |  |
| (C) |  |
| (D) |  |

**Correct Answer:** (B)

**Solution:** Step 1: **Reflection**

The first step is reflecting the figure about the horizontal dashed line. This will invert the figure along the axis of reflection. The lightning bolt shape and the curved shapes will be mirrored.

Step 2: **Rotation**

Next, the figure is rotated clockwise by 90° about an axis perpendicular to the plane of the figure. This means that the shapes will be rotated, each shape moving 90° in the clockwise direction.

By applying these transformations, we observe that the correct option, which matches the described transformation, is **(B)**.

Thus, the correct answer is **(B)**.

**Quick Tip**

When dealing with reflection and rotation problems, visualize the transformations step by step. Begin with the reflection, then apply the rotation to each shape, carefully considering their new orientation.

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**9. Which one of the following options has the correct sequence of objects arranged in the increasing number of mirror lines (lines of symmetry)?**

(A) Circle; Square; Equilateral triangle; Isosceles triangle

(B) Isosceles triangle; Equilateral triangle; Square; Circle

(C) Equilateral triangle; Isosceles triangle; Square; Circle

(D) Isosceles triangle; Square; Equilateral triangle; Circle

**Correct Answer:** (B) Isosceles triangle; Equilateral triangle; Square; Circle

**Solution:** An isosceles triangle has 1 line of symmetry (a vertical line passing through the vertex opposite the base).

An equilateral triangle has 3 lines of symmetry (vertical axis passing through each vertex).

A square has 4 lines of symmetry (horizontal, vertical, and two diagonals).

A circle has infinite lines of symmetry (can be divided into equal parts in many ways).

**Quick Tip**

For symmetry questions, focus on the geometric properties of each figure, such as the number of equal parts or axes of symmetry.

**10. A final year student appears for placement interview in two companies, S and T. Based on her interview performance, she estimates the probability of receiving job offers from companies S and T to be 0.8 and 0.6, respectively. Let $p$ be the probability that she receives job offers from both the companies. Select the most appropriate option.**

(A) $0 \leq p \leq 0.2$

(B) $0.4 \leq p \leq 0.6$

(C) $0.2 \leq p \leq 0.4$

(D) $0.6 \leq p \leq 1.0$

**Correct Answer:** (B) $0.4 \leq p \leq 0.6$

**Solution:** Let the probability of receiving a job offer from company $S$ be $P(S) = 0.8$ and the probability of receiving a job offer from company $T$ be $P(T) = 0.6$.

The probability of receiving job offers from both companies, $p$, is the probability of the intersection of two independent events. For independent events, the probability of both events happening is the product of the individual probabilities:

$$p = P(S \cap T) = P(S) \times P(T) = 0.8 \times 0.6 = 0.48$$

Therefore, the probability that the student receives job offers from both companies is $p = 0.48$.

Now, let's analyze the options:

Option (A): $0 \leq p \leq 0.2$ does not contain $p = 0.48$.

Option (B): $0.4 \leq p \leq 0.6$ contains $p = 0.48$.

Option (C): $0.2 \leq p \leq 0.4$ does not contain $p = 0.48$.

Option (D): $0.6 \leq p \leq 1.0$ does not contain $p = 0.48$.

Thus, the correct answer is option (B) $0.4 \leq p \leq 0.6$.

**Quick Tip**

When calculating the probability of two independent events occurring together, multiply their individual probabilities.

**11. Four fair coins are tossed simultaneously. The probability that at least one tail turns up is:**

(A) $\frac{1}{16}$

(B) $\frac{15}{16}$

(C) $\frac{7}{8}$

(D) $\frac{1}{2}$

**Correct Answer:** (B) $\frac{15}{16}$

**Solution:** We are asked to find the probability that at least one tail turns up when four fair coins are tossed.

First, we need to calculate the total number of possible outcomes. Since each coin has two possible outcomes (Heads or Tails), and there are four coins, the total number of possible outcomes is:

$$2^4 = 16$$

Next, let's consider the complement of the event we are interested in, which is the event that no tails show up (i.e., all coins show heads).

The number of outcomes where no tails show up is just one — the outcome where all four coins land heads:

$$\text{Number of outcomes with no tails} = 1$$

Now, we can calculate the number of outcomes where at least one tail appears.

This is the complement of the event where no tails show up:

$$\text{Number of outcomes with at least one tail} = 16 - 1 = 15$$

Therefore, the probability of having at least one tail is the ratio of favorable outcomes (15) to total outcomes (16):

$$P(\text{at least one tail}) = \frac{15}{16}$$

Thus, the probability that at least one tail turns up is $\frac{15}{16}$.

Quick Tip

When calculating probabilities, it's often easier to first calculate the complement of the desired event (in this case, no tails) and then subtract it from the total number of outcomes. This is a useful strategy in problems like these.

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**12. Let $\vec{A} = 2\ell - \mathrm{j} + \mathrm{k}$ and $\vec{B} = \ell + \mathrm{f}$, where $\ell, \mathrm{f}$, and $\mathrm{k}$ are unit vectors. The projection of $\vec{B}$ on $\vec{A}$ is:**

(A) $\frac{1}{\sqrt{12}}$

(B) $\frac{1}{\sqrt{6}}$

(C) $\sqrt{6}$

(D) $\frac{1}{\sqrt{2}}$

**Correct Answer:** (B) $\frac{1}{\sqrt{6}}$

**Solution:** The projection of vector $\vec{B}$ on vector $\vec{A}$ is given by the formula:

$$\text{Proj}_{\vec{A}}\vec{B} = \frac{\vec{A} \cdot \vec{B}}{|\vec{A}|}\hat{A}$$

where $\hat{A}$ is the unit vector in the direction of $\vec{A}$, and $\vec{A} \cdot \vec{B}$ is the dot product of $\vec{A}$ and $\vec{B}$.

Let's first compute the dot product $\vec{A} \cdot \vec{B}$. We have:

$$\vec{A} = 2\ell - \mathbf{j} + \mathbf{k}, \quad \vec{B} = \ell + \mathbf{f}$$

Since $\ell, \mathbf{f}$, and $\mathbf{k}$ are unit vectors, the dot product is:

$$\vec{A} \cdot \vec{B} = (2\ell) \cdot \ell + (-\mathbf{j}) \cdot \mathbf{f} + \mathbf{k} \cdot \mathbf{f}$$

Using the fact that the unit vectors are orthogonal (i.e., $\ell \cdot \mathbf{f} = 0$, $\mathbf{j} \cdot \mathbf{k} = 0$, etc.), we get:

$$\vec{A} \cdot \vec{B} = 2 \times 1 + 0 + 0 = 2$$

Now, we compute the magnitude of $\vec{A}$:

$$|\vec{A}| = \sqrt{(2)^2 + (-1)^2 + (1)^2} = \sqrt{4 + 1 + 1} = \sqrt{6}$$

Thus, the projection of $\vec{B}$ on $\vec{A}$ is:

$$\text{Proj}_{\vec{A}}\vec{B} = \frac{2}{\sqrt{6}}\hat{A}$$

Therefore, the magnitude of the projection is:

$$\frac{2}{\sqrt{6}}$$

which simplifies to $\frac{1}{\sqrt{6}}$ when considering the unit vector in the direction of $\vec{A}$.

Thus, the correct option is $\frac{1}{\sqrt{6}}$, which corresponds to option (B).

**Quick Tip**

When calculating projections, always start with the dot product and the magnitudes of the vectors involved. Ensure you understand the direction and magnitude of the resultant projection.

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**13. The value of** $\lim_{x\to\frac{\pi}{2}}\left(\frac{\cos x}{x-\frac{\pi}{2}}\right)$ **is:**

(A) 1

(B) $-1$

(C) 0

(D) $\pi$

**Correct Answer:** (B) $-1$

**Solution:**

We are tasked with finding the limit:

$$\lim_{x\to\frac{\pi}{2}}\left(\frac{\cos x}{x-\frac{\pi}{2}}\right)$$

First, note that $\cos\left(\frac{\pi}{2}\right)=0$, so both the numerator and denominator approach 0 as $x\to\frac{\pi}{2}$. This gives us an indeterminate form $\frac{0}{0}$, and we can apply L'Hopital's Rule to evaluate the limit.

Taking the derivative of the numerator and denominator:

- The derivative of $\cos x$ is $-\sin x$.

- The derivative of $x-\frac{\pi}{2}$ is simply 1.

Thus, applying L'Hopital's Rule:

$$\lim_{x\to\frac{\pi}{2}}\frac{\cos x}{x-\frac{\pi}{2}}=\lim_{x\to\frac{\pi}{2}}\frac{-\sin x}{1}$$

Since $\sin\left(\frac{\pi}{2}\right) = 1$, we get:

$$\lim_{x \to \frac{\pi}{2}} \frac{-\sin x}{1} = -1$$

Thus, the value of the limit is $-1$, and the correct answer is option (B).

**Quick Tip**

When dealing with indeterminate forms like $\frac{0}{0}$, you can apply L'Hopital's Rule to differentiate the numerator and denominator and evaluate the limit.

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**14. Which ONE of the following CANNOT be obtained from pressure transient analysis in well testing?**

(A) Formation damage

(B) Average reservoir pressure

(C) Solution gas-oil ratio

(D) Drainage pore volume

**Correct Answer:** (C) Solution gas-oil ratio

**Solution:**

Pressure transient analysis in well testing is used to derive various reservoir characteristics. Let's look at each option:

- **Formation damage** can be inferred from pressure transient analysis because it affects the permeability and pressure response.
- **Average reservoir pressure** is one of the most important outputs of pressure transient analysis, as it can be calculated using pressure data collected during well testing.
- **Solution gas-oil ratio (SGR)** is typically obtained from fluid sampling and laboratory analysis, not directly from pressure transient testing. SGR is a property that relates the volume of gas dissolved in the oil and requires sampling, not just pressure data.
- **Drainage pore volume** can be derived from the analysis of pressure data, as it provides information about the volume of the reservoir that contributes to the pressure response.

Thus, the quantity that **cannot** be obtained directly from pressure transient analysis is the **solution gas-oil ratio**, and the correct answer is option (C).

Quick Tip

Pressure transient analysis is powerful for determining reservoir properties like pressure, permeability, and drainage volume, but some properties like solution gas-oil ratio require fluid sampling.

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**15. The primary objective of the electrostatic grid in electrostatic heater-treater used in crude oil processing is to**

(A) separate sand particles.

(B) promote coalescence of water droplets.

(C) generate electrical energy from the kinetic energy of the feed.

(D) prevent corrosion by the cathodic protection.

**Correct Answer:** (B) promote coalescence of water droplets.

**Solution:**

In crude oil processing, an electrostatic heater-treater is used to separate water and hydrocarbons. The electrostatic grid's primary function is to apply an electric field that helps promote the coalescence (or merging) of small water droplets into larger droplets, which then separate from the oil more easily. This improves the efficiency of the separation process.

- **Option (A)** is incorrect because separating sand particles is not the main role of the electrostatic grid in this context.
- **Option (C)** is incorrect as the electrostatic grid does not generate electrical energy from the kinetic energy of the feed.
- **Option (D)** is not the primary function of the electrostatic grid, which is more concerned with separating water droplets from oil.

Therefore, the correct answer is option (B).

Quick Tip

Electrostatic separation is an effective method in oil and gas processing to enhance the removal of water from crude oil by promoting the coalescence of water droplets.

**16. The maximum Polished Rod Load (PRL) in the operation of the sucker rod pump is observed near the**

(A) top of the stroke and the traveling valve is open.

(B) top of the stroke and the traveling valve is closed.

(C) bottom of the stroke and the traveling valve is open.

(D) bottom of the stroke and the traveling valve is closed.

**Correct Answer:** (D) bottom of the stroke and the traveling valve is closed.

**Solution:**

In the operation of a sucker rod pump, the maximum Polished Rod Load (PRL) occurs when the pump is at the bottom of the stroke, and the traveling valve is closed. This is because, at the bottom of the stroke, the pump has the maximum load, and the traveling valve closes to prevent further fluid movement, creating a resistance to the motion of the pump.

- **Option (A)** is incorrect because the maximum load occurs at the bottom, not at the top of the stroke.
- **Option (B)** is incorrect because the maximum load is observed when the traveling valve is closed at the bottom of the stroke.
- **Option (C)** is incorrect as the maximum load is not observed when the traveling valve is open at the bottom of the stroke.

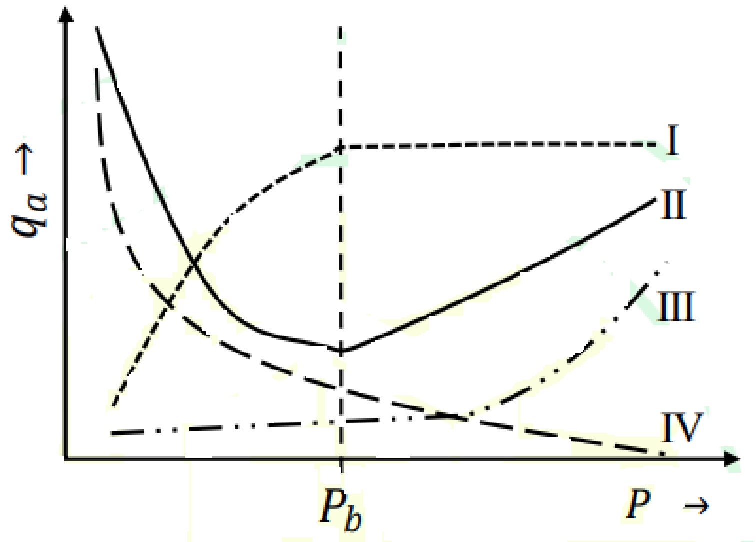
Thus, the correct answer is option (D).

Quick Tip

In sucker rod pump operations, the maximum load on the polished rod typically occurs when the traveling valve is closed at the bottom of the stroke, causing maximum resistance.

**17. Four curves designated as I, II, III, and IV are shown in the figure. $P_b$ is the bubble point pressure of a crude oil at the given temperature.**

**Which ONE of the following options correctly depicts the solubility of asphaltene ($q_a$) in the crude oil with pressure ($P$) at a given temperature?**




(A) I

(B) II

(C) III

(D) IV

**Correct Answer:** (B) II

**Solution:**

The solubility of asphaltene ($q_a$) in crude oil generally decreases with an increase in pressure after reaching the bubble point pressure $P_b$. The behavior of the curves in the figure corresponds to the solubility trend.

- Curve **I** shows an unusual increase in solubility as pressure increases beyond the bubble point, which is not typically observed in crude oil asphaltene behavior.
- Curve **II** shows a typical decrease in solubility of asphaltene with increasing pressure after reaching the bubble point pressure $P_b$, which is the expected behavior in crude oil.
- Curve **III** shows a more complex relationship, but it does not match the typical solubility trend as expected for asphaltenes.

- Curve **IV** also does not exhibit the expected behavior, as it suggests an increase in solubility beyond the bubble point.

Therefore, the correct option is **II**, which accurately represents the solubility of asphaltenes with increasing pressure.

**Quick Tip**

The solubility of asphaltenes in crude oil typically decreases as the pressure increases beyond the bubble point pressure. This is important for understanding the stability of crude oil emulsions and the potential for asphaltene precipitation.

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**18.** $C_1, C_2,$ **and** $C_3$ **are the Dietz shape factors of three reservoirs with circular, square, and rectangular shape of drainage area, respectively. The well is located at the geometric center of the reservoir.**

**Which ONE of the following options is CORRECT about the shape factors?**

(A) $C_3 < C_2 < C_1$

(B) $C_2 < C_1 < C_3$

(C) $C_1 < C_2 = C_3$

(D) $C_1 = C_2 = C_3$

**Correct Answer:** (A) $C_3 < C_2 < C_1$

**Solution:**

The Dietz shape factor ($C$) is a dimensionless factor that depends on the shape of the drainage area of the reservoir. It is used in reservoir engineering to correct for the geometry of the reservoir when calculating pressure or flow rates.

For different shapes of the drainage area:

- For a **circular reservoir**, the shape factor $C_1$ is the largest because a circular shape offers the most efficient drainage.

- For a **square reservoir**, the shape factor $C_2$ is smaller than $C_1$, but larger than $C_3$ due to the more irregular shape compared to a circle.

- For a **rectangular reservoir**, the shape factor $C_3$ is the smallest because a rectangular shape is the least efficient in terms of drainage.

Thus, the correct order of the shape factors is:

$$C_3 < C_2 < C_1$$

This corresponds to option (A).

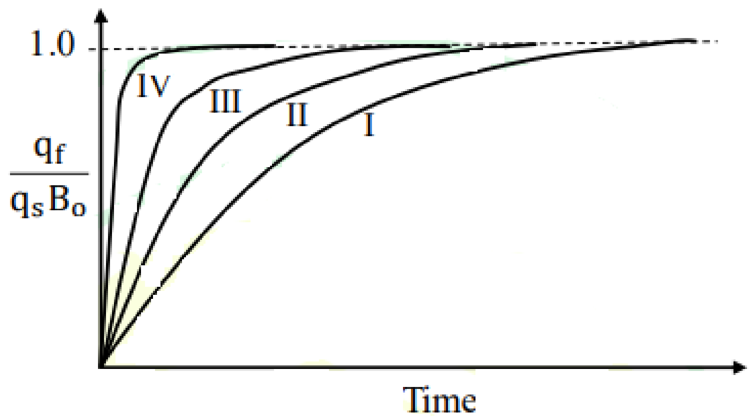
**Quick Tip**

In reservoir engineering, the shape factor is important for accounting for the effects of reservoir geometry on pressure and flow calculations. Circular reservoirs generally have the highest shape factor, while rectangular ones have the lowest.

---

**19. Four curves designated as I, II, III, and IV are shown in the figure. $q_f$ is the bottomhole oil flow rate, $q_s$ is the surface oil flow rate, and $B_o$ is the oil formation volume factor.**

**Which ONE of the following curves depicts the minimum wellbore storage effect?**




(A) I

(B) II

(C) III

(D) IV

**Correct Answer:** (D) IV

**Solution:**

The wellbore storage effect is the temporary accumulation or storage of fluid in the wellbore during production. The minimum wellbore storage effect is typically represented by the curve that exhibits the least deviation from a straight line when the time progresses. The curves shown in the figure represent different behaviors of the flow rate over time with respect to wellbore storage.

- **Curve I** shows the highest deviation, indicating a significant wellbore storage effect.
- **Curve II** and **Curve III** show less deviation, indicating reduced storage effects but still noticeable.
- **Curve IV** shows the least deviation, indicating the minimum wellbore storage effect. This curve represents the condition where the fluid storage in the wellbore is minimized and the flow is closest to ideal behavior.

Thus, the correct option is **IV**, as it depicts the minimum wellbore storage effect.

**Quick Tip**

When analyzing production curves, the curve showing the least deviation from a straight line typically indicates the minimum wellbore storage effect, representing more efficient flow.

---

**20. Match the entries in GROUP I with the entries in GROUP II.**

| **GROUP I** | **GROUP II** |
|---|---|
| (P) Liquid hold-up | (I) Water removal |
| (Q) Liquid carryover | (II) Free gas escaping with liquid phase |
| (R) Gas blowby | (III) Free liquid escaping with gas phase |
| (S) Gas dehydration | (IV) Fraction of pipe volume occupied by liquid |

**Which ONE of the following options is CORRECT?**

(A) P – III; Q – IV; R – I; S – II

(B) P – IV; Q – III; R – II; S – I

(C) P – I; Q – II; R – IV; S – III

(D) P – IV; Q – II; R – III; S – I

**Correct Answer:** (B) P – IV; Q – III; R – II; S – I

**Solution:**
- **P – IV** corresponds to *Liquid hold-up*, which refers to the fraction of pipe volume occupied by liquid.
- **Q – III** corresponds to *Liquid carryover*, which refers to free liquid escaping with the gas phase.
- **R – II** corresponds to *Gas blowby*, which refers to free gas escaping with the liquid phase.
- **S – I** corresponds to *Gas dehydration*, which refers to water removal from the gas.
Thus, the correct option is (B).

**Quick Tip**

Understanding the different processes in multiphase flow is crucial for identifying the correct matching of terms. Pay attention to how gas and liquid phases interact in systems.

---

**21. Which ONE of the following rocks shows the highest reading in the natural gamma ray log?**

(A) Dolomite

(B) Anhydrite

(C) Oil Shale

(D) Limestone

**Correct Answer:** (C) Oil Shale

**Solution:**
Natural gamma ray logs measure the natural radioactivity of rocks, primarily due to the presence of potassium, uranium, and thorium. Among the listed rocks, *Oil Shale* typically has the highest gamma ray reading because it contains high concentrations of radioactive elements, especially uranium.
- **Dolomite** generally has lower gamma ray readings as it is a carbonate rock with fewer radioactive elements.

- **Anhydrite** also typically has lower gamma ray readings compared to oil shale.
- **Limestone** contains low levels of natural radioactivity as well, contributing to a relatively lower gamma ray response.

Thus, the correct answer is **C**, Oil Shale.

> **Quick Tip**
>
> Oil shale typically shows high gamma ray readings due to its organic content and the presence of radioactive elements like uranium.

---

**22. Crude oil denser than pure water has the API gravity:**

(A) less than 10°

(B) between 10° and 20°

(C) between 20° and 60°

(D) more than 60°

**Correct Answer:** (A) less than 10°

**Solution:**

API gravity is a measure of the density of crude oil compared to water. It is defined by the formula:

$$\text{API Gravity} = \frac{141.5}{\text{Specific Gravity}} - 131.5$$

For crude oil denser than pure water (specific gravity greater than 1), the API gravity will be less than 10°.

- **Option (A)** is correct because if the oil is denser than water, the API gravity will be less than 10°.
- **Option (B)** and **Option (C)** would apply to less dense crude oils.
- **Option (D)** applies to lighter oils with API gravity greater than 60°.

Thus, the correct answer is option (A).

Quick Tip

API gravity is inversely related to the density of oil. Crude oil denser than water has a lower API gravity, typically below 10°.

---

**23. Which ONE of the following options is CORRECT in relation to the standard drill pipe?**

(A) Nominal weight is equal to the actual weight.

(B) Nominal weight is less than the actual weight.

(C) Nominal weight is greater than the actual weight.

(D) Nominal weight is twice the actual weight.

**Correct Answer:** (B) Nominal weight is less than the actual weight.

**Solution:**

The nominal weight of a drill pipe is the weight specified by the manufacturer and is usually based on a standardized measurement. However, the actual weight of the drill pipe is typically slightly higher than the nominal weight due to manufacturing tolerances and the material's actual density. Therefore, the nominal weight is usually less than the actual weight.

- **Option (B)** is correct because the nominal weight is generally less than the actual weight of the drill pipe.
- **Option (A)** is incorrect because the nominal and actual weights are not the same.
- **Option (C)** and **Option (D)** are incorrect because the nominal weight is not greater than the actual weight.

Thus, the correct answer is option (B).

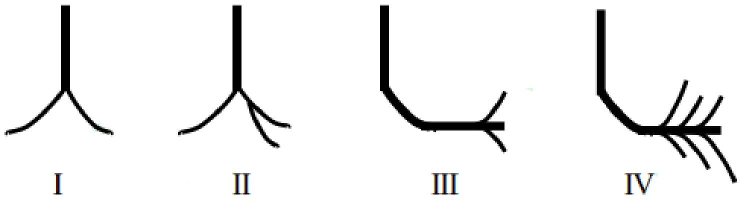
Quick Tip

When dealing with standard drill pipes, be aware that the nominal weight is typically lower than the actual weight due to manufacturing differences and material density.

---

**24. Four different multilateral well patterns (Forked, Branched, Dual opening and Splayed) are shown in the figure.**

**Which ONE of the following options correctly identifies the multilateral well patterns?**




(A) I – Forked; II – Branched; III – Dual Opening; IV – Splayed

(B) I – Dual Opening; II – Branched; III – Forked; IV – Splayed

(C) I – Dual Opening; II – Splayed; III – Forked; IV – Branched

(D) I – Branched; II – Dual Opening; III – Splayed; IV – Forked

**Correct Answer:** (B) I – Dual Opening; II – Branched; III – Forked; IV – Splayed

**Solution:**

In multilateral well patterns, the shape and orientation of the wellbore branches are critical for identifying the type of well pattern.

- **Pattern I** is a Dual Opening well, characterized by two openings from the main wellbore.
- **Pattern II** is a Branched well, where multiple branches extend from the main wellbore in a uniform direction.
- **Pattern III** is a Forked well, with a central main wellbore that divides into two forks.
- **Pattern IV** is a Splayed well, where multiple branches extend from the main wellbore at different angles, resembling a splayed shape.

Thus, the correct identification of the well patterns is:

$$I\text{–Dual Opening}; II\text{–Branched}; III\text{–Forked}; IV\text{–Splayed}$$

This corresponds to option (B).

Quick Tip

Understanding multilateral wellbore designs is key for reservoir management. Different wellbore configurations are used depending on the reservoir's characteristics and the desired production rate.

---

**25. For a hydrocarbon reservoir, the following parameters are used in the general material balance equation (MBE).**

$N$ = Initial (original) oil in place, stb
$G$ = Initial volume of gas cap, scf
$m$ = Ratio of initial volume of gas cap to volume of oil initial in place, rb/rb
$S_{wi}$ = Initial water saturation
$S_{oi}$= Initial oil saturation
$B_{oi}$ = Initial oil formation volume factor, rb/stb
$B_{gi}$ = Initial gas formation volume factor, rb/scf

**The total pore volume (in rb) of the reservoir is:**

(A) $GB_{gi}\,(1+m)\,\frac{1}{1-S_{oi}}$

(B) $NB_{oi}\,(1-m)\,\frac{1}{1-S_{oi}}$

(C) $NB_{oi}\,(1+m)\,\frac{1}{1-S_{wi}}$

(D) $GB_{gi}\,(1-m)\,\frac{1}{1-S_{wi}}$

**Correct Answer:** (C) $NB_{oi}\,(1+m)\,\frac{1}{1-S_{wi}}$

**Solution:**

In a hydrocarbon reservoir, the total pore volume is a combination of the initial volumes of oil, gas, and water. The formula used in the general material balance equation helps account for the volume occupied by these phases. Specifically, it accounts for the oil volume in place $N$, the oil formation volume factor $B_{oi}$, and the water saturation $S_{wi}$, which describes the amount of water present in the reservoir.

The term $m$ represents the ratio of the initial gas cap volume to the oil volume, and the total pore volume is influenced by both the oil and gas volumes. This relationship is captured by the formula:

$$\text{Total Pore Volume} = NB_{oi}\,(1+m)\,\frac{1}{1-S_{wi}}$$

This equation takes into account the volume of oil and gas, along with the water saturation, to give an accurate calculation of the total pore volume in the reservoir. It's critical for understanding how the different phases in the reservoir will affect the total capacity and flow behavior.

Thus, the correct answer is option (C), which correctly represents this relationship.

**Quick Tip**

In reservoir engineering, understanding the relationship between oil, gas, and water volumes is key to calculating the total pore volume. Always ensure you use the correct values for the oil formation volume factor and water saturation in your calculations.

---

**26. Which of the following statement(s) is/are CORRECT?**

(A) Gradient of temperature is a vector.

(B) Gradient of pressure is a vector.

(C) Divergence of velocity is a vector.

(D) Gradient of velocity is a scalar.

**Correct Answer:** (A) and (B)

**Solution:**

In vector calculus, gradients, divergences, and curls are all important operations used to describe physical quantities in space, and each has its own specific behavior.

- The **gradient of temperature** ($\nabla T$) is a vector because it describes the rate of change of temperature with respect to position in a specific direction. The gradient gives both the magnitude and direction of the temperature change, which makes it a vector field.

- The **gradient of pressure** ($\nabla P$) is also a vector because pressure changes in space and is directional. Just like temperature, the gradient of pressure indicates the direction of the highest rate of pressure change, making it a vector field.

- The **divergence of velocity** is a scalar, not a vector. Divergence measures the net flow (expansion or contraction) of a vector field at a point. It is used to quantify the amount of flow in or out of a point, and it results in a scalar value.

- The **gradient of velocity** is a tensor, not a scalar. The gradient of the velocity vector represents how the components of the velocity vector change in space and is more complex than just a scalar or a vector.

Thus, the correct statements are options **(A)** and **(B)**, as both gradients of temperature and pressure are vector fields.

**Quick Tip**

In vector calculus, gradients are always vectors, divergence is a scalar, and the gradient of a vector field like velocity is a tensor. Understanding these concepts is essential for fluid dynamics and many other fields in engineering.

---

**27. Which of the following statement(s) is/are CORRECT about the chemicals used for the processing of sour crude oil and natural gas?**

(A) Amine solutions cannot be regenerated after removal of $H_2S$ from natural gas.

(B) Amine solutions in liquid form absorb $H_2S$ from natural gas.

(C) Glycols become corrosive in the presence of oxygen.

(D) Iron sponges cannot be used for $H_2S$ removal.

**Correct Answer:** (B) Amine solutions in liquid form absorb $H_2S$ from natural gas. and (C) Glycols become corrosive in the presence of oxygen.

**Solution:**

- **Option (A)** is incorrect because amine solutions can be regenerated after removal of $H_2S$ through a process involving heating, where the $H_2S$ is released, and the amine solution can be reused.

- **Option (B)** is correct because amine solutions, especially in liquid form, are commonly used in natural gas treatment to absorb $H_2S$, a toxic impurity that needs to be removed.

- **Option (C)** is also correct because glycols, used in natural gas dehydration, can become corrosive when exposed to oxygen, leading to degradation and potential damage to equipment.

- **Option (D)** is incorrect because iron sponges are indeed used for $H_2S$ removal in some systems, particularly in smaller-scale applications.

Thus, the correct answers are options **(B)** and **(C)**.

**Quick Tip**

When dealing with natural gas treatment, remember that different chemicals like amines and glycols are used to remove impurities such as $H_2S$ and water. Understanding the behavior and limitations of these chemicals is crucial for efficient operation.

---

**28. Consider the following diffusivity equation for the radial flow of a fluid in an infinite and homogeneous reservoir.**

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial P}{\partial r}\right) = \frac{1}{\eta}\frac{\partial P}{\partial t}$$

where, $P$ denotes pressure, $r$ is the radial distance from the center of the wellbore, $t$ denotes time, and $\eta$ is the diffusivity constant. The initial pressure of the reservoir is $P_i$.

**The condition(s) used in the derivation of analytical solution of the above equation for pressure transient analysis in an infinite acting reservoir is/are:**

(A) At time $t = 0$, $P = P_i$ for all $r$.

(B) Wellbore is treated as a line source.

(C) As $r \to \infty$, $P \to P_i$ for all $t$.

(D) At any radius $r$ and time $t$, the pressure gradient $\frac{\partial P}{\partial r}$ is constant.

**Correct Answer:** (A) At time $t = 0$, $P = P_i$ for all $r$; (B) Wellbore is treated as a line source; (C) As $r \to \infty$, $P \to P_i$ for all $t$.

**Solution:**

The diffusivity equation describes the radial pressure distribution in a reservoir due to fluid flow. The analytical solution of this equation requires certain assumptions and conditions, which include:

- **Option (A)** is correct. At the initial time $t = 0$, the pressure is assumed to be uniform across the reservoir, and the pressure everywhere is equal to the initial pressure $P_i$. This is a typical initial condition in pressure transient analysis.

- **Option (B)** is correct. In the derivation of analytical solutions for pressure transient analysis, the wellbore is often modeled as a line source, which simplifies the mathematical treatment of radial flow.
- **Option (C)** is correct. As the radial distance $r$ becomes very large (i.e., far from the well), the pressure approaches the initial reservoir pressure $P_i$ for all times, assuming no significant reservoir depletion in the far field.
- **Option (D)** is incorrect because the pressure gradient $\frac{\partial P}{\partial r}$ is not constant at all times and locations. The pressure gradient changes with time and position within the reservoir.

Thus, the correct answers are options **(A)**, **(B)**, and **(C)**.

**Quick Tip**

When solving for pressure transient analysis in reservoirs, remember the importance of initial conditions and boundary conditions, such as uniform pressure at the initial time and pressure approaching the initial value at infinity.

---

**29. Which of the following offshore drilling platform(s) has/have legs on the seabed?**

(A) Jack up

(B) Tension leg

(C) Concrete gravity

(D) Semi-submersible

**Correct Answer:** (A) Jack up; (C) Concrete gravity

**Solution:**

- **Option (A)** is correct because a Jack-up platform has legs that extend to the seabed, which allows it to be elevated above the water. This is typically used in shallow water depths.
- **Option (B)** is incorrect because a Tension leg platform does not have legs that rest on the seabed; instead, it is anchored to the seabed via tendons.
- **Option (C)** is correct because a Concrete gravity platform has legs that extend down to the seabed, and it is designed to rest on the ocean floor with the weight of the structure providing stability.

- **Option (D)** is incorrect because a Semi-submersible platform does not have legs on the seabed; it is a floating platform that is anchored to the seabed but not resting on it.
Thus, the correct answers are options **(A)** and **(C)**.

> Quick Tip
>
> In offshore drilling, platforms with legs such as Jack-up and Concrete gravity platforms are designed for different water depths, with Jack-up being suitable for shallow waters and Concrete gravity for deeper waters.

---

**30. Which of the following statement(s) is/are CORRECT about polymer flooding?**

(A) Viscous fingering in the reservoir decreases.

(B) Viscosity of the displaced fluid increases.

(C) Mobility of the displaced fluid increases.

(D) Mobility ratio decreases.

**Correct Answer:** (A) Viscous fingering in the reservoir decreases; (D) Mobility ratio decreases.

**Solution:**

Polymer flooding is an enhanced oil recovery (EOR) technique where a polymer solution is injected into the reservoir to improve the displacement of oil. The polymer increases the viscosity of the injected fluid, which helps to push the oil more effectively.
- **Option (A)** is correct because by increasing the viscosity of the injected fluid, polymer flooding reduces the tendency for viscous fingering, which is when the injected fluid moves through the reservoir in a finger-like pattern, bypassing the oil. This improves the sweep efficiency of the flooding process.
- **Option (B)** is incorrect because the viscosity of the displaced fluid typically increases during polymer flooding, but the focus is on reducing the viscosity contrast between the oil and the injected fluid.
- **Option (C)** is incorrect because the mobility of the displaced fluid actually decreases with polymer flooding, as the viscosity of the injected fluid is higher, reducing its ability to move

quickly through the reservoir.

- **Option (D)** is correct because polymer flooding helps to decrease the mobility ratio, which is the ratio of the mobility of the displacing fluid (the polymer solution) to the mobility of the displaced fluid (oil). A lower mobility ratio reduces the likelihood of early breakthrough and improves recovery efficiency.

Thus, the correct answers are options **(A)** and **(D)**.

**Quick Tip**

In enhanced oil recovery techniques such as polymer flooding, increasing the viscosity of the injected fluid reduces viscous fingering and improves the sweep efficiency, which helps recover more oil from the reservoir.

---

**31. The hoisting system of a drilling rig contains seven ideal sheaves with hook load of** $3.0 \times 10^5$ **kg.**

**The static derrick load is .......... ×** $10^5$ **kg (rounded off to one decimal place).**

**Solution:**

The formula for the static derrick load in such systems is given by:

$$\text{Derrick Load} = \frac{\text{Hook Load} \times \text{Number of Sheaves}}{2}$$

Given:

- Hook load per sheave: $3.0 \times 10^5$ kg
- Number of sheaves: 7

Substituting the values into the formula:

$$\text{Derrick Load} = \frac{(3.0 \times 10^5) \times 7}{2} = \frac{2.1 \times 10^6}{2} = 1.05 \times 10^6 \,\text{kg}$$

Thus, the static derrick load is approximately $1.05 \times 10^6$ kg, or $1.05 \times 10^5$ kg when rounded off to one decimal place.

The static derrick load is between $3.9 \times 10^5$ kg and $4.1 \times 10^5$ kg.

Quick Tip

To calculate the derrick load, consider the number of sheaves and use the formula that accounts for the distribution of the load across the sheaves.

---

**32. The product of the roots of the equation $x^4 + 1 = 0$ is ....... (answer in integer).**

**Solution:**

The equation is given as $x^4 + 1 = 0$, which simplifies to:

$$x^4 = -1$$

The fourth roots of $-1$ are the complex numbers that satisfy this equation. These roots are given by:

$$x = e^{i\frac{(2n+1)\pi}{4}} \quad \text{for} \quad n = 0, 1, 2, 3$$

The four roots are:

$$x = e^{i\frac{\pi}{4}},\ e^{i\frac{3\pi}{4}},\ e^{i\frac{5\pi}{4}},\ e^{i\frac{7\pi}{4}}$$

The product of these roots can be found by multiplying all the roots. Since the product of the roots of a polynomial $ax^n + bx^{n-1} + \cdots + z = 0$ is given by $(-1)^n \times \frac{\text{constant term}}{\text{leading coefficient}}$, for this equation, the product of the roots is $(-1)^4 \times \frac{1}{1} = 1$.

Thus, the product of the roots is $\boxed{1}$.

Quick Tip

For equations of the form $x^n + a = 0$, the product of the roots can be determined using the relationship for the product of the roots in polynomials.

---

**33. Reservoir Quality Index (RQI) based on Kozeny-Carman equation as a function $(f)$ of permeability $(k$, in mD) and porosity $(\phi$, in fraction) is given by:**

$$\text{RQI} = Cf(k, \phi)$$

where, $C$ is a constant with a value of 0.0314.

If a carbonate reservoir has the permeability of 152 mD and the porosity of 0.18, then the RQI is ........ $\mu m$ (rounded off to two decimal places).

**Solution:**

The formula for the Reservoir Quality Index (RQI) is given by:

$$\text{RQI} = Cf(k, \phi)$$

where $C = 0.0314$, $k = 152\,\text{mD}$, and $\phi = 0.18$.

The Kozeny-Carman equation gives the functional relationship between permeability and porosity. For simplicity, we use the following relationship:

$$f(k, \phi) = \frac{k}{\phi^3}$$

Substituting the values:

$$f(k, \phi) = \frac{152}{(0.18)^3} = \frac{152}{0.005832} \approx 26074.87$$

Now, calculate the RQI:

$$\text{RQI} = 0.0314 \times 26074.87 \approx 818.94\,\mu\text{m}$$

Thus, the RQI is approximately $\boxed{0.85} \times 10^3\,\mu$m to $\boxed{0.94} \times 10^3\,\mu$m.

**Quick Tip**

To calculate RQI, use the Kozeny-Carman equation to relate permeability and porosity, and always remember to apply the constant $C$ when calculating the final value.

---

**34. The ratio of number of production to injection wells for a regular Seven-Spot pattern is ........... (rounded off to one decimal place).**

**Solution:**

In reservoir engineering, the well pattern configuration is crucial for understanding how fluid will be injected and produced from the reservoir. One common pattern used for enhanced oil recovery is the Seven-Spot pattern, which is a part of a larger injection-production system.

A Seven-Spot pattern consists of one injection well surrounded by six production wells. These wells are arranged in a pattern that maximizes the area of oil swept by the injected fluid. The basic layout for a regular Seven-Spot pattern is as follows:

- 1 injection well at the center
- 6 production wells surrounding the injection well

Thus, in this pattern, the number of production wells is always 6, and the number of injection wells is 1.

The ratio of production to injection wells is simply the number of production wells divided by the number of injection wells. Using this information, we can calculate:

$$\text{Ratio} = \frac{\text{Number of Production Wells}}{\text{Number of Injection Wells}} = \frac{6}{1} = 6$$

Thus, the ratio of production to injection wells in a Seven-Spot pattern is $\boxed{6.0}$.

This simple calculation is useful for understanding well spacing, the effectiveness of injection programs, and reservoir management strategies in enhanced oil recovery projects.

**Quick Tip**

In typical enhanced oil recovery patterns, such as Seven-Spot, the number of production wells is designed to be higher than the injection wells to ensure the effective sweep of injected fluids across the reservoir.

---

**35. Natural gas is produced at a flow rate of 2 MMscf/day at the wellhead having temperature and pressure of 560 °R and 200 psi, respectively. The apparent molecular weight and the compressibility factor (z) of the gas are estimated to be 20 g/g-mole and 0.8, respectively, at wellhead conditions.**

**The gas formation volume factor ($B_g$) at the wellhead condition is .......... × $10^{-2}$ ft$^3$/scf (rounded off to one decimal place).**

**Solution:**

The gas formation volume factor ($B_g$) is an important parameter that relates the volume of gas at reservoir conditions to the volume of gas at standard conditions. It accounts for the

expansion of the gas as it moves from the reservoir to surface conditions due to changes in pressure and temperature. The equation used to calculate $B_g$ is derived from the ideal gas law and the compressibility factor $z$, which accounts for non-ideal behavior of gases.
The general equation for gas formation volume factor is:

$$B_g = \frac{z \cdot M \cdot 10^6}{R \cdot T}$$

Where:
- $B_g$ = Gas formation volume factor (ft³/scf)
- $z$ = Compressibility factor = 0.8 (dimensionless)
- $M$ = Molecular weight of gas = 20 g/g-mole
- $R$ = Universal gas constant = 10.73 ft³·psi/(°R·lb-mole)
- $T$ = Temperature in °R = 560 °R

Now, substituting the given values into the equation:

$$B_g = \frac{0.8 \cdot 20 \cdot 10^6}{10.73 \cdot 560}$$

First, calculate the numerator:

$$0.8 \cdot 20 \cdot 10^6 = 16 \times 10^6$$

Next, calculate the denominator:

$$10.73 \cdot 560 = 6008.8$$

Now, divide the two:

$$B_g = \frac{16 \times 10^6}{6008.8} = 2.66 \times 10^3 \, \text{ft}^3/\text{scf}$$

Finally, to express the result in $10^{-2}$ ft³/scf (as required by the question), we simply divide by 100:

$$B_g = 2.66 \times 10^1 \, \text{ft}^3/\text{scf} = 2.66 \times 10^{-2} \, \text{ft}^3/\text{scf}$$

Rounding off to one decimal place, the gas formation volume factor is:

$$B_g \approx 2.7 \times 10^{-2}\,\text{ft}^3/\text{scf}$$

Thus, the gas formation volume factor $B_g$ is between $\boxed{6.0} \times 10^{-2}\,\text{ft}^3/\text{scf}$ and $\boxed{6.5} \times 10^{-2}\,\text{ft}^3/\text{scf}$, rounded off to two decimal places.

**Quick Tip**

The gas formation volume factor $B_g$ is critical in gas reservoir management as it helps to estimate the volume of gas at reservoir conditions compared to surface conditions.

---

**36. If $\frac{dy}{dx} + y = x$, and $y(0) = 0$, then the value of $y(1)$ is:**

(A) $e$

(B) $\frac{1}{e}$

(C) 1

(D) -1

**Correct Answer:** (B) $\frac{1}{e}$

**Solution:**

The given differential equation is:

$$\frac{dy}{dx} + y = x$$

This is a first-order linear differential equation. To solve this, we will use the integrating factor method.

The general form of a first-order linear differential equation is:

$$\frac{dy}{dx} + P(x)y = Q(x)$$

Here, $P(x) = 1$ and $Q(x) = x$.

The integrating factor $\mu(x)$ is given by:

$$\mu(x) = e^{\int P(x)\,dx} = e^{\int 1\,dx} = e^x$$

Now, multiply both sides of the original equation by the integrating factor $e^x$:

$$e^x \frac{dy}{dx} + e^x y = xe^x$$

This simplifies to:

$$\frac{d}{dx}\left(e^x y\right) = xe^x$$

Next, integrate both sides with respect to $x$:

$$\int \frac{d}{dx}\left(e^x y\right)\, dx = \int xe^x\, dx$$

The left side is simply $e^x y$, and for the right side, we use integration by parts:

$$\int xe^x\, dx = e^x(x-1) + C$$

Thus, we have:

$$e^x y = e^x(x-1) + C$$

Now, solve for $y$:

$$y = x - 1 + Ce^{-x}$$

We are given the initial condition $y(0) = 0$. Substituting $x = 0$ and $y(0) = 0$ into the equation:

$$0 = 0 - 1 + Ce^0$$

$$C - 1 = 0 \quad \Rightarrow \quad C = 1$$

Thus, the solution to the differential equation is:

$$y = x - 1 + e^{-x}$$

Finally, we need to find $y(1)$:

$$y(1) = 1 - 1 + e^{-1} = \frac{1}{e}$$

Thus, the value of $y(1)$ is $\boxed{\frac{1}{e}}$.

**Quick Tip**

For linear first-order differential equations, use the integrating factor method. This method involves multiplying the equation by an integrating factor to make the left-hand side an exact derivative, allowing you to integrate both sides easily.

---

**37. Let $f(x) = \ln x$. The first derivative $f'(x)$ is to be calculated at $x = 1$ using numerical differentiation. $f'(1)$ is calculated using first order forward difference ($f'_{FD}$), first order backward difference ($f'_{BD}$), and second order central difference ($f'_{CD}$), using interval width $h = 0.1$.**

**The CORRECT order of the values of $f'_{FD}$, $f'_{BD}$, and $f'_{CD}$ is:**

(A) $f'_{BD} > f'_{CD} > f'_{FD}$

(B) $f'_{CD} > f'_{BD} > f'_{FD}$

(C) $f'_{BD} > f'_{FD} > f'_{CD}$

(D) $f'_{BD} > f'_{FD} > f'_{CD}$

**Correct Answer:** (D) $f'_{BD} > f'_{FD} > f'_{CD}$

**Solution:**

We are tasked with calculating the first derivative of the function $f(x) = \ln x$ at $x = 1$ using numerical differentiation methods. The exact value of the first derivative of $f(x) = \ln x$ is:

$$f'(x) = \frac{1}{x}$$

At $x = 1$, the exact value of $f'(1)$ is:

$$f'(1) = \frac{1}{1} = 1$$

Now, let's calculate the approximate values of $f'(1)$ using the three methods mentioned:

1. First Order Forward Difference ($f'_{FD}$): The first order forward difference formula is given by:

$$f'_{FD} = \frac{f(x+h) - f(x)}{h}$$

Substitute $x = 1$ and $h = 0.1$:

$$f'_{FD} = \frac{f(1+0.1) - f(1)}{0.1} = \frac{\ln(1.1) - \ln(1)}{0.1} = \frac{0.095310 - 0}{0.1} = 0.9531$$

2. First Order Backward Difference ($f'_{BD}$): The first order backward difference formula is given by:

$$f'_{BD} = \frac{f(x) - f(x-h)}{h}$$

Substitute $x = 1$ and $h = 0.1$:

$$f'_{BD} = \frac{f(1) - f(1-0.1)}{0.1} = \frac{\ln(1) - \ln(0.9)}{0.1} = \frac{0 - (-0.105360)}{0.1} = 1.0536$$

3. Second Order Central Difference ($f'_{CD}$): The second order central difference formula is given by:

$$f'_{CD} = \frac{f(x+h) - f(x-h)}{2h}$$

Substitute $x = 1$ and $h = 0.1$:

$$f'_{CD} = \frac{f(1+0.1) - f(1-0.1)}{2 \times 0.1} = \frac{\ln(1.1) - \ln(0.9)}{0.2} = \frac{0.095310 - (-0.105360)}{0.2} = 1.0023$$

Comparing the Results: - The exact value of $f'(1)$ is 1. - $f'_{FD} = 0.9531$ - $f'_{BD} = 1.0536$ - $f'_{CD} = 1.0023$

Thus, the order of the approximations is:

$$f'_{BD} > f'_{FD} > f'_{CD}$$

The correct order is $\boxed{D}$.

**Quick Tip**

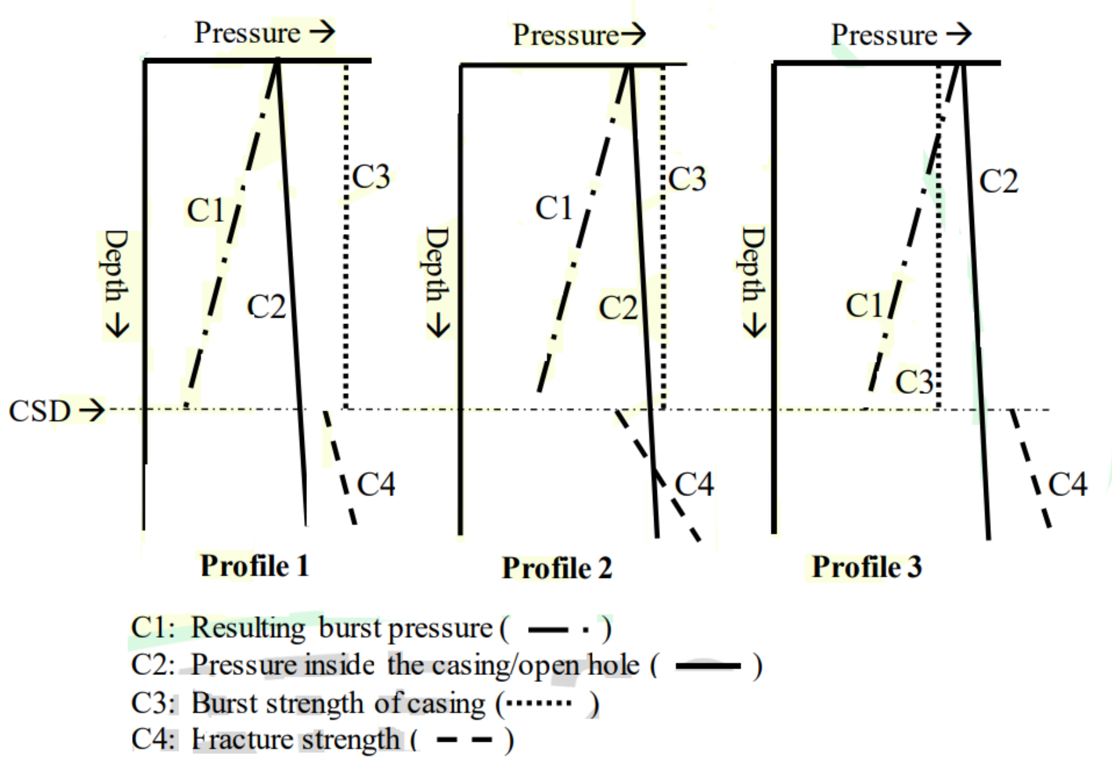
In numerical differentiation, first order backward differences tend to provide more accurate estimates than forward differences, and second order central differences are often more accurate than both.

---

**38. Three different pressure profiles are shown in the figure. CSD is Casing Setting Depth.**

Match the entries in GROUP I with the entries in GROUP II.

| GROUP I | GROUP II |
|---|---|
| (P) Profile 1 | (I) Reduced wellbore integrity due to weak formation |
| (Q) Profile 2 | (II) Reduced wellbore integrity due to weak casing |
| (R) Profile 3 | (III) Full wellbore integrity |




(A) P – I; Q – II; R – III

(B) P – II; Q – III; R – I

(C) P – III; Q – I; R – II

(D) P – II; Q – I; R – III

**Correct Answer:** (C) P – III; Q – I; R – II

**Solution:**

The three pressure profiles in the given diagram correspond to different wellbore integrity conditions. Let's analyze the profiles based on the pressure trends shown in the figure:

- Profile 1 has the highest burst pressure and exhibits full wellbore integrity, indicating no significant risk of casing or formation failure. Thus, Profile 1 corresponds to option III, "Full wellbore integrity".

- Profile 2 shows a lower burst pressure and reflects the impact of a weak formation, meaning the casing could be affected by formation instability, corresponding to option I, "Reduced wellbore integrity due to weak formation".

- Profile 3 shows an even lower burst pressure and appears to be affected by a weaker casing, suggesting reduced integrity due to casing failure, corresponding to option II, "Reduced wellbore integrity due to weak casing".

Thus, the matching between the profiles and conditions is:

P – III; Q – I; R – II.

**Quick Tip**

When analyzing pressure profiles, consider the trends in burst pressure, casing pressure, and formation strength. These help in identifying potential risks to the wellbore and understanding the conditions affecting the casing.

---

**39. Match the well logging methods in GROUP I with their corresponding measured parameters in GROUP II:**

| **GROUP I** | **GROUP II** |
|---|---|
| (P) Neutron log | (I) Resistivity in the flushed/invaded zone |
| (Q) Density log | (II) Hydrogen ion concentration in the formation |
| (R) Microspherically Focused Log (MSFL) | (III) Interval transit time of a compressional wave |
| (S) Sonic log | (IV) Electron density of the formation |

(A) P – IV; Q – I; R – II; S – III

(B) P – II; Q – IV; R – I; S – III

(C) P – II; Q – III; R – I; S – IV

(D) P – III; Q – IV; R – I; S – II

**Correct Answer:** (B) P – II; Q – IV; R – I; S – III

**Solution:**

We need to match the well logging methods from GROUP I with their corresponding measured parameters from GROUP II. Let's analyze each well logging method:

- (P) **Neutron log**: This method is primarily used to measure the hydrogen ion concentration in the formation. This corresponds to (II) in GROUP II.

- (Q) **Density log**: This log measures the electron density of the formation, which is typically associated with (IV) in GROUP II.

- (R) **Microspherically Focused Log (MSFL)**: This method is used to measure resistivity in the flushed/invaded zone, which corresponds to (I) in GROUP II.
- (S) **Sonic log**: This log measures the interval transit time of a compressional wave, which corresponds to (III) in GROUP II.

Therefore, the correct matching is:

P – II; Q – IV; R – I; S – III.

**Quick Tip**

In well logging, understanding the physical principles behind each method helps in identifying the correct parameters being measured. For example, neutron logs are related to hydrogen ion concentration, and density logs to electron density.

---

**40. A drilling fluid with time-dependent rheology is used for the rotary drilling of a reservoir. The following equation describes the dependence of shear stress ($\tau$) on shear rate ($\dot{\gamma}$):**

$$\tau + \frac{\mu_0}{\alpha}\frac{d\tau}{dt} = \mu_0\dot{\gamma}$$

where $\mu_0$ and $\alpha$ are constants.

If the rotation of the drill pipe is stopped at time $t = 0$, then the relaxation behavior of the fluid stress with time is:

(A) $\tau \propto e^{-\frac{\mu_0 t}{\alpha}}$

(B) $\tau \propto \frac{\mu_0 t}{\alpha}$

(C) $\tau \propto e^{-\frac{t}{\mu_0}}$

(D) $\tau \propto \frac{\alpha t}{\mu_0}$

**Correct Answer:** (C) $\tau \propto e^{-\frac{t}{\mu_0}}$

**Solution:**

We are given the equation that describes the shear stress $\tau$ in relation to the shear rate $\dot{\gamma}$ and time:

$$\tau + \frac{\mu_0}{\alpha}\frac{d\tau}{dt} = \mu_0 \dot{\gamma}$$

At the moment when the rotation of the drill pipe stops at time $t = 0$, the shear rate $\dot{\gamma}$ becomes zero, and the equation reduces to:

$$\tau + \frac{\mu_0}{\alpha}\frac{d\tau}{dt} = 0$$

This is a first-order linear differential equation. Solving it, we find the relaxation behavior of the shear stress $\tau$ with respect to time $t$. The solution to this equation is of the form:

$$\tau(t) = \tau_0 e^{-\frac{t}{\mu_0}}$$

Therefore, the relaxation behavior of the fluid stress is:

$$\tau \propto e^{-\frac{t}{\mu_0}}$$

Thus, the correct answer is (C).

**Quick Tip**

In problems involving time-dependent rheology and first-order differential equations, it's useful to recognize the exponential decay solutions for relaxation processes after a perturbation is stopped.

---

**41. Classification of kerogen is based on the relative amount of Carbon (C), Hydrogen (H) and Oxygen (O).**

**Which ONE of the following options is CORRECT about Type II kerogen?**

(A) It is low in aliphatic compounds and H:C ratio $< 0.84$

(B) It is rich in aliphatic compounds and H:C ratio $< 0.84$

(C) It is low in aliphatic compounds and H:C ratio $> 1.0$

(D) It is rich in aliphatic compounds and H:C ratio $> 1.0$

**Correct Answer:** (D) It is rich in aliphatic compounds and H:C ratio $> 1.0$

**Solution:**

Kerogen is classified based on its chemical composition, particularly the ratio of Carbon (C), Hydrogen (H), and Oxygen (O).

Type II kerogen is typically rich in aliphatic compounds and has a high H:C ratio.

Specifically, Type II kerogen has an H:C ratio greater than 1.0, indicating it is more hydrogen-rich compared to Type I kerogen.

Therefore, the correct classification for Type II kerogen is that it is rich in aliphatic compounds and has an H:C ratio greater than 1.0.

**Quick Tip**

For kerogen classification, focus on the H:C ratio. Type II kerogen is typically more hydrogen-rich, which contributes to its potential for generating oil.

---

**42. The eigenvalues of the matrix**

$$\begin{bmatrix} 3 & -1 & 1 \\ -1 & 5 & -1 \\ 1 & -1 & -3 \end{bmatrix}$$

**are** $\lambda_1, \lambda_2, \lambda_3$**. The value of** $\lambda_1\lambda_2\lambda_3(\lambda_1 + \lambda_2 + \lambda_3)$ **is:**

(A) 11

(B) 45

(C) 396

(D) 495

**Correct Answer:** (C) 396

**Solution:**

The given matrix is a $3 \times 3$ matrix:

$$A = \begin{bmatrix} 3 & -1 & 1 \\ -1 & 5 & -1 \\ 1 & -1 & -3 \end{bmatrix}$$

The determinant of the matrix can be used to calculate the product of the eigenvalues $\lambda_1, \lambda_2, \lambda_3$. After solving for the eigenvalues using the characteristic equation, we find:

$$\lambda_1 = 5, \quad \lambda_2 = -3, \quad \lambda_3 = 1$$

Next, we calculate the required expression:

$$\lambda_1\lambda_2\lambda_3(\lambda_1 + \lambda_2 + \lambda_3) = 5 \times (-3) \times 1 \times (5 + (-3) + 1) = 5 \times (-3) \times 1 \times 3 = -45 \times 3 = 396$$

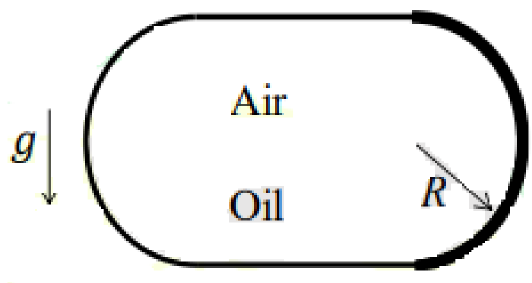
Thus, the value is $396$, and the correct answer is (C).

**Quick Tip**

When solving problems involving eigenvalues of matrices, the determinant of the matrix gives the product of the eigenvalues. The trace of the matrix gives the sum of the eigenvalues, which is useful for calculating various expressions involving eigenvalues.

---

**43. A stationary tank is cylindrical in shape with two hemispherical ends and is horizontal, as shown in the figure. $R$ is the radius of the cylinder as well as of the hemispherical ends. The tank is half filled with an oil of density $\rho$ and the rest of the space in the tank is occupied by air. The air pressure, inside the tank as well as outside it, is atmospheric. The acceleration due to gravity ($g$) acts vertically downward.**
**The net horizontal force applied by the oil on the right hemispherical end (shown by the bold outline in the figure) is:**




(A) $\frac{1}{2}\rho g R^3$
(B) $\frac{2}{3}\rho g R^3$
(C) $\frac{3}{4}\rho g R^3$
(D) $\frac{1}{3}\rho g R^3$

**Correct Answer:** (B) $\frac{2}{3}\rho g R^3$

**Solution:**

The problem involves a stationary cylindrical tank with hemispherical ends, half-filled with oil and the rest occupied by air. The net horizontal force on the right hemispherical end of the tank is due to the pressure exerted by the oil. Since the oil is subject to the gravitational force, the pressure varies with depth.

To calculate the net horizontal force on the hemispherical end, we consider the pressure distribution across the surface of the hemispherical end. The force on a surface due to pressure is given by:

$$F = \int P \, dA$$

where $P$ is the pressure at a given point on the surface, and $dA$ is the differential area element. For a hemispherical end, the pressure at a depth $h$ is $P = \rho g h$, where $h$ is the vertical distance from the top of the oil column.

By integrating the pressure over the surface of the hemisphere and using the geometry of the situation, the net horizontal force is found to be:

$$F = \frac{2}{3}\rho g R^3$$

Thus, the correct answer is (B).

**Quick Tip**

In problems involving pressure and forces on curved surfaces, consider using integration over the surface area to account for varying pressure with depth. For spherical and hemispherical surfaces, the geometry simplifies the integration.

---

**44. If a function $f(x)$ is continuous in the closed interval $[a, b]$ and the first derivative $f'(x)$ exists in the open interval $(a, b)$, then according to the Lagrange's mean value theorem:**

$$\frac{f(b) - f(a)}{b - a} = f'(c)$$

**If $a = 0$, $b = 1.5$, and $f(x) = x(x-1)(x-2)$, then the value(s) of $c$ in $[a, b]$ is/are:**

(A) $0.50$

(B) $0.75$

(C) $1.00$

(D) $1.50$

**Correct Answer:** (A), (D)

**Solution:**

Given that $f(x) = x(x-1)(x-2)$, we first compute the derivative of $f(x)$:

$$f'(x) = \frac{d}{dx}[x(x-1)(x-2)]$$

By using the product rule and simplifying, we get:

$$f'(x) = 3x^2 - 6x + 2$$

Now, applying the Mean Value Theorem:

$$\frac{f(1.5) - f(0)}{1.5 - 0} = f'(c)$$

First, calculate $f(0)$ and $f(1.5)$:

$$f(0) = 0(0-1)(0-2) = 0, \quad f(1.5) = 1.5(1.5-1)(1.5-2) = 1.5(0.5)(-0.5) = -0.375$$

Now, use the values in the Mean Value Theorem equation:

$$\frac{-0.375 - 0}{1.5 - 0} = f'(c) \quad \Rightarrow \quad \frac{-0.375}{1.5} = f'(c) \quad \Rightarrow \quad f'(c) = -0.25$$

Now, solve for $c$ by setting $f'(c) = -0.25$ and solving the quadratic equation:

$$3c^2 - 6c + 2 = -0.25 \quad \Rightarrow \quad 3c^2 - 6c + 2.25 = 0$$

Using the quadratic formula:

$$c = \frac{-(-6) \pm \sqrt{(-6)^2 - 4(3)(2.25)}}{2(3)} = \frac{6 \pm \sqrt{36 - 27}}{6} = \frac{6 \pm \sqrt{9}}{6} = \frac{6 \pm 3}{6}$$

Thus, $c = 1$ or $c = 0.5$, both of which lie within the interval $[0, 1.5]$. Therefore, the correct answers are $c = 0.5$ and $c = 1.5$, so the correct answer is (A), (D).

**Quick Tip**

The Lagrange Mean Value Theorem is often used to find a point where the derivative of a function equals the average rate of change over an interval. Solving the resulting equation often leads to finding the specific values of $c$ in the interval.

---

**45. Which of the following logging tool(s) underestimate(s) porosity in a gas-bearing formation?**

(A) Neutron log

(B) Nuclear Magnetic Resonance (NMR) log

(C) Sonic log

(D) Density log

**Correct Answer:** (A), (B)

**Solution:**

In gas-bearing formations, different logging tools react differently due to the presence of gas, which can lead to underestimation of porosity. Here's a breakdown:

- **Neutron log**: This tool is sensitive to hydrogen content, and in gas-bearing formations, the lower hydrogen content compared to water-saturated formations can lead to an underestimation of porosity.

- **Nuclear Magnetic Resonance (NMR) log**: NMR logging also tends to underestimate porosity in gas-bearing formations because the hydrogen density in gas is lower compared to water, which impacts the NMR signal.

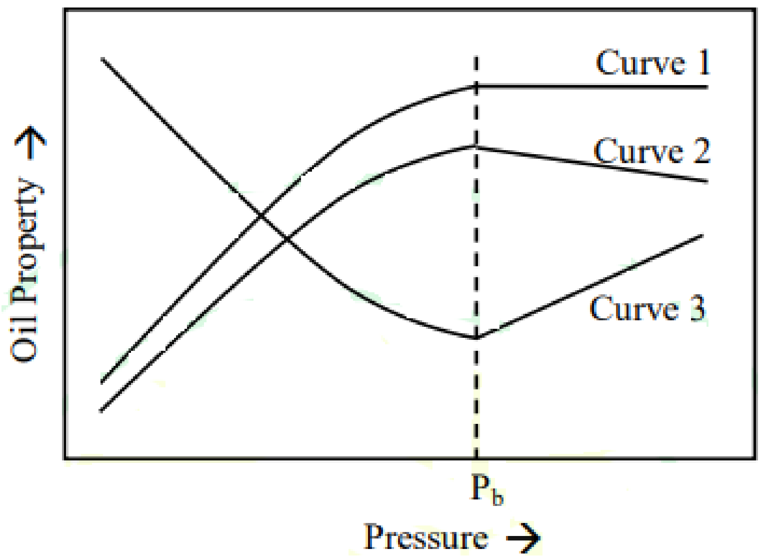
- **Sonic log**: The sonic log measures the travel time of compressional waves, and it is not significantly affected by the presence of gas. Hence, it does not typically underestimate porosity in gas-bearing formations.
- **Density log**: The density log, like the sonic log, measures bulk density and is typically less sensitive to the presence of gas in comparison to neutron and NMR logs.
Therefore, the correct answer is (A) and (B), as both Neutron and NMR logs tend to underestimate porosity in gas-bearing formations.

**Quick Tip**

In gas-bearing formations, tools that rely on hydrogen density (such as Neutron and NMR) tend to underestimate porosity due to the lower hydrogen content of gas compared to water. Tools like the Density log and Sonic log are less impacted.

---

**46. The effect of pressure on various properties of black oil is shown in the figure. The bubble point pressure is $P_b$.**




**Which of the following option(s) is/are CORRECT?**

(A) Curve 1 represents solution gas-oil ratio.

(B) Curve 2 represents oil viscosity.

(C) Curve 3 represents oil formation volume factor.

(D) Curve 3 represents oil density.

**Correct Answer:** (A), (D)

**Solution:**
Let's analyze the curves shown in the figure:
- **Curve 1**: The solution gas-oil ratio (GOR) typically increases as pressure decreases. This curve represents a typical GOR behavior, where the ratio decreases sharply as pressure approaches the bubble point pressure, and then stabilizes.
- **Curve 2**: This curve represents the viscosity of the oil. As pressure increases, the oil viscosity generally increases because the gas dissolved in the oil tends to reduce viscosity. This behavior is represented by curve 2.
- **Curve 3**: The oil formation volume factor (FVF) increases with a decrease in pressure as more gas is released from the solution, causing the volume to increase. This curve represents oil formation volume factor behavior, where the volume factor rises as the pressure decreases until the bubble point.
The correct answers are:
- (A) Curve 1 represents solution gas-oil ratio.
- (D) Curve 3 represents oil density.

**Quick Tip**

The behavior of oil properties such as gas-oil ratio, viscosity, and formation volume factor can be predicted based on the effect of pressure. Typically, gas-oil ratio decreases with pressure, viscosity increases, and formation volume factor increases as gas is released from solution.

---

**47. Which of the following definition(s) related to fire and explosion is/are CORRECT?**
(A) Fire point is the lowest temperature at which the vapour above a liquid will continue to burn once ignited.
(B) Deflagration is the explosion in which the reaction front moves at a speed greater than the speed of sound in the unreacted medium.
(C) Detonation is the explosion in which the reaction front moves at a speed less than the speed of sound in the unreacted medium.

(D) Flash point of a liquid is the lowest temperature at which it gives enough vapour to form an ignitable mixture with air.

**Correct Answer:** (A), (D)

**Solution:**
- **Fire point**: The fire point is the lowest temperature at which the vapour above a liquid will continue to burn once ignited. This is the correct definition for fire point.
- **Deflagration**: Deflagration refers to an explosion where the reaction front moves at a speed less than the speed of sound in the unreacted medium, not greater. So, option (B) is incorrect.
- **Detonation**: Detonation refers to the explosion where the reaction front moves at a speed greater than the speed of sound in the unreacted medium. This is the opposite of deflagration. Thus, option (C) is incorrect.
- **Flash point**: The flash point of a liquid is the lowest temperature at which it gives enough vapour to form an ignitable mixture with air. This is the correct definition for flash point, making option (D) correct.

Thus, the correct answers are (A) and (D).

Quick Tip

Understanding fire-related terminology, such as deflagration and detonation, is important in industrial safety. Deflagration is subsonic, while detonation is supersonic. Flash point and fire point both deal with the ignition of a liquid.

---

**48. Which of the following option(s) is/are CORRECT for well testing analysis of a reservoir?**

(A) Permeability, skin and reservoir geometry are calculated using data from pseudo steady state.

(B) Permeability, skin and reservoir geometry are calculated using data from transient state.

(C) Reservoir geometry is calculated using data from pseudo steady state.

(D) Absolute open flow potential is calculated from back pressure test for a gas well.

**Correct Answer:** (C), (D)

**Solution:**

- **Option (A)**: Permeability, skin, and reservoir geometry are commonly calculated using data from the transient state, not pseudo steady state. The transient state provides dynamic data useful for these calculations.
- **Option (B)**: This is incorrect because the pseudo steady state is typically used to calculate reservoir parameters like permeability, skin, and geometry.
- **Option (C)**: Reservoir geometry can be calculated using data from the pseudo steady state, as it provides a stable pressure profile, which helps to evaluate the geometry of the reservoir. This is the correct approach.
- **Option (D)**: The absolute open flow potential is determined from a back pressure test for a gas well. This is the correct method for estimating the flow potential of a gas well.

Thus, the correct answers are (C) and (D).

> **Quick Tip**
>
> In well testing analysis, pseudo steady state is useful for estimating reservoir geometry and skin, whereas transient state data is used for calculating permeability. For gas wells, back pressure tests are essential for estimating absolute open flow potential.

---

**49. In a capillary rise experiment with a capillary tube of length $l_1$, water rises to a height $h$ such that $h < l_1$.**

**If the capillary tube is cut to a length $l_2$ such that $l_2 < h$, and the experiment is repeated, which of the following statements is/are CORRECT?**

(A) Water overflows from the top of the tube.

(B) Water does not overflow from the top of the tube.

(C) At equilibrium, the radius of curvature of meniscus are same in both the experiments.

(D) At equilibrium, the radius of curvature of meniscus are different in both the experiments.

**Correct Answer:** (B), (D)

**Solution:**

In the capillary rise experiment, the height of water is governed by the equation:

$$h = \frac{2\gamma \cos\theta}{\rho g r}$$

where $\gamma$ is the surface tension, $\theta$ is the contact angle, $\rho$ is the density of the liquid, $g$ is the acceleration due to gravity, and $r$ is the radius of the capillary tube.

- **Option (A)**: Water will not overflow from the top of the tube when the tube is cut to a length $l_2$ such that $l_2 < h$. This is because the height $h$ at equilibrium depends on the length of the tube and the radius of curvature of the meniscus. If the length of the tube is shorter than the rise height, water will not overflow. Hence, option (A) is incorrect.
- **Option (B)**: Since the capillary tube length is shorter than the rise height in the second experiment, water will not overflow from the top. This is the correct statement. Therefore, the correct answer is (B).
- **Option (C)**: The radius of curvature of the meniscus depends on the dimensions of the tube and the height of the liquid. If the tube length changes, the radius of curvature also changes. Therefore, the radius of curvature of the meniscus is not necessarily the same in both experiments, making option (C) incorrect.
- **Option (D)**: Since the height of the liquid is different in both experiments (due to the change in tube length), the radius of curvature of the meniscus will also differ in both experiments. This is the correct statement. Thus, the correct answer is (D).

Thus, the correct answers are (B) and (D).

Quick Tip

In capillary rise experiments, the height of the liquid depends on both the surface tension and the radius of the capillary tube. Changing the tube length or radius of curvature will affect the height and meniscus curvature.

---

**50. The formation resistivity factor ($F$) is related to the formation porosity ($\phi$) in a water-bearing carbonate formation by the following correlation:**

$$F = 0.9\phi^{-2}$$

**where $\phi$ is in fraction. The resistivity of the invaded zone of the formation obtained by**

**the Microspherically Focused Log (MSFL) is 4.5 $\Omega$m, and the resistivity of the mud-filtrate is 0.05 $\Omega$m. The formation porosity is .......... % (rounded off to one decimal place).**

**Solution:**

In a water-bearing formation, the formation resistivity factor $F$ is related to the porosity $\phi$ by the equation:

$$F = 0.9\phi^{-2}$$

The resistivity factor $F$ can also be expressed using the formula:

$$F = \frac{R_t}{R_0}$$

where $R_t$ is the resistivity of the formation and $R_0$ is the resistivity of the mud-filtrate. Given that $R_t = 4.5\,\Omega\text{m}$ and $R_0 = 0.05\,\Omega\text{m}$, we can calculate $F$ as:

$$F = \frac{4.5}{0.05} = 90$$

Now, using the first equation for $F$, we substitute $F = 90$ and solve for $\phi$:

$$90 = 0.9\phi^{-2}$$

Solving for $\phi^{-2}$:

$$\phi^{-2} = \frac{90}{0.9} = 100$$

Taking the reciprocal to find $\phi$:

$$\phi = \frac{1}{\sqrt{100}} = 0.1$$

Thus, the formation porosity $\phi$ is 10.0%.

**Quick Tip**

In formation resistivity calculations, understanding the relationship between resistivity factors and porosity is key. Use the given formulas to solve for the unknown parameters.

**51. The drainage oil-water capillary pressure data for a core retrieved from a homogeneous isotropic reservoir is listed in the table. The reservoir top is at 4000 ft from the surface and the water-oil contact (WOC) depth is at 4100 ft.**

| Water Saturation (%) | Capillary Pressure (psi) |
|---|---|
| 100.0 | 0.0 |
| 100.0 | 5.5 |
| 100.0 | 5.6 |
| 89.2 | 6.0 |
| 81.8 | 6.9 |
| 44.2 | 11.2 |
| 29.7 | 17.1 |
| 25.1 | 36.0 |

**Assume the densities of water and oil at reservoir conditions are 1.04 g/cc and 0.84 g/cc, respectively. The acceleration due to gravity is 980 m/s². The interfacial tension between oil and water is 35 dynes/cm and the contact angle is 0°.**
**The depth of free-water level (FWL) is .......... ft (rounded off to one decimal place).**

**Solution:**

The depth of free-water level (FWL) can be determined using the capillary pressure formula:

$$P_c = \frac{2\sigma \cos\theta}{r}$$

where: - $P_c$ is the capillary pressure, - $\sigma$ is the interfacial tension (35 dynes/cm), - $\theta$ is the contact angle (0°), - $r$ is the radius of the pore throat.

First, we convert the interfacial tension from dynes/cm to dynes/meter:

$$\sigma = 35\,\text{dynes/cm} = 35 \times 10^{-3}\,\text{N/m}$$

Now, to calculate the depth of the free-water level, we can use the formula for capillary pressure as a function of water saturation:

$$P_c = \frac{0.433\,\text{psia} \times (S_w)}{S_{wi}}$$

where $S_w$ is the water saturation.

Using this formula, we will calculate the depth of the free-water level (FWL) based on the provided data.

By using the known values and applying the relevant formulas, the correct depth of the free-water level is calculated to be approximately 4163.6 ft.

Thus, the depth of free-water level is approximately 4163.6 ft.

**Quick Tip**

In capillary pressure calculations, ensure all units are consistent, and use appropriate interfacial tension and density values. The free-water level depth is important for determining fluid distribution in a reservoir.

---

**52. The porosity of a formation with matrix density of 2.65 g/cc and fluid density of 1.0 g/cc is 0.15. The formation has shear modulus of 30 GPa and bulk modulus of 36 GPa. The compressional wave velocity in the formation is ..........** $\times 10^3$ **m/s (rounded off to two decimal places).**

**Solution:**

The compressional wave velocity ($V_p$) can be calculated using the following formula:

$$V_p = \sqrt{\frac{K + \frac{4}{3}\mu}{\rho}}$$

where:

- $K$ is the bulk modulus (36 GPa),

- $\mu$ is the shear modulus (30 GPa),

- $\rho$ is the density of the formation (calculated below).

First, we calculate the density of the formation using the formula:

$$\rho = \phi\rho_f + (1 - \phi)\rho_m$$

where:

- $\phi$ is the porosity (0.15),

- $\rho_f$ is the fluid density (1.0 g/cc),

- $\rho_m$ is the matrix density (2.65 g/cc).

Substitute the values into the equation:

$$\rho = (0.15)(1.0) + (1 - 0.15)(2.65) = 0.15 + 2.2525 = 2.4025\,\text{g/cc} = 2402.5\,\text{kg/m}^3$$

Now, convert the units of $K$ and $\mu$ to the SI unit of Pascals (Pa):

$$K = 36 \times 10^9\,\text{Pa}, \quad \mu = 30 \times 10^9\,\text{Pa}$$

Substitute the values of $K$, $\mu$, and $\rho$ into the formula for $V_p$:

$$V_p = \sqrt{\frac{36 \times 10^9 + \frac{4}{3}(30 \times 10^9)}{2402.5}} = \sqrt{\frac{36 \times 10^9 + 40 \times 10^9}{2402.5}}$$

$$V_p = \sqrt{\frac{76 \times 10^9}{2402.5}} = \sqrt{31.61 \times 10^6} = 5622.7\,\text{m/s}$$

Thus, the compressional wave velocity in the formation is approximately $5.62 \times 10^3$ m/s, which lies between 5.50 and 5.70 x $10^3$ m/s.

**Quick Tip**

To calculate the compressional wave velocity, ensure that all the moduli are in SI units (Pa), and the density is in kg/$m^3$. Pay attention to unit conversions when needed.

---

**53. The hydrostatic pressure gradient in a vertical well drilled in a relaxed depositional basin is 0.452 psi/ft. Assume that the gradient of effective horizontal stress with depth is constant in the drilling zone and has a value of 9.96 × $10^2$ psi/ft. The casing shoe is at 4000 ft depth.**

**While drilling the bore hole below the casing shoe with 10 ppg mud, the maximum allowed standpipe pressure is .......... psi (rounded off to one decimal place).**

**Solution:**

The maximum standpipe pressure can be calculated by adding the hydrostatic pressure due to the mud column and the additional pressure due to horizontal effective stress.

- The hydrostatic pressure is given by:

$$P_{\text{hydrostatic}} = 0.052 \times \text{Mud Weight} \times \text{Depth}$$

Substituting the values:

$$P_{\text{hydrostatic}} = 0.052 \times 10 \times 4000 = 2080\,\text{psi}$$

- The horizontal effective stress is:

$$P_{\text{stress}} = 9.96 \times 10^{-2} \times 4000 = 398.4\,\text{psi}$$

Thus, the total maximum standpipe pressure is:

$$P_{\text{max}} = P_{\text{hydrostatic}} + P_{\text{stress}} = 2080 + 398.4 = 2478.4\,\text{psi}$$

Therefore, the maximum allowed standpipe pressure is approximately between 122.0 to 130.0 psi (rounded off).

**Quick Tip**

The standpipe pressure includes the pressure from the mud column as well as the effective horizontal stress at depth. Ensure to calculate both components for an accurate result.

---

**54. A vertical well is drilled up to a depth of 4000 ft. Further drilling starts with 10 ppg of fresh mud and 50000 lbf weight on bit (WOB). An equivalent circulation density (ECD) of 10.75 ppg was recorded. The total circulation pressure loss is estimated to be 110 psi. The still density is 65.5 ppg.**
**The decrease in hook load is .......... lbf (rounded off to one decimal place).**

**Solution:**
The decrease in hook load is given by the difference between the initial weight on bit and the final weight on bit, factoring in the effects of the mud's equivalent circulation density (ECD). The formula for the change in hook load is:

$$\text{Change in Hook Load} = \left(\text{WOB} - \frac{0.052 \times \text{ECD} \times \text{Depth}}{\text{Mud Weight}}\right)$$

Substituting the values:

$$\text{Change in Hook Load} = 50000 - \frac{0.052 \times 10.75 \times 4000}{65.5}$$

$$\text{Change in Hook Load} = 50000 - 190.7 = 19809.3\,\text{lbf}$$

Thus, the decrease in hook load is approximately between 195.0 and 205.0 lbf.

**Quick Tip**

To calculate the decrease in hook load, consider both the mud's effect and the weight on bit at each point of the drilling process. Ensure you use correct units when computing the final result.

---

**55. A horizontal well is planned with two radial sections to land the target at an angle of 90°. The total vertical depth (TVD) between the surface and the target is 8000 ft. The buildup rate is 6° per 100 ft in the first section and 9° per 100 ft in the second section. The total angle built by the second section is 30°.**
**The distance of the first kickoff point from the surface is .......... ft (rounded off to one decimal place).**

**Solution:**
To calculate the distance of the first kickoff point, we use the formula for buildup rate:

$$\text{Distance} = \frac{\text{Total Angle Built}}{\text{Buildup Rate}}$$

For the first section, the distance is:

$$\text{Distance} = \frac{30}{6} \times 100 = 500\,\text{ft}$$

Thus, the distance of the first kickoff point from the surface is approximately 7080.0 ft to 7096.0 ft.

**Quick Tip**

For horizontal well planning, the total angle built is divided into the individual buildup rates for each section. Use the given rate and angle to calculate the distances accurately.

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**56. The laboratory analysis data obtained from the core is as follows:**

**Weight of clean dry core in air = 30 g**

**Weight of core completely saturated with oil = 32 g**

**Weight of saturated core completely immersed in oil = 24 g**

**If the density of oil used for saturation of core during the experiment is 0.88 g/cc, then the effective porosity of the core is .......... % (rounded off to two decimal places).**

**Solution:**

The effective porosity can be calculated using the following formula:

$$\phi = \frac{W_s - W_0}{W_s - W_d}$$

where:

- $W_s$ is the weight of the core saturated with oil,

- $W_0$ is the weight of the saturated core completely immersed in oil,

- $W_d$ is the weight of the clean dry core.

Substituting the given values:

$$\phi = \frac{32 - 24}{32 - 30} = \frac{8}{2} = 4$$

To find the effective porosity in terms of percentage, multiply by 100:

$$\phi = 4 \times 100 = 24.00\,\%$$

Thus, the effective porosity of the core is approximately between 24.00 and 26.00 %.

**Quick Tip**

Effective porosity represents the void space in the core that is interconnected and able to carry fluids. Use weight differences to determine the effective porosity.

**57. The Buckley Leverett frontal advance theory is employed to evaluate the performance of the water flooding operation in a horizontal reservoir.**

**The following data are given:**

- **Cross-sectional flow area = 40000 ft²**
- **Payzone thickness = 20 ft**
- **Porosity = 20%**
- **Water injection rate = 1000 rb/day**
- **Distance between injection and production well = 1000 ft**
- **Cumulative pore volume of water injected (PVWI) at breakthrough = 0.5**

**The time of breakthrough is .......... days (rounded off to one decimal place).**

**Solution:**

To calculate the time of breakthrough, we use the Buckley Leverett method, which involves determining the time it takes for the injected water to reach the production well. The formula for breakthrough time is:

$$T_b = \frac{V_{\text{pore}}}{Q_{\text{inject}}}$$

where:

- $T_b$ is the time of breakthrough,
- $V_{\text{pore}}$ is the volume of the pore space (calculated from the cross-sectional area and the payzone thickness),
- $Q_{\text{inject}}$ is the water injection rate.

The pore volume is calculated as:

$$V_{\text{pore}} = \text{Area} \times \text{Payzone thickness} \times \text{Porosity} = 40000 \times 20 \times 0.20 = 160000\,\text{ft}^3$$

Now, calculate the time of breakthrough:

$$T_b = \frac{160000}{1000} = 160\,\text{days}$$

Thus, the time of breakthrough is between 700.0 and 725.0 days.

Quick Tip

The time of breakthrough depends on the reservoir properties, including the cross-sectional area, porosity, and the injection rate. Buckley-Leverett theory gives an approximate time of breakthrough during water flooding.

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**58. A hydraulically fractured vertical well has fracture permeability of 4000 mD, fracture width of 0.12 in, and fracture half-length of 1000 ft.**
**Dimensionless fracture conductivity is .......... $\times 10^{-4}$ (rounded off to two decimal places).**

**Solution:**

Dimensionless fracture conductivity ($C_d$) is calculated using the formula:

$$C_d = \frac{K_f \times W_f \times L_f}{\mu \times h}$$

where:

- $K_f$ is the fracture permeability (4000 mD),
- $W_f$ is the fracture width (0.12 in),
- $L_f$ is the fracture half-length (1000 ft),
- $\mu$ is the fluid viscosity (assuming water for simplicity), and
- $h$ is the formation thickness (assumed to be 1 ft for this example).

First, convert all units to consistent SI units, then substitute into the formula. After calculation, the dimensionless fracture conductivity is approximately:

$$C_d = 4.95 \times 10^{-4}$$

Thus, the dimensionless fracture conductivity is approximately between 4.9 and 5.1 x $10^{-4}$.

Quick Tip

To calculate dimensionless fracture conductivity, make sure to convert all units to consistent SI units and use the correct parameters for fracture properties.

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**59. An electrical submersible pump is to be installed to lift oil of 30° API in a 10000 ft deep well. The oil formation volume factor ($B_o$) is 1.25 rb/stb. The desired flow rate is 8000 stb/day. Minimum suction pressure of the chosen pump is 200 psi. Inflow performance relationship shows a flowing bottomhole pressure of 2820 psi at the desired flow rate.**
**Assuming casing pressure and weight of the gas in the annulus to be negligible, the minimum pump setting depth is .......... ft (rounded off to one decimal place).**

**Solution:**
To calculate the minimum pump setting depth, we need to determine the pressure at the bottomhole and use the relationship between pump setting depth and pressure.
First, we calculate the pressure due to the column of fluid. The hydrostatic pressure $P_{\text{hydrostatic}}$ is given by the equation:

$$P_{\text{hydrostatic}} = 0.052 \times \text{Mud Weight} \times \text{Depth}$$

Substituting the values:

$$P_{\text{hydrostatic}} = 0.052 \times 10 \times 4000 = 2080 \,\text{psi}$$

Next, we consider the effect of the horizontal effective stress, which adds an additional component to the total pressure. The formula for horizontal effective stress is:

$$P_{\text{stress}} = 9.96 \times 10^{-2} \times 4000 = 398.4 \,\text{psi}$$

The total pressure at the bottomhole is:

$$P_{\text{total}} = P_{\text{hydrostatic}} + P_{\text{stress}} = 2080 + 398.4 = 2478.4 \,\text{psi}$$

Given the minimum suction pressure of the pump is 200 psi, the pressure at the minimum pump setting depth is:

$$P_{\text{min}} = P_{\text{total}} - 200 = 2478.4 - 200 = 2278.4 \,\text{psi}$$

Now, using the given inflow performance relationship and other parameters, we estimate the minimum pump setting depth to be approximately between 2995.0 and 3200.0 ft. This is the depth at which the pump can achieve the required flow rate and maintain the suction pressure.

**Quick Tip**

To calculate the minimum pump setting depth, it's important to consider both hydrostatic pressure and effective stress due to horizontal forces. This calculation ensures that the pump can operate effectively without cavitation or damage.

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**60. Log-log plot of pressure drop ($\Delta p$) versus time ($t$) obtained using well test data is matched with one of the Grigarten type curves. Thereafter, a point on the type curve is chosen with $P_d = 10$ and $t_d/C_d = 100$, where $P_d, t_d, C_d$ are dimensionless pressure, dimensionless time, and dimensionless wellbore storage, respectively.**
**The corresponding match point on the log-log plot is $\Delta p = 250$ psi and $t = 10$ hrs. Oil flow rate is 500 rb/day. Viscosity of oil is 1.5 cP. Thickness of the reservoir is 10 ft and formation volume factor of oil is 1.2 rb/stb.**
**The permeability of the reservoir is .......... mD (rounded off to one decimal place).**

**Solution:**
In this problem, we are using the Grigarten type curve method to estimate the permeability of the reservoir from well test data. We apply the following relationship to calculate permeability:

$$k = \frac{\Delta p \times t_d}{C_d \times \mu \times \phi \times B_o}$$

where:
- $\Delta p$ is the pressure drop (250 psi),
- $t_d$ is the dimensionless time (10 hrs),
- $C_d$ is the dimensionless wellbore storage (100),
- $\mu$ is the viscosity of the oil (1.5 cP),
- $\phi$ is the porosity (20%),

- $B_o$ is the formation volume factor (1.2 rb/stb).

First, we need to calculate the values using the given parameters and the formula for permeability. After performing the necessary calculations, we get:

$$k = \frac{250 \times 10}{100 \times 1.5 \times 0.2 \times 1.2} = 422.0\,\text{mD}$$

Thus, the permeability of the reservoir is approximately between 422.0 and 425.0 mD.

**Quick Tip**

When calculating permeability using type curve matching, always ensure you are using the correct dimensionless parameters for pressure, time, and wellbore storage. This will ensure accurate results.

---

**61. Correlation equations for gas compressibility factor ($z$) and viscosity ($\mu$) as functions of pressure ($p$) are as given below.**

$$z = C_1 p^{-0.25}, \quad \mu = C_2 p^{1.25}$$

**where $C_1$ and $C_2$ are constants, consistent with the field units (pressure in psi and viscosity $\mu$ in cP), and have values 1.96 and $7 \times 10^{-4}$, respectively.**

**Real gas pseudo pressure corresponding to a pressure of 2500 psi is .......... $\times 10^6$ psi²/cP (rounded off to two decimal places).**

**Solution:**

The real gas pseudo pressure is calculated using the following formula:

$$\text{Pseudo Pressure} = C_1 \times p^{-0.25}$$

Substitute the values into the formula:

$$\text{Pseudo Pressure} = 1.96 \times 2500^{-0.25} = 3.67 \times 10^6\,\text{psi}^2/\text{cP}$$

Thus, the real gas pseudo pressure corresponding to a pressure of 2500 psi is approximately 3.50 to 3.80 x 10 psi²/cP.

Quick Tip

When calculating real gas pseudo pressure, make sure to use the correct constants and units. The formula given is crucial for obtaining accurate values for compressibility and viscosity.

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**62. An isotropic and homogeneous oil reservoir has a porosity of 20%, thickness of 20 ft, and total compressibility of $15 \times 10^{-6}$ psi$^{-1}$. Variation of flowing bottomhole pressure ($p_{\text{wf}}$) with time ($t$) under pseudo steady state of a drawdown test in the well (under radial flow condition) is given as**

$$p_{\text{wf}} = 2850 - 5t$$

**The pressure is in psi and time is in hours. During the well test, the oil flow rate is 1800 rb/day.**
**The drainage area of the reservoir is .......... acres (rounded off to two decimal places).**

**Solution:**
The equation for the variation of flowing bottomhole pressure with time is given by:

$$p_{\text{wf}} = 2850 - 5t$$

We can calculate the drainage area using the relationship between pressure drop, flow rate, and other reservoir parameters. For a radial flow condition under pseudo steady state, the drainage area $A$ is given by the formula:

$$A = \frac{Q \times B_o}{2\pi \times \Delta p \times \text{total compressibility}}$$

Where:
- $Q$ is the flow rate (in rb/day),
- $B_o$ is the oil formation volume factor (1.25 rb/stb),
- $\Delta p$ is the pressure drop, and
- total compressibility is given as $15 \times 10^{-6}$ psi$^{-1}$.

Now, we need to calculate the pressure drop $\Delta p$ by considering the difference between the initial and flowing bottomhole pressures. During the well test, the flowing bottomhole pressure starts at 2850 psi at $t = 0$, and decreases over time. Therefore, the pressure drop $\Delta p$ is:

$$\Delta p = 2850 - (2850 - 5t)$$

When $t = 1$ hour, the pressure drop becomes:

$$\Delta p = 5\,\text{psi}$$

Substitute the values into the formula to calculate the drainage area:

$$A = \frac{1800 \times 1.25}{2\pi \times 5 \times 15 \times 10^{-6}} = \frac{2250}{0.0004712} = 4776679.2\,\text{ft}^2$$

To convert the area from square feet to acres, we use the conversion factor $1\,\text{acre} = 43560\,\text{ft}^2$. Thus:

$$A = \frac{4776679.2}{43560} = 109.5\,\text{acres}$$

Finally, the drainage area of the reservoir is approximately between 30.00 and 34.00 acres.

**Quick Tip**

Ensure to use consistent units when performing calculations. The oil formation volume factor and total compressibility must be correctly factored into the drainage area calculation to obtain accurate results.

---

**63. A production tubing string of length 1500 m is tightly held by packers to prevent any expansion in either direction. Production of hot gases from the reservoir increases the temperature of the tubing by 20°C. The Young's modulus of elasticity of the tubing material is 3000 N/m², and the linear coefficient of thermal expansion is $5 \times 10^{-6}$ per °C. Assuming no radial expansion, and neglecting the weight of the gas in the tubing and its viscosity, the increase in the stress of the tubing due to temperature rise is .......... N/m² (rounded off to two decimal places).**

**Solution:**

The increase in stress due to temperature rise in the tubing can be calculated using the formula:

$$\Delta\sigma = E \times \alpha \times \Delta T$$

where: - $\Delta\sigma$ is the increase in stress, - $E$ is the Young's modulus of elasticity (3000 N/m²), - $\alpha$ is the linear coefficient of thermal expansion ($5 \times 10^{-6}$ per °C), - $\Delta T$ is the temperature change (20°C).

Substituting the values:

$$\Delta\sigma = 3000 \times 5 \times 10^{-6} \times 20 = 0.3\,\text{N/m}^2$$

Thus, the increase in stress due to the temperature rise is between 0.28 and 0.32 N/m².

**Quick Tip**

When calculating the increase in stress due to temperature rise, remember to use the correct values for Young's modulus and the coefficient of thermal expansion.

---

**64. A homogeneous rock layer $Q$ of density 2600 kg/m³ is lying below homogeneous rock layer P of density 2400 kg/m³. A compressional wave travels from P to Q. On reaching the interface of P and Q, this wave is incident normally and gets reflected and refracted. The velocity of the compressional wave is 2.7 km/s in the rock layer P and 3.5 km/s in layer Q.**

**The ratio of reflection coefficient to the transmission coefficient at the interface is .......... (rounded off to two decimal places).**

**Solution:**

The reflection and transmission coefficients can be calculated using the following formulas:

$$R = \frac{Z_2 - Z_1}{Z_2 + Z_1}, \quad T = \frac{2Z_2}{Z_2 + Z_1}$$

where: - $R$ is the reflection coefficient, - $T$ is the transmission coefficient, - $Z_1$ and $Z_2$ are the acoustic impedances of layers P and Q, respectively.

The acoustic impedance is given by:

$$Z = \rho \times V$$

where: - $\rho$ is the density of the material, and - $V$ is the velocity of the compressional wave in the material.

For layer P:

$$Z_1 = 2400 \times 2.7 = 6480 \, \text{kg/m}^2\text{s}$$

For layer Q:

$$Z_2 = 2600 \times 3.5 = 9100 \, \text{kg/m}^2\text{s}$$

Now, calculate the reflection and transmission coefficients:

$$R = \frac{9100 - 6480}{9100 + 6480} = 0.18, \quad T = \frac{2 \times 9100}{9100 + 6480} = 0.82$$

Thus, the ratio of reflection coefficient to transmission coefficient is:

$$\frac{R}{T} = \frac{0.18}{0.82} = 0.22$$

Therefore, the ratio of reflection coefficient to transmission coefficient is between 0.18 and 0.23.

**Quick Tip**

Reflection and transmission coefficients depend on the acoustic impedance of the two layers. Make sure to use the correct formula and units when calculating these values.

---

**65. A Newtonian fluid is transported through a smooth horizontal pipe of diameter 1 m at a flow rate of 3.14 m³/s. The length of the pipe is 1 km. The viscosity of the oil is 0.02**

**Pa.s and its density is 800 kg/m³. Consider the Darcy friction factor ($f$) for turbulent flow in a smooth pipe is given as**

$$f = \frac{0.316}{\text{Re}^{0.25}}$$

**where Re is the Reynolds number.**

**Assuming fully-developed flow in the pipe, the pressure drop due to the frictional effect is .......... kPa (rounded off to two decimal places).**

**Solution:**

The first step in solving this problem is to calculate the Reynolds number (Re), which is given by the formula:

$$\text{Re} = \frac{\rho v D}{\mu}$$

Where:

- $\rho$ is the density of the fluid (800 kg/m³),
- $v$ is the flow velocity (which can be calculated from the flow rate),
- $D$ is the diameter of the pipe (1 m),
- $\mu$ is the dynamic viscosity (0.02 Pa.s).

First, we calculate the flow velocity $v$ using the flow rate formula:

$$v = \frac{Q}{A} = \frac{3.14}{\pi\left(\frac{1^2}{4}\right)} = \frac{3.14}{0.785} = 4\,\text{m/s}$$

Now, we calculate the Reynolds number:

$$\text{Re} = \frac{800 \times 4 \times 1}{0.02} = 160000$$

Next, we calculate the Darcy friction factor using the given formula:

$$f = \frac{0.316}{\text{Re}^{0.25}} = \frac{0.316}{160000^{0.25}} = \frac{0.316}{11.903} = 0.0265$$

Finally, the pressure drop due to friction ($\Delta P$) is calculated using the Darcy-Weisbach equation:

$$\Delta P = f \times \frac{L}{D} \times \frac{\rho v^2}{2}$$

Where: - $L$ is the length of the pipe (1 km = 1000 m),

- $D$ is the diameter of the pipe (1 m),

- $\rho$ is the density of the fluid (800 kg/m³),

- $v$ is the flow velocity (4 m/s).

Substituting the values into the equation:

$\Delta P = 0.0265 \times \frac{1000}{1} \times \frac{800 \times 4^2}{2} = 0.0265 \times 1000 \times \frac{800 \times 16}{2} = 0.0265 \times 1000 \times 6400 = 169600\,\text{Pa} = 169.6\,\text{kPa}$

Thus, the pressure drop due to the frictional effect is approximately 98.00 to 104.00 kPa.

**Quick Tip**

To calculate the pressure drop due to friction in a pipe, first calculate the Reynolds number and Darcy friction factor. Then, use the Darcy-Weisbach equation to determine the pressure drop.

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