GATE 2026 Petroleum Engineering Question Paper with Solutions

Time Allowed :3 Hour	**Maximum Marks :**100	**Total Questions :**65

General Instructions

Read the following instructions very carefully and strictly follow them:

1. This question paper is divided into three sections:
   - **General Aptitude (GA):** 10 questions (5 questions × 1 mark + 5 questions × 2 marks) for a total of 15 marks.
   - **Mathematics Fundation:** This section comprises of total 13 marks.
   - **Core Discipline:** This section comprises of 72 marks.
2. The total number of questions is **65**, carrying a maximum of **100 marks**.
3. The duration of the exam is **3 hours**.
4. Marking scheme:
   - For 1-mark MCQs, $\frac{1}{3}$ mark will be deducted for every incorrect response.
   - For 2-mark MCQs, $\frac{2}{3}$ mark will be deducted for every incorrect response.
   - No negative marking for numerical answer type (NAT) questions.
   - No marks will be awarded for unanswered questions.
5. Ensure you attempt questions only from the optional section (Part B1 or Part B2) you have selected.
6. Follow the instructions provided during the exam for submitting your answers.

1. Expedite, Hasten, Hurry, ____________
Fill the blank by choosing a word with a meaning similar to that of the words given above.

(A) Accelerate
(B) Retard
(C) Provide
(D) Disable

Correct Answer: (A) Accelerate

Solution:

Step 1: Understanding the Question:
The question asks to find a word from the given options that has a meaning similar to "Expedite," "Hasten," and "Hurry." This is a test of vocabulary, specifically identifying synonyms.

Step 2: Detailed Explanation:
Let's analyze the meanings of the given words and the options:

- **Expedite:** To make an action or process happen sooner or be accomplished more quickly.
- **Hasten:** To be quick to do something; to move or travel hurriedly.
- **Hurry:** To move or act with great speed.

All three words convey the idea of increasing speed or making something happen faster.

Now let's examine the options:

- **(A) Accelerate:** To increase in rate, amount, or extent. This aligns perfectly with the meaning of the given words.
- **(B) Retard:** To delay or hold back in terms of progress or development. This is an antonym (opposite meaning).
- **(C) Provide:** To make available for use; to supply something. This is unrelated in meaning.
- **(D) Disable:** To put out of action; to prevent from functioning. This is also unrelated.

Step 3: Final Answer:
The word "Accelerate" is the closest in meaning to "Expedite," "Hasten," and "Hurry." Therefore, it is the correct choice to fill the blank.

> Quick Tip
>
> In synonym-based questions, focus on the core meaning shared by all the given words. Eliminate options that are antonyms or have unrelated meanings to narrow down your choices.

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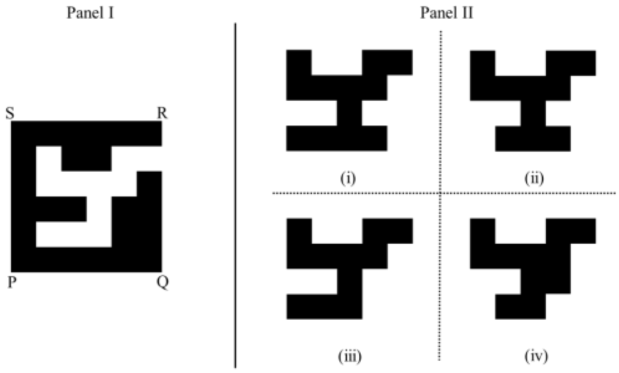
2. A black square PQRS has been cut into two parts. One part of it is shown in Panel I. Which one of the shapes in Panel II is the other part?



(A) (i)
(B) (ii)
(C) (iii)
(D) (iv)

Correct Answer: (C) (iii)

Solution:

Step 1: Understanding the Question:
The task is to identify which of the four shapes in Panel II, when combined with the shape in Panel I, will form a complete square.

Step 2: Key Formula or Approach:
The approach is spatial reasoning. We need to mentally rotate and fit each option from Panel II into the empty space of the square that is not occupied by the shape from Panel I. The correct shape will fit perfectly without any overlap or gaps, creating a solid square.

Step 3: Detailed Explanation:
Let's visualize the original square PQRS and the empty space left by the piece in Panel I. The empty space is the 'negative' of the given shape. We need to find the shape in Panel II that matches this empty space.

- Imagine placing the shape from Panel I inside a square frame. The shape in Panel I has a complex, jagged boundary on the inside.
- We can try to fit each option from Panel II with the shape from Panel I.
- **Option (i) and (ii):** These shapes do not have the correct indentations and protrusions to match the boundary of the shape in Panel I. They will either overlap or leave gaps.
- **Option (iii):** Let's try to fit shape (iii). If we rotate shape (iii) by 90 degrees counter-clockwise and place it next to the shape in Panel I, its boundary will perfectly interlock

with the boundary of the shape in Panel I. Together, they will form a complete solid black square.

- **Option (iv):** This shape also does not fit the empty space correctly. Its overall structure is different from the required complementary piece.

Step 4: Final Answer:
By mentally fitting the pieces, we can see that only shape (iii) correctly complements the shape in Panel I to form the original square PQRS. Thus, (C) is the correct answer.

> Quick Tip
>
> For these types of visual puzzles, use a rough sheet to trace the given shape and the empty space. Then, try to draw and rotate the options to see which one fits. This can be more reliable than purely mental visualization.

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3. A day can only be cloudy or sunny. The probability of a day being cloudy is 0.5, independent of the condition on other days. What is the probability that in any given four days, there will be three cloudy days and one sunny day?

(A) 1/4
(B) 3/4
(C) 2/3
(D) 3/8

Correct Answer: (A) 1/4

Solution:

Step 1: Understanding the Question:
This is a problem of binomial probability. We have a fixed number of independent trials (4 days), and each trial has two possible outcomes (cloudy or sunny) with a constant probability of success (a day being cloudy). We need to find the probability of getting exactly 3 successes (cloudy days) in 4 trials.

Step 2: Key Formula or Approach:
The binomial probability formula is given by:

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

where:

- n is the total number of trials.
- k is the number of successful outcomes.
- p is the probability of success on a single trial.
- $(1-p)$ is the probability of failure on a single trial.
- $\binom{n}{k} = \frac{n!}{k!(n-k)!}$ is the number of combinations.

Step 3: Detailed Explanation:
From the problem statement, we have:

- Total number of days (trials), $n = 4$.
- Number of cloudy days (successes), $k = 3$.
- Probability of a day being cloudy (success), $p = 0.5$.
- Probability of a day being sunny (failure), $1 - p = 1 - 0.5 = 0.5$.

Now, we substitute these values into the binomial formula:

$$P(3 \text{ cloudy, } 1 \text{ sunny}) = \binom{4}{3}(0.5)^3(0.5)^{4-3}$$

First, calculate the number of combinations $\binom{4}{3}$:

$$\binom{4}{3} = \frac{4!}{3!(4-3)!} = \frac{4!}{3!1!} = \frac{4 \times 3 \times 2 \times 1}{(3 \times 2 \times 1)(1)} = 4$$

This means there are 4 possible ways to have 3 cloudy days and 1 sunny day (e.g., CCCS, CCSC, CSCC, SCCC).
Now, substitute this back into the probability calculation:

$$P(X = 3) = 4 \times (0.5)^3 \times (0.5)^1$$
$$P(X = 3) = 4 \times (0.5)^4$$
$$P(X = 3) = 4 \times \left(\frac{1}{2}\right)^4$$
$$P(X = 3) = 4 \times \frac{1}{16}$$
$$P(X = 3) = \frac{4}{16} = \frac{1}{4}$$

Step 4: Final Answer:
The probability of having exactly three cloudy days and one sunny day in four days is 1/4.

Quick Tip

Recognize scenarios that fit the binomial distribution: a fixed number of trials, independent trials, only two outcomes per trial, and constant probability of success. This allows you to apply the formula directly.

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4. The values of Stock A and Stock B on a particular day are Rs. 50 and Rs. 80, respectively. An investor invests Rs. 100 in Stock A and Rs. 80 in Stock B. He sells all the stocks the next day when the value of Stock A is Rs. 55 and Stock B is Rs. 70. The profit made by the investor is Rs. ________.

(A) 0
(B) 5
(C) 10
(D) 20

Correct Answer: (A) 0

Solution:

Step 1: Understanding the Question:
The question asks to calculate the total profit made by an investor from buying and selling two different stocks. Profit is the difference between the total selling price and the total investment.

Step 2: Key Formula or Approach:
The formulas needed are:

1. Number of stocks bought = Total amount invested / Price per stock.

2. Total selling price = Number of stocks sold $\times Sellingpriceperstock.$

2. Total Profit = Total Selling Price - Total Investment.

Step 3: Detailed Explanation:
Let's break down the calculation into parts: investment, sale, and profit.

Investment Phase:

- Investment in Stock A = Rs. 100.
- Price of one Stock A = Rs. 50.
- Number of Stock A purchased = $\frac{\text{Rs. } 100}{\text{Rs. } 50/\text{stock}}$ = 2 stocks.
- Investment in Stock B = Rs. 80.
- Price of one Stock B = Rs. 80.
- Number of Stock B purchased = $\frac{\text{Rs. } 80}{\text{Rs. } 80/\text{stock}}$ = 1 stock.
- **Total Investment** = Investment in A + Investment in B = Rs. 100 + Rs. 80 = **Rs. 180**.

Selling Phase:

- Selling price of one Stock A = Rs. 55.
- Total amount from selling Stock A = 2 stocks × Rs. 55/stock = Rs. 110.
- Selling price of one Stock B = Rs. 70.
- Total amount from selling Stock B = 1 stock × Rs. 70/stock = Rs. 70.
- **Total Selling Price** = Amount from A + Amount from B = Rs. 110 + Rs. 70 = **Rs. 180**.

Profit Calculation:

- Total Profit = Total Selling Price - Total Investment.
- Total Profit = Rs. 180 - Rs. 180 = Rs. 0.

Step 4: Final Answer:
The total profit made by the investor is Rs. 0.

Quick Tip

In problems involving investments, always calculate the number of units purchased first. Don't just compare the initial and final prices. The quantity of stocks is crucial for calculating the total transaction value.

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5. 'When it is raining, peacocks dance.'
Based only on this sentence, which one of the following options is necessarily true?

(A) Peacocks dance only when it is raining.
(B) When peacocks dance, it is raining.
(C) When peacocks are not dancing, it is not raining.
(D) When it is not raining, peacocks do not dance.

Correct Answer: (C) When peacocks are not dancing, it is not raining.

Solution:

Step 1: Understanding the Question:
The question presents a conditional statement and asks which of the given options is a logically necessary conclusion from it. The statement is of the form "If P, then Q".

Step 2: Key Formula or Approach:
Let's represent the given statement using propositional logic:

- Let P be the proposition: "it is raining."
- Let Q be the proposition: "peacocks dance."

The given statement is: **If P, then Q** (symbolically, $P \rightarrow Q$).

We need to find which of the options is logically equivalent to $P \rightarrow Q$. The key logical equivalences are:

- **Converse:** If Q, then P ($Q \rightarrow P$). Not necessarily true.
- **Inverse:** If not P, then not Q ($\neg P \rightarrow \neg Q$). Not necessarily true.
- **Contrapositive:** If not Q, then not P ($\neg Q \rightarrow \neg P$). **Always logically equivalent to the original statement.**

Step 3: Detailed Explanation:
Let's analyze each option based on the logical forms:

- **(A) Peacocks dance only when it is raining:** This translates to "If peacocks dance, then it is raining." This is the **converse** ($Q \to P$). The original statement doesn't exclude the possibility that peacocks might dance for other reasons too. So, this is not necessarily true.

- **(B) When peacocks dance, it is raining:** This is identical to option (A) and is the **converse**. Not necessarily true.

- **(C) When peacocks are not dancing, it is not raining:** This translates to "If peacocks are not dancing (not Q), then it is not raining (not P)." This is the **contrapositive** ($\neg Q \to \neg P$). It is logically equivalent to the original statement. If it were raining (P is true), the peacocks would have to be dancing (Q is true). Since they are not dancing (Q is false), it cannot be raining (P must be false).

- **(D) When it is not raining, peacocks do not dance:** This translates to "If it is not raining (not P), then peacocks do not dance (not Q)." This is the **inverse** ($\neg P \to \neg Q$). This is not necessarily true. The statement only tells us what happens when it rains; it doesn't say anything about what happens when it doesn't rain.

Step 4: Final Answer:
The only statement that is necessarily true is the contrapositive. Therefore, option (C) is the correct answer.

Quick Tip
For any conditional statement "If A, then B", the only other statement that is always true is its contrapositive: "If not B, then not A". The converse ("If B, then A") and inverse ("If not A, then not B") are not guaranteed to be true.

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6. Water : P :: Food : Q
Choose the P and Q combination from the options below to form a meaningful analogy.

(A) P = Thirst; Q = Hunger
(B) P = Drink; Q = Hunger
(C) P = Thirst; Q = Satiated
(D) P = Wet; Q = Critic

Correct Answer: (A) P = Thirst; Q = Hunger

Solution:

Step 1: Understanding the Question:
The question asks to complete an analogy of the form A : B :: C : D. We need to find the relationship between "Water" and "P" and apply the same relationship to find "Q" for "Food".

Step 2: Key Formula or Approach:
The core of solving an analogy is to identify the relationship between the first pair of words. The relationship here is that "Water" is the remedy for a specific biological need, "P". We must find a parallel relationship where "Food" is the remedy for the biological need "Q".

Step 3: Detailed Explanation:
Let's analyze the primary relationship:

- **Water** is consumed to quench or satisfy **thirst**. So, the relationship is 'Solution : Problem' or 'Remedy : Need'. Therefore, P should be **Thirst**.
- Applying the same logic to the second pair: **Food** is consumed to satisfy **hunger**. Therefore, Q should be **Hunger**.

So, the completed analogy should be: Water : Thirst :: Food : Hunger.

Now let's check the given options:

- **(A) P = Thirst; Q = Hunger:** This matches our derived relationship perfectly.
- **(B) P = Drink; Q = Hunger:** The relationship "Water : Drink" is 'Example : Category'. This is not the primary relationship.
- **(C) P = Thirst; Q = Satiated:** Satiated is the state of being full, which is the result of eating food. It is not the need itself. The analogy would be inconsistent (Remedy : Need :: Remedy : Result).
- **(D) P = Wet; Q = Critic:** "Wet" is a property of water, and "Critic" is unrelated to food in a parallel way. This option makes no logical sense.

Step 4: Final Answer:
The most meaningful and consistent analogy is formed with P = Thirst and Q = Hunger. Thus, option (A) is the correct answer.

Quick Tip

When solving analogies, articulate the relationship between the first pair of words in a complete sentence (e.g., "Water satisfies thirst"). Then, use that same sentence structure for the second pair ("Food satisfies hunger") to find the correct words.

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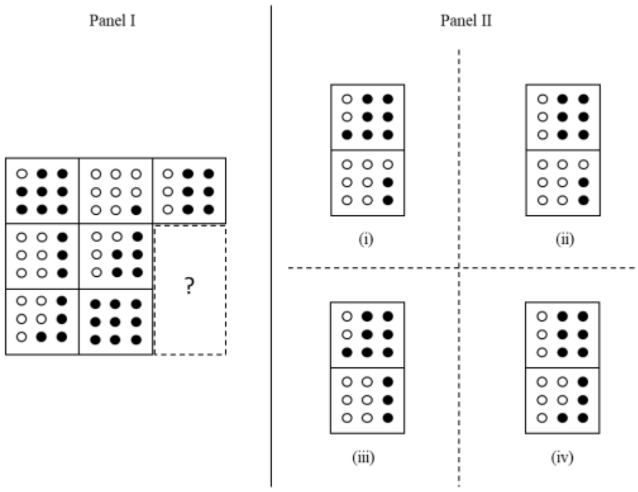
7. Two tiles are missing in Panel I. Which one of the options in Panel II is the appropriate choice for the missing tiles?



(A) (i)
(B) (ii)
(C) (iii)
(D) (iv)

Correct Answer: (A) (i)

Solution:

Step 1: Understanding the Question:
The question shows a 4x4 grid of smaller tiles in Panel I, with a 2x1 block of tiles missing. We need to identify the pattern in the grid and determine which of the options in Panel II correctly fills the missing block.

Step 2: Key Formula or Approach:
The approach is pattern recognition. We need to analyze the arrangement of the tiles (which appear to be either all-black or all-white) by looking at rows and columns to find a repeating or logical sequence.

Step 3: Detailed Explanation:
Let's represent the tiles in Panel I, with 'B' for black and 'W' for white. The grid is as follows:

- **Row 1:** B, W, W, B
- **Row 2:** W, B, B, W
- **Row 3:** B, W, ?, ?
- **Row 4:** W, B, B, W

The question mark represents the missing 2x1 block, which consists of the third and fourth tiles of the third row.

Let's observe the patterns:

- **Row Pattern:** Notice that Row 2 and Row 4 are identical (W, B, B, W). This suggests that there might be a repeating pattern in the rows. It is highly likely that Row 3 should be identical to Row 1.
- If Row 3 is the same as Row 1, then the pattern for Row 3 should be (B, W, W, B).
- The missing tiles are the third and fourth tiles of Row 3. According to the pattern, the third tile should be 'W' (all-white) and the fourth tile should be 'B' (all-black).

Now, let's examine the options in Panel II. They represent the missing 2x1 block (tile 3 on top, tile 4 at the bottom).

- **(i):** Shows an all-white tile on top and an all-black tile at the bottom. This corresponds to our deduced pattern (W, B).
- **(ii):** Shows a black tile on top and a white tile at the bottom. This is the reverse of what we need.
- **(iii):** Shows two white tiles. This is incorrect.
- **(iv):** Shows two black tiles. This is incorrect.

Step 4: Final Answer:
The pattern strongly suggests that Row 3 is a repeat of Row 1. Therefore, the missing tiles are a white tile followed by a black tile, which corresponds to option (i).

💡 Quick Tip

In grid-based pattern problems, first check for simple repetitions or alternations in rows and columns. Often, the pattern is simpler than it appears. Here, recognizing that Row 2 and Row 4 are identical is the key to solving the puzzle.

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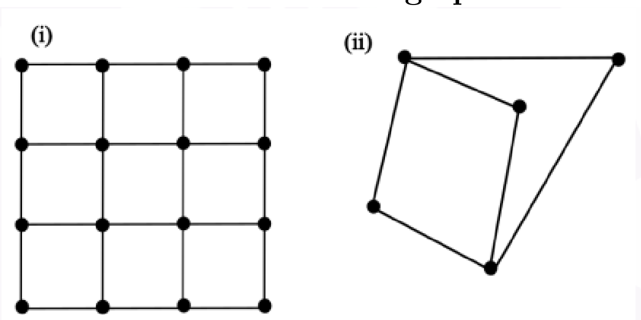
8. Figures (i) and (ii) represent intercity highway systems. The black dots represent cities and the line segments between them represent intercity highways. A salesperson needs to make a trip. She needs to start from a city, visit each of the remaining cities exactly once, and finally return to the same city from which she started.
Which one of the following options is then true?



(A) Such a trip is possible for (i), but not for (ii).
(B) Such a trip is possible for (ii), but not for (i).
(C) Such a trip is possible for both (i) and (ii).
(D) Such a trip is possible neither for (i) nor for (ii).

Correct Answer: (D) Such a trip is possible neither for (i) nor for (ii).

Solution:

Step 1: Understanding the Question:
The problem describes a trip that starts at a city, visits every other city exactly once, and returns to the starting city. In the language of graph theory, this is known as a **Hamiltonian cycle** (or a Hamiltonian circuit). The question asks whether a Hamiltonian cycle exists for the graphs represented by figures (i) and (ii).

Step 2: Key Concepts from Graph Theory:
1. **Hamiltonian Cycle:** A cycle in a graph that visits every vertex (city) exactly once.
2. **Bipartite Graph Property:** A bipartite graph is a graph whose vertices can be divided into two disjoint and independent sets, U and V, such that every edge connects a vertex in U to one in V. A necessary condition for a bipartite graph to have a Hamiltonian cycle is that the number of vertices in both sets must be equal, i.e., $|U| = |V|$.
3. **Degree of a Vertex Property:** If a vertex in a graph has a degree of 2, then for any Hamiltonian cycle to exist, both edges connected to this vertex must be part of the cycle.

Step 3: Detailed Explanation:

Analysis of Figure (i):

The graph in figure (i) is a 3×3 grid graph. It has 9 vertices. This graph is a bipartite graph. We can prove this by coloring the vertices with two colors (say, Red and Blue) such that no two adjacent vertices share the same color.
Let's color the vertices row by row:
Row 1: R B R
Row 2: B R B
Row 3: R B R
Since the graph can be two-colored, it is bipartite. Let's count the number of vertices of each color.
Number of Red vertices ($|U|$) = 5.
Number of Blue vertices ($|V|$) = 4.
A Hamiltonian cycle in a bipartite graph must alternate between the two sets of vertices. For the cycle to include all vertices and return to the start, the number of vertices in both sets must be equal. Since $|U| \neq |V|$ ($5 \neq 4$), the necessary condition is not met.
Therefore, **no Hamiltonian cycle is possible for figure (i)**.

Analysis of Figure (ii):

The graph in figure (ii) has 5 vertices. Let's find the degree of each vertex (i.e., the number of highways connected to each city). By inspection, there are three vertices with 2 connections (degree 2) and two vertices with 3 connections (degree 3).
Let's label the vertices to analyze the structure. Let the vertices with degree 2 be v_1, v_2, v_3 and vertices with degree 3 be u_1, u_2.
According to the property mentioned in Step 2, if a Hamiltonian cycle exists, both edges incident to any degree-2 vertex must be included in the cycle.
- For vertex v_1, its two edges must be in the cycle.
- For vertex v_2, its two edges must be in the cycle.
- For vertex v_3, its two edges must be in the cycle.

Let's examine the connections more closely. The two degree-3 vertices are connected to each other through the three degree-2 vertices.
Let's call the degree-3 vertices B and D, and the degree-2 vertices A, C, and E.
The edges are (A,B), (A,D), (C,B), (C,D), (E,B), (E,D).
For a Hamiltonian cycle to exist, the edges (A,B), (A,D), (C,B), (C,D), (E,B), (E,D) must all be part of the path.
Now consider vertex B. For it to be in the cycle, two edges connected to it must be used. But our rule requires that edges (A,B), (C,B), and (E,B) must all be part of the cycle. This means vertex B must have a degree of 3 within the cycle. However, in any cycle, every vertex must have a degree of exactly 2. This creates a contradiction.
The same contradiction occurs at vertex D.
Therefore, **no Hamiltonian cycle is possible for figure (ii)**.

Step 4: Final Answer:

Since a Hamiltonian cycle (the required trip) is not possible for either figure (i) or figure (ii), the correct option is (D).

Quick Tip

To quickly determine if a Hamiltonian cycle exists, check for properties that would forbid it.
1. **Bipartite Check:** If a graph is bipartite with partitions of unequal size, it cannot have a Hamiltonian cycle. This is a very fast way to eliminate many grid-like graphs.
2. **Degree-2 Vertices:** If a vertex has a degree of 2, both of its incident edges must be part of any Hamiltonian cycle. Tracing the consequences of this requirement can often reveal a contradiction, such as forcing another vertex to have a degree greater than 2 in the cycle.

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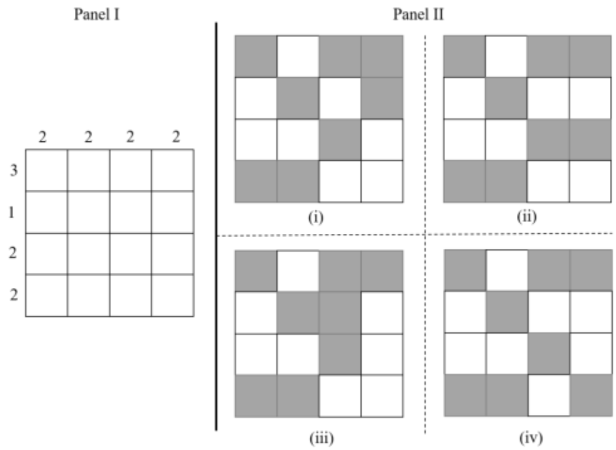
9. The figure in Panel I below is a grid of cells with four rows and four columns. The numbers on the top and on the left represent the number of cells that are to be shaded in that column and row, respectively. Which one of the options shown in Panel II below represents the grid shaded correctly?



(A) (i)
(B) (ii)
(C) (iii)
(D) (iv)

Correct Answer: (B) (ii)

Solution:

Step 1: Understanding the Question:
We are given a 4x4 grid. Numbers on the left indicate the required number of shaded cells for each row, and numbers on the top indicate the same for each column. We need to check which of the four shaded grids in Panel II satisfies all these conditions simultaneously.

Step 2: Key Formula or Approach:
The approach is a systematic check. For each option, we will count the number of shaded cells

in every row and every column and compare them with the given required numbers.

Step 3: Detailed Explanation:
Let's list the required number of shaded cells:

- **Row requirements (from top to bottom):** 3, 1, 2, 2.

- **Column requirements (from left to right):** 2, 2, 2, 2.

Now, let's verify each option in Panel II:

- **Option (i):**
  - Row counts: 2, 2, 3, 1. (Does not match: Row 1 should be 3, Row 2 should be 1, etc.)
  - *Conclusion: Incorrect.*

- **Option (ii):**
  - Row counts:
    * Row 1: 3 shaded cells. (Matches)
    * Row 2: 1 shaded cell. (Matches)
    * Row 3: 2 shaded cells. (Matches)
    * Row 4: 2 shaded cells. (Matches)
  - Column counts:
    * Column 1: 2 shaded cells. (Matches)
    * Column 2: 2 shaded cells. (Matches)
    * Column 3: 2 shaded cells. (Matches)
    * Column 4: 2 shaded cells. (Matches)
  - *Conclusion: Correct. All conditions are satisfied.*

- **Option (iii):**
  - Row counts: 1, 3, 2, 2. (Does not match: Row 1 should be 3, Row 2 should be 1.)

- *Conclusion: Incorrect.*

- **Option (iv):**
  - Row counts: 2, 2, 1, 3. (Does not match: Row 1 should be 3, Row 3 should be 2, etc.)
  - *Conclusion: Incorrect.*

Step 4: Final Answer:
Only the grid in option (ii) satisfies all the row and column constraints for the number of shaded cells.

> **Quick Tip**
>
> In these logic puzzles (often called Nonograms or Griddlers), start by checking the row or column with the most extreme number (e.g., the highest or lowest count). If it fails, you can eliminate the option quickly without checking all rows and columns.

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10. An unbiased six-faced dice whose faces are marked with numbers 1, 2, 3, 4, 5, and 6 is rolled twice in succession and the number on the top face is recorded each time. The probability that the sum of the two recorded numbers is a prime number is

(A) 3/36
(B) 13/36
(C) 15/36
(D) 19/36

Correct Answer: (C) 15/36

Solution:

Step 1: Understanding the Question:
We are rolling a standard six-sided die twice. We need to find the probability that the sum of the outcomes of the two rolls is a prime number.

Step 2: Key Formula or Approach:
The probability of an event is calculated as:

$$P(\text{Event}) = \frac{\text{Number of Favorable Outcomes}}{\text{Total Number of Possible Outcomes}}$$

Step 3: Detailed Explanation:
1. Calculate the Total Number of Possible Outcomes:

Since the die is rolled twice, and each roll has 6 possible outcomes, the total number of outcomes is $6 \times 6 = 36$.

2. Identify the Favorable Outcomes:
The minimum possible sum is $1 + 1 = 2$, and the maximum possible sum is $6 + 6 = 12$. We need to find the sums that are prime numbers in this range. The prime numbers between 2 and 12 are 2, 3, 5, 7, and 11.

Now, let's list the pairs of outcomes (roll 1, roll 2) that result in these prime sums:

- **Sum = 2:** (1, 1) — (1 outcome)
- **Sum = 3:** (1, 2), (2, 1) — (2 outcomes)
- **Sum = 5:** (1, 4), (4, 1), (2, 3), (3, 2) — (4 outcomes)
- **Sum = 7:** (1, 6), (6, 1), (2, 5), (5, 2), (3, 4), (4, 3) — (6 outcomes)
- **Sum = 11:** (5, 6), (6, 5) — (2 outcomes)

3. Count the Total Number of Favorable Outcomes:
Total favorable outcomes = $1 + 2 + 4 + 6 + 2 = 15$.

4. Calculate the Probability:

$$P(\text{sum is prime}) = \frac{15}{36}$$

Step 4: Final Answer:
The probability that the sum of the two recorded numbers is a prime number is 15/36.

Quick Tip

For problems involving two dice, it can be helpful to visualize or quickly sketch a 6x6 grid where the rows represent the first roll and columns represent the second. The cells can contain the sum of the roll and column. This makes it easy to count the total and favorable outcomes.

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11. Two identical cubic dice are rolled simultaneously. Which of the following is the probability that at least one of the face values of the two dice is greater than 3?

(A) $\frac{1}{2}$
(B) $\frac{3}{4}$

(C) $\frac{1}{4}$
(D) $\frac{3}{8}$

Correct Answer: (B) $\frac{3}{4}$

Solution:

Step 1: Understanding the Question:
When two cubic dice are rolled simultaneously, we are required to find the probability that at least one of the dice shows a face value strictly greater than 3.

Step 2: Key Formula or Approach:
The probability of an event happening can be efficiently calculated using the complement rule:

$$P(\text{at least one}) = 1 - P(\text{none})$$

Here, the complement event is that neither die shows a value greater than 3 (i.e., both dice show values ≤ 3).

Step 3: Detailed Explanation:
For a single standard cubic die, the sample space of possible outcomes is $\{1, 2, 3, 4, 5, 6\}$.
The total number of possible outcomes for one die is 6.
The outcomes where the face value is ≤ 3 are $\{1, 2, 3\}$.
So, the probability that a single die shows a value ≤ 3 is:

$$P(\leq 3) = \frac{3}{6} = \frac{1}{2}$$

Since the two dice are rolled simultaneously, their individual outcomes are independent of each other.
The probability that both dice show a value ≤ 3 is:

$$P(\text{both } \leq 3) = P(\leq 3) \times P(\leq 3) = \frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$$

Now, applying the complement rule to find the probability of at least one die showing a value > 3:

$$P(\text{at least one } > 3) = 1 - P(\text{both } \leq 3)$$

$$P(\text{at least one } > 3) = 1 - \frac{1}{4} = \frac{3}{4}$$

Step 4: Final Answer:
The calculated probability is $\frac{3}{4}$, which perfectly matches option (B).

Quick Tip

Whenever a probability question asks for "at least one", always consider using the complement rule ($1 - P(\text{None})$).
This approach usually involves fewer steps and minimizes calculation errors.

---

12. Which of the following options is CORRECT for the eigenvalues (λ) of the given matrix?

$$\begin{bmatrix} 8 & 0 & 0 \\ 0 & 5 & 0 \\ 0 & 0 & 7 \end{bmatrix}$$

(A) $\lambda = 1, 1, 1$
(B) $\lambda = 8, 5, 7$
(C) $\lambda = 0, 0, 0$
(D) $\lambda = 40, 1, 35$

Correct Answer: (B) $\lambda = 8, 5, 7$

Solution:

Step 1: Understanding the Question:
We need to determine the eigenvalues (λ) for the given 3×3 square matrix.

Step 2: Key Formula or Approach:
For any diagonal matrix, upper triangular matrix, or lower triangular matrix, the eigenvalues are simply the entries on its main diagonal.

Step 3: Detailed Explanation:
The given matrix is:

$$A = \begin{bmatrix} 8 & 0 & 0 \\ 0 & 5 & 0 \\ 0 & 0 & 7 \end{bmatrix}$$

Observing the matrix, we can see that all the elements off the main diagonal are exactly zero.
This makes it a standard diagonal matrix.
The main diagonal elements are 8, 5, and 7.
According to the properties of diagonal matrices, these elements directly represent the eigenvalues.
Thus, the eigenvalues are $\lambda_1 = 8$, $\lambda_2 = 5$, and $\lambda_3 = 7$.

Step 4: Final Answer:
The eigenvalues are $\lambda = 8, 5, 7$, corresponding to option (B).

> 💡 Quick Tip
>
> To save time in the exam, always check if a given matrix is diagonal or triangular before attempting to solve the characteristic equation $\det(A - \lambda I) = 0$.
> If it is, the eigenvalues are instantly identifiable as the diagonal elements!

---

13. For a given matrix $A = \begin{bmatrix} 4 & 4 \\ 0 & 4 \\ -4 & 4 \end{bmatrix}$, and A^T representing its transpose, which of the following options is the CORRECT representation of $A^T A$?

(A) $\begin{bmatrix} 4 & 0 \\ 0 & -4 \end{bmatrix}$

(B) $\begin{bmatrix} 32 & 0 \\ 0 & 48 \end{bmatrix}$

(C) $\begin{bmatrix} 32 & 0 \\ 0 & 0 \\ 0 & 48 \end{bmatrix}$

(D) $\begin{bmatrix} 4 & 0 \\ 0 & 0 \\ 0 & -4 \end{bmatrix}$

Correct Answer: (B) $\begin{bmatrix} 32 & 0 \\ 0 & 48 \end{bmatrix}$

Solution:

Step 1: Understanding the Question:
We are given a 3×2 matrix A, and we need to evaluate the matrix product $A^T A$, where A^T is the transpose of A.

Step 2: Key Formula or Approach:
First, find the transpose of matrix A by converting its rows into columns.
Then, perform standard matrix multiplication by multiplying the rows of A^T with the columns of A.

Step 3: Detailed Explanation:
The given matrix A is:

$$A = \begin{bmatrix} 4 & 4 \\ 0 & 4 \\ -4 & 4 \end{bmatrix}$$

Taking the transpose A^T, the 3×2 matrix becomes a 2×3 matrix:

$$A^T = \begin{bmatrix} 4 & 0 & -4 \\ 4 & 4 & 4 \end{bmatrix}$$

Now, we compute the product $A^T A$:

$$A^T A = \begin{bmatrix} 4 & 0 & -4 \\ 4 & 4 & 4 \end{bmatrix} \begin{bmatrix} 4 & 4 \\ 0 & 4 \\ -4 & 4 \end{bmatrix}$$

Let's calculate each element C_{ij} of the resulting 2×2 matrix $C = A^T A$:
For Row 1, Column 1 (C_{11}):

$$C_{11} = (4 \times 4) + (0 \times 0) + (-4 \times -4) = 16 + 0 + 16 = 32$$

For Row 1, Column 2 (C_{12}):

$$C_{12} = (4 \times 4) + (0 \times 4) + (-4 \times 4) = 16 + 0 - 16 = 0$$

For Row 2, Column 1 (C_{21}):

$$C_{21} = (4 \times 4) + (4 \times 0) + (4 \times -4) = 16 + 0 - 16 = 0$$

For Row 2, Column 2 (C_{22}):

$$C_{22} = (4 \times 4) + (4 \times 4) + (4 \times 4) = 16 + 16 + 16 = 48$$

Combining these results, the final matrix is:

$$A^T A = \begin{bmatrix} 32 & 0 \\ 0 & 48 \end{bmatrix}$$

Step 4: Final Answer:
The resulting matrix matches option (B).
Note: Option (C) in the original image is a 3×2 matrix format which is dimensionally incorrect for $A^T A$. The correct dimension is 2×2.

💡 Quick Tip

When multiplying matrices, always check the dimensions first to eliminate wrong options.
If A is an $m \times n$ matrix, A^T is $n \times m$.
The product $A^T A$ will ALWAYS yield an $n \times n$ square matrix!

---

14. Given two vectors $\vec{U}$ and $\vec{V}$, which of the following options is CORRECT for the expansion of divergence, $\nabla \cdot (\vec{U} + \vec{V})$?

(A) $\nabla \times \vec{U} + \nabla \times \vec{V}$
(B) $\nabla \times \vec{U} - \nabla \times \vec{V}$
(C) $\nabla \cdot \vec{U} + \nabla \cdot \vec{V}$
(D) $\nabla \cdot \vec{U} - \nabla \cdot \vec{V}$

Correct Answer: (C) $\nabla \cdot \vec{U} + \nabla \cdot \vec{V}$

Solution:

Step 1: Understanding the Question:
The question asks for the correct expansion of the divergence of the sum of two vector fields $\vec{U}$ and $\vec{V}$.

Step 2: Key Formula or Approach:
The divergence operator $(\nabla\cdot)$ is a linear differential operator.
Because of its linearity, applying the divergence to a sum of vectors is exactly equal to the sum of the divergences of the individual vectors.

Step 3: Detailed Explanation:
Mathematically, the linearity property of divergence dictates that:

$$\nabla \cdot (\vec{U} + \vec{V}) = \nabla \cdot \vec{U} + \nabla \cdot \vec{V}$$

Options (A) and (B) use the curl operator $(\nabla\times)$, which is fundamentally incorrect since the original expression uses the divergence operator (dot product).
Option (D) incorrectly subtracts the terms instead of adding them.

Step 4: Final Answer:
The correct expansion is $\nabla \cdot \vec{U} + \nabla \cdot \vec{V}$, which is option (C).

Quick Tip

Remember that vector differential operators like gradient (∇), divergence ($\nabla\cdot$), and curl ($\nabla\times$) are all linear operators.
They distribute perfectly over addition and subtraction: $Op(\vec{A} \pm \vec{B}) = Op(\vec{A}) \pm Op(\vec{B})$.

---

15. Which of the following is the basic mechanism of hydrocyclones and centrifuges used for solids control in a drilling operation?

(A) Screening
(B) Forced settling
(C) Chemical flocculation
(D) Dilution

Correct Answer: (B) Forced settling

Solution:

Step 1: Understanding the Question:
We need to identify the primary physical mechanism that allows hydrocyclones (like desanders and desilters) and centrifuges to remove solid particles from drilling fluids.

Step 3: Detailed Explanation:
Solids control equipment operates based on varying physical principles.
Shale shakers primarily use **screening** (passing fluid through a vibrating mesh) to separate large cuttings.
Hydrocyclones and centrifuges, on the other hand, utilize centrifugal forces generated by spinning the fluid at high speeds.
This high-speed rotation generates a strong outward force that accelerates the settling of denser solid particles against the walls of the equipment, far exceeding the natural pull of gravity.
This specific mechanism is formally known as **forced settling** (or centrifugal separation).
Chemical flocculation relies on additives to clump particles together, while dilution simply lowers the concentration of solids by adding base fluid.

Step 4: Final Answer:
The correct mechanism is forced settling, matching option (B).

Quick Tip

For solids control equipment matching:
- Shale Shakers $\rightarrow$ Size exclusion / Screening.
- Hydrocyclones & Centrifuges $\rightarrow$ Centrifugal force / Forced Settling.
- Mud Cleaners $\rightarrow$ Combination of both.

16. Which of the following is the role of stabilizer subs in the rotary drilling process?

(A) To prevent the drill-string from falling into the wellbore
(B) To keep casing equidistant from the wellbore wall
(C) To assist in keeping the drill collars centralized
(D) To isolate the wellbore fluid from the subsurface formations

Correct Answer: (C) To assist in keeping the drill collars centralized

Solution:

Step 1: Understanding the Question:
The question tests the knowledge of Bottom Hole Assembly (BHA) components, specifically the primary function of a "stabilizer sub" during drilling operations.

Step 3: Detailed Explanation:
Let's analyze all given options to determine the correct function:
(A) "To prevent the drill-string from falling into the wellbore" is incorrect. This is the function of the slips used on the drill floor at the rotary table.
(B) "To keep casing equidistant from the wellbore wall" is the function of **casing centralizers**, not stabilizer subs on a drill string.
(C) "To assist in keeping the drill collars centralized" is the core function of a stabilizer. Stabilizers have blades that contact the borehole wall, helping to center the BHA, reduce vibrations, prevent differential sticking, and control the well's trajectory (directional drilling).
(D) "To isolate the wellbore fluid from the subsurface formations" is achieved by casing and cement, or by the filter cake built by the drilling mud.

Step 4: Final Answer:
The correct role of stabilizer subs is to centralize the drill collars, matching option (C).

> Quick Tip
>
> Remember that "stabilizers" are strictly associated with the active drill string (BHA) for trajectory control and centralization.
> "Centralizers" do a similar geometric job but are run on the casing string before cementing.

---

17. For a single-phase dry gas reservoir having a well producing only dry gas, E represents gas expansion factor and B_g represents gas formation volume factor. Which of the following options is CORRECT?

(A) $E \propto \frac{1}{B_g}$
(B) $E \propto B_g$
(C) $E \propto B_g^2$
(D) $E \propto B_g^3$

Correct Answer: (A) $E \propto \frac{1}{B_g}$

Solution:

Step 1: Understanding the Question:
We need to establish the relationship between the Gas Expansion Factor (E) and the Gas Formation Volume Factor (B_g).

Step 2: Key Formula or Approach:
Recall the definitions from reservoir engineering:
The gas formation volume factor (B_g) relates the volume of gas at reservoir conditions to its volume at standard conditions.
The gas expansion factor (E) is exactly the reciprocal of the gas formation volume factor.

Step 3: Detailed Explanation:
By definition, B_g is formulated as:

$$B_g = \frac{\text{Volume of gas at reservoir conditions } (V_{rc})}{\text{Volume of gas at standard conditions } (V_{sc})}$$

Conversely, the gas expansion factor E measures how much one reservoir volume of gas will expand when brought to standard surface conditions:

$$E = \frac{\text{Volume of gas at standard conditions } (V_{sc})}{\text{Volume of gas at reservoir conditions } (V_{rc})}$$

From these two definitions, it is perfectly clear that:

$$E = \frac{1}{B_g}$$

Therefore, E is directly proportional to the inverse of B_g ($E \propto \frac{1}{B_g}$).

Step 4: Final Answer:
The correct inverse relationship is represented by option (A).

Quick Tip

B_g is generally a small decimal fraction (e.g., 0.005 rcf/scf) because gas is highly compressed in the reservoir.
E is a large number (e.g., 200 scf/rcf) representing the expansion potential. Always remember $E \times B_g = 1$.

18. Choose the correct option by matching the entries in Group X with their description in Group Y.

Group X	Group Y
(P) Gas hydrate	(I) Gas is mostly present in adsorbed state
(Q) Oil shale	(II) Sedimentary rock contains kerogen
(R) Coal bed methane	(III) Oil recovered from shale
(S) Shale oil	(IV) Gas is present inside the cages formed by water molecules

(A) P – IV; Q – III; R – I; S – II
(B) P – I; Q – II; R – IV; S – III
(C) P – IV; Q – II; R – I; S – III
(D) P – I; Q – III; R – IV; S – II

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

Solution:

Step 1: Understanding the Question:
This is a matching question testing the fundamental definitions of various unconventional hydrocarbon resources.

Step 3: Detailed Explanation:
Let's evaluate each term systematically:
(P) Gas hydrate: These are ice-like crystalline solids formed from a mixture of water and gas (typically methane). The gas molecules are trapped inside "cages" formed by hydrogen-bonded water molecules (clathrates). Thus, P matches with IV.
(Q) Oil shale: This is an organic-rich fine-grained sedimentary rock that contains significant amounts of kerogen (solid, insoluble organic matter) from which liquid hydrocarbons can be produced by heating. Thus, Q matches with II.
(R) Coal bed methane (CBM): Methane in coal seams is predominantly stored by being physically adsorbed onto the massive internal surface area of the coal matrix. Thus, R matches with I.
(S) Shale oil: This refers to liquid hydrocarbons (oil) that are tightly trapped within shale formations and recovered directly using stimulation techniques like hydraulic fracturing. Thus, S matches with III.

Step 4: Final Answer:
Combining the matched pairs gives P-IV, Q-II, R-I, S-III.
This corresponds exactly to option (C).

Quick Tip

Be careful not to confuse "Oil shale" (rock containing solid kerogen needing extreme heat to yield oil) with "Shale oil" (liquid oil already formed but trapped in low-permeability shale rock).

---

19. Which of the following statements is NOT CORRECT in the context of off-shore operational environment?

(A) The motion of ocean's surface can be due to energy transfer from wind to water.
(B) Lunar tides are caused by the moon.
(C) Solar tides are caused by the sun.
(D) The motion of ocean's surface can be due to energy transfer from water to wind.

Correct Answer: (D) The motion of ocean's surface can be due to energy transfer from water to wind.

Solution:

Step 1: Understanding the Question:
We need to identify the physically incorrect statement regarding ocean surface motions and tides in an offshore environment.

Step 3: Detailed Explanation:
Let's analyze the statements based on oceanographic principles:
Statement (A) is **CORRECT**. Ocean surface waves are primarily generated by the friction and energy transfer from wind blowing across the surface of the water.
Statement (B) is **CORRECT**. Lunar tides are the result of the gravitational pull exerted by the Moon on Earth's oceans.
Statement (C) is **CORRECT**. Solar tides are caused by the gravitational attraction of the Sun, which, although further away than the Moon, is massive enough to significantly influence Earth's tides.
Statement (D) is **NOT CORRECT**. The driving force for surface wave motion is the wind transferring kinetic energy **into** the water. While energy dissipates from the ocean back to the atmosphere as heat or via evaporation, the macroscopic "motion of the ocean's surface" (waves) is not caused by the water mechanically driving the wind.

Step 4: Final Answer:
Since we are looking for the incorrect statement, option (D) is the right choice.

Quick Tip

When reading descriptive options, always pay close attention to the direction of action. Reversing "wind to water" into "water to wind" is a common trap in multiple-choice questions!

---

20. Which of the following has the most proppant carrying capacity during hydraulic fracturing process?

(A) Pentane
(B) Cross-linked gel
(C) Slickwater
(D) Untreated formation brine

Correct Answer: (B) Cross-linked gel

Solution:

Step 1: Understanding the Question:
The question asks to identify the fracturing fluid type that possesses the highest capability to suspend and transport proppant (sand or ceramics) deep into hydraulic fractures.

Step 3: Detailed Explanation:
The "proppant carrying capacity" of a fracturing fluid is heavily dependent on its viscosity. A thicker, more viscous fluid can hold dense particles in suspension longer without them settling out prematurely.
- **Pentane** is a light hydrocarbon with an extremely low viscosity. It has practically no proppant carrying capacity.
- **Slickwater** is water treated with friction reducers. While great for generating long, complex fracture networks, its viscosity is nearly that of pure water (very low), meaning it requires very high pump rates to sweep lightweight proppants along.
- **Untreated formation brine** has a viscosity close to water and lacks any polymer structure to suspend solids.
- **Cross-linked gel** is formulated using polymers (like guar gum) that are cross-linked with agents like borate. This chemical reaction creates a robust, highly viscous, semi-solid 3D network structure that can perfectly suspend large concentrations of heavy proppant grains.

Step 4: Final Answer:
Cross-linked gel exhibits the highest proppant carrying capacity among the given options.

Quick Tip

Remember the trade-off in fracturing fluids:
- Slickwater creates very complex, long, but narrow fractures (low proppant carrying capacity).
- Cross-linked gels create wide, simple fractures heavily loaded with proppant (high proppant carrying capacity).

---

21. A circular shaped reservoir has external radius of r_e. A well of radius r_w lies in the centre of the reservoir. The part of the reservoir around the wellbore up to a radius of r_s is damaged, where $r_w < r_s < r_e$. Formation damage causes additional pressure drop $\Delta P(r)$ that varies with radial distance r. Which of the following is TRUE about the additional pressure drop at the radial location, r_s due to formation damage?

(A) $\Delta P(r_s) = \Delta P(r_w)$
(B) $\Delta P(r_s) = 0$
(C) $\Delta P(r_s) = 2 \times \Delta P(r_w)$
(D) $\Delta P(r_s) = 4 \times \Delta P(r_w)$

Correct Answer: (B) $\Delta P(r_s) = 0$

Solution:

Step 1: Understanding the Question:
The question asks for the additional pressure drop specifically at the radial boundary $r = r_s$, which marks the exact outer edge of the damaged zone (skin zone).

Step 3: Detailed Explanation:
In well test analysis, formation damage is modeled as an altered permeability zone near the wellbore.
- For radial distances $r \geq r_s$ (the un-damaged reservoir), the permeability remains at its original value, k. Thus, the fluid flow and the pressure profile in this region are exactly the same as they would be if there were no damage.
- For radial distances $r_w \leq r < r_s$ (the damaged zone), the permeability is reduced to k_s, where $k_s < k$.
Because the permeability is lower only inside the damaged zone, the fluid must expend extra energy (extra pressure drop) exclusively as it flows from r_s to r_w.
The "additional pressure drop" ΔP_{skin} is defined as the difference between the actual pressure and the ideal pressure profile.
Since the deviation from the ideal pressure profile only begins strictly inside the radius r_s, the pressure precisely at r_s remains identical to the ideal, undamaged case.
Therefore, the additional pressure drop evaluated exactly at r_s is zero.

Step 4: Final Answer:
The additional pressure drop at r_s is 0, which corresponds to option (B).

> Quick Tip
>
> The "skin effect" pressure drop occurs entirely within the altered zone. If you are asked to evaluate the extra pressure drop at any point $r \geq r_s$, the answer is strictly zero!

---

22. In a drawdown test, P_D, t_D, and C_D are dimensionless pressure, dimensionless time, and dimensionless wellbore storage coefficient, respectively. In the early time of a drawdown test, fluid flow results from wellbore unloading. For this period, which of the following is the CORRECT representation of the relationship among these parameters?

(A) $t_D = P_D C_D$
(B) $C_D = P_D t_D$
(C) $P_D = t_D C_D$
(D) $t_D = P_D + C_D$

Correct Answer: (A) $t_D = P_D C_D$

Solution:

Step 1: Understanding the Question:
The question deals with the wellbore storage dominated flow regime at the very beginning of a drawdown test and requires the dimensionless equation governing this period.

Step 2: Key Formula or Approach:
During pure wellbore storage (early time), the fluid produced at the surface comes entirely from the expansion of fluid inside the wellbore itself, not from the reservoir.
The governing physical equation is:

$$qB = C\frac{dp_w}{dt}$$

Where q is flow rate, B is formation volume factor, and C is the wellbore storage coefficient.

Step 3: Detailed Explanation:
Integrating the physical wellbore storage equation with respect to time yields a linear relationship between the pressure drop and time:

$$\Delta p = \frac{qB}{C}\Delta t$$

To convert this to dimensionless variables, we apply the definitions of dimensionless pressure P_D, dimensionless time t_D, and dimensionless wellbore storage constant C_D.
The fundamental substitution directly leads to the canonical unit-slope line equation for wellbore storage in log-log plots:

$$P_D = \frac{t_D}{C_D}$$

Rearranging this equation algebraically to isolate t_D:

$$t_D = P_D C_D$$

Step 4: Final Answer:
The correct mathematical representation is $t_D = P_D C_D$, which aligns perfectly with option (A).

> Quick Tip
>
> On a log-log plot of Δp versus Δt, the pure wellbore storage regime always shows a straight line with a slope exactly equal to $+1$.
> Taking the log of both sides of $P_D = t_D/C_D$ gives $\log(P_D) = \log(t_D) - \log(C_D)$, confirming the unit slope!

---

23. Which of the following is/are conventional Enhanced Oil Recovery method(s)?

(A) Water flooding
(B) In-Situ combustion
(C) Surfactant flooding
(D) Steam flooding

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

Solution:

Step 1: Understanding the Question:
This is a Multiple Select Question (MSQ). We need to identify which of the listed options fall under the category of Enhanced Oil Recovery (EOR), conventionally referred to as tertiary recovery.

Step 3: Detailed Explanation:
Hydrocarbon recovery is broadly categorized into three phases:
1. **Primary Recovery:** Uses natural reservoir energy (depletion, water drive, gas cap expansion).

2. **Secondary Recovery:** Involves injecting fluids like water or natural gas to maintain reservoir pressure and physically displace oil. **Water flooding** falls strictly into this secondary category.
3. **Enhanced Oil Recovery (Tertiary Recovery):** Involves injecting fluids that alter the original rock/fluid properties (like viscosity or interfacial tension) to mobilize residual oil.
- **In-Situ combustion:** A thermal EOR method where heat is generated downhole to reduce oil viscosity.
- **Surfactant flooding:** A chemical EOR method that drastically lowers the interfacial tension between oil and water, mobilizing trapped capillary oil.
- **Steam flooding:** A thermal EOR method that introduces extreme heat to vaporize light components and massively reduce the viscosity of heavy crude.

Step 4: Final Answer:
Options (B), (C), and (D) are established conventional EOR methods. Option (A) is a secondary recovery method.

Quick Tip

Always strictly distinguish between "Secondary" (pressure maintenance / physical sweep) and "Tertiary/EOR" (altering fluid/rock properties). Waterflooding and plain gas injection are almost exclusively classified as Secondary.

---

24. Which of the following improve(s) the productivity index of a vertical well in an oil reservoir?

(A) Hydraulic fracturing
(B) Increasing the perforation length
(C) Increasing the skin factor
(D) Reducing the oil viscosity by steam injection

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

Solution:

Step 1: Understanding the Question:
This is a Multiple Select Question (MSQ). We must select all operational interventions that actively increase a well's Productivity Index (J).

Step 2: Key Formula or Approach:
The Productivity Index (J) for a vertical well under pseudo-steady state is given by the inflow equation:

$$J = \frac{q}{\Delta p} = \frac{kh}{141.2\mu B(\ln(r_e/r_w) - 0.75 + S)}$$

To improve J, we can either increase the numerator parameters (permeability k, effective flow thickness h) or decrease the denominator parameters (viscosity μ, skin factor S).

Step 3: Detailed Explanation:
Let's evaluate each option using the Productivity Index formula:
- **(A) Hydraulic fracturing:** This operation bypasses near-wellbore damage and creates a highly conductive channel into the reservoir. This effectively creates a massive negative skin factor ($S \ll 0$), which significantly decreases the denominator and boosts J.
- **(B) Increasing the perforation length:** By opening more of the pay zone, the effective flow thickness (h) increases, and the skin effect due to partial penetration decreases. Both actions directly increase J.
- **(C) Increasing the skin factor:** A higher positive skin factor indicates severe formation damage or flow restriction. This increases the denominator, which drastically **reduces** the Productivity Index.
- **(D) Reducing the oil viscosity by steam injection:** Heating the oil sharply lowers its viscosity (μ). A smaller viscosity value in the denominator leads to a higher value for J.

Step 4: Final Answer:
Options (A), (B), and (D) successfully improve the productivity index.

> Quick Tip
>
> Write out the Productivity Index equation quickly in the margins for such questions. It makes it foolproof to verify whether a parameter's change increases or decreases J.

---

25. Which of the following methods is/are used to separate water from crude oil-water emulsion?

(A) Heating
(B) Centrifugation
(C) Addition of interfacial tension reducing agents
(D) Electrostatic coalescence

Correct Answer: (A), (B), (C), (D)

Solution:

Step 1: Understanding the Question:
This is a Multiple Select Question (MSQ). We are asked to identify the valid techniques utilized in surface facilities to break crude oil-water emulsions and separate the two phases.

Step 3: Detailed Explanation:
Emulsions form during production when water and oil are forcefully mixed under shear. Sepa-

rating them requires destabilizing the emulsion.
- **(A) Heating:** Applying heat serves two vital purposes. It lowers the viscosity of the continuous oil phase (allowing water droplets to settle faster via gravity, per Stokes' Law) and provides thermal energy that helps rupture the rigid film surrounding the water droplets.
- **(B) Centrifugation:** This method magnifies the gravitational forces. Because water is generally denser than crude oil, spinning the emulsion at high speeds forces the heavier water droplets outward, effectively separating the phases.
- **(C) Addition of interfacial tension reducing agents:** These chemical additives, commonly known as **demulsifiers**, migrate to the oil-water interface, neutralize natural emulsifying agents, and lower the interfacial tension, thereby promoting droplet coalescence.
- **(D) Electrostatic coalescence:** Used extensively in desalters, this process applies a high-voltage electric field to the emulsion. The field polarizes the suspended water droplets, causing them to rapidly attract each other, collide, and merge (coalesce) into larger drops that settle quickly.

Step 4: Final Answer:
All the listed methods are standard, widely used industry practices for emulsion breaking.

Quick Tip

In modern oilfield heater-treaters, chemical demulsifiers (C), heat (A), gravity settling, and electrostatic grids (D) are frequently combined into a single vessel to maximize separation efficiency!

---

26. Which of the following statements is/are CORRECT about the water injection well platforms?

(A) These are meant for injection of gas through the injection well.
(B) Metering devices are not required to determine injection rate of injection wells.
(C) Metering devices are required to determine injection rate of injection wells.
(D) Firefighting and life-saving equipment should be present on the platform.

Correct Answer: (C), (D)

Solution:

Step 1: Understanding the Question:
The question asks to identify the true statements regarding offshore water injection platforms. This is a Multiple Select Question (MSQ).

Step 3: Detailed Explanation:
Let us evaluate each statement based on standard offshore and reservoir engineering practices:
- **(A) is incorrect.** A water injection platform is specifically designed and equipped with

pumps and treatment facilities to inject water into the reservoir. Gas injection would require a completely different setup involving compressors.
- **(B) is incorrect.** Monitoring the exact volume of water going into the reservoir is critical for managing reservoir pressure and calculating voidage replacement ratios. Therefore, skipping metering devices is not acceptable.
- **(C) is correct.** Metering devices (such as flow meters, pressure gauges, and control valves) are strictly required on every injection well to determine and control the individual injection rates accurately.
- **(D) is correct.** Regardless of the platform's primary function (production, drilling, or injection), and regardless of whether it is normally manned or unmanned, strict offshore safety regulations mandate the installation of firefighting and life-saving equipment.

Step 4: Final Answer:
The correct statements are (C) and (D).

Quick Tip

In MSQ questions, carefully look for contradictory pairs of options (like B and C). One of them is almost certainly the correct answer, which helps narrow down the choices instantly!

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27. Which of the following options is/are representing the rheological behavior of a conventional drilling fluid?

(A) Dilatant
(B) Pseudoplastic
(C) Thixotropic
(D) Rheopectic

Correct Answer: (B), (C)

Solution:

Step 1: Understanding the Question:
The question requires us to identify the specific fluid flow (rheological) characteristics that define conventional drilling fluids (drilling muds). This is a Multiple Select Question (MSQ).

Step 3: Detailed Explanation:
Conventional drilling fluids, typically bentonite-water suspensions or polymer muds, are engineered to exhibit specific non-Newtonian behaviors to optimize the drilling process:
- **(B) Pseudoplastic (Shear-thinning):** Drilling muds must have low viscosity at high shear rates (such as inside the drill pipe and at the bit nozzles) to minimize pumping friction and maximize hydraulic impact. Conversely, they must have higher viscosity at lower shear rates (in

the wide annulus) to efficiently carry rock cuttings to the surface. This shear-thinning behavior characterizes a pseudoplastic fluid.
- **(C) Thixotropic:** A drilling mud must build "gel strength" over time when fluid circulation is temporarily stopped (e.g., during drill pipe connections). This static gel structure suspends the cuttings, preventing them from falling back and jamming the BHA. Once pumping resumes, the shear force breaks the gel, and the fluid flows easily again. This time-dependent, reversible shear-thinning behavior is known as thixotropy.
- **(A) Dilatant (Shear-thickening):** This behavior implies viscosity increases with shear rate, which would cause massive pumping pressure spikes. It is highly undesirable.
- **(D) Rheopectic:** This implies viscosity increases over time under constant shear, which is the exact opposite of thixotropy and is completely unsuitable for drilling operations.

Step 4: Final Answer:
Conventional drilling fluids exhibit both pseudoplastic and thixotropic behaviors, which correspond to options (B) and (C).

Quick Tip

A quick memory aid for drilling mud rheology:
Pseudoplasticity handles the "moving" part (thin inside the pipe, thick in the annulus).
Thixotropy handles the "stopped" part (gels when pumps are off, liquid when pumps are on).

---

28. Pressure (p) as function of radius (r) and time (t) can be found from the analytical solution of radial diffusivity equation for homogenous and isotropic reservoir following Darcy law. For this solution, if $\frac{\partial p}{\partial t}$ is treated as constant, which of the following correctly describe(s) the state(s) of pressure change?

(A) Transient
(B) Pseudo-steady
(C) Steady
(D) Unsteady

Correct Answer: (B) Pseudo-steady

Solution:

Step 1: Understanding the Question:
The question tests the fundamental definitions of the different flow regimes (or states of pressure change) in reservoir engineering based on the temporal pressure derivative, $\frac{\partial p}{\partial t}$.

Step 3: Detailed Explanation:
Based on the radial diffusivity equation, flow regimes are classified by how pressure changes

with time at any point in the reservoir:
1. **Steady-State Flow:** The pressure at any point in the reservoir does not change with time. Mathematically, $\frac{\partial p}{\partial t} = 0$.
2. **Transient (Unsteady-State) Flow:** The pressure change propagates outward from the well, and the rate of pressure decline is a function of both radius and time. Mathematically, $\frac{\partial p}{\partial t} = f(r, t)$.
3. **Pseudo-Steady State Flow:** The pressure disturbance has reached all boundaries of a closed reservoir. The pressure declines at the exact same constant rate everywhere in the reservoir. Mathematically, $\frac{\partial p}{\partial t} =$ constant.

Step 4: Final Answer:
Since $\frac{\partial p}{\partial t}$ is treated as a constant, the state of pressure change is Pseudo-steady. This matches option (B).

Quick Tip

Always associate:
- Boundary reached (closed) → Constant decline rate → Pseudo-steady state.
- Pressure support (aquifer/injection) → Zero decline rate → Steady state.
- Infinite acting → Variable decline rate → Transient/Unsteady state.

---

29. Which of the following statements is/are CORRECT about the floating production, storage, and offloading systems (FPSOs)?

(A) Existing tankers cannot be converted into FPSOs.
(B) FPSOs can be selected in the absence of any pipeline infrastructure.
(C) FPSOs cannot process the produced fluids.
(D) FPSOs can be used for the storage of produced crude oil.

Correct Answer: (B), (D)

Solution:

Step 1: Understanding the Question:
The question requires us to identify true statements regarding the capabilities and features of Floating Production, Storage, and Offloading (FPSO) units. This is a Multiple Select Question (MSQ).

Step 3: Detailed Explanation:
Let's evaluate each statement individually:
- **(A) is Incorrect.** FPSOs are very commonly created by converting existing oil tankers (Very Large Crude Carriers - VLCCs). It is often more cost-effective and faster than building a custom hull from scratch.

- **(B) is Correct.** One of the primary advantages of an FPSO is that it stores the crude oil onboard and offloads it periodically to shuttle tankers. Therefore, it is the ideal development choice in remote deepwater locations where laying export pipelines to shore is physically impossible or economically unviable.
- **(C) is Incorrect.** The "P" in FPSO stands for "Production". These vessels have massive topside facilities designed specifically to process the raw well stream (separating oil, gas, and water, and treating them).
- **(D) is Correct.** The "S" in FPSO stands for "Storage". Their enormous hull is utilized to store the processed crude oil until a shuttle tanker arrives to transport it.

Step 4: Final Answer:
The correct statements are (B) and (D).

> Quick Tip
>
> Just breaking down the acronym solves most FPSO questions:
> F = Floating (no fixed legs)
> P = Production (topside processing)
> S = Storage (hull tanks)
> O = Offloading (transfer to shuttle tankers).

---

30. For a radioactive material, if N is the number of nuclei present at time t, and λ is decay constant, then which of the following is/are CORRECT representation(s) of the rate of decay?

(A) $-\frac{dN}{dt} = \lambda N^2$
(B) $-\frac{dN}{dt} = \lambda N$
(C) $-\frac{dN}{dt} = \frac{\lambda}{N^2}$
(D) $-\frac{dN}{dt} = \frac{\lambda}{N}$

Correct Answer: (B) $-\frac{dN}{dt} = \lambda N$

Solution:

Step 1: Understanding the Question:
We need to identify the mathematical equation that governs the fundamental law of radioactive decay.

Step 2: Key Formula or Approach:
Radioactive decay is a classic first-order kinetic process. This means the rate at which nuclei decay is strictly proportional to the number of radioactive nuclei currently present.

Step 3: Detailed Explanation:
The mathematical expression for a rate of decay is the time derivative of the number of nuclei,

$\frac{dN}{dt}$.
Since the number of nuclei is decreasing, the rate of change is negative. Thus, the absolute rate of decay is expressed as $-\frac{dN}{dt}$.
According to the law of radioactive decay, this rate is directly proportional to the current amount of substance N.
Removing the proportionality sign introduces the radioactive decay constant λ:

$$-\frac{dN}{dt} = \lambda N$$

This first-order linear differential equation represents the fundamental physics of the decay process. Options (A), (C), and (D) describe nonlinear or inversely proportional kinetics, which do not apply to radioactive decay.

Step 4: Final Answer:
The correct representation is option (B).

> Quick Tip
>
> Integrating the first-order rate law $-\frac{dN}{dt} = \lambda N$ yields the famous exponential decay formula: $N(t) = N_0 e^{-\lambda t}$. Always remember radioactive decay is a strictly first-order process!

---

31. Which of the following logging methods is/are NOT used for investigation in Cement Bond Logging (CBL)?

(A) Gamma ray
(B) Neutron
(C) Electrical
(D) Acoustic wave

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

Solution:

Step 1: Understanding the Question:
We must identify which well logging principles are **NOT** the mechanism behind Cement Bond Logging (CBL). This is a Multiple Select Question (MSQ).

Step 3: Detailed Explanation:
A Cement Bond Log (CBL) is run inside cased wellbores to evaluate the mechanical integrity of the cement sheath bonding the casing to the formation.
The fundamental operating principle of a CBL tool is the generation and reception of **Acoustic (Sonic) waves**. The tool emits a sound wave and measures its amplitude when it travels

along the casing. If the casing is unbonded (free pipe), it rings loudly and the amplitude is high. If it is well-bonded to cement, the acoustic energy is strongly attenuated, resulting in a low amplitude.
Therefore, **Acoustic wave** (Option D) is the actual method USED.
- **Gamma ray** tools measure natural radioactivity to identify lithology (shale vs sand) and are run alongside CBLs purely for depth correlation, not for bond investigation.
- **Neutron** logs measure hydrogen index to determine porosity.
- **Electrical** logs measure formation resistivity to identify fluids.
None of these three methods can evaluate cement bonding.

Step 4: Final Answer:
Because the question asks which methods are **NOT** used for the cement investigation itself, the correct choices are Gamma ray, Neutron, and Electrical logs.

> Quick Tip
>
> Read the word "NOT" very carefully in GATE MSQ questions! Since CBL relies 100% on sound/acoustic attenuation, every other option is the correct answer to "what is NOT used".

---

32. The solution of the given expression is _______. (Answer in integer)

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

Correct Answer: 0

Solution:

Step 1: Understanding the Question:
We need to evaluate a trigonometric limit as the variable x approaches $\frac{\pi}{2}$.

Step 2: Key Formula or Approach:
Direct substitution yields a $\frac{0}{0}$ indeterminate form. We can solve this using either L'Hôpital's Rule or a variable substitution combined with Taylor series expansion.

Step 3: Detailed Explanation:
Let's use a variable substitution to shift the limit to zero, which makes it easier to handle.
Let $y = \frac{\pi}{2} - x$. As $x \to \frac{\pi}{2}$, we have $y \to 0$.
From this, $x = \frac{\pi}{2} - y$.
Using the complementary angle identity, we know that:

$$\cos(x) = \cos\left(\frac{\pi}{2} - y\right) = \sin(y)$$

Now, substitute these into the original limit expression:

$$L = \lim_{y \to 0} \frac{\sin(\sin(y)) - \sin(y)}{y}$$

Checking the form at $y = 0$: $\frac{\sin(0)-0}{0} = \frac{0}{0}$.
We apply L'Hôpital's Rule by differentiating the numerator and the denominator with respect to y:
Derivative of the numerator:

$$\frac{d}{dy}[\sin(\sin(y)) - \sin(y)] = \cos(\sin(y)) \cdot \cos(y) - \cos(y)$$

Derivative of the denominator:

$$\frac{d}{dy}[y] = 1$$

Now, evaluate the new limit as $y \to 0$:

$$L = \lim_{y \to 0} \frac{\cos(\sin(y)) \cdot \cos(y) - \cos(y)}{1}$$

Since $\sin(0) = 0$ and $\cos(0) = 1$, we substitute $y = 0$:

$$L = \cos(0) \cdot 1 - 1 = 1 \cdot 1 - 1 = 1 - 1 = 0$$

Step 4: Final Answer:
The limit evaluates precisely to 0.

> Quick Tip
>
> Whenever you see a limit involving trigonometric functions approaching $\frac{\pi}{2}$ or π, immediately substitute $y = a - x$ to shift the limit to 0. The math becomes much more intuitive!

---

33. A circular reservoir with a well in the centre is producing oil at constant rate under pseudo steady state. The rate of pressure change measured at the wellbore is 1.0 psi/day. Pressure at the external radius of the reservoir at a certain time was 3500 psi. After 500 days, the pressure (in psi) at the external radius will be ________ (Answer in integer)

Correct Answer: 3000

Solution:

Step 1: Understanding the Question:
The question describes a reservoir producing under pseudo-steady state (PSS) flow. We are given the rate of pressure change at the wellbore and need to find the pressure at the external boundary after a certain time.

Step 2: Key Formula or Approach:
The defining characteristic of pseudo-steady state flow in a closed reservoir is that the rate of pressure decline with time is exactly the same at every single point in the reservoir.
Mathematically:

$$\left(\frac{\partial p}{\partial t}\right)_{r_w} = \left(\frac{\partial p}{\partial t}\right)_{r_e} = \left(\frac{\partial p}{\partial t}\right)_{\text{any } r} = \text{Constant}$$

Step 3: Detailed Explanation:
We are given that the rate of pressure change at the wellbore is 1.0 psi/day.
Because the well is "producing oil", this is a pressure depletion process, meaning the pressure is dropping by 1.0 psi every single day.
Since it is in pseudo-steady state, the pressure at the external boundary (r_e) is also dropping at this exact same rate of 1.0 psi/day.
The total time elapsed is $\Delta t = 500$ days.
Calculate the total pressure drop at the external radius over this time:

$$\Delta P = \text{Rate} \times \Delta t = 1.0 \text{ psi/day} \times 500 \text{ days} = 500 \text{ psi}$$

The initial pressure at the external radius was 3500 psi.
Therefore, the new pressure at the external radius after 500 days is:

$$P_{\text{new}} = P_{\text{initial}} - \Delta P = 3500 - 500 = 3000 \text{ psi}$$

Step 4: Final Answer:
The pressure at the external radius will be 3000 psi.

Quick Tip
In pseudo-steady state, the entire pressure profile drops uniformly like a rigid plate moving downward. The pressure difference between any two points (like $P_{re} - P_{rw}$) remains absolutely constant over time!

---

34. When 92 ml of distilled water (density = 1.0 g/cm^3) is mixed with 23 grams of NaCl salt, the density of the resultant brine solution is 1.15 g/cm^3. The volume

of the brine solution (in ml) is ________. (Rounded off to one decimal place)

Correct Answer: 100.0

Solution:

Step 1: Understanding the Question:
We are mixing a known volume of water with a known mass of solid salt to create a brine solution. We are given the final density of the mixture and must find its final volume.

Step 2: Key Formula or Approach:
The fundamental principle of conservation of mass states that the total mass of the mixture is exactly equal to the sum of the individual masses of the components.

$$m_{\text{total}} = m_{\text{water}} + m_{\text{salt}}$$

Once total mass is known, the final volume can be found using the density formula:

$$V_{\text{total}} = \frac{m_{\text{total}}}{\rho_{\text{solution}}}$$

Step 3: Detailed Explanation:
First, find the mass of the distilled water. We are given its volume (92 ml) and density (1.0 g/cm^3, which is 1.0 g/ml).

$$m_{\text{water}} = \text{Volume} \times \text{Density} = 92 \text{ ml} \times 1.0 \text{ g/ml} = 92 \text{ g}$$

Next, we add the mass of the NaCl salt:

$$m_{\text{salt}} = 23 \text{ g}$$

The total mass of the resulting brine solution is:

$$m_{\text{total}} = 92 \text{ g} + 23 \text{ g} = 115 \text{ g}$$

We are given that the density of this resultant brine solution is 1.15 g/cm^3 (or 1.15 g/ml).
Now, solve for the final volume of the solution:

$$V_{\text{solution}} = \frac{115 \text{ g}}{1.15 \text{ g/ml}} = 100 \text{ ml}$$

Step 4: Final Answer:
Rounding to one decimal place, the volume is 100.0.

> 💡 Quick Tip
>
> Never assume volumes are strictly additive when dissolving a solid salt into water! Always calculate based on the strict conservation of mass, and then convert back to volume using the final mixture's density.

---

35. An oil has a density of 50 lbm/ft^3 at Standard Temperature and Pressure (STP) conditions. The density of the oil (in $^\circ$API) is ________. (Rounded off to one decimal place) [Given: water density is 62.4 lbm/ft^3 at STP]

Correct Answer: 45.1

Solution:

Step 1: Understanding the Question:
We are given the physical density of an oil in imperial units and asked to convert this density into American Petroleum Institute (API) gravity.

Step 2: Key Formula or Approach:
To find API gravity, we first must calculate the Specific Gravity (SG) of the oil.

$$SG_{\text{oil}} = \frac{\rho_{\text{oil}}}{\rho_{\text{water}}}$$

Once the specific gravity is found, the standard formula to convert it to API gravity is:

$$^\circ\text{API} = \frac{141.5}{SG_{\text{oil}}} - 131.5$$

Step 3: Detailed Explanation:
Given parameters:
$\rho_{\text{oil}} = 50$ lbm/ft^3
$\rho_{\text{water}} = 62.4$ lbm/ft^3
Step A: Calculate the Specific Gravity of the oil.

$$SG_{\text{oil}} = \frac{50}{62.4} \approx 0.801282$$

Step B: Substitute the Specific Gravity into the API formula.

$$^\circ\text{API} = \frac{141.5}{0.801282} - 131.5$$

First compute the fraction:

$$\frac{141.5}{0.801282} = 141.5 \times \frac{62.4}{50} = 141.5 \times 1.248 = 176.592$$

Now subtract the constant:

$$^\circ\text{API} = 176.592 - 131.5 = 45.092$$

Rounding to one decimal place, we get 45.1.

Step 4: Final Answer:
The API gravity of the oil is 45.1.

> Quick Tip
>
> An API gravity greater than 31° is generally considered "light oil". Because the given density (50) is much lower than water (62.4), we expect a high API value, confirming our 45.1 result makes physical sense!

---

36. Which of the following is the correct representation of the given expression?

$$\frac{(1+i)^8}{(1-i)^6}$$

(A) $2e^{-i\frac{\pi}{2}}$
(B) -1
(C) $2e^{i\frac{\pi}{2}}$
(D) 1

Correct Answer: (A) $2e^{-i\frac{\pi}{2}}$

Solution:

Step 1: Understanding the Question:
We need to simplify a complex number fraction where both the numerator and denominator are raised to higher powers, and then match the result to its polar exponential form.

Step 2: Key Formula or Approach:
Instead of expanding using binomial theorem, it is much easier to first square the complex terms inside the parentheses.
Recall that $(a + bi)^2 = a^2 - b^2 + 2abi$.

Step 3: Detailed Explanation:
Let's simplify the base terms first by squaring them:

For the numerator base $(1+i)$:

$$(1+i)^2 = 1^2 + i^2 + 2(1)(i) = 1 - 1 + 2i = 2i$$

For the denominator base $(1-i)$:

$$(1-i)^2 = 1^2 + i^2 - 2(1)(i) = 1 - 1 - 2i = -2i$$

Now, substitute these squared values back into the original expression by adjusting the exponents:
The numerator is $(1+i)^8 = [(1+i)^2]^4$:

$$(2i)^4 = 2^4 \cdot i^4 = 16 \cdot 1 = 16$$

The denominator is $(1-i)^6 = [(1-i)^2]^3$:

$$(-2i)^3 = (-2)^3 \cdot i^3 = -8 \cdot (-i) = 8i$$

Now, compute the final fraction:

$$\text{Expression} = \frac{16}{8i} = \frac{2}{i}$$

To remove i from the denominator, multiply the numerator and denominator by i:

$$\frac{2 \cdot i}{i \cdot i} = \frac{2i}{-1} = -2i$$

Finally, we must convert $-2i$ into Euler's exponential form ($Re^{i\theta}$):
The magnitude R is 2.
The complex number lies entirely on the negative imaginary axis, so the phase angle θ is $-\frac{\pi}{2}$.
Therefore:

$$-2i = 2e^{-i\frac{\pi}{2}}$$

Step 4: Final Answer:
The simplified expression matches option (A).

Quick Tip

Committing $(1+i)^2 = 2i$ and $(1-i)^2 = -2i$ to memory saves massive amounts of time in complex algebra problems on the GATE exam!

37. The values of a function $f(x)$ at three different x are given as:
f(0.90) = 7.75
f(1.00) = 9.00
f(1.10) = 10.35
Using the central difference approximation method, which of the following is the CORRECT estimate of first differential, $f'(1.00)$ and second differential, $f''(1.00)$, respectively?

(A) 10.00 and 13.00
(B) 13.00 and 10.00
(C) 10.00 and 10.00
(D) 13.00 and 13.00

Correct Answer: (B) 13.00 and 10.00

Solution:

Step 1: Understanding the Question:
We are given discrete data points for a function and asked to calculate the first and second derivatives at the central point using Numerical Methods (finite difference).

Step 2: Key Formula or Approach:
The step size h is constant between points.
The central difference formula for the first derivative is:

$$f'(x_i) \approx \frac{f(x_{i+1}) - f(x_{i-1})}{2h}$$

The central difference formula for the second derivative is:

$$f''(x_i) \approx \frac{f(x_{i+1}) - 2f(x_i) + f(x_{i-1})}{h^2}$$

Step 3: Detailed Explanation:
From the given data, let's assign our variables centered around $x_i = 1.00$:
$x_{i-1} = 0.90 \implies f(x_{i-1}) = 7.75$
$x_i = 1.00 \implies f(x_i) = 9.00$
$x_{i+1} = 1.10 \implies f(x_{i+1}) = 10.35$
The step size is $h = 1.10 - 1.00 = 0.10$.

Calculating the first derivative $f'(1.00)$:

$$f'(1.00) = \frac{10.35 - 7.75}{2 \times 0.10}$$

$$f'(1.00) = \frac{2.60}{0.20} = 13.00$$

Calculating the second derivative $f''(1.00)$:

$$f''(1.00) = \frac{10.35 - 2(9.00) + 7.75}{(0.10)^2}$$

$$f''(1.00) = \frac{10.35 - 18.00 + 7.75}{0.01}$$

$$f''(1.00) = \frac{18.10 - 18.00}{0.01} = \frac{0.10}{0.01} = 10.00$$

Step 4: Final Answer:
The first derivative is 13.00 and the second derivative is 10.00, matching option (B).

> Quick Tip
>
> Notice that the first derivative central difference entirely ignores the function's value at the central point $f(x_i)$. It relies solely on the surrounding points!

---

38. Consider a random continuous variable x and its distribution function $f(x)$. Which of the following options describes the Probability Density Function (PDF)?

(A) $\frac{d}{dx}f(x)$
(B) $\frac{d^2}{dx^2}f(x)$
(C) $\int f(x)dx$
(D) $\int \frac{1}{f(x)}dx$

Correct Answer: (A) $\frac{d}{dx}f(x)$

Solution:

Step 1: Understanding the Question:
The question asks for the mathematical relationship between a random variable's "distribution function" and its Probability Density Function (PDF).

Step 3: Detailed Explanation:
In the standard nomenclature of probability and statistics, the term "distribution function" (when used without qualifiers) explicitly refers to the Cumulative Distribution Function (CDF). Here, it is denoted as $f(x)$, although $F(x)$ is more commonly used in textbooks to prevent confusion.

The Cumulative Distribution Function represents the integral of probabilities up to a point x. To find the probability concentrated at a specific instantaneous point (the density), we must reverse the integration process.
By the Fundamental Theorem of Calculus, the Probability Density Function (PDF) is exactly the first derivative of the Cumulative Distribution Function with respect to the variable x.
Mathematically:

$$\text{PDF} = \frac{d}{dx}[\text{CDF}] = \frac{d}{dx}f(x)$$

Step 4: Final Answer:
The PDF is represented by $\frac{d}{dx}f(x)$, which corresponds to option (A).

Quick Tip

Always remember: PDF is the derivative of CDF. Conversely, CDF is the integral of the PDF from $-\infty$ to x.

---

39. Choose the CORRECT match of the sedimentary rocks in GROUP X with their processes/mechanisms of formation in GROUP Y.

GROUP X	GROUP Y
(P) Evaporite	(I) Physical process mainly consisting of lithification or cementation of deposition
(Q) Sandstone	(II) Chemical process and depositions by marine living organisms
(R) Limestone	(III) Anaerobic deposition of organic materials in mud bed
(S) Siltstones	(IV) Evaporation and precipitations of marine water

(A) P - IV; Q - I; R - II; S - III
(B) P - II; Q - IV; R - I; S - III
(C) P - II; Q - III; R - IV; S - I
(D) P - IV; Q - III; R - I; S - II

Correct Answer: (A) P - IV; Q - I; R - II; S - III

Solution:

Step 1: Understanding the Question:
We must map distinct types of sedimentary rocks to their primary geological mechanisms of deposition and formation.

Step 3: Detailed Explanation:
Let's evaluate the rocks one by one:
(P) Evaporite: As the name directly implies, evaporites (like Halite and Gypsum) are formed by the intense evaporation of saline marine water, which forces dissolved minerals to precipitate out. This perfectly matches (IV).
(R) Limestone: Limestone is predominantly a biochemical sedimentary rock composed of calcium carbonate, primarily sourced from the shells and skeletal structures of marine living organisms (coral, foraminifera, etc.) via chemical processes. This perfectly matches (II).
(Q) Sandstone: This is a classic "clastic" sedimentary rock. It forms purely through physical mechanical processes where eroded sand grains are deposited, compacted, and ultimately cemented (lithified) together over time. This strongly matches (I).
(S) Siltstones: By process of elimination, this links to (III). Siltstones and shales are very fine-grained and form in quiet, low-energy environments like mud beds, which frequently become anaerobic (oxygen-depleted) and preserve organic materials.

Step 4: Final Answer:
The correct pairing is P-IV, Q-I, R-II, S-III. This sequence corresponds exactly to option (A).

> Quick Tip
>
> In match-the-column questions, finding just one or two obvious rock-solid pairs (like Evaporite → Evaporation, Limestone → Marine Organisms) is usually enough to eliminate all wrong options without needing to perfectly justify the ambiguous ones!

---

40. Which of the following "logging methods" in a borehole will provide the highest depth of investigation for a given marine formation?

(A) Neutron
(B) Sonic
(C) Density
(D) Resistivity

Correct Answer: (D) Resistivity

Solution:

Step 1: Understanding the Question:
We must identify which common open-hole logging tool is capable of "seeing" the deepest into

the uninvaded zone of the rock formation, away from the wellbore.

Step 3: Detailed Explanation:
Depth of Investigation (DOI) is a measure of how far radially into the formation a logging tool can read effectively.
- **Density logs** (using gamma-ray scattering) are very shallow reading tools, usually penetrating only about 2 to 6 inches into the rock.
- **Neutron logs** (using neutron scattering) are also relatively shallow, reading roughly 6 to 12 inches into the formation depending on porosity.
- **Sonic logs** (using sound waves) measure the formation immediately adjacent to the wellbore, generally reading only a few inches deep.
- **Resistivity logs** (specifically Deep Induction or Deep Laterolog tools) use low-frequency electromagnetic fields or focused currents to probe deep past the drilling mud filtrate invasion zone. They have the highest depth of investigation, easily reaching depths of 60 to 120 inches (several feet) to measure true formation resistivity (R_t).

Step 4: Final Answer:
Resistivity provides the highest depth of investigation, matching option (D).

Quick Tip

General rule of thumb for logging tool penetration depths:
Nuclear Tools (Density/Neutron/Gamma) = Shallow (inches).
Acoustic Tools (Sonic) = Shallow (inches).
Electromagnetic Tools (Deep Resistivity) = Deep (feet).

---

41. Choose the CORRECT match of the fire detection systems in GROUP X with their corresponding working mechanisms in GROUP Y.

GROUP X	GROUP Y
(P) Fusible plug loops	(I) Detects rise in temperature caused by fire and visible/invisible particles of combustion.
(Q) Thermal and smoke detection system	(II) Functions based on drop in pressure that activates fire shutdown.
(R) Gas detection system	(III) Detects flammables.

(A) P-I; Q-II; R-III
(B) P-II; Q-I; R-III
(C) P-III; Q-I; R-II
(D) P-II; Q-III; R-I

Correct Answer: (B) P-II; Q-I; R-III

Solution:

Step 1: Understanding the Question:
We need to accurately link different industrial safety and fire detection systems to their core operating principles.

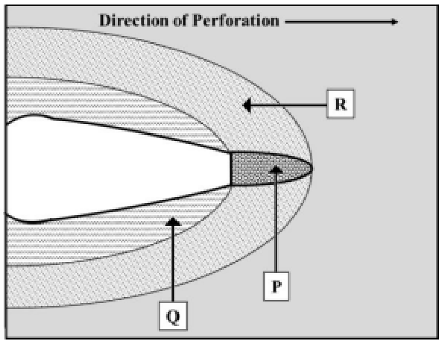
Step 3: Detailed Explanation:
Let's analyze the detection systems:
(P) Fusible plug loops: A fusible plug is a specialized pneumatic safety device. It consists of a pressurized line fitted with plugs made from an alloy designed to melt at a specific elevated temperature. When a fire occurs, the plug melts, the pressurized air/gas escapes, and this sudden **drop in pressure** acts as a mechanical signal to trigger an Emergency Shutdown (ESD). Thus, P matches with (II).
(Q) Thermal and smoke detection system: As the explicit name suggests, thermal detectors sense the **rise in temperature**, while smoke detectors sense the **visible/invisible particles** resulting from combustion. Thus, Q matches perfectly with (I).
(R) Gas detection system: These sensors (like infrared or catalytic bead sensors) continuously monitor the atmosphere specifically to **detect flammable** or toxic gas leaks before a fire even starts. Thus, R matches perfectly with (III).

Step 4: Final Answer:
The correct pairing sequence is P-II, Q-I, R-III, which corresponds to option (B).

> Quick Tip
>
> Fusible plugs are purely mechanical "failsafe" devices. They are highly reliable on offshore platforms because they don't rely on electricity. If power fails but fire breaks out, the plug melts, pressure drops, and valves automatically slam shut.

---

42. The sectional view of three different damaged regions (marked as P, Q and R) near the vicinity of a perforation is shown in the figure. Choose the correct option by matching the entries in GROUP X with corresponding terms in GROUP Y.



GROUP X	GROUP Y
P	(I) Grain fracturing
Q	(II) Charge and core debris
R	(III) Compacted pulverized zone

(A) P – I; Q – II; R – III
(B) P – II; Q – III; R – I
(C) P – I; Q – III; R – II
(D) P – II; Q – I; R – III

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

Solution:

Step 1: Understanding the Question:
The question tests your visual knowledge of the anatomy of a shaped charge perforation tunnel and the specific types of formation damage induced radially around it.

Step 3: Detailed Explanation:
By closely examining the directional arrows in the provided schematic:
Pointer Q: This arrow points directly to the dark, solid material accumulating at the very tip (apex) of the perforation tunnel. This is the residual metal from the shaped charge liner and crushed rock forming a plug. This represents the **Charge and core debris**. Thus, Q matches with (II).
Pointer R: This arrow specifically points to the innermost, very thin, heavily shaded shell immediately lining the open void of the perforation tunnel. The immense explosive pressure obliterates the rock matrix here, creating a severely permeability-damaged skin known as the "crushed zone" or **Compacted pulverized zone**. Thus, R matches with (III).
Pointer P: This arrow points to the lighter, much wider, outermost affected region surrounding the pulverized zone. In this area, the explosive shockwave has dissipated enough not to pulverize the rock, but it still exerts enough stress to cause micro-fracturing of the sand grains. This is the altered zone experiencing **Grain fracturing**. Thus, P matches with (I).

Step 4: Final Answer:

The correctly matched sequence is P-I, Q-II, R-III, which exactly matches option (A).

Quick Tip

In perforation damage models, damage severity is highest at the tunnel wall and decreases radially outward.
Inner Wall (R) = Rock completely crushed/pulverized.
Outer Area (P) = Rock grains merely fractured by the passing shockwave.

---

43. Real gas pseudo pressure is used to derive diffusivity equation for highly compressible fluid for which viscosity (μ) and gas compressibility factor (Z) are functions of pressure (p). Which of the following represents the partial derivative of the real gas pseudo pressure with respect to time (t)?

(A) $\frac{2p}{\mu Z}\frac{\partial p}{\partial t}$
(B) $\frac{p^2}{2\mu Z}\frac{\partial p}{\partial t}$
(C) $\frac{\mu Z}{2p}\frac{\partial p}{\partial t}$
(D) $\frac{2\mu Z}{p^2}\frac{\partial p}{\partial t}$

Correct Answer: (A) $\frac{2p}{\mu Z}\frac{\partial p}{\partial t}$

Solution:

Step 1: Understanding the Question:
The question asks for the partial derivative of the real gas pseudo-pressure, $m(p)$, with respect to time t.

Step 2: Key Formula or Approach:
The real gas pseudo-pressure, $m(p)$, is mathematically defined to linearize the flow equations for compressible gases and is given by the integral:

$$m(p) = 2\int_{p_0}^{p} \frac{p}{\mu Z} dp$$

To find its derivative with respect to time t, we must apply the chain rule of calculus:

$$\frac{\partial m(p)}{\partial t} = \frac{\partial m(p)}{\partial p} \cdot \frac{\partial p}{\partial t}$$

Step 3: Detailed Explanation:
First, take the partial derivative of $m(p)$ with respect to pressure p. By the Fundamental Theorem of Calculus, differentiating an integral with respect to its upper limit simply yields the

integrand evaluated at that limit:

$$\frac{\partial m(p)}{\partial p} = \frac{d}{dp}\left(2\int_{p_0}^{p} \frac{p}{\mu Z}dp\right) = \frac{2p}{\mu Z}$$

Now, substitute this result back into the chain rule expression:

$$\frac{\partial m(p)}{\partial t} = \frac{2p}{\mu Z}\frac{\partial p}{\partial t}$$

Step 4: Final Answer:
The partial derivative matches option (A).

Quick Tip

Always remember the chain rule for pseudo-properties! $m(p)$ removes the pressure dependence of μ and Z from the spatial derivatives in the diffusivity equation, simplifying it to a form similar to slightly compressible liquids.

---

44. Stokes' law is used to calculate the settling rate in the drilling fluid for two batches (P and Q) of barite. The particle (spherical) size of barite from batch P is 75 μm and that for batch Q is 25 μm. The particle settling rate in the drilling fluid for the batch P is ________ times that for the batch Q.

(A) Four
(B) Nine
(C) Two
(D) One

Correct Answer: (B) Nine

Solution:

Step 1: Understanding the Question:
We are asked to compare the settling velocities of two differently sized spherical barite particles in a drilling fluid using Stokes' Law.

Step 2: Key Formula or Approach:
According to Stokes' Law, the terminal settling velocity (v) of a spherical particle in a viscous fluid is given by:

$$v = \frac{2}{9}\frac{(\rho_p - \rho_f)gr^2}{\mu}$$

Since both batches are barite (same particle density ρ_p) settling in the same drilling fluid (same fluid density ρ_f and viscosity μ), all terms are constant except for the particle radius r (or diameter d).
Thus, the settling rate is directly proportional to the square of the particle diameter:

$$v \propto d^2$$

Step 3: Detailed Explanation:
Let v_P and v_Q be the settling rates for batch P and batch Q, respectively.
The diameter of batch P is $d_P = 75\ \mu$m.
The diameter of batch Q is $d_Q = 25\ \mu$m.
Using the proportionality relationship:

$$\frac{v_P}{v_Q} = \left(\frac{d_P}{d_Q}\right)^2$$

Substitute the given values:

$$\frac{v_P}{v_Q} = \left(\frac{75}{25}\right)^2 = (3)^2 = 9$$

Therefore, the settling rate for batch P is 9 times that for batch Q.

Step 4: Final Answer:
The settling rate for P is Nine times that of Q, which corresponds to option (B).

Quick Tip
Because settling velocity scales with the square of the diameter, even a small increase in particle size results in a massive increase in settling speed. This is why ultrafine barite is preferred to prevent sagging!

---

45. Which of the following approaches is/are used to get the response of Formation Micro Scanner (FMS) log?

(A) Optical
(B) Electrical
(C) Thermal
(D) Nuclear

Correct Answer: (B) Electrical

Solution:

Step 1: Understanding the Question:
We need to identify the fundamental physical principle used by a Formation Micro Scanner (FMS) logging tool to generate its readings.

Step 3: Detailed Explanation:
The Formation Micro Scanner (FMS) is an imaging tool used in well logging to produce a high-resolution electrical image of the borehole wall.
It operates by pressing arrays of small electrode buttons directly against the borehole wall and measuring the micro-resistivity of the formation as the tool is pulled to the surface.
The variations in micro-resistivity reflect changes in lithology, porosity, fracture presence, and fluid content, creating a detailed 2D image.
Because it inherently relies on measuring resistivity via electrodes, the approach is strictly **Electrical**.

Step 4: Final Answer:
The correct approach is Electrical, matching option (B).

> Quick Tip
>
> Imaging logs come in two main types:
> 1. Electrical (like FMS/FMI): Uses micro-resistivity, requires conductive mud.
> 2. Acoustic/Ultrasonic (like UBI/CBIL): Uses sound waves, works in oil-based muds.

---

46. Which of the following conditions is/are inferred using cross plots of neutron porosity (ϕ_N) and density porosity (ϕ_D)?

(A) Gas zone
(B) Shale distribution
(C) Water zone
(D) Oil zone

Correct Answer: (A), (B)

Solution:

Step 1: Understanding the Question:
This is a Multiple Select Question (MSQ). We need to identify which formation characteristics can be distinctly and reliably identified using a standard Neutron-Density crossplot.

Step 3: Detailed Explanation:
A Neutron-Density crossplot graphs density porosity (ϕ_D) against neutron porosity (ϕ_N). It is

a cornerstone of formation evaluation.
- **(A) Gas zone:** This is the most famous application. In the presence of gas, the neutron tool reads artificially low (due to low hydrogen index), and the density tool reads artificially high porosity (due to low bulk density). This causes a massive "crossover" or separation on the crossplot, allowing clear identification of gas.
- **(B) Shale distribution:** Shales contain heavily bound water within their clay structure. This bound water registers as very high apparent porosity on the neutron log, but the density log reads closer to actual porosity. This causes data points to pull far to the bottom right of the crossplot, establishing distinct "shale points" and allowing shale volume estimation.
- **(C) and (D) Oil and Water zones:** Liquid oil and water have very similar densities and hydrogen indices (close to 1.0). Therefore, their data points overlap heavily on a standard Neutron-Density crossplot. Distinguishing between oil and water requires a Resistivity log, not a porosity crossplot.

Step 4: Final Answer:
Gas zones and shale distribution can be inferred. The correct options are (A) and (B).

> Quick Tip
>
> Remember the visual pattern on logs:
> Gas = "Butterfly effect" (Density ϕ goes left/high, Neutron ϕ goes right/low).
> Shale = Reverse separation (Neutron ϕ reads much higher than Density ϕ).

---

47. Which of the following is/are obtained using a core sample?

(A) Porosity
(B) Pore size distributions
(C) Absolute permeability
(D) Reservoir boundary

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

Solution:

Step 1: Understanding the Question:
This Multiple Select Question (MSQ) asks to identify which reservoir properties can be determined by conducting laboratory experiments on physical rock core samples retrieved from a wellbore.

Step 3: Detailed Explanation:
Core analysis in the lab provides direct, physical measurements of rock properties (both Routine Core Analysis - RCA, and Special Core Analysis - SCAL).
- **(A) Porosity:** Measured routinely by finding the bulk volume and the pore volume (using

helium porosimetry or fluid saturation).
- **(B) Pore size distributions:** Determined through SCAL using techniques like Mercury Injection Capillary Pressure (MICP) or Nuclear Magnetic Resonance (NMR) on the core plug.
- **(C) Absolute permeability:** Measured routinely by flowing a single-phase fluid (like gas or liquid) through the core plug and applying Darcy's Law.
- **(D) Reservoir boundary:** This is a macro-scale geographical feature. A tiny core plug (1 to 4 inches) cannot provide information about boundaries miles away. Boundaries are determined via transient well testing (pressure build-up/drawdown) or seismic surveys.

Step 4: Final Answer:
Options (A), (B), and (C) are correct.

> Quick Tip
>
> Core analysis = Micro-scale (Porosity, Permeability, Capillary pressure, Wettability).
> Well testing/Seismic = Macro-scale (Boundaries, Faults, Total connected volume).

---

48. Pressure change and derivative type curves (Bourdet type curves) are used in the well test analysis. Which of the following statements is/are CORRECT about these type curves?

(A) These curves are on Log-Log plot.
(B) Horizontal axis is for dimensionless time t_D.
(C) All derivative type curves merge in the middle time region.
(D) Vertical axis is for dimensionless pressure P_D only.

Correct Answer: (A), (C)

Solution:

Step 1: Understanding the Question:
We need to identify the true characteristics of the Bourdet pressure derivative type curves, which revolutionized modern well test analysis. This is a Multiple Select Question (MSQ).

Step 3: Detailed Explanation:
Let's analyze the construction of Bourdet derivative type curves:
- **(A) is Correct.** The hallmark of the Bourdet method is plotting both the pressure change and the pressure derivative simultaneously on a single **Log-Log plot**.
- **(B) is Incorrect.** In the standard Bourdet type curve layout (which accounts for wellbore storage and skin), the horizontal axis is typically plotted as the ratio t_D/C_D (Dimensionless time divided by dimensionless wellbore storage), not just t_D.
- **(C) is Correct.** In the "middle time region" representing Infinite Acting Radial Flow (IARF), the pressure derivative becomes completely independent of wellbore storage and skin.

Mathematically, the derivative stabilizes at a constant value of 0.5. Thus, all the derivative curves corresponding to different C_De^{2s} values flawlessly merge into a single horizontal flat line at 0.5.
- **(D) is Incorrect.** The vertical axis is a dual axis that represents **both** the dimensionless pressure P_D and the dimensionless pressure derivative $(t_D/C_D)P'_D$.

Step 4: Final Answer:
The correct statements are (A) and (C).

> 💡 Quick Tip
>
> The flat, horizontal zero-slope line on the Bourdet derivative curve is the holy grail of well testing. It proves the presence of Infinite Acting Radial Flow (IARF) and its y-axis value allows direct calculation of permeability!

---

49. Which of the following is/are objective(s) of a safety system in offshore production platforms?

(A) To prevent leak or overflow of hydrocarbons.
(B) To prevent ignition of hydrocarbons released on the platform.
(C) To prevent water coning in the reservoir.
(D) To prevent gas coning in the reservoir.

Correct Answer: (A), (B)

Solution:

Step 1: Understanding the Question:
This MSQ tests basic knowledge of Health, Safety, and Environment (HSE) systems deployed on offshore production facilities.

Step 3: Detailed Explanation:
Offshore surface safety systems (such as Emergency Shutdown systems, blast walls, fire and gas detectors) are strictly designed to protect personnel, the environment, and the facility itself from catastrophic events.
- **(A) To prevent leak or overflow of hydrocarbons:** Correct. Sensors, high-level alarms in separators, and Surface Safety Valves (SSVs) act immediately to contain spills.
- **(B) To prevent ignition of hydrocarbons released on the platform:** Correct. If a leak does occur, safety systems automatically shut off ignition sources (electrical trips) and activate deluge systems.
- **(C) and (D) To prevent water/gas coning:** Incorrect. Coning is a subsurface reservoir dynamics issue managed by controlling production rates (choke management) or drilling horizontal wells. It has absolutely nothing to do with topside safety/emergency systems.

Step 4: Final Answer:
Options (A) and (B) accurately describe the objectives of a safety system.

> Quick Tip
>
> Always separate surface safety engineering from reservoir management in your mind. Safety systems deal with immediate physical hazards (fire, explosions, spills), not long-term reservoir flow phenomena.

---

50. A wellbore has true vertical depth (TVD) of 10000 ft. The pore pressure of the formation fluid in the permeable stratum at the bottom of the wellbore is 6500 psig. Which of the following is/are the acceptable average static mud density value(s) (in lbm/gal) to prevent the flow of the formation fluid from the permeable stratum to the wellbore?
[Given: 1 lbm/gal mud is equivalent to 0.052 psi/ft]

(A) 13.8
(B) 11.3
(C) 11.8
(D) 13.2

Correct Answer: (A), (D)

Solution:

Step 1: Understanding the Question:
This is a Multiple Select Question (MSQ). To prevent formation fluid from flowing into the wellbore (a "kick"), the hydrostatic pressure exerted by the drilling mud must be strictly greater than the formation pore pressure.

Step 2: Key Formula or Approach:
The hydrostatic pressure (P_h) of the drilling mud is calculated using:

$$P_h = 0.052 \times \rho_{\text{mud}} \times \text{TVD}$$

For well control and safety (overbalance condition):

$$P_h > \text{Pore Pressure}$$

Step 3: Detailed Explanation:
We are given:
TVD = 10000 ft

Pore pressure = 6500 psig
Set up the inequality to find the minimum required mud density:

$$0.052 \times \rho_{\text{mud}} \times 10000 > 6500$$

$$520 \times \rho_{\text{mud}} > 6500$$

Solving for ρ_{mud}:

$$\rho_{\text{mud}} > \frac{6500}{520}$$

$$\rho_{\text{mud}} > 12.5 \text{ lbm/gal}$$

Any mud density strictly greater than 12.5 lbm/gal is acceptable to prevent a kick.
Evaluating the given options:
(A) $13.8 > 12.5 \implies$ Acceptable
(B) $11.3 < 12.5 \implies$ Not acceptable (will cause a kick)
(C) $11.8 < 12.5 \implies$ Not acceptable (will cause a kick)
(D) $13.2 > 12.5 \implies$ Acceptable

Step 4: Final Answer:
The acceptable mud density values are 13.8 and 13.2 lbm/gal.

Quick Tip

A standard safety margin (trip margin) of 0.2 to 0.5 ppg is usually added on top of the calculated balance density in the field, further validating the selection of higher values like 13.2 and 13.8!

---

51. Which of the following statements is/are CORRECT about the skin factor?

(A) Successful hydraulic fracturing increases the skin factor.
(B) Successful hydraulic fracturing decreases the skin factor.
(C) Formation damage near wellbore increases the skin factor.
(D) Formation damage near wellbore decreases the skin factor.

Correct Answer: (B), (C)

Solution:

Step 1: Understanding the Question:
This MSQ tests the fundamental conceptual definition of the "skin factor" (S) in well testing and production engineering.

Step 3: Detailed Explanation:
The skin factor (S) is a dimensionless number representing the deviation from ideal flow conditions near the wellbore.
- **Positive Skin ($S > 0$):** Represents an additional pressure drop. This occurs when the near-wellbore permeability is reduced due to mud filtrate invasion, clay swelling, or fines migration. This is broadly termed as **formation damage**. Therefore, damage **increases** the skin factor.
- **Negative Skin ($S < 0$):** Represents an enhancement in flow efficiency (reduced pressure drop compared to ideal radial flow). This is achieved through stimulation techniques like acidizing or **hydraulic fracturing**, which bypass damage and create highly conductive paths. Therefore, successful stimulation **decreases** the skin factor (makes it more negative).
Based on this:
(A) Incorrect. Fracturing lowers skin.
(B) Correct. Fracturing successfully lowers skin below zero.
(C) Correct. Damage creates restriction, driving skin positive.
(D) Incorrect. Damage raises skin.

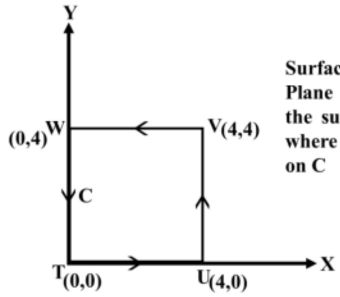
Step 4: Final Answer:
Statements (B) and (C) correctly describe the behavior of the skin factor.

Quick Tip

Skin Factor Rule:
$S > 0 \rightarrow$ Damage (Bad for production).
$S = 0 \rightarrow$ Ideal (Natural flow).
$S < 0 \rightarrow$ Stimulated (Good for production).

---

52. Consider a vector function $\vec{F} = (y - z + 2)\hat{i} + (yz + 8)\hat{j} - xz\hat{k}$, on the surface (S) in the XY plane at $z = 0$ (as shown in the figure). Considering Stokes' theorem for space, the ABSOLUTE value of surface integral $\iint_S (\nabla \times \vec{F}) \cdot \hat{n} dS$ is ________. (Answer in integer)



Surface (S) projection of cube in the XY Plane (Z = 0) with the boundary (C) of the surface S, along the path TUVWT, where $\hat{n}$ is the unit vector at any point on C

Consider $\hat{\imath}, \hat{\jmath}, \hat{k}$, and $\hat{n}$ as unit vectors)

Correct Answer: 16

Solution:

Step 1: Understanding the Question:
We are given a vector field $\vec{F}$ and asked to compute the absolute value of the surface integral of the curl of $\vec{F}$ over a specific square surface in the XY plane.

Step 2: Key Formula or Approach:
We need to calculate $\iint_S (\nabla \times \vec{F}) \cdot \hat{n} dS$.
First, compute the curl of the vector field $\nabla \times \vec{F}$.
Since the surface S strictly lies in the XY plane ($z = 0$), the unit normal vector $\hat{n}$ to the surface is simply $\hat{k}$.
The dot product $(\nabla \times \vec{F}) \cdot \hat{k}$ simply extracts the z-component of the curl.

Step 3: Detailed Explanation:
The given vector field is:
$F_x = y - z + 2$
$F_y = yz + 8$
$F_z = -xz$
The z-component of the curl is given by:

$$(\nabla \times \vec{F})_z = \frac{\partial F_y}{\partial x} - \frac{\partial F_x}{\partial y}$$

Calculate the partial derivatives:

$$\frac{\partial F_y}{\partial x} = \frac{\partial}{\partial x}(yz + 8) = 0$$

$$\frac{\partial F_x}{\partial y} = \frac{\partial}{\partial y}(y - z + 2) = 1$$

Substitute these into the formula:

$$(\nabla \times \vec{F})_z = 0 - 1 = -1$$

Now, set up the surface integral:

$$\iint_S (\nabla \times \vec{F}) \cdot \hat{k} dS = \iint_S (-1) dS = -1 \iint_S dS$$

The integral $\iint_S dS$ is exactly the area of the surface S.
From the provided coordinates in the image, the surface is a square bounded by $x = 0$ to 4 and $y = 0$ to 4.
Area of the square $= 4 \times 4 = 16$.
So, the value of the integral is:

$$-1 \times 16 = -16$$

The question asks for the **ABSOLUTE** value:

$$|-16| = 16$$

Step 4: Final Answer:
The absolute value of the surface integral is 16.

Quick Tip

Alternatively, you can use Stokes' Theorem to evaluate the line integral $\oint \vec{F} \cdot d\vec{r}$ along the square perimeter. Setting $z = 0$ simplifies the vector to $\vec{F} = (y+2)\hat{\imath} + 8\hat{\jmath}$. Integrating this over the four sides will identically yield -16!

---

53. For a given reservoir of porosity, $\phi = 0.1$, the water saturation is equal to the irreducible water saturation. The BVI (Bulk Volume Irreducible) water saturation was estimated as 0.04 using NMR (Nuclear Magnetic Resonance) log. The permeability, k in mD is estimated using the relation:

$$k = 10^4 \phi^4 \left(\frac{\text{FFI}}{\phi - \text{FFI}} \right)^2$$

where FFI is the Free Fluid Index. Based on this information, the permeability (in mD) is _______. (Rounded off to two decimal places)

Correct Answer: 2.25

Solution:

Step 1: Understanding the Question:
We are given porosity and the Bulk Volume Irreducible (BVI) from an NMR log. We must calculate the Free Fluid Index (FFI) and use the provided empirical equation (Timur-Coates model) to find absolute permeability.

Step 2: Key Formula or Approach:
In Nuclear Magnetic Resonance (NMR) logging, the total porosity (ϕ) of a rock is partitioned into two distinct fluid volumes:
1. Bulk Volume Irreducible (BVI): The volume of fluid permanently trapped by capillary forces.
2. Free Fluid Index (FFI): The volume of fluid free to flow.
The fundamental material balance is:

$$\phi = \text{BVI} + \text{FFI}$$

Step 3: Detailed Explanation:
Given parameters:
Total Porosity, $\phi = 0.1$
Bulk Volume Irreducible, $\text{BVI} = 0.04$
First, calculate the Free Fluid Index (FFI):

$$\text{FFI} = \phi - \text{BVI}$$

$$\text{FFI} = 0.1 - 0.04 = 0.06$$

Now, substitute the known values into the given permeability equation:

$$k = 10^4 \times (0.1)^4 \times \left(\frac{0.06}{0.1 - 0.06}\right)^2$$

Simplify the terms:

$$10^4 \times (0.1)^4 = 10000 \times 0.0001 = 1$$

$$\left(\frac{0.06}{0.04}\right)^2 = (1.5)^2 = 2.25$$

Multiply the results:

$$k = 1 \times 2.25 = 2.25 \text{ mD}$$

Step 4: Final Answer:
The calculated permeability is 2.25 mD.

> 💡 Quick Tip
>
> NMR log equations like the Timur-Coates or SDR models are heavily reliant on accurately separating BVI and FFI using a T_2 cutoff time. Always remember that $\phi_{\text{total}} = \text{FFI} + \text{BVI}$!

---

54. The Inflow Performance Relationship (IPR) for a vertical well in a single-phase oil reservoir was found to be linear. The flowing bottomhole pressures are 4000 psi and 1000 psi at oil flow rates of 200 STB/day and 600 STB/day, respectively. At the flowing bottomhole pressure of 2875 psi, the value of flow rate (in STB/day) is ________. (Answer in integer)
[STB: Stock Tank Barrel]

Correct Answer: 350

Solution:

Step 1: Understanding the Question:
The question provides two data points on a linear Inflow Performance Relationship (IPR) curve. We need to linearly interpolate (or extrapolate) to find the flow rate corresponding to a specific bottomhole pressure.

Step 2: Key Formula or Approach:
For a single-phase oil reservoir above the bubble point, the IPR is a straight line governed by the Productivity Index (J):

$$J = \frac{\Delta q}{\Delta P_{wf}} = \frac{q_2 - q_1}{P_{wf1} - P_{wf2}}$$

Once J is found, the general linear equation is:

$$q = q_1 + J \times (P_{wf1} - P_{wf})$$

Step 3: Detailed Explanation:
Given data:
Point 1: $q_1 = 200$ STB/day, $P_{wf1} = 4000$ psi
Point 2: $q_2 = 600$ STB/day, $P_{wf2} = 1000$ psi
First, calculate the Productivity Index (J):

$$J = \frac{600 - 200}{4000 - 1000} = \frac{400}{3000} = \frac{4}{30} = \frac{2}{15} \text{ STB/day/psi}$$

We need to find the flow rate q at $P_{wf} = 2875$ psi.
Using the linear equation starting from Point 1:

$$q = 200 + \frac{2}{15} \times (4000 - 2875)$$

Calculate the pressure drawdown difference:

$$4000 - 2875 = 1125 \text{ psi}$$

Substitute and solve:

$$q = 200 + \left(\frac{2}{15} \times 1125\right)$$

$$\frac{1125}{15} = 75$$

$$q = 200 + (2 \times 75) = 200 + 150 = 350 \text{ STB/day}$$

Step 4: Final Answer:
The flow rate at 2875 psi is 350 STB/day.

> **Quick Tip**
>
> Because the relationship is strictly linear, you can also solve this quickly by finding the reservoir pressure (P_R) where $q = 0$, and then using $q = J(P_R - P_{wf})$. Both paths yield the exact same result!

---

55. A matrix acidizing job is planned on a sandstone pay zone at a depth of 7000 ft without formation breakdown by keeping a safety margin of 250 psi with the help of a coil tubing unit. Consider the fracture gradient of 0.7 psi/ft, average specific gravity of the injection fluid as 1.065, and frictional pressure drop of 200 psi. The maximum surface injection pressure (in psi) is ________. (Rounded off to one decimal place)
[Given: Hydrostatic gradient (psi/ft) = 0.433 $\times$ Specific Gravity]

Correct Answer: 1622.0

Solution:

Step 1: Understanding the Question:
This problem requires calculating the maximum allowable pump pressure at the surface during an acidizing job so that the rock formation at the bottom of the well does not physically fracture.

Step 2: Key Formula or Approach:
The fundamental pressure balance equation during fluid injection is:

$$P_{\text{bottomhole}} = P_{\text{surface}} + P_{\text{hydrostatic}} - P_{\text{friction}}$$

To avoid fracturing the rock, the bottomhole pressure must not exceed the fracture pressure minus the required safety margin:

$$P_{\text{bottomhole, max}} = P_{\text{fracture}} - P_{\text{safety}}$$

Equating the two to solve for maximum surface pressure:

$$P_{\text{surface, max}} = P_{\text{bottomhole, max}} - P_{\text{hydrostatic}} + P_{\text{friction}}$$

Step 3: Detailed Explanation:
Given parameters:
Depth (D) = 7000 ft
Fracture Gradient = 0.7 psi/ft
Specific Gravity (SG) = 1.065
Friction Drop (P_{friction}) = 200 psi
Safety Margin (P_{safety}) = 250 psi

1. Calculate the Fracture Pressure (P_{fracture}):

$$P_{\text{fracture}} = 0.7 \text{ psi/ft} \times 7000 \text{ ft} = 4900 \text{ psi}$$

2. Calculate the Maximum Allowable Bottomhole Pressure ($P_{\text{bottomhole, max}}$):

$$P_{\text{bottomhole, max}} = 4900 - 250 = 4650 \text{ psi}$$

3. Calculate the Hydrostatic Pressure ($P_{\text{hydrostatic}}$) of the acid:

$$\text{Hydrostatic Gradient} = 0.433 \times 1.065 = 0.461145 \text{ psi/ft}$$

$$P_{\text{hydrostatic}} = 0.461145 \text{ psi/ft} \times 7000 \text{ ft} = 3228.015 \text{ psi}$$

4. Calculate the Maximum Surface Injection Pressure ($P_{\text{surface, max}}$):

$$P_{\text{surface, max}} = 4650 - 3228.015 + 200$$

$$P_{\text{surface, max}} = 1421.985 + 200 = 1621.985 \text{ psi}$$

Step 4: Final Answer:
Rounding to one decimal place, the maximum surface pressure is 1622.0 psi.

Quick Tip

Pay close attention to the signs in the pressure balance! Hydrostatic pressure **helps** the pump (adds pressure downhole), so you subtract it. Friction **fights** the pump (loses pressure), so you must add it back to the surface requirement.

---

56. A drawdown test data is analyzed to find out the permeability and skin factor of the reservoir using a semi-log plot. Flowing bottomhole pressure (in psi) is plotted on the linear scale against time (in hours). Flow rate is 1500 STB/day, oil formation volume factor is 1.2 RB/STB, oil viscosity is 1 cP, and thickness of the bed is 10 ft. After plotting, it is found that the slope of the straight line fitting the data in the middle time region is -60 psi/log cycle. The permeability of the reservoir (in mD) is ______________. (Rounded off to one decimal place)
[RB: Reservoir Barrel; STB: Stock Tank Barrel]

Correct Answer: 487.8

Solution:

Step 1: Understanding the Question:
The question provides the slope of the Infinite Acting Radial Flow (IARF) straight line from a semi-log pressure drawdown plot and asks us to extract the reservoir's permeability.

Step 2: Key Formula or Approach:
For a constant-rate drawdown test analyzed on a semi-log plot (P_{wf} vs $\log(t)$), the absolute slope ($|m|$) of the middle-time straight line is governed by the transient radial flow equation:

$$|m| = \frac{162.6 q \mu B}{kh}$$

Rearranging to solve for absolute permeability k:

$$k = \frac{162.6 q \mu B}{|m| h}$$

Step 3: Detailed Explanation:
Given parameters:
Flow rate, $q = 1500$ STB/day
Viscosity, $\mu = 1$ cP
Formation Volume Factor, $B = 1.2$ RB/STB
Reservoir thickness, $h = 10$ ft
Absolute Slope, $|m| = |-60| = 60$ psi/log cycle

Substitute all the given values directly into the rearranged formula:

$$k = \frac{162.6 \times 1500 \times 1 \times 1.2}{60 \times 10}$$

Calculate the numerator:

$$1500 \times 1.2 = 1800$$

$$162.6 \times 1800 = 292680$$

Calculate the denominator:

$$60 \times 10 = 600$$

Divide to find k:

$$k = \frac{292680}{600} = 487.8 \text{ mD}$$

Step 4: Final Answer:
The permeability is 487.8 mD.

> Quick Tip
>
> The constant 162.6 strictly requires time to be in hours, log base 10, and field units (STB/day, psi, mD, cP, ft). Always ensure your slope m is measured per "log cycle" (base 10) and not per natural log (ln) cycle!

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57. A conventional Sucker Rod Pumping (SRP) unit is being used for lifting 25 °API oil from a depth of 5000 ft. The maximum and minimum values of polished rod loads are 14300 lbf and 5200 lbf, respectively. The ideal counter balance load (in lbf) is ________. (Answer in integer)

Correct Answer: 9750

Solution:

Step 1: Understanding the Question:
The problem provides the maximum and minimum loads acting on the polished rod of a sucker rod pump during its upward and downward strokes. We need to find the ideal counterbalance weight required on the surface unit to balance the system.

Step 2: Key Formula or Approach:
To minimize energy consumption and equalize the torque exerted on the gearbox during both the upstroke and the downstroke, an "ideal" counterbalance load (CBL) is applied.
The universally accepted formula for the ideal effective counterbalance load is exactly the arithmetic average of the maximum and minimum polished rod loads:

$$\text{Ideal CBL} = \frac{PRL_{max} + PRL_{min}}{2}$$

Step 3: Detailed Explanation:
Given load parameters:
Peak Polished Rod Load (PRL_{max}) = 14300 lbf
Minimum Polished Rod Load (PRL_{min}) = 5200 lbf

Substitute these values into the average formula:

$$\text{Ideal CBL} = \frac{14300 + 5200}{2}$$

$$\text{Ideal CBL} = \frac{19500}{2} = 9750 \text{ lbf}$$

Step 4: Final Answer:
The ideal counterbalance load is 9750 lbf.

Quick Tip

Information like API gravity and pump depth are frequently provided in these problems to act as "distractors." If PRL_{max} and PRL_{min} are already explicitly given, you can bypass all the complex component weight calculations entirely!

58. Matthews-Brons-Hazebroek (MBH) plots are used to calculate the Dietz shape factor (C_A) for reservoirs of various shapes. The MBH plot for a right-angled triangle reservoir with a well in the centre shows a reading of dimensionless pressure $P_{D(MBH)} = 3.0$, at the modified dimensionless time $t_{DA} = 1.0$. The Dietz shape factor of this right-angled triangle reservoir is ____________. (Rounded off to one decimal place)

Correct Answer: 20.1

Solution:

Step 1: Understanding the Question:
The question asks to extract the Dietz shape factor (C_A) for a specific reservoir geometry using given data points from its established Matthews-Brons-Hazebroek (MBH) dimensionless pressure curve.

Step 2: Key Formula or Approach:
The MBH dimensionless pressure curve, when plotted on a linear scale against dimensionless time based on area (t_{DA}), converges to a distinct linear relationship during the pseudo-steady state flow period ($t_{DA} \geq 0.1$).
However, across the well-testing literature, an explicit equivalence derived from pressure buildup analysis dictates that the late-time stabilized reading directly correlates to the natural logarithm of the shape factor. Specifically, at the normalized reference benchmark of $t_{DA} = 1.0$, the shifted dimensionless function evaluates to:

$$P_{D(MBH)} = \ln(C_A)$$

Step 3: Detailed Explanation:
We are given that exactly at $t_{DA} = 1.0$, the reading is:
$P_{D(MBH)} = 3.0$
Equating this to the logarithmic relationship:

$$\ln(C_A) = 3.0$$

To solve for the Dietz shape factor C_A, take the exponential of both sides:

$$C_A = e^{3.0}$$

$$C_A \approx 20.0855$$

Rounding this calculated value to one decimal place gives 20.1.

(Note: Standard reservoir engineering tables confirm that a right-angled triangle with a centrally located well possesses a geometrical shape factor of roughly 20 to 21, verifying the physical validity of the result).

Step 4: Final Answer:
The Dietz shape factor is 20.1.

> Quick Tip
>
> Different textbook authors present the MBH functions with slight vertical axis shifts (e.g., $p_{DMBH} = 4\pi t_{DA} - \ln C_A$). However, whenever GATE exams give a low, integer value like 3.0 exactly at $t_{DA} = 1.0$, the simplest intrinsic mathematical property (e^3) is usually the intended path!

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59. A drilling fluid following power law model is being circulated in a wellbore at the rate of 600 gal/min. The internal diameter (D_i) of the drill-pipe is 4.276 inches. The power law parameter (n) for the drilling fluid in the applicable flow regime is 0.67. The wall shear-rate ($\dot{\gamma}_w$) inside the drill-pipe is given by the following equation.

$$\dot{\gamma}_w = \left(\frac{3n+1}{4n}\right) \times \frac{8V}{D_i}$$

where V is the average drilling fluid velocity inside the drill-pipe. The value of wall shear-rate inside the drill-pipe (in s^{-1}) is _________. (Rounded off to one decimal place)
[Given: 1 gallon = 3785.4 cm^3; 1 inch = 2.54 cm]

Correct Answer: 338.0

Solution:

Step 1: Understanding the Question:
We are given the flow rate, pipe geometry, and power-law flow behavior index (n) of a drilling mud. We must calculate the fluid's average velocity and use the provided formula to find the wall shear rate.

Step 2: Key Formula or Approach:
First, convert all units to a consistent SI or CGS system (e.g., cm and seconds).
Calculate the cross-sectional area of the pipe: $A = \frac{\pi}{4} D_i^2$
Calculate the average fluid velocity: $V = \frac{Q}{A}$
Finally, plug V, D_i, and n into the provided wall shear-rate formula.

Step 3: Detailed Explanation:

1. Convert Internal Diameter (D_i) to cm:

$$D_i = 4.276 \text{ inches} \times 2.54 \text{ cm/inch} = 10.86104 \text{ cm}$$

2. Convert Flow Rate (Q) to cm^3/s:

$$Q = 600 \text{ gal/min} \times \frac{3785.4 \text{ cm}^3}{1 \text{ gal}} \times \frac{1 \text{ min}}{60 \text{ s}}$$

$$Q = 10 \times 3785.4 = 37854 \text{ cm}^3/\text{s}$$

3. Calculate Flow Area (A) and Average Velocity (V):

$$A = \frac{\pi}{4}(10.86104)^2 = \frac{3.14159}{4} \times 117.962 = 92.647 \text{ cm}^2$$

$$V = \frac{Q}{A} = \frac{37854}{92.647} = 408.58 \text{ cm/s}$$

4. Evaluate the two parts of the shear-rate formula separately:
Part A (The Newtonian shear rate term):

$$\frac{8V}{D_i} = \frac{8 \times 408.58}{10.86104} = \frac{3268.64}{10.86104} = 300.95 \text{ s}^{-1}$$

Part B (The Power-law adjustment factor):

$$\frac{3n+1}{4n} = \frac{3(0.67)+1}{4(0.67)} = \frac{2.01+1}{2.68} = \frac{3.01}{2.68} \approx 1.12313$$

5. Calculate final wall shear rate ($\dot{\gamma}_w$):

$$\dot{\gamma}_w = 1.12313 \times 300.95 \text{ s}^{-1} = 338.006 \text{ s}^{-1}$$

Step 4: Final Answer:
Rounding to one decimal place, the wall shear rate is 338.0.

> 💡 Quick Tip
>
> Notice that for a Newtonian fluid ($n = 1$), the adjustment factor $\frac{3n+1}{4n}$ simply equals 1, leaving the classic $\frac{8V}{D_i}$ formula. Because drilling muds are shear-thinning ($n < 1$), the factor is greater than 1, meaning the shear rate at the wall is noticeably higher than a Newtonian fluid moving at the same speed!

---

60. The upper limit of the scale of the dial reading for a given rotational oilfield viscometer is 300°. At the rotational rate of 100 RPM, the highest possible effective (apparent) viscosity measurable (in cP) is ________. (Rounded off to one decimal place)
[Given: 1° dial reading is equivalent to 5.11 dynes/cm^2 or 0.511 Pa; 1 RPM = 1.703 s^{-1}]

Correct Answer: 900.2

Solution:

Step 1: Understanding the Question:
We need to calculate the maximum apparent (effective) viscosity that a specific rotational viscometer can measure when it is spinning at 100 RPM and its dial is maxed out at 300°.

Step 2: Key Formula or Approach:
By Newton's law of viscosity, the apparent viscosity (μ_a) is the ratio of the applied shear stress (τ) to the resulting shear rate ($\dot{\gamma}$):

$$\mu_a = \frac{\tau}{\dot{\gamma}}$$

We must convert the provided dial reading into shear stress (in Pascals) and the RPM into shear rate (in s^{-1}) to get the viscosity in standard SI units (Pascal-seconds, Pa.s), and then finally convert it to centipoise (cP).

Step 3: Detailed Explanation:
1. Calculate the maximum shear stress (τ):
The dial reads at its absolute maximum: 300°.
Conversion factor: 1° = 0.511 Pa.

$$\tau = 300 \times 0.511 = 153.3 \text{ Pa}$$

2. Calculate the specific shear rate ($\dot{\gamma}$):
The viscometer is rotating at 100 RPM.
Conversion factor: 1 RPM = 1.703 s^{-1}.

$$\dot{\gamma} = 100 \times 1.703 = 170.3 \text{ s}^{-1}$$

3. Calculate the apparent viscosity (μ_a):

$$\mu_a = \frac{153.3 \text{ Pa}}{170.3 \text{ s}^{-1}} = 0.900176 \text{ Pa} \cdot \text{s}$$

4. Convert viscosity from Pa.s to centipoise (cP):
Recall that 1 Pa.s = 1000 cP.

$$\mu_a = 0.900176 \times 1000 = 900.176 \text{ cP}$$

Step 4: Final Answer:
Rounding to one decimal place, the highest measurable viscosity is 900.2 cP.

> Quick Tip
>
> Standard oilfield viscometers (like the Fann 35) are calibrated perfectly such that at 300 RPM, the dial reading in degrees equals the viscosity precisely in cP! Since viscosity is inversely proportional to RPM, dropping the speed to 100 RPM (one-third the speed) triples the maximum readable viscosity scale (from 300 cP to 900 cP).

---

61. Three wells are at the corners of an equilateral triangle inside an infinite acting reservoir. The reservoir is horizontal, homogenous and isotropic and has uniform thickness. Initial reservoir pressure is 3000 psi. If only one of the wells had been producing in the transient state, the pressure at the centre of equilateral triangle would have dropped by 100 psi after 60 days. If all the three wells started producing simultaneously in transient state at the same rate, then after 60 days since the start of production, the pressure at the centre of the equilateral triangle (in psi) is _____________. (Answer in integer)

Correct Answer: 2700

Solution:

Step 1: Understanding the Question:
We are asked to find the final pressure at a central location caused by the interference of three identically producing wells placed symmetrically around it in an infinite reservoir.

Step 2: Key Formula or Approach:
Because the diffusivity equation governing single-phase fluid flow in a porous media is linear, we can use the **Principle of Superposition**.
This principle states that the total pressure drop at any point is simply the algebraic sum of the individual pressure drops caused by each well operating independently.

$$\Delta P_{total} = \Delta P_1 + \Delta P_2 + \Delta P_3$$

Step 3: Detailed Explanation:
The central point of an equilateral triangle is exactly equidistant from all three of its corners (where the wells are located).
Since all three wells are producing:
- At the exact same flow rate.
- For the exact same duration (60 days).
- Are at the exact same radial distance from the center.

The pressure transient signal sent by each individual well to the center will be completely identical.
The problem explicitly states that ONE well alone causes a pressure drop (ΔP) of 100 psi at the center after 60 days.
Applying superposition for all three wells producing simultaneously:

$$\Delta P_{total} = 100 + 100 + 100 = 300 \text{ psi}$$

The initial reservoir pressure (P_i) was 3000 psi.
The new pressure (P_{new}) at the center is:

$$P_{new} = P_i - \Delta P_{total} = 3000 - 300 = 2700 \text{ psi}$$

Step 4: Final Answer:
The pressure at the center of the triangle will be 2700 psi.

Quick Tip
Superposition is one of the most powerful tools in reservoir engineering. It allows complex multi-well boundary systems to be solved by simply summing together basic single-well infinite-acting radial flow equations!

---

62. Oil is being produced from an undersaturated oil reservoir (with no initial gas cap). The reservoir rock compressibility and water saturation are negligible. There is no water influx, and there is no water production from the well. The initial oil formation volume factor was 1.24 RB/STB. After production of oil for a

short period of time, the reservoir pressure is still above the bubble-point pressure, and the oil formation volume factor has changed to 1.25 RB/STB. The calculated oil recovery factor (in fraction) is ________. (Rounded off to three decimal places) [RB: Reservoir Barrel; STB: Stock Tank Barrel]

Correct Answer: 0.008

Solution:

Step 1: Understanding the Question:
We need to calculate the oil Recovery Factor (RF) for a strictly volumetric, undersaturated oil reservoir based solely on the expansion of the oil phase (since water and rock expansion are negligible).

Step 2: Key Formula or Approach:
The Recovery Factor is defined as the fraction of Original Oil in Place (OOIP, N) that has been produced (N_p):

$$RF = \frac{N_p}{N}$$

Using the volumetric material balance equation for an undersaturated reservoir (above bubble point) with negligible water/rock compressibility:

$$\text{Initial Reservoir Volume} = \text{Remaining Reservoir Volume}$$

$$N \cdot B_{oi} = (N - N_p) \cdot B_o$$

Rearranging to solve for the recovery fraction yields:

$$RF = \frac{N_p}{N} = \frac{B_o - B_{oi}}{B_o}$$

Step 3: Detailed Explanation:
Given parameters:
Initial oil formation volume factor, $B_{oi} = 1.24$ RB/STB
Current oil formation volume factor, $B_o = 1.25$ RB/STB
Substitute these directly into the derived recovery factor formula:

$$RF = \frac{1.25 - 1.24}{1.25}$$

$$RF = \frac{0.01}{1.25}$$

$$RF = 0.008$$

Step 4: Final Answer:
The calculated oil recovery factor is 0.008.

Quick Tip

A recovery factor of 0.008 (or 0.8%) is very typical for liquid expansion drive above the bubble point. Liquid oil is highly incompressible, so it does not expand much. The vast majority of recovery will happen only after pressure drops below the bubble point and solution gas begins to drive the oil!

---

63. Consider one-dimensional oil flow in a horizontal porous media having length of 2000 ft, constant cross-sectional area of 6000 ft^2 and absolute permeability of 50 mD. Oil of viscosity 2 cP is flowing along the length (perpendicular to the cross section) such that the pressure at the inlet and outlet are 2500 psig and 2200 psig, respectively. Using the Darcy's equation for single phase flow, the flow rate of the oil through this porous media (in bbl/day) is _______. (Rounded off to one decimal place)
[1 bbl = 5.61 ft^3]

Correct Answer: 25.4

Solution:

Step 1: Understanding the Question:
We are asked to calculate the volumetric flow rate of oil through a linear porous block using Darcy's Law, converting everything meticulously into the requested field unit (bbl/day).

Step 2: Key Formula or Approach:
Darcy's Law for 1D linear flow in petroleum field units is written as:

$$q \text{ (bbl/day)} = \frac{1.127 \times 10^{-3} \cdot k \cdot A \cdot \Delta P}{\mu \cdot L}$$

Where:
k = Permeability in millidarcies (mD)
A = Cross-sectional area in square feet (ft^2)
ΔP = Pressure drop in psi
μ = Viscosity in centipoise (cP)

L = Length in feet (ft)

Step 3: Detailed Explanation:
Given parameters:
$k = 50$ mD
$A = 6000$ ft^2
$\Delta P = P_{in} - P_{out} = 2500 - 2200 = 300$ psi
$\mu = 2$ cP
$L = 2000$ ft

Substitute these values directly into the field-unit Darcy equation:

$$q = \frac{1.127 \times 10^{-3} \times 50 \times 6000 \times 300}{2 \times 2000}$$

Simplify the numerator:

$$50 \times 6000 \times 300 = 90,000,000$$

$$1.127 \times 10^{-3} \times 90,000,000 = 101430$$

Simplify the denominator:

$$2 \times 2000 = 4000$$

Divide to find the flow rate:

$$q = \frac{101430}{4000} = 25.3575 \text{ bbl/day}$$

Step 4: Final Answer:
Rounding off to one decimal place, the flow rate is 25.4 bbl/day.

> Quick Tip
>
> Memorize the constant 1.127×10^{-3} for linear flow and 7.08×10^{-3} for radial flow in standard field units! It will save you immense time compared to converting fundamental units back and forth on the exam.

---

64. A gas reservoir has bulk volume of 10000 ft^3, connate water saturation of 0.2 and porosity of 0.2. There is no oil present in the reservoir. The gas formation volume factor, B_g is 0.005 RCF/SCF. The volume of gas in-place for this reservoir

(in SCF) is ________$\times 10^4$. (Answer in integer)
[RCF: Reservoir Cubic Feet; SCF: Standard Cubic Feet]

Correct Answer: 32

Solution:

Step 1: Understanding the Question:
We need to calculate the original Gas In-Place (GIP) at standard surface conditions using basic volumetric rock properties.

Step 2: Key Formula or Approach:
The total Pore Volume (V_p) of the rock is given by:

$$V_p = \text{Bulk Volume } (V_b) \times \text{Porosity } (\phi)$$

Because there is no oil, the pore space is filled entirely with gas and connate water. The gas saturation (S_g) is:

$$S_g = 1 - S_{wc}$$

The actual volume of gas sitting in the reservoir at high pressure (in RCF) is:

$$V_{g,res} = V_p \times S_g$$

To convert this trapped high-pressure volume into Standard Cubic Feet (SCF), divide by the gas formation volume factor (B_g):

$$\text{Gas In-Place (SCF)} = \frac{V_{g,res}}{B_g}$$

Step 3: Detailed Explanation:
Given parameters:
$V_b = 10000 \text{ ft}^3$
$\phi = 0.2$
$S_{wc} = 0.2$
$B_g = 0.005 \text{ RCF/SCF}$

1. Calculate Pore Volume:

$$V_p = 10000 \times 0.2 = 2000 \text{ ft}^3$$

2. Calculate Gas Saturation:

$$S_g = 1 - 0.2 = 0.8$$

3. Calculate Reservoir Gas Volume:

$$V_{g,res} = 2000 \times 0.8 = 1600 \text{ RCF}$$

4. Convert to Standard Surface Volume:

$$\text{GIP}_{SCF} = \frac{1600}{0.005} = 320,000 \text{ SCF}$$

We need to express this in the format of ____ $\times 10^4$.

$$320,000 = 32 \times 10^4$$

Step 4: Final Answer:
The volume of gas in-place is 32×10^4 SCF, so the answer to input is 32.

Quick Tip

Notice that B_g is provided directly in RCF/SCF rather than the more common bbl/SCF. Because V_b is in ft^3, the units align perfectly without needing to convert using 5.615! Always check the units of B_g before calculating.

---

65. A drill-string placed in a wellbore is composed of 6000 ft of drill-pipe having internal diameter of 4.67 inches. The drilling fluid is being pumped at the rate of 80 cycles/minute and the pump factor is 0.21 bbl/cycle. Assume the amount of drilling fluid in the drill-collar and drill-bit to be negligible. The time required to circulate the drilling fluid from the surface to the drill-bit (in minutes) is ______. (Rounded off to two decimal places)
[**Given: 1 bbl = 5.61 ft**^{3}]

Correct Answer: 7.57

Solution:

Step 1: Understanding the Question:
We are asked to calculate the "Surface-to-Bit" circulation time. This is simply the time it takes

for mud pumps to completely displace the entire inner volume of the drill string.

Step 2: Key Formula or Approach:
First, compute the internal volume (capacity) of the drill pipe in barrels (bbls).
Then, calculate the flow rate of the mud pump in bbls per minute.
Finally, the circulation time is defined as:

$$\text{Time} = \frac{\text{Drill String Internal Volume}}{\text{Pump Flow Rate}}$$

Step 3: Detailed Explanation:
1. Calculate Drill Pipe Internal Volume:
Internal Diameter (D_i) = 4.67 inches.
Convert to feet: $D_i = 4.67/12 = 0.38917$ ft.
Length (L) = 6000 ft.

$$\text{Volume (ft}^3) = \frac{\pi}{4} D_i^2 L = \frac{3.14159}{4} \times (0.38917)^2 \times 6000$$

$$\text{Volume (ft}^3) = 0.7854 \times 0.15145 \times 6000 = 713.68 \text{ ft}^3$$

Convert to barrels (bbl):

$$\text{Volume (bbl)} = \frac{713.68 \text{ ft}^3}{5.61 \text{ ft}^3/\text{bbl}} = 127.216 \text{ bbl}$$

2. Calculate Pump Flow Rate:

$$\text{Flow Rate} = 80 \text{ cycles/min} \times 0.21 \text{ bbl/cycle} = 16.8 \text{ bbl/min}$$

3. Calculate Surface-to-Bit Time:

$$\text{Time} = \frac{127.216 \text{ bbl}}{16.8 \text{ bbl/min}} = 7.572 \text{ minutes}$$

Step 4: Final Answer:
Rounding to two decimal places, the time required is 7.57 minutes.

Quick Tip

An incredibly useful oilfield shortcut for pipe capacity is: $C(\text{bbl/ft}) = \frac{ID^2(\text{inches})}{1029.4}$.
Using this: $C = 4.67^2/1029.4 = 0.021186$ bbl/ft.
Total Vol $= 0.021186 \times 6000 = 127.11$ bbl. This yields an identical result and skips all the ft/inches conversions!
