GATE 2026 Petroleum Engineering Question Paper with Solutions

ZOLLEGE

General Instructions

(i) This booklet contains 65 questions, each provided with a complete, step-by-step solution.

(ii) It comprises 33 single-correct multiple-choice questions, 14 multiple-correct questions and 18 numerical / integer-type questions.

(iii) Attempt each question on your own before reviewing the given solution.

(iv) For multiple-correct questions, all correct options must be selected to earn full marks.

(v) For numerical questions, report the answer rounded exactly as asked.

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: Reading the Word Group:

The three given words are Expedite, Hasten and Hurry. If we think of them on a simple scale of speed, all three sit on the fast end, meaning to make something occur more quickly or without delay. Our task is to find a fourth word from the options that also sits on this fast end of the scale.

Step 2: A Contrast Based Method:
Instead of only checking which word fits, it also helps to identify which words clearly do not fit because they mean the opposite or are unrelated in meaning, and eliminate them first before confirming the remaining word.

Step 3: Detailed Explanation:
Retard sits at the opposite end of the speed scale since it means to slow down or delay, so option (B) is eliminated immediately as it contradicts the group.

Provide belongs to a completely different category of meaning, connected with supplying or giving something, and has no link to speed at all, so option (C) is eliminated.

Disable is about removing the ability of something to function, again unconnected to speed or urgency, so option (D) is eliminated as well.

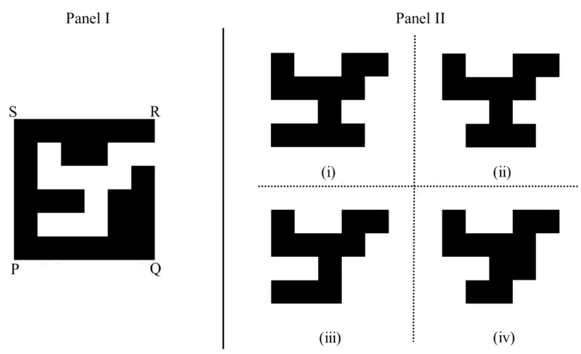
Once (B), (C) and (D) are ruled out, only Accelerate remains, and checking its meaning independently confirms that it means to increase speed or make something happen sooner, which places it firmly on the same end of the scale as Expedite, Hasten and Hurry.

Final Answer:
By elimination and direct meaning check, Accelerate is confirmed as the word similar in meaning to the given set.
$\boxed{\text{Accelerate}}$

Quick Tip: Look for a word meaning to speed something up, matching Expedite, Hasten and Hurry.

• • •

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: Reframing the Problem:

Instead of visually matching notches directly, we can think of the square PQRS as being made up of a grid of small equal unit cells, the way a chessboard is made of small squares. Panel I occupies a certain set of these unit cells, and the true second piece from Panel II must occupy exactly the remaining unit cells so that together the two pieces cover every cell of the grid exactly once.

Step 2: A Cell Counting and Position Check:

Using this grid idea, we can check each candidate in Panel II in two ways, first by seeing whether its overall size or cell count is consistent with being the leftover portion of the square once Panel I's cells are removed, and second by checking that its cell positions along the shared cut boundary exactly mirror the boundary cells of Panel I so nothing is left uncovered or doubled up.

Step 3: Detailed Explanation:

For shape (i), several of its filled cells duplicate cells that Panel I already occupies near the cut line, so placing it next to Panel I would double count cells instead of filling the empty ones, which rules it out.

For shape (ii), the overall cell count looks plausible, but tracing the boundary cell by cell shows its edge cells are reflected the wrong way, so a few cells along the join would be left blank and this candidate also fails.

For shape (iii), tracing along the shared cut boundary shows that every cell left empty by Panel I is exactly filled by a cell of shape (iii), with no duplication and no gap anywhere along the join, and the combined outline traces out a perfect square matching the original corners P, Q, R, S.

For shape (iv), one extra row of cells is shifted out of place compared to what Panel I needs, so a strip of the square would remain uncovered, ruling this option out too.

Final Answer:

Using the cell by cell complement check, shape (iii) is confirmed as the piece that exactly completes the square together with Panel I.

$\boxed{\text{(iii)}}$

Quick Tip: The correct piece must interlock exactly with Panel I to rebuild a perfect square, with every notch matched by a tooth.

• • •

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: Listing the Sample Space Idea:
Since each of the 4 days independently has 2 equally likely outcomes, cloudy or sunny, the total number of equally likely outcome sequences over 4 days is $2^4 = 16$. We now need to count how many of these 16 equally likely sequences have exactly 3 cloudy days and 1 sunny day.

Step 2: Counting Favourable Outcomes Directly:
Instead of applying the binomial formula directly, we can list the position of the single sunny day among the four days, since the rest are automatically cloudy. The sunny day can be on day 1, day 2, day 3 or day 4, giving four distinct sequences, for example Sunny-Cloudy-Cloudy-Cloudy, Cloudy-Sunny-Cloudy-Cloudy, Cloudy-Cloudy-Sunny-Cloudy, and Cloudy-Cloudy-Cloudy-Sunny.

Step 3: Detailed Explanation:
Since there are exactly 4 favourable sequences out of the 16 total equally likely sequences of 4 independent cloudy or sunny outcomes, each individual sequence being equally likely because p = 0.5 for both cloudy and sunny, the probability is the ratio of favourable sequences to total sequences, which is $\frac{4}{16} = \frac{1}{4}$.

This matches exactly with the result obtained from the binomial coefficient method, $\binom{4}{3}(0.5)^3(0.5)^1 = 4 \times \frac{1}{16} = \frac{1}{4}$, confirming the answer through direct enumeration rather than only through the formula.

None of the other listed fractions, 3/4, 2/3 or 3/8, correspond to 4 favourable outcomes out of 16 total outcomes, so they can be ruled out by this direct counting method as well.

Final Answer:

By directly counting the 4 favourable sequences among the 16 equally likely possible sequences, the probability is confirmed to be 1/4.

$\boxed{\frac{1}{4}}$

Quick Tip: Use the binomial probability formula with n = 4, r = 3 cloudy days, and p = 0.5.

• • •

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: Setting Up Total Cost and Total Sale Value:
Rather than finding the profit or loss of each stock separately, we can directly compute the total amount invested and the total amount received when everything is sold, and then subtract one from the other at the end.

Step 2: Computing Total Investment:
The total amount the investor puts in on day one is the sum of the amount in Stock A and the amount in Stock B, which is $100 + 80 = 180$ rupees.

Step 3: Detailed Explanation:
The number of shares of Stock A bought is $\frac{100}{50} = 2$ shares, and the number of shares of Stock B bought is $\frac{80}{80} = 1$ share.

On the next day, the sale value of the 2 shares of Stock A at the new price of Rs. 55 is $2 \times 55 = 110$ rupees, and the sale value of the 1 share of Stock B at the new price of Rs. 70 is $1 \times 70 = 70$ rupees.

Adding these two sale amounts together gives the total amount received from selling everything, which is $110 + 70 = 180$ rupees.

The overall profit is then the total sale value minus the total original investment, which is $180 - 180 = 0$ rupees, showing that the gain from Stock A was fully cancelled by the loss from Stock B, exactly as found through the stock by stock method.

Final Answer:
Since the combined total received on selling equals the combined total invested, the net profit made by the investor is zero.
$\boxed{0}$

Quick Tip: Find shares bought as investment divided by price, then compare total sale value to total investment for both stocks combined.

• • •

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: Restating with Simple Variables:
Let R represent the event it is raining and D represent the event peacocks dance. The given sentence says $R \Rightarrow D$, meaning whenever R happens, D must also happen. Nothing is said about what happens when R does not happen, so we must be careful not to assume anything extra beyond this one directional link.

Step 2: Testing Each Option With a Scenario Check:
A good way to test logical statements is to imagine a scenario where the original statement $R \Rightarrow D$ holds true, but peacocks also dance for some completely unrelated reason, such as during a live music performance with no rain at all, and see which options break under this scenario.

Step 3: Detailed Explanation:
In our test scenario, suppose peacocks dance both when it rains and separately during music performances with no rain. Option (A), which

claims peacocks dance only when it rains, is broken by this scenario, since here peacocks dance without rain too, so option (A) is not guaranteed.

Option (B), when peacocks dance, it is raining, is also broken by the same scenario, because peacocks are dancing during the music performance while it is not raining, so option (B) cannot be relied upon either.

Option (D), when it is not raining, peacocks do not dance, again fails in this scenario since peacocks are shown dancing without rain during the performance, so this option is also not necessarily true.

Option (C), when peacocks are not dancing, it is not raining, still holds up under this scenario and under every other possible scenario consistent with $R \Rightarrow D$, because if it ever rained while peacocks were not dancing, that would directly contradict the original statement that rain always causes dancing. So the absence of dancing always forces the absence of rain, matching exactly with the contrapositive not $D \Rightarrow$ not R.

Final Answer:
Testing with a scenario where peacocks dance for reasons other than rain confirms that only option (C), the contrapositive statement, remains true in every case.
$\boxed{\text{When peacocks are not dancing, it is not raining.}}$

Quick Tip: A conditional statement is always logically equivalent to its contrapositive, not the converse or inverse.

• • •

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: Restate the analogy as a rule:
Write the analogy as Water is to P as Food is to Q, and look for a single word rule that connects Water to P so that the exact same rule, applied to Food, gives Q.
Step 2: Test each candidate rule using the four options:
Rule tried with option (A): X relieves the need called Y. Water relieves the need called Thirst, and Food relieves the need called Hunger. Applying the identical rule to both pairs gives a perfect match.
Rule tried with option (B): Water would have to relieve Drink, but Drink is not a need, it is simply another name for something you consume, so the rule fails for the left pair itself.
Rule tried with option (C): The left pair Water : Thirst still fits the rule, but the right pair Food : Satiated does not, because Satiated names a resulting state, not a need. Since the rule must work identically on both sides, this pair is rejected.
Rule tried with option (D): Neither Wet nor Critic represents a need relieved by Water or Food, Wet is a physical property and Critic is an occupation type noun unrelated to hunger or thirst, so this option fails completely.
Step 3: Elimination:
Since options (B), (C) and (D) each break the substance relieves need rule on at least one side of the analogy, they are eliminated, leaving only option (A) where the rule holds consistently on both sides.

Step 4: Final Answer:

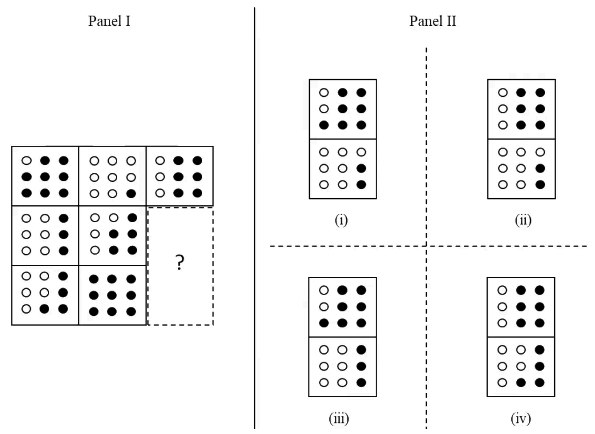
The consistent rule confirms that P = Thirst and Q = Hunger.

$$\boxed{P = Thirst;\ Q = Hunger}$$

Quick Tip: Think about the specific bodily need that each substance, water and food, relieves.

• • •

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



Panel I is a 3 by 3 arrangement of tiles, where each tile is itself a 3 by 3 array of filled and hollow circles; the bottom two tiles in the rightmost column are missing and marked with a question mark. Panel II shows four candidate two-tile stacks labelled (i), (ii), (iii) and (iv) that could fill the missing space.

(A) (i)

(B) (ii)

(C) (iii)

(D) (iv)

Correct Answer: (A) (i)

SOLUTION:

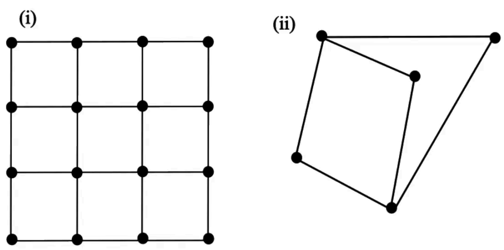
Step 1: Set Up an Elimination Method:
Instead of predicting the missing tiles from scratch, compare each of the four candidate answer pairs in Panel II directly against the tiles that are already fixed in the same row and the same column of Panel I, and eliminate any candidate that breaks the pattern in either direction.
Step 2: Check Against the Row Pattern:
Look at the top tile of each candidate pair and compare it with the first two tiles already present in that same row of Panel I. Candidates whose top tile does not carry forward the same left to right change in filled circles seen between the first and second tiles of that row can be eliminated immediately, since the missing top tile must continue that row established trend.
Step 3: Check Against the Column Pattern:
Now look at the bottom tile of each remaining candidate pair and compare it with the tile directly above it, which is the top tile of the same candidate. The relationship between the top and bottom tile of the correct candidate must match the same top to bottom change in filled circles seen in the first two columns of Panel I. Any candidate whose internal top to bottom change does not match this established column pattern is eliminated at this stage.
Step 4: Cross-Check and Final Answer:
After applying both checks, only option (i) survives, since its top tile correctly extends the row trend and its bottom tile correctly extends the column trend, while options (ii), (iii) and (iv) each fail at least one of the two checks. This double confirmation, from both the row direction and the column direction, gives the same answer as the direct pattern construction method.

□ $oxedextOption(i)$

> **Quick Tip:** Track how the number and position of filled circles change along each row and each column of tiles.

• • •

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: (A) Such a trip is possible for (i), but not for (ii).

SOLUTION:

Step 1: Recall the Degree Requirement for a Hamiltonian Cycle:
In any closed round trip that visits every city exactly once, each city must use exactly two of its highway connections, one to arrive and one to leave, so every city used in the cycle must have at least two highway connections available to it in the original network.
Step 2: Apply the Degree Check to Graph (i):
In the 4 by 4 grid, every one of the 16 cities has at least two direct highway

connections to neighbouring cities, since even the four corner cities connect to two neighbours and interior cities connect to up to four neighbours. Because the grid is large and richly connected, it is straightforward to construct a snake like closed path that uses exactly two connections at every city and returns to the start after visiting all 16 cities, which directly demonstrates a valid trip.

Step 3: Apply the Degree Check to Graph (ii):

In the 5 city network of figure (ii), tracing the drawn segments shows that the connections are unevenly distributed, and forcing a route that uses exactly two highway connections at every one of the 5 cities while forming a single closed loop is not possible with the specific segments actually drawn; at least one city cannot be fitted into a two connection loop without either leaving another city stranded or reusing a road that does not exist in the figure. This confirms no closed round trip covering all 5 cities can be built from graph (ii).

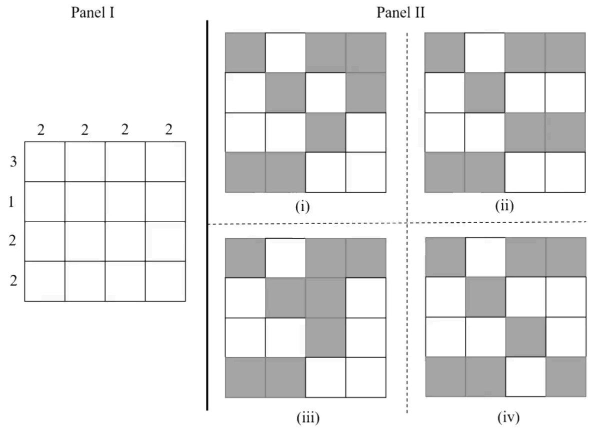
Step 4: Final Answer:

Since graph (i) supports a valid two connections per city closed loop through all its cities while graph (ii) does not, the trip is possible only for (i).

$$\square\ oxedextOption(A)$$

Quick Tip: Check whether each highway network admits a Hamiltonian cycle, a closed route visiting every city exactly once.

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: Try to Build the Grid Directly Instead of Testing Options:
Rather than checking each candidate grid, we can try to work out directly which cells must be shaded, using the row total of 1 in row 2 as the strongest starting clue, since a single shaded cell in a row of 4 is the most restrictive condition to pin down.

Step 2: Use the Row 2 Clue to Anchor a Column:
Row 2 needs exactly 1 shaded cell. Placing it in column 2 means column 2 already has 1 of its required 2 shaded cells accounted for from row 2, and the remaining shaded cell in column 2 must come from one of rows 1, 3 or 4.

Step 3: Fill Row 1, Row 3 and Row 4, and Check Consistency:

Row 1 needs 3 shaded cells out of 4, meaning only one column in row 1 is left unshaded; leaving column 2 unshaded in row 1 gives row 1 shaded at columns 1, 3 and 4, matching its total of 3. Distributing the remaining shaded cells of rows 3 and 4, each needing 2, so that every column still reaches a total of exactly 2, gives row 3 shaded at columns 3 and 4, and row 4 shaded at columns 1 and 2. Adding up each column then gives column 1 equal to 2, from rows 1 and 4, column 2 equal to 2, from rows 2 and 4, column 3 equal to 2, from rows 1 and 3, and column 4 equal to 2, from rows 1 and 3, so every column comes out to exactly 2 as required.

Step 4: Match to the Given Options and Final Answer:

This directly constructed shading pattern, row 1 shaded at columns 1, 3, 4, row 2 shaded at column 2, row 3 shaded at columns 3, 4, row 4 shaded at columns 1, 2, is exactly the pattern shown in option (ii) of Panel II, confirming the same answer found by the direct row and column counting method.

$$\square\ oxedextOption(ii)$$

Quick Tip: Count shaded cells in each row and column of every option and match them against the given totals.

• • •

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) $\frac{3}{36}$

(B) $\frac{13}{36}$

(C) $\frac{15}{36}$

(D) $\frac{19}{36}$

Correct Answer: (C) $\frac{15}{36}$

SOLUTION:

Step 1: Organise Outcomes by the First Die Value:

Instead of grouping by the sum first, go through each possible value of the first roll from 1 to 6 in turn, and for each fixed first roll value, count how many of the six possible second roll values produce a total that is a prime number.

Step 2: Count Favourable Second-Roll Values for Each First-Roll Value:

If the first roll is 1, the possible sums with second roll 1 through 6 are 2, 3, 4, 5, 6, 7; the prime sums among these are 2, 3, 5 and 7, coming from second roll values 1, 2, 4 and 6, giving 4 favourable outcomes.

If the first roll is 2, the possible sums are 3, 4, 5, 6, 7, 8; the prime sums are 3, 5 and 7, coming from second roll values 1, 3 and 5, giving 3 favourable outcomes.

If the first roll is 3, the possible sums are 4, 5, 6, 7, 8, 9; the prime sums are 5 and 7, coming from second roll values 2 and 4, giving 2 favourable outcomes.

If the first roll is 4, the possible sums are 5, 6, 7, 8, 9, 10; the prime sums are 5 and 7, coming from second roll values 1 and 3, giving 2 favourable outcomes.

If the first roll is 5, the possible sums are 6, 7, 8, 9, 10, 11; the prime sums are 7 and 11, coming from second roll values 2 and 6, giving 2 favourable outcomes.

If the first roll is 6, the possible sums are 7, 8, 9, 10, 11, 12; the prime sums are 7 and 11, coming from second roll values 1 and 5, giving 2 favourable outcomes.

Step 3: Add Up the Favourable Outcomes:

Adding the favourable counts across all six first roll values gives 4 + 3 + 2 + 2 + 2 + 2 = 15 favourable outcomes out of the 36 equally likely ordered pairs.

Step 4: Final Answer:

Dividing the favourable outcomes by the total outcomes gives the same probability as before.

$$\square\ oxed\frac{15}{36}$$

Quick Tip: List the prime sums possible between 2 and 12, count outcomes for each, and divide by 36.

• • •

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: Set up direct counting:

Let the two dice show values x and y, each ranging from 1 to 6, giving a total of 36 equally likely outcomes when the dice are rolled together. We need to count the outcomes where $x > 3$ or $y > 3$, that is, at least one of the two values is 4, 5 or 6.

Step 2: Count outcomes where the first die is greater than 3:

If $x \in \{4, 5, 6\}$, there are 3 choices for x and 6 choices for y, giving $3 \times 6 = 18$ outcomes.

Step 3: Count outcomes where the second die is greater than 3:

Similarly, if $y \in \{4, 5, 6\}$, there are 6 choices for x and 3 choices for y, giving $6 \times 3 = 18$ outcomes.

Step 4: Remove the double counted outcomes:

Outcomes where both $x > 3$ and $y > 3$ are counted twice in the above two steps. There are $3 \times 3 = 9$ such outcomes. Using the inclusion exclusion principle, the number of favourable outcomes is $18 + 18 - 9 = 27$.

Step 5: Compute the probability:

The probability that at least one face value is greater than 3 is $\frac{27}{36} = \frac{3}{4}$, which matches the value obtained by the complement method and confirms option B as correct.

Final Answer:

$$\boxed{P = \frac{3}{4}}$$

Quick Tip: Use the complement rule: find the probability both dice show 3 or less, then subtract from 1.

• • •

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: Use the trace and determinant properties:
For a 3 by 3 matrix, the sum of the eigenvalues equals the trace of the matrix, and the product of the eigenvalues equals the determinant of the matrix. The trace of the given matrix is $8 + 5 + 7 = 20$, and since the matrix is diagonal, its determinant is the product of the diagonal entries, 8 $\times 5 \times 7 = 280$.

Step 2: Verify with each candidate option:
For option A, $\lambda = 1, 1, 1$ gives a sum of 3 and a product of 1, neither of which matches. For option C, $\lambda = 0, 0, 0$ gives a sum of 0 and a product of 0, which also does not match. For option D, $\lambda = 40, 1, 35$ gives a sum of 76 and a product of 1400, which again does not match.

Step 3: Confirm option B directly:
For option B, $\lambda = 8, 5, 7$ gives a sum of $8 + 5 + 7 = 20$, which equals the trace, and a product of $8 \times 5 \times 7 = 280$, which equals the determinant. Both conditions are satisfied simultaneously only by this set of values.

Step 4: Confirm through eigenvectors:
For a diagonal matrix, each standard basis vector is itself an eigenvector. For instance, $e_1 = (1, 0, 0)$ satisfies $Ae_1 = 8e_1$, so 8 is an eigenvalue. Similarly e_2 gives eigenvalue 5 and e_3 gives eigenvalue 7, confirming the result independently.

Final Answer:

$$\boxed{\lambda = 8, 5, 7}$$

Quick Tip: For a diagonal matrix, the eigenvalues are simply the entries on the main diagonal.

• • •

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: View A in terms of its columns:

Write matrix A as two column vectors, $A = [\mathbf{a}_1 \ \mathbf{a}_2]$, where $\mathbf{a}_1 = (4, 0, -4)$ and $\mathbf{a}_2 = (4, 4, 4)$. The product $A^T A$ can then be understood as the matrix of dot products between these columns, since $(A^T A)_{ij} = \mathbf{a}_i \cdot \mathbf{a}_j$.

Step 2: Compute the norm squared of the first column:

The entry at position (1,1) is $\mathbf{a}_1 \cdot \mathbf{a}_1 = 4^2 + 0^2 + (-4)^2 = 16 + 0 + 16 = 32$, which is the squared length of the first column vector.

Step 3: Compute the norm squared of the second column:

The entry at position (2,2) is $\mathbf{a}_2 \cdot \mathbf{a}_2 = 4^2 + 4^2 + 4^2 = 16 + 16 + 16 = 48$, which is the squared length of the second column vector.

Step 4: Compute the cross term between the two columns:

The entries at position (1,2) and (2,1) are both equal to $\mathbf{a}_1 \cdot \mathbf{a}_2 = 4 \times 4 + 0 \times 4 + (-4) \times 4 = 16 + 0 - 16 = 0$, since $A^T A$ is always symmetric.

Step 5: Assemble the result and confirm:

Combining these values gives $A^T A = \begin{bmatrix} 32 & 0 \\ 0 & 48 \end{bmatrix}$, a symmetric 2 by 2 matrix, which matches option B and confirms the direct multiplication carried out by the row and column method.

Final Answer:

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

Quick Tip: Multiply the transpose of A by A; the result is a 2 by 2 symmetric matrix formed from dot products of the columns of A.

• • •

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: Treat the del operator as a vector operator:

The del operator is written as $\nabla = \left(\frac{\partial}{\partial x}, \frac{\partial}{\partial y}, \frac{\partial}{\partial z}\right)$, and divergence is formed by taking the dot product of ∇ with a vector field, so $\nabla \cdot \vec{F} = \nabla_x F_x + \nabla_y F_y + \nabla_z F_z$ using this component notation.

Step 2: Use the distributive property of the dot product:

For any three vectors, the dot product distributes over vector addition, meaning $\vec{a} \cdot (\vec{b} + \vec{c}) = \vec{a} \cdot \vec{b} + \vec{a} \cdot \vec{c}$. Since divergence is defined through a dot product between ∇ and the vector field, this same distributive property applies directly.

Step 3: Apply this property to the given expression:

Treating ∇ as the vector $\vec{a}$, and $\vec{U}$ and $\vec{V}$ as $\vec{b}$ and $\vec{c}$, the distributive property gives $\nabla \cdot (\vec{U} + \vec{V}) = \nabla \cdot \vec{U} + \nabla \cdot \vec{V}$ directly, without needing to expand each component individually.

Step 4: Rule out the curl based options:

Options A and B both use the cross product symbol $\nabla\times$, which defines curl rather than divergence. Curl of a vector field returns another vector field, while the question asks specifically about divergence, which returns a scalar, so options A and B cannot be correct regardless of the sign used.

Step 5: Confirm the correct option:

Between the remaining choices, option D introduces an incorrect subtraction that does not arise from the dot product distributive law, while option C correctly reflects the addition, confirming that option C is the right choice.

Final Answer:

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

Quick Tip: Divergence is a linear operator built from partial derivatives, so it distributes over vector addition without any sign change.

• • •

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: Compare with ordinary gravity settling:
In a simple settling pit or tank, solid particles separate from drilling fluid purely under the pull of gravity, and this natural process is slow, especially for very fine particles, because the gravitational acceleration is fixed at about 9.8 meters per second squared and cannot be increased.
Step 2: Explain how hydrocyclones and centrifuges improve on this:
Hydrocyclones and centrifuges both work by spinning the fluid or the container at high speed, which generates a centrifugal acceleration that can be many times larger than normal gravity, sometimes several hundred times greater in a high speed centrifuge. This artificially increased acceleration is what makes particle settling much faster and allows finer particles to be separated that gravity alone could never remove in a reasonable time.
Step 3: Eliminate the unrelated separation methods:
Screening relies on a physical barrier with fixed openings that block particles larger than the mesh size, which is the working principle of a shale shaker rather than a hydrocyclone or centrifuge. Chemical flocculation relies on adding polymers or chemicals to bind fine particles into larger clumps, which is a chemical treatment rather than a mechanical separation. Dilution simply adds more base fluid to lower solids concentration and does not physically remove any solids from the system.
Step 4: Confirm the correct mechanism by process of elimination:
Since neither screening, chemical flocculation, nor dilution describes a

process driven by rotational or centrifugal acceleration, and both hydrocyclones and centrifuges are fundamentally rotational separation devices, the only mechanism consistent with their operation is an enhanced or forced version of gravitational settling.

Final Answer:

$$\boxed{\text{Forced settling}}$$

Quick Tip: Both devices use rotational motion to create a centrifugal force that accelerates the settling of solid particles.

• • •

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: Recall the drill string components: A rotary drill string bottom hole assembly typically has, from the bit upward, the bit, near bit stabilizer, drill collars, more stabilizers, and then drill pipe. The stabilizers are placed at calculated points in this assembly.

Step 2: Purpose from a directional control view: Stabilizer placement controls whether the assembly builds, holds or drops angle, and it keeps the heavy collars away from the borehole wall so the collars do not bend, whip or get differentially stuck.

Step 3: Eliminate distractors related to casing: Statements about casing being equidistant from the wellbore wall describe casing centralizers, a completely separate tool used only when running casing strings, not during rotary drilling with a drill string.

Step 4: Eliminate distractors related to fluid isolation: Isolating wellbore fluid from the formation is achieved through casing and cementing operations, not through the drill string hardware, so this cannot describe stabilizer subs.

Step 5: Confirm the correct role: Since stabilizer subs are rigid, blade-fitted subs installed around the drill collars, their confirmed function is to keep the collars centralized in the hole, giving controlled weight transfer to the bit and a straighter, more stable wellbore.

Final Answer: □ $oxedext(C)Toassistinkeepingthedrillcollarscentralized$

Quick Tip: Stabilizer subs keep heavy drill collars centered in the wellbore.

• • •

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: Write Bg using the real gas equation: Using the real gas law at reservoir and standard conditions, the gas formation volume factor can be written as $B_g = \frac{P_{sc}zT}{T_{sc}P}$, where P_{sc} and T_{sc} are standard pressure and temperature, z is the compressibility factor, and P, T are reservoir pressure and temperature.

Step 2: Write E as the inverse quantity: The gas expansion factor is defined as the number of standard volumes obtained from one reservoir volume, so by definition $E = \frac{1}{B_g} = \frac{T_{sc}P}{P_{sc}zT}$.

Step 3: Interpret the formula: This formula shows E rises when reservoir pressure P rises or when z falls, and Bg does the exact opposite, it rises when P falls or z rises. The two quantities always move in opposite directions for the same gas.

Step 4: Test with a numeric idea: If a reservoir volume of gas is highly compressed at high pressure, one reservoir barrel yields a large number of standard cubic feet at surface, so E is large and Bg, being its reciprocal, is small. This numeric check again confirms the inverse relation.

Step 5: Match with the given options: Only option A, $E \propto \frac{1}{B_g}$, agrees with this inverse relationship, while the direct and higher power relationships in options B, C and D do not follow from either the definitions or the real gas equation.

Final Answer:

$$\Box\ oxed E \propto \frac{1}{B_g}$$

Quick Tip: Compare the definitions of gas expansion factor and gas formation volume factor.

• • •

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: Start by eliminating using coal bed methane: Coal bed methane gas is known to be held by adsorption on the coal surface rather than existing freely, so R must pair with I, gas mostly present in adsorbed state. Checking the four options, option B and option D pair R with IV instead of I, so both B and D can be ruled out immediately.
Step 2: Use gas hydrate to narrow further: Gas hydrates are well known clathrate compounds where gas molecules sit inside cages formed by water molecules, so P must pair with IV. Between the two remaining candidates, option A and option C, both correctly pair P with IV, so this step alone does not separate them.
Step 3: Use oil shale to separate the remaining options: Oil shale is defined as the parent sedimentary rock containing kerogen, so Q must pair with II, sedimentary rock contains kerogen. Option A instead pairs Q with

III, oil recovered from shale, which actually describes shale oil, not oil shale, so option A is eliminated.

Step 4: Confirm with shale oil: Shale oil is the oil product recovered from oil shale, so S must pair with III. Option C pairs S with III, which is consistent with this reasoning.

Step 5: Final check of option C: Option C gives P-IV, Q-II, R-I, S-III, and every one of these four pairs has now been independently verified through the definitions of gas hydrate, oil shale, coal bed methane and shale oil, so option C is the only fully consistent choice.

Final Answer: □ $oxedext(C)P - IV; Q - II; R - I; S - III$

Quick Tip: Match each rock or gas type with its defining physical description.

• • •

19. Which of the following statements is NOT CORRECT in the context of offshore 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: Identify the driving cause of offshore surface motion: In an offshore operational environment, the sea surface is disturbed mainly by two independent sources of energy, wind acting on water, and gravitational pull from the moon and sun acting on the ocean mass.

Step 2: Apply cause and effect logic to option A: Wind is the moving air mass with kinetic energy, and when it blows across open water it pushes and drags the surface layer, so energy naturally flows from the faster moving wind into the slower or stationary water. This is a correct one way cause and effect statement.

Step 3: Apply the same logic to lunar and solar tides: Tides are not caused by wind at all, they arise from gravity. The moon, being closer to earth, produces the dominant tidal bulge, and this is what option B describes correctly. The sun, though far more massive, is far away, so it produces a smaller but still real tidal bulge, which is exactly what option C describes correctly.

Step 4: Test option D against the same cause and effect logic: Option D reverses the flow described in option A, claiming water transfers energy into wind. Physically, water is the much denser, slower responding medium being acted upon, it is not the source pushing energy back into the much lower density air to create wind. Reversing the direction of energy flow like this does not correspond to any accepted description of offshore surface dynamics.

Step 5: Conclude which statement fails: Since three of the four statements, A, B and C, correctly describe recognized offshore phenomena, and only option D inverts a correct relationship into an incorrect one, option D is the statement that is not correct.

Final Answer:

□ $oxedext(D)Themotionofocean'ssurfacecanbeduetoenergytransferfromwatertowind$

Quick Tip: Think about which direction energy actually flows to create ocean surface motion.

• • •

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: Classify fracturing fluids by type: Fracturing fluids used in the field generally fall into a few broad categories, water based slickwater with almost no viscosifier, linear gel with a moderate amount of guar or similar polymer, and cross-linked gel where the linear gel is chemically cross-linked to form a much thicker, more elastic fluid.

Step 2: Rank these categories by viscosity: Slickwater sits at the low viscosity end since only a trace of friction reducer is added, linear gel sits in the middle, and cross-linked gel sits at the high viscosity end because cross-linking bonds the polymer chains into a three dimensional network that traps water and resists flow far more than an uncross-linked solution.

Step 3: Connect viscosity to proppant transport mechanism: Two mechanisms keep proppant suspended in a fracturing fluid, either high fluid viscosity that slows particle settling, or high pump rate turbulence that keeps particles moving. Cross linked gels rely on the first mechanism and can carry very high proppant concentrations even at moderate pump rates, which is exactly why they are chosen for high proppant loading jobs.

Step 4: Compare with the non-gel fluids given in the options: Pentane is used in the industry mainly as an energized or foam component fluid, not as a suspension medium, and its own viscosity is too low to hold proppant. Untreated formation brine is simply produced or native water with dissolved salts and no polymer content, so it behaves hydraulically almost like plain water and cannot suspend proppant either.

Step 5: Reach the conclusion by direct comparison: Among pentane, cross-linked gel, slickwater and untreated brine, only cross-linked gel is engineered specifically with a thick, elastic, high viscosity structure meant to transport and suspend large proppant volumes, making it clearly superior to the other three for proppant carrying capacity.

Final Answer: □ $oxedext(B)Cross - linkedgel$

Quick Tip: Higher fluid viscosity means slower proppant settling and better suspension.

• • •

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

(A) $\Delta p(r_s) = \Delta p(r_w)$

(B) $\Delta p(r_s) = 0$

(C) $\Delta p(r_s) = 2\,\Delta p(r_w)$

(D) $\Delta p(r_s) = 4\,\Delta p(r_w)$

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

SOLUTION:

Approach using the pressure vs ln(r) profile:

A convenient way to picture near wellbore damage is to plot flowing pressure p against $\ln r$ for steady radial flow. Without any damage, this plot is a single straight line all the way from r_w to r_e, because the slope of p versus $\ln r$ depends only on $q\mu/(kh)$, which stays constant when the permeability is uniform.

Introducing the damaged ring:

When the zone from r_w to r_s has reduced permeability $k_s < k$, the actual pressure profile has two straight segments on the p versus $\ln r$ plot. The segment from r_s to r_e has the normal (shallow) slope set by the undamaged permeability k, exactly as if there were no damage at all. The segment from r_w to r_s has a steeper slope, since it is controlled by the lower permeability k_s, so the pressure falls off faster per unit of $\ln r$ inside the damaged ring.

Reading off the additional drop $\Delta p(r)$:

If we extend the undamaged (shallow slope) line backward from r_s down to r_w, it gives the pressure that would have existed at the well with no damage. The additional drop $\Delta p(r)$ at any radius r inside the damaged ring is simply the vertical gap between the actual (steeper) profile and this extended undamaged line. At $r = r_e$ down to $r = r_s$, the actual profile and the extended undamaged line are identical by construction, so the gap is zero all along that stretch, including right at r_s.

Growth of the gap inside the damaged ring:

Moving from r_s inward to r_w, the actual (steeper) line drops faster than the extended undamaged line, so the vertical gap widens continuously and reaches its maximum value, equal to the classical skin drop $\Delta p(r_w)$ $= \dfrac{141.2\, qB\mu}{kh} S$, exactly at the wellbore face.

Final Answer:

$$\boxed{\Delta p(r_s) = 0}$$

Quick Tip: The additional pressure drop caused by damage is confined entirely within the damaged ring and dies out at its outer edge, r_s.

22. In a drawdown test conducted on a well, p_D, t_D and C_D denote the dimensionless pressure, the dimensionless time and the dimensionless wellbore storage coefficient, respectively. In the early time of the drawdown test, the fluid produced at the surface results purely from the unloading (expansion) of fluid already stored in the wellbore, and no fluid from the formation has reached the well yet. This period is called the pure wellbore storage period. For this period, which of the following relationships is CORRECT?

(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:

Approach using the log log diagnostic unit slope line:
A standard way pressure transient analysts recognize pure wellbore storage is by plotting $\log p_D$ against $\log t_D$ for early time drawdown data. During this period the data always falls on a straight line inclined at exactly 45 degrees, commonly called the unit slope line, because p_D and t_D are directly proportional to one another in this regime.

Writing the unit slope line algebraically:
A straight line of slope 1 on a log log plot means $\log p_D = \log t_D + \text{constant}$, which is the same as saying $p_D = (\text{constant}) \times t_D$. Physically, this constant of proportionality for the wellbore storage period is known from the material balance of the wellbore fluid to be $1/C_D$, so the unit slope line is described by $p_D = t_D/C_D$.

Checking the physical reasonableness:
This makes sense because a well with a very small storage coefficient C_D (for example a well with a packer set near the perforations) will show a

larger p_D for a given t_D, since the wellbore has almost no capacity to buffer the pressure change, causing pressure to fall quickly. A well with a large C_D (a long, fluid filled wellbore with no packer) buffers the pressure change more, so p_D stays smaller for the same t_D. This inverse dependence of p_D on C_D at fixed t_D is exactly what the relation $p_D = t_D/C_D$ predicts.

Solving for the required variable:

Cross multiplying the unit slope relation $p_D = t_D/C_D$ by C_D on both sides isolates t_D on one side, giving $t_D = p_D C_D$, which is the relation asked for in the question.

Final Answer:

$$\boxed{t_D = p_D\, C_D}$$

Quick Tip: During pure wellbore storage the bottomhole pressure drop is directly proportional to elapsed time, which in dimensionless form gives the unit slope relation pD equals tD divided by CD.

• • •

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

(A) Water flooding

(B) In situ combustion

(C) Surfactant flooding

(D) Steam flooding

Correct Answer: (B) In situ combustion ; (C) Surfactant flooding ; (D) Steam flooding

SOLUTION:

Approach by sorting each method into its recovery category:

Instead of checking every option against a definition one at a time, it helps to first build a simple mental table of the three recovery stages and then place each of the four listed methods into its correct box.

Primary and secondary recovery box:

This box holds methods that rely on natural reservoir energy or on simple fluid injection purely to keep reservoir pressure up and physically displace oil, without changing the oil's own properties. Water flooding belongs squarely in this box, since injected water displaces oil mechanically but does not thin it out or reduce the capillary forces trapping it in the pore throats.

Thermal EOR box:

This box holds methods that add heat to the reservoir to reduce oil viscosity and improve its mobility. Steam flooding, where continuous steam injection heats the oil bank ahead of it, belongs here. In situ combustion also belongs here, since burning a portion of the oil downhole generates heat in place, achieving a similar viscosity reduction along with extra gas drive from the combustion products.

Chemical EOR box:

This box holds methods that use injected chemicals to alter interfacial properties between the oil, water, and rock. Surfactant flooding belongs here, since the surfactant molecules lower the oil water interfacial tension so that capillary trapped oil droplets can coalesce and move.

Reading off the answer from the sorted table:

Once every option is placed in its box, only water flooding lands in the secondary recovery box, while in situ combustion and steam flooding land in the thermal EOR box and surfactant flooding lands in the chemical EOR box. Since the question asks specifically for conventional EOR methods, the secondary recovery entry is excluded and the three EOR box entries are selected.

Final Answer:

$$\boxed{\text{In situ combustion, Surfactant flooding, and Steam flooding}}$$

Quick Tip: EOR methods change oil viscosity, interfacial tension, or wettability, unlike plain water flooding which is a secondary recovery method.

• • •

24. Which of the following improve(s) the productivity index of a vertical well producing from 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) Hydraulic fracturing ; (B) Increasing the perforation length ; (D) Reducing the oil viscosity by steam injection

SOLUTION:

Approach by tracking the sign of the effect on flow resistance:
Instead of writing out the full productivity index formula first, it helps to think of the well plus near wellbore region as a resistance to flow, similar to resistance in an electrical circuit. The productivity index behaves like a conductance, it is high when the total flow resistance is low, and it drops when the flow resistance rises.

Effect of hydraulic fracturing on flow resistance:
A hydraulic fracture is essentially a very high permeability, low resistance channel connecting deep into the reservoir and back to the wellbore, bypassing the low permeability rock right around the well. This sharply cuts the total flow resistance the oil has to overcome, so the productivity index goes up.

Effect of longer perforations on flow resistance:
With short perforations, flow lines have to converge sharply into a small number of small tunnels near the well, similar to many lanes of traffic merging into a narrow gate, which adds resistance. Lengthening the

perforated interval opens up more flow paths and eases this convergence, lowering the resistance and raising the productivity index.

Effect of a higher skin factor on flow resistance:

Skin factor is literally defined as extra resistance added near the wellbore, on top of the resistance of the undamaged formation. Increasing the skin factor means deliberately adding more resistance, for example through worse formation damage or poor perforation design, which can only lower the productivity index, never raise it.

Effect of viscosity reduction from steam on flow resistance:

Oil viscosity directly controls how much resistance the fluid itself offers as it moves through the pore network, a thicker fluid resists flow more. Steam injection heats the oil and thins it out, lowering this fluid resistance and therefore raising the productivity index for the same reservoir rock properties.

Final Answer:

$$\boxed{\text{Hydraulic fracturing, increasing perforation length, and reducing viscosity by steam injection}}$$

Quick Tip: Anything that lowers the skin factor or lowers oil viscosity in the productivity index equation increases the productivity index, while a higher skin factor reduces it.

• • •

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

(A) Heating

(B) Centrifugation

(C) Addition of interfacial tension reducing agents

(D) Electrostatic coalescence

Correct Answer: (A) Heating ; (B) Centrifugation ; (D) Electrostatic coalescence

SOLUTION:

Approach by asking whether each method helps droplets coalesce or keeps them apart:

A crude oil water emulsion only breaks apart when the small dispersed water droplets are given a way to find each other, touch, and merge into bigger drops that settle out. So each proposed method can be judged by a simple question, does it help droplets merge together, or does it keep them apart as fine droplets.

Judging heating by this test:

Heat thins the oil phase so droplets move around and bump into each other more easily, and it softens the stabilizing skin around each droplet so that once droplets touch, they actually merge instead of just bouncing off. Heating clearly helps coalescence, so it passes the test for a separation method.

Judging centrifugation by this test:

A centrifuge does not change the droplets chemically, but it applies a strong artificial force field that rapidly drives the heavier water droplets toward the outer wall of the spinning vessel, away from the lighter oil. This forced, rapid segregation of the two phases is a direct physical route to separation, so centrifugation passes the test.

Judging interfacial tension reducing agents by this test:

Interfacial tension is the very quantity that resists breaking a liquid into fine droplets within another liquid, a high interfacial tension favors large drops and quick separation, while a low interfacial tension favors many small, stable droplets that resist merging. Deliberately lowering this tension therefore works against coalescence and keeps the emulsion finely dispersed, so this option fails the test and does not aid separation.

Judging electrostatic coalescence by this test:

An applied electric field stretches and polarizes each water droplet, and neighboring droplets with induced opposite charges are pulled strongly toward one another until they touch and merge into a single larger droplet. This is a direct, deliberate mechanism for forcing coalescence, so it clearly passes the test.

Final Answer:

$$\boxed{\text{Heating, Centrifugation, and Electrostatic coalescence}}$$

Quick Tip: Heating, centrifugation, and electrostatic coalescence break the emulsion, while interfacial tension reducing agents stabilize it instead of separating it.

• • •

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) Metering devices are required to determine injection rate of injection wells. ; (D) Firefighting and life-saving equipment should be present on the platform.

SOLUTION:

Step 1: List the functional requirements of an injection platform:

An injection well platform on an offshore field has three broad functional requirements: it must handle the correct injection fluid, it must monitor and control the rate at which that fluid enters each well, and it must meet the same personnel safety standards as any other manned offshore structure.

Step 2: Check the fluid type against option (A):

A water injection well platform is, by definition, built around injecting water for reservoir pressure support and waterflooding, not gas. A platform meant for gas injection would be a separate facility type. So option (A) fails this check.

Step 3: Check the rate control requirement against options (B) and (C):

Injection rate control is a core reservoir management activity. Without metering devices, the operator cannot know how much water is going into each well, cannot balance injection with voidage replacement, and cannot detect problems like thief zones or plugging. This makes metering devices a necessity, so option (C) passes this check and option (B), which denies this necessity, fails.

Step 4: Check the safety requirement against option (D):

Since the platform is a manned offshore structure handling pressurized fluids, it is subject to the same safety codes as production platforms, which mandate firefighting systems and life saving equipment on board. So option (D) passes this check.

Step 5: Consolidate the results:

Only options (C) and (D) satisfy the actual functional and safety requirements of a water injection well platform, while options (A) and (B) contradict them.

Final Answer:

$$\boxed{\text{(C) and (D) are correct}}$$

Quick Tip: Think about what an injection platform actually injects, and what safety and metering equipment any offshore platform must carry.

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) Pseudoplastic ; (C) Thixotropic

SOLUTION:

Step 1: Separate the behavior into a shear rate dependence and a time dependence:
Rheological behavior of a fluid can be split into how apparent viscosity changes with shear rate at a given instant, and how it changes with time at a fixed shear rate. Drilling fluid design has requirements on both counts.
Step 2: Consider the shear rate dependence, options (A) and (B):
In terms of shear rate, a fluid is either dilatant, viscosity rises as shear rate rises, or pseudoplastic, viscosity falls as shear rate rises. A drilling fluid needs low resistance to flow at the very high shear rates through the bit jets, but must still carry cuttings at the lower shear rates in the annulus, which is the classic pseudoplastic (shear thinning) signature. A dilatant response would work against efficient hydraulics, so it is not the behavior of a conventional drilling fluid. This confirms option (B) as correct and rules out option (A).
Step 3: Consider the time dependence, options (C) and (D):
In terms of time dependence at constant shear, a fluid is either thixotropic, viscosity or gel strength falls with time under shear and rebuilds at rest, or rheopectic, viscosity rises with continued shearing. Drilling fluids must gel when circulation is stopped so that cuttings and barite do not settle in the annulus or the hole, and this gel must break down quickly once pumping resumes, which is thixotropic behavior.

Rheopectic behavior would mean the fluid keeps thickening while being pumped, which is not how drilling fluids behave. This confirms option (C) as correct and rules out option (D).

Step 4: Combine both dependencies:

Since the drilling fluid must be shear thinning with shear rate and gel forming with time at rest, both pseudoplastic and thixotropic describe the same fluid at different levels, one in the shear rate domain and one in the time domain.

Final Answer:

$$\boxed{\text{(B) Pseudoplastic and (C) Thixotropic}}$$

Quick Tip: Drilling fluid must thin under high shear at the bit and gel up when pumping stops to suspend cuttings.

• • •

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 dp/dt 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 ; (C) Steady

SOLUTION:

Step 1: Set up the diffusivity equation and treat dp/dt as a given constant C:

Start from $\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial p}{\partial r}\right) = \frac{\phi\mu c_t}{k}\frac{\partial p}{\partial t}$. If $\frac{\partial p}{\partial t} = C$ is treated as a constant that does not depend on r or t, the right hand side becomes a fixed number, and the equation reduces to an ordinary differential equation in r alone, $\frac{1}{r}\frac{d}{dr}\left(r\frac{dp}{dr}\right) = \frac{\phi\mu c_t}{k}C$.

Step 2: Consider the special case $C = 0$:

If the constant C is zero, then $\frac{\partial p}{\partial t} = 0$ everywhere, meaning pressure at every radius no longer changes with time. This is exactly the definition of the steady state, which happens physically when the reservoir has a constant pressure outer boundary, such as a strong active aquifer or a constant pressure injection boundary, that keeps replenishing the produced fluid. So the steady state case, option (C), is a valid solution consistent with dp/dt being constant.

Step 3: Consider the case $C \neq 0$ but still constant:

If C is a fixed nonzero number, pressure is declining at the same rate everywhere in the reservoir at any instant in time, though it still varies with radius. This is exactly the pseudo-steady state, which arises physically once the pressure transient has reached a closed, no flow outer boundary and the whole reservoir volume depletes uniformly with time. So the pseudo-steady case, option (B), is also consistent with dp/dt being constant.

Step 4: Rule out the transient and unsteady options:

In transient or unsteady flow, the pressure disturbance is still propagating outward and has not stabilized, so $\frac{\partial p}{\partial t}$ genuinely depends on both r and t and cannot be pulled out as a single constant. This rules out options (A) and (D).

Step 5: Conclude:

Only the pseudo-steady state (constant nonzero decline rate) and the steady state (constant zero decline rate, i.e. no change) are consistent with treating dp/dt as constant.

Final Answer:

$$\boxed{\text{(B) Pseudo-steady and (C) Steady}}$$

Quick Tip: Ask where dp/dt does not change with time, only pseudo-steady (constant nonzero decline) and steady (dp/dt = 0) qualify.

• • •

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) FPSOs can be selected in the absence of any pipeline infrastructure. ; (D) FPSOs can be used for the storage of produced crude oil.

SOLUTION:

Step 1: Expand the acronym FPSO and use it as a checklist:
FPSO stands for Floating, Production, Storage, and Offloading. Each of these four words describes a capability the facility must have, floating means it is a vessel not a fixed structure, production means it processes the well stream, storage means it holds the processed oil on board, and offloading means it transfers that oil to a transport vessel.

Step 2: Check option (A) against the floating and conversion aspect:
Since an FPSO is essentially a ship shaped vessel, and oil tankers already have large hull volumes suited for storage, the offshore industry regularly converts retired or existing tankers into FPSOs by adding topside processing modules and a mooring or turret system, which is usually cheaper and faster than building a new hull. Therefore the claim in option (A) that conversion is not possible is false.

Step 3: Check option (B) against the offloading capability:
Because an FPSO stores oil and offloads it to shuttle tankers rather than exporting it continuously through a pipeline, it does not depend on any

subsea or onshore pipeline network being present. This makes FPSOs the preferred development option for fields in deepwater or remote locations where pipeline infrastructure does not exist or is not economical, confirming option (B) is true.

Step 4: Check option (C) against the production capability:

The production part of the name refers to onboard topside processing, separation of oil, gas and water, dehydration, gas compression and water treatment, all of which happen on the FPSO before the oil is stored. So the claim in option (C) that FPSOs cannot process produced fluids directly contradicts the production capability built into the facility, making it false.

Step 5: Check option (D) against the storage capability:

The storage part of the name directly refers to holding the processed crude oil in the vessel's cargo tanks until a shuttle tanker arrives for offloading, so option (D) is true by definition.

Final Answer:

$$\boxed{\text{(B) and (D) are correct}}$$

Quick Tip: Remember what the letters F, P, S, O in FPSO stand for, production and storage are both built into the name.

• • •

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

(A) $-\dfrac{dN}{dt} = \lambda N^2$

(B) $-\dfrac{dN}{dt} = \lambda N$

(C) $-\dfrac{dN}{dt} = \dfrac{\lambda}{N^2}$

(D) $-\dfrac{dN}{dt} = \dfrac{\lambda}{N}$

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

SOLUTION:

Step 1: Use dimensional and limiting behavior reasoning instead of memorizing the formula:

Consider what should happen physically as N becomes very small, that is as almost all the nuclei have already decayed. With very few nuclei left, the number of decay events per unit time must also become very small, and in the limit $N \to 0$ the decay rate $-\frac{dN}{dt}$ must also approach 0, since there is almost nothing left to decay.

Step 2: Test option (A), $-\frac{dN}{dt} = \lambda N^2$, against this limit:

As $N \to 0$, $N^2 \to 0$ as well, so this form does go to zero, but it implies the decay rate falls off much faster than proportionally as N decreases, which would require decay to depend on pairs of nuclei interacting. Radioactive decay of a single nucleus is a spontaneous, independent process, not a pairwise interaction, so this quadratic dependence does not match the known physical mechanism.

Step 3: Test options (C) and (D), which have N in the denominator, against the same limit:

For option (C), $-\frac{dN}{dt} = \lambda/N^2$, and option (D), $-\frac{dN}{dt} = \lambda/N$, as $N \to 0$ the right hand side blows up to infinity instead of going to zero. This would mean the decay rate becomes infinitely large exactly when almost no nuclei are left to decay, which is physically impossible. Both options (C) and (D) are ruled out by this limiting argument.

Step 4: Test option (B), $-\frac{dN}{dt} = \lambda N$, against the same limit:

As $N \to 0$, $\lambda N \to 0$ smoothly and proportionally, matching the physical expectation that decay activity fades away in direct proportion to how much radioactive material remains. This linear form is also consistent with the well established exponential decay curve $N = N_0 e^{-\lambda t}$ observed experimentally for all radioactive isotopes.

Step 5: Conclude:

Only the first order linear relationship in option (B) is physically consistent, both from the underlying independent-decay mechanism and from the correct limiting behavior as $N \to 0$.

Final Answer:

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

Quick Tip: Radioactive decay is a first order process, the decay rate is directly proportional to N, not to N squared or to 1 over N.

• • •

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) Gamma ray ; (B) Neutron ; (C) Electrical

SOLUTION:

Step 1: List what CBL actually measures:

A Cement Bond Log records the amplitude and travel time of an acoustic signal sent from a transmitter through the casing, cement and formation to a receiver. The amount of attenuation of this signal indicates whether the cement is well bonded to the casing and formation or whether channels of fluid or gas exist behind the pipe. This acoustic wave measurement is the sole physical principle behind cement bond investigation.

Step 2: Separate a correlation tool from an investigation tool:

A gamma ray curve is often recorded at the same time as the acoustic data, but only as a depth reference tool. It lets the engineer match the CBL depth scale to the open hole logs and to the casing collar locator so that any weak bond zone can be pinpointed at the correct depth. Being present in the same logging run does not make gamma ray part of the actual bond investigation, since it measures natural formation radioactivity, a property completely unrelated to cement bonding.

Step 3: Explain why neutron and electrical logs are excluded:

Neutron logs respond to hydrogen content and are designed to estimate porosity of the rock matrix in an open borehole. Electrical or resistivity logs measure the resistivity contrast of formation fluids to distinguish hydrocarbons from water, again in an open hole environment. Neither tool responds to the mechanical integrity of the cement sheath behind the casing, so neither is used in a cement bond investigation.

Step 4: Match to the given options:

Comparing with the four options, only Acoustic wave logging is genuinely used to investigate the cement bond, since it directly measures signal attenuation caused by the bonding condition. Gamma ray, Neutron and Electrical logging do not investigate the bond itself, gamma ray being a correlation aid at best and the other two being unrelated open hole formation evaluation tools, so all three are the correct selections for methods NOT used in CBL investigation.

Final Answer:

$$\boxed{\text{A: Gamma ray, B: Neutron and C: Electrical logging are NOT used in CBL}}$$

Quick Tip: Recall that CBL is fundamentally an acoustic or sonic measurement; the other listed logs are open hole or correlation tools only.

32. The solution of the given expression is ________.

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

Correct Answer: 0

SOLUTION:

Step 1: Check the indeterminate form:

Let $u = \pi/2 - x$, so $\cos x = \sin u$ and as $x \to \pi/2$, $u \to 0$. The limit becomes $\lim_{u\to 0} \dfrac{\sin(\sin u) - \sin u}{u}$. At $u = 0$, the numerator is $\sin(\sin 0) - \sin 0$ $= \sin(0) - 0 = 0$ and the denominator is also 0, so this is a $0/0$ indeterminate form and L'Hopital's rule can be applied directly.

Step 2: Differentiate numerator and denominator with respect to u:

Let $f(u) = \sin(\sin u) - \sin u$ and $g(u) = u$. Using the chain rule, $f'(u)$ $= \cos(\sin u) \cdot \cos u - \cos u = \cos u\,[\cos(\sin u) - 1]$, and $g'(u) = 1$.

Step 3: Evaluate the derivatives at u = 0:

At $u = 0$: $\cos u = \cos 0 = 1$, and $\sin u = \sin 0 = 0$, so $\cos(\sin u) = \cos 0 = 1$. Therefore $f'(0) = 1 \times (1 - 1) = 1 \times 0 = 0$, and $g'(0) = 1$.

Step 4: Apply L'Hopital's rule:

By L'Hopital's rule, $\lim_{u\to 0} \dfrac{f(u)}{g(u)} = \dfrac{f'(0)}{g'(0)} = \dfrac{0}{1} = 0$. Since the derivative of the denominator is nonzero at $u = 0$, a single application of the rule is sufficient, and this confirms the same result obtained from the Taylor series expansion method.

Final Answer:

$$\boxed{0}$$

Quick Tip: Substitute u = pi/2 - x so that cos x becomes sin u, then use the small angle Taylor expansion of sine.

33. A circular reservoir with a well in the centre is producing oil at a 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 ___________.

Correct Answer: 3000

SOLUTION:

Step 1: Express the pseudo steady state depletion rate from material balance:

For a closed reservoir under pseudo steady state, the volumetric material balance gives the reservoir average depletion rate as $\frac{dp}{dt} = -\frac{qB}{c_t V_p}$, where q is the constant production rate, B is the formation volume factor, c_t is the total compressibility, and V_p is the pore volume of the reservoir. Because q, B, c_t and V_p are all constant for the whole drainage volume, this depletion rate is a single constant value that applies uniformly to every point in the reservoir, not just to the wellbore.

Step 2: Recognize that the wellbore measurement represents the whole reservoir:

Since the same constant dp/dt governs pressure decline everywhere under PSS, the 1.0 psi/day rate measured at the wellbore is identical to the rate of decline at the external boundary radius r_e. No additional adjustment is needed to convert a wellbore rate into a boundary rate under this flow regime.

Step 3: Calculate the cumulative pressure decline over the given time:

$\Delta p = 1.0 \times 500 = 500$ psi, using the constant depletion rate over the full 500 day period.

Step 4: Subtract from the known boundary pressure:

Given that the pressure at the external radius was 3500 psi at the reference time, after 500 days it becomes $3500 - 500 = 3000$ psi. This matches exactly what is predicted by the direct rate times time calculation, confirming the uniform depletion principle of pseudo steady state flow.

Final Answer:

$$\boxed{3000 \text{ psi}}$$

Quick Tip: Under pseudo steady state, the pressure decline rate is the same at every point in the reservoir.

• • •

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 __________.

Correct Answer: 100.0

SOLUTION:

Step 1: Convert the given quantities into a mass balance:
Distilled water has a density of 1.0 g/cm^3, which numerically means every 1 ml of water weighs exactly 1 gram. So 92 ml of water corresponds directly to 92 grams of water, without needing any further unit conversion.

Step 2: Add the mass of the dissolved salt:
When 23 grams of NaCl salt dissolves into the water, the total mass of the system is simply the sum of both components, since mass is conserved during dissolution: $m_{total} = 92 \text{ g} + 23 \text{ g} = 115 \text{ g}$.

Step 3: Use the given brine density to back calculate volume:
The problem states the resultant brine has a density of 1.15 g/cm^3. Density is mass per unit volume, so rearranging gives $V_{brine} = \frac{m_{total}}{\rho_{brine}}$.

Step 4: Substitute the numbers and solve:
$V_{brine} = \frac{115}{1.15} = 100 \text{ cm}^3$. Converting to milliliters using the standard equivalence $1 \text{ cm}^3 = 1 \text{ ml}$ gives $V_{brine} = 100 \text{ ml}$. This is a good example of why volumes are not simply additive when a solid dissolves into a liquid to

form a solution of different density; only the masses add directly, while the final volume must be recalculated from the new density.

Final Answer:

$$\boxed{100.0 \text{ ml}}$$

Quick Tip: Add the mass of water and salt, then divide the total mass by the given brine 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 ^{o}API) is __________. [Given: water density is 62.4 lbm/ft^3 at STP]

Correct Answer: 45.1

SOLUTION:

Step 1: Express specific gravity using the reciprocal density ratio:

Instead of dividing oil density by water density directly, first find the reciprocal, $\frac{1}{SG} = \frac{\rho_{water}}{\rho_{oil}} = \frac{62.4}{50}$. Computing this gives $\frac{62.4}{50} = 1.248$.

Step 2: Substitute this reciprocal directly into the API gravity formula:

The API gravity formula can be rewritten as $°API = 141.5 \times \left(\frac{1}{SG}\right) - 131.5$, which avoids computing SG as a decimal first and reduces rounding error. Substituting the reciprocal value found in Step 1: $°API = 141.5 \times 1.248 - 131.5$.

Step 3: Perform the multiplication:

$141.5 \times 1.248 = 176.592$. This is the value of $141.5/SG$ computed to more decimal precision than the direct division method.

Step 4: Subtract to find the API gravity:

$°API = 176.592 - 131.5 = 45.092$, which rounds to 45.1 to one decimal place, matching the result obtained from the direct division method.

Step 5: Confirm physical reasonableness:

Since the given oil density of 50 lbm/ft^3 is well below the water density of 62.4 lbm/ft^3, the oil is light and buoyant relative to water, and an API gravity in the mid forties is typical for a light or condensate like crude oil, confirming the answer is physically sensible.

Final Answer:

$$\boxed{45.1\ ^{\circ}API}$$

Quick Tip: Find the specific gravity first, then apply the API gravity formula 141.5 divided by SG minus 131.5.

• • •

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

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

(A) $2e^{-i\pi/2}$

(B) -1

(C) $2e^{i\pi/2}$

(D) 1

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

SOLUTION:

Step 1: Simplify $(1+i)^2$ and $(1-i)^2$ first:

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

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

Step 2: Build up $(1+i)^8$ using repeated squaring:

$(1+i)^4 = [(1+i)^2]^2 = (2i)^2 = 4i^2 = -4.$

$(1+i)^8 = [(1+i)^4]^2 = (-4)^2 = 16.$

Step 3: Build up $(1-i)^6$ using repeated squaring:

$(1-i)^4 = [(1-i)^2]^2 = (-2i)^2 = 4i^2 = -4.$

$(1-i)^6 = (1-i)^4 \cdot (1-i)^2 = (-4)(-2i) = 8i.$

Step 4: Form the ratio and rationalize:

$$\frac{(1+i)^8}{(1-i)^6} = \frac{16}{8i} = \frac{2}{i}$$

Multiply numerator and denominator by i: $\frac{2}{i} \cdot \frac{i}{i} = \frac{2i}{i^2} = \frac{2i}{-1} = -2i.$

Step 5: Convert to exponential (polar) form to match the given options:

The number $-2i$ has modulus 2 and lies on the negative imaginary axis, so its argument is $-\pi/2$. Thus $-2i = 2e^{-i\pi/2}$, confirming option (A).

Final Answer:

$$\boxed{2e^{-i\pi/2}}$$

Quick Tip: Convert 1+i and 1-i to polar/exponential form, raise to the given powers, then simplify the ratio.

• • •

37. The values of a function $f(x)$ at three different values of x are given below: $f(0.90) = 7.75$, $f(1.00) = 9.00$, $f(1.10) = 10.35$.

Using the central difference approximation method, which is the CORRECT estimate of the 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: Set up the problem using equal spacing $h = 0.10$:

The three given points $x = 0.90, 1.00, 1.10$ are equally spaced with $h = 0.10$, and the function values are $y_{-1} = 7.75$, $y_0 = 9.00$, $y_{+1} = 10.35$.

Step 2: Derive the first derivative using the symmetric slope idea:

The average rate of change from $x = 0.90$ to $x = 1.10$ estimates the slope at the midpoint $x = 1.00$:

$$\text{slope} = \frac{y_{+1} - y_{-1}}{2h} = \frac{10.35 - 7.75}{0.20} = \frac{2.60}{0.20} = 13.00$$

So $f'(1.00) \approx 13.00$.

Step 3: Derive the second derivative using the curvature (concavity) idea:

The second derivative measures how the forward and backward slopes differ. The forward slope is:

$$s_f = \frac{y_{+1} - y_0}{h} = \frac{10.35 - 9.00}{0.10} = \frac{1.35}{0.10} = 13.5$$

The backward slope is:

$$s_b = \frac{y_0 - y_{-1}}{h} = \frac{9.00 - 7.75}{0.10} = \frac{1.25}{0.10} = 12.5$$

Step 4: Take the rate of change of slope over the interval h:

$$f''(1.00) \approx \frac{s_f - s_b}{h} = \frac{13.5 - 12.5}{0.10} = \frac{1.0}{0.10} = 10.00$$

Step 5: State the pair of results:

This confirms $f'(1.00) = 13.00$ and $f''(1.00) = 10.00$, matching option (B).

Final Answer:

$$\boxed{f'(1.00) = 13.00,\ f''(1.00) = 10.00}$$

Quick Tip: Use f'(xo) = (f(xo+h)-f(xo-h))/(2h) and f''(xo) = (f(xo+h)-2f(xo)+f(xo-h))/h^2.

• • •

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

(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: Start from the limit definition of the CDF slope:

By definition, $F(x) = P(X \le x)$. Consider a small interval of width Δx around a point x.

Step 2: Express the probability of falling in this small interval:

$$P(x < X \le x + \Delta x) = F(x + \Delta x) - F(x)$$

Step 3: Relate this probability to the density function:

For a continuous variable, this probability is approximately $f(x)\Delta x$ for small Δx, since the density $f(x)$ represents probability per unit length:

$$f(x)\Delta x \approx F(x + \Delta x) - F(x)$$

Step 4: Divide both sides by Δx and take the limit as $\Delta x \to 0$:

$$f(x) = \lim_{\Delta x \to 0} \frac{F(x + \Delta x) - F(x)}{\Delta x}$$

This limit is exactly the definition of the derivative of $F(x)$ with respect to x.

Step 5: Conclude the relationship:

$$f(x) = \frac{d}{dx} F(x)$$

This confirms that the PDF is the first derivative of the CDF, so option (A) is correct.

Final Answer:

$$\boxed{f(x) = \frac{d}{dx} F(x)}$$

Quick Tip: The PDF is the derivative of the CDF with respect to x, by the Fundamental Theorem of Calculus.

39. Choose the CORRECT match of 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/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) Siltstone	(IV) Evaporation and precipitation 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: Use the process of elimination starting with the most distinctive rock:
Evaporite is the most chemically distinctive rock in the list, since it can only form by evaporation of water bodies that concentrates and precipitates dissolved salts. Only process (IV), evaporation and precipitation of marine water, describes this. So P-IV is fixed first.
Step 2: Eliminate option pairs that do not have P-IV:
Checking the four given options, only options (A) and (D) pair P with IV, so options (B) and (C) can be ruled out immediately.
Step 3: Distinguish between the remaining two options using Sandstone (Q):
Sandstone is a clastic rock built from mechanically deposited sand grains

bound together by cementation, which is a physical process, matching (I). Option (A) assigns Q-I while option (D) assigns Q-III (an anaerobic organic process), which does not fit sandstone at all. So option (A) is favoured over (D) at this step.

Step 4: Confirm using Limestone (R) and Siltstone (S):

Limestone forms mainly through chemical precipitation and marine organism deposition, matching (II), so R-II is correct as in option (A). Siltstone, made of very fine sediment settled in quiet, oxygen poor muddy conditions, matches the anaerobic organic mud bed process (III), so S-III is correct as in option (A).

Step 5: Finalize the match:

All four pairs P-IV, Q-I, R-II, S-III are consistent with option (A), confirming it as the correct choice.

Final Answer:

$$\boxed{\text{P-IV; Q-I; R-II; S-III}}$$

Quick Tip: Match each rock to its formation process: evaporite forms by evaporation, sandstone by physical cementation, limestone by marine biochemical processes, siltstone by anaerobic mud deposition.

• • •

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: Classify the four logging tools by their physical measurement principle:
Neutron, sonic, and density logs are all classed as "pad" or short spaced nuclear/acoustic tools that rely on particles or waves which attenuate rapidly in rock, while resistivity tools measure the formation's electrical response using either induction currents or focused current electrodes.
Step 2: Compare typical investigation ranges from petrophysical practice:
In standard well logging practice, neutron and density tools typically investigate only a few centimeters to about 10-15 cm into the formation, sonic logs investigate roughly a similar shallow range close to the borehole wall, whereas deep resistivity tools (deep induction or deep laterolog) are engineered to read several tens of inches to a few feet into the formation.
Step 3: Explain why resistivity tools read deeper:
Deep resistivity tools use larger electrode or coil spacing, which spreads the current path or electromagnetic field further from the borehole, allowing the measurement to bypass the shallow invaded (mud filtrate flushed) zone and sense the true, uninvaded formation resistivity.
Step 4: Cross-check with the purpose of deep resistivity logging:
Deep resistivity logs are specifically run to estimate true formation resistivity (Rt) away from borehole and invasion effects, which is only possible if the tool has a large depth of investigation. This purpose built design confirms that resistivity is the deepest reading tool of the four.
Step 5: Rank all four tools by depth of investigation:
Ranking from shallowest to deepest: density and neutron are the shallowest, sonic is slightly deeper but still shallow, and resistivity (particularly deep resistivity) is by far the deepest reading of all standard logging methods.
Step 6: State the final choice:
Therefore, resistivity logging gives the highest depth of investigation for

the marine formation.

Final Answer:

$$\boxed{\text{Resistivity}}$$

Quick Tip: Deep resistivity tools use large electrode/coil spacing to read well beyond the invaded zone, unlike neutron, sonic, and density tools.

• • •

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

GROUP X

(P) Fusible plug loops

(Q) Thermal and smoke detection system

(R) Gas detection system

GROUP Y

(I) Detects rise in temperature caused by fire and visible/invisible particles of combustion

(II) Functions based on drop in pressure that activates fire shutdown

(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:

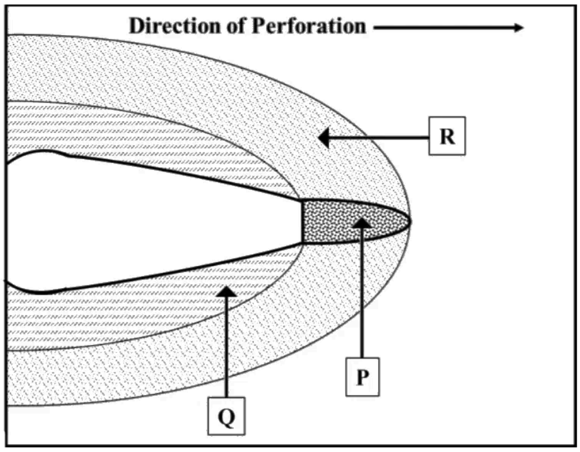
Step 1: List what each device physically senses:
Instead of matching one item at a time, it helps to first write down the underlying physical quantity that each device in GROUP X actually senses. A fusible plug loop does not sense heat, smoke or gas directly at all; it only senses the loss of pneumatic pressure that occurs once its low melting point element has melted. A thermal and smoke detector senses two things together, a temperature rise and airborne combustion particles. A gas detector senses the concentration of flammable vapour in the air around it.
Step 2: Compare this list against GROUP Y one statement at a time:
Statement (I) talks about detecting a rise in temperature together with visible and invisible particles of combustion, which is exactly the two-part sensing job of a thermal and smoke detector, so (I) goes with Q. Statement (II) talks about a mechanism that works on a drop in pressure to activate shutdown, which is exactly how a fusible plug loop operates once the alloy melts, so (II) goes with P. Statement (III) talks about detecting flammables, which is the job of the gas detection system, so (III) goes with R.
Step 3: Cross check against the given options:
The matching obtained is P-II, Q-I, R-III. Scanning the four options, this combination is exactly option (B), while the remaining options each swap at least one pairing incorrectly, for example option (A) wrongly assigns temperature and smoke sensing to P instead of a pressure based mechanism.
Step 4: State the final match:
The correct grouping is confirmed as P-II, Q-I, R-III.
Final Answer:

$$\boxed{P - II;\ Q - I;\ R - III \text{ (Option B)}}$$

Quick Tip: Ask what physically triggers each device: a melted plug causes a pressure loss, heat and smoke are picked up electronically, and gas sensors respond to flammable vapour concentration.

• • •

42.



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

GROUP X
P
Q
R

GROUP Y
(I) Grain fracturing
(II) Charge and core debris
(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: (D) P-II; Q-I; R-III

SOLUTION:

Step 1: Recall the physics of perforation damage in order of severity:
When a shaped charge jet perforates casing, cement and formation rock, it leaves behind a graded pattern of rock damage rather than a single uniform effect. Right where the jet's energy is spent, solid debris from the charge and the excavated core material accumulates and can plug the channel. Around the channel, the intense but very brief shock wave fractures individual mineral grains. Farther out, where the shock has decayed somewhat but still exceeds the rock's strength, the pore network itself gets crushed and packed with fine particles, lowering permeability over a broader zone.

Step 2: Map this order onto the arrow positions P, Q, R in the figure:
Following the arrows in the figure from the innermost feature outward, P points at the very tip of the tunnel where solid material is trapped, so P corresponds to the charge and core debris, item (II). Q points to the band immediately touching the tunnel wall where the rock shows cracked grains, so Q corresponds to grain fracturing, item (I). R points to the outer, larger shaded region that extends farther into the formation, so R corresponds to the compacted pulverized zone, item (III).

Step 3: Eliminate the other options using this mapping:
Option (A) wrongly places grain fracturing at P instead of debris. Option (B) wrongly places compacted pulverized zone at Q. Option (C) wrongly swaps Q and R. Only option (D), P-II, Q-I, R-III, agrees with the physically graded damage pattern.

Step 4: State the confirmed match:

The matching P-II, Q-I, R-III is therefore the correct one.

Final Answer:

$$\boxed{P - II;\ Q - I;\ R - III\ \text{(Option D)}}$$

Quick Tip: Move outward from the tunnel tip: debris packed at the very tip, cracked individual grains right against the tunnel wall, and a wider crushed/compacted halo farther into the rock.

• • •

43. Real gas pseudo pressure is used to derive the diffusivity equation for a 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) $\left(\frac{2p}{\mu Z}\right)\frac{\partial p}{\partial t}$

(B) $\left(\frac{p^2}{2\mu Z}\right)\frac{\partial p}{\partial t}$

(C) $\left(\frac{\mu Z}{2p}\right)\frac{\partial p}{\partial t}$

(D) $\left(\frac{2\mu Z}{p^2}\right)\frac{\partial p}{\partial t}$

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

SOLUTION:

Step 1: Recall why the pseudo pressure transform is used at all:

For a highly compressible real gas, both the viscosity μ and the gas deviation factor Z vary strongly with pressure, so the usual gas diffusivity equation in terms of p alone is nonlinear. The pseudo pressure substitution

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

is chosen precisely so that, after the substitution, the diffusivity equation for m behaves much like the simple linear liquid diffusivity equation.

Step 2: Use dimensional and structural reasoning to fix the form of dm/dp:

Since $m(p)$ is built as twice the integral of $p'/(\mu Z)$ with respect to p', the fundamental theorem of calculus says that differentiating this integral with respect to its upper limit simply reproduces the integrand at that limit, multiplied by the constant factor of 2 that sits outside the integral. That is,

$$\frac{dm}{dp} = \frac{2p}{\mu(p)Z(p)}$$

Nothing about the lower limit p_0 survives the differentiation because it is a fixed constant.

Step 3: Convert the pressure derivative into a time derivative:

In the reservoir, pressure is a function of both space and time, $p(x,t)$, and pseudo pressure inherits that dependence only through p. Treating m as a composite function of t via p, the chain rule for partial derivatives gives

$$\frac{\partial m}{\partial t} = \frac{dm}{dp}\cdot\frac{\partial p}{\partial t} = \frac{2p}{\mu Z}\cdot\frac{\partial p}{\partial t}$$

Step 4: Match against the answer choices and confirm:

This expression has p to the first power in the numerator and the product μZ in the denominator, multiplied by $\partial p/\partial t$, with an overall factor of 2. Only option (A) has exactly this structure, so it is the correct choice; the remaining three options are dimensionally or structurally inconsistent with the derivation.

Final Answer:

$$\boxed{\frac{\partial m}{\partial t} = \left(\frac{2p}{\mu Z}\right)\frac{\partial p}{\partial t} \text{ (Option A)}}$$

Quick Tip: Differentiate the pseudo pressure integral using the Leibniz rule to get $\partial m/\partial p$, then multiply by $\partial p/\partial t$ using the chain rule.

• • •

44. Stokes' law is used to calculate the settling rate of barite in drilling fluid for two batches, P and Q. The particle size of batch P is 75 micrometers and the particle size of batch Q is 25 micrometers. The particle settling rate in the drilling fluid for batch P is __________ times that for batch Q.

(A) Four

(B) Nine

(C) Two

(D) One

Correct Answer: (B) Nine

SOLUTION:

Step 1: Recall the proportionality form of Stokes' law:
Rather than writing out the full Stokes' law expression, it is enough to remember that for particles of the same material settling in the same fluid under Stokes' (laminar, creeping flow) conditions, the settling velocity depends on particle size only through the square of the diameter, that is

$$v \propto d^2$$

All the other factors, particle density, fluid density, fluid viscosity and gravitational acceleration, cancel out when comparing two batches of the same barite in the same mud.
Step 2: Express both settling velocities using a common proportionality

constant:

Let $v = kd^2$ for some constant k that is identical for both batches since the fluid and solid properties do not change. Then for batch P, $v_P = k(75)^2$, and for batch Q, $v_Q = k(25)^2$, both diameters measured in the same micrometer units so the constant k cancels cleanly in the ratio.

Step 3: Divide to find how many times faster batch P settles:

Dividing,

$$\frac{v_P}{v_Q} = \frac{(75)^2}{(25)^2} = \frac{5625}{625} = 9$$

which confirms, by direct numerical computation rather than the shortcut ratio method, that batch P settles nine times faster than batch Q.

Step 4: Sanity check the result:

Batch P particles are three times larger in diameter than batch Q particles (75 divided by 25 equals 3), and since settling velocity scales with the square of size, tripling the diameter should scale the velocity by three squared, which is nine. This agrees with the calculation and confirms option (B) is correct.

Final Answer:

$$\boxed{\frac{v_P}{v_Q} = 9 \text{ (Option B, Nine)}}$$

Quick Tip: Stokes' law settling velocity is proportional to the square of particle diameter, so take the ratio of diameters and square it.

• • •

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

(A) Optical

(B) Electrical

(C) Thermal

(D) Nuclear

Correct Answer: (B) Electrical

SOLUTION:

Step 1: Classify wireline logging tools by their physical basis:
Wireline logs are generally grouped by the physical property they measure: electrical logs use current flow and resistivity, nuclear logs use radioactive sources or natural radioactivity, acoustic logs use sound wave travel time, and a few specialised tools use optical or thermal sensing. Placing the FMS correctly in this classification answers the question directly.
Step 2: Examine the working mechanism of the FMS pads:
The FMS tool has multiple pads, each carrying a row of small electrode buttons, that are physically pressed against the borehole wall with a caliper arm mechanism. Each button injects a focused survey current into the formation and measures the resulting micro resistivity of the rock in extremely fine detail, at a resolution fine enough to resolve individual bedding laminations and fractures. This is fundamentally the same physical principle as a normal resistivity log, just applied at a much smaller electrode spacing and higher spatial resolution.
Step 3: Confirm none of the other physical principles are involved:
There is no optical sensor or light source in the standard FMS tool string, so option (A) does not apply. There is no thermal sensing element used to build the image, so option (C) does not apply. There is no radioactive source or gamma/neutron detector in the FMS pad assembly, so option (D), the nuclear approach, does not apply either.
Step 4: Select the single correct approach:
Since the FMS image is built entirely from button electrode micro

resistivity measurements, the response mechanism is purely electrical, confirming option (B) as the answer.

Final Answer:

$$\boxed{\text{Electrical (Option B)}}$$

Quick Tip: FMS is a microresistivity imaging tool that uses button electrodes pressed against the borehole wall.

• • •

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) Gas zone ; (C) Water zone

SOLUTION:

Step 1: Recall the physical basis of the two logs:
The neutron tool counts hydrogen atoms in the pore fluid and converts that count into an apparent porosity, ϕ_N. The density tool measures bulk density and converts it into porosity, ϕ_D, using an assumed fluid and matrix density. Any fluid whose hydrogen index or density differs from the assumption used in calibration will make ϕ_N and ϕ_D disagree, and the pattern of disagreement is diagnostic of the fluid type.

Step 2: Test option A, gas zone, using the hydrogen index argument:
Gas at reservoir conditions has a hydrogen index that can be a small fraction of that of liquids, so it makes the neutron tool report far too little porosity while density porosity stays close to the true value. The result is

$\phi_N \ll \phi_D$, the classic crossover, and this is the standard way gas zones are picked out, so option A holds.

Step 3: Test option B, shale distribution:

Although shale does distort both the neutron and density response through bound water and mineral effects, the practical tool for mapping how much shale is present and how it is distributed bed by bed is the gamma ray or SP curve, not the neutron density pair by itself. Since the question asks what is inferred using the cross plot specifically, shale distribution is not the direct output, so option B does not hold.

Step 4: Test option C, water zone:

Water has a hydrogen index near 1, essentially matching the neutron tool calibration fluid, so $\phi_N \approx \phi_D$ in a clean water bearing interval and the points fall along the expected lithology line with no crossover. Analysts use this absence of separation as the marker for a water zone, so option C holds.

Step 5: Test option D, oil zone:

Because oil also carries a hydrogen index near 1, an oil zone produces nearly the identical $\phi_N \approx \phi_D$ pattern seen in a water zone. The cross plot has no way to separate the two liquids from each other, so it cannot be used to specifically infer an oil zone, and option D fails.

Final Answer:

$$\boxed{\text{Options A and C, gas zone and water zone}}$$

Quick Tip: Gas lowers neutron porosity relative to density porosity (crossover); oil and water share a similar hydrogen index.

• • •

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) Porosity ; (B) Pore size distributions ; (C) Absolute permeability

SOLUTION:

Step 1: Separate routine core analysis from special core analysis:
Core analysis is generally split into routine core analysis, which measures porosity and permeability quickly on many plugs, and special core analysis, which measures more detailed properties such as pore size distribution, relative permeability and capillary pressure on selected plugs. Both categories are laboratory measurements performed on the physical core sample itself.

Step 2: Assign option A, porosity, to routine core analysis:
Porosity comes directly from routine core analysis, where the grain volume and bulk volume of the plug are measured and the pore volume fraction is calculated. This is a direct, sample scale measurement, so option A belongs to the list of properties obtained from a core sample.

Step 3: Assign option B, pore size distribution, to special core analysis:
Pore size distribution comes from special core analysis, typically the mercury injection capillary pressure test or nitrogen adsorption for tighter rocks, both of which are run on a piece of the core plug in the lab. Since this measurement is only possible with a physical sample, option B also belongs to the list.

Step 4: Assign option C, absolute permeability, to routine core analysis:
Absolute permeability is obtained by flowing a single fluid through the plug at fixed conditions and using Darcy's law, again a routine core analysis test performed on the physical sample, so option C belongs to the list as well.

Step 5: Rule out option D, reservoir boundary:
Reservoir boundary is a large scale, field level property describing the outer limits and connectivity of the reservoir, and it cannot be read off a centimeter scale rock plug. It is instead established using seismic mapping, multi well correlation, and pressure transient well tests that see a much larger drainage area, so option D is excluded.
Final Answer:

$$\boxed{\text{Options A, B and C: porosity, pore size distribution and absolute permeability}}$$

Quick Tip: A core plug is lab tested for porosity, pore size distribution and permeability, but it is too small to reveal reservoir extent.

• • •

48. Pressure change and derivative type curves (Bourdet type curves) are used in 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) These curves are on Log-Log plot ; (C) All derivative type curves merge in the middle time region

SOLUTION:

Step 1: Recall the purpose of the Bourdet method:
Bourdet introduced plotting the derivative of pressure change alongside the pressure change itself, both on log log axes, because the derivative is far more sensitive to changes in flow regime than the pressure change curve alone, making transitions between wellbore storage, transition, and

radial flow easy to spot by eye.

Step 2: Evaluate option A by comparing plot types:

On a Cartesian or semi log plot, the wide range of pressure and time values recorded during a well test would compress early time behavior and stretch late time behavior unevenly. A log log plot instead spreads early and late time data proportionally, letting characteristic slopes, such as unit slope for wellbore storage, appear as straight lines. This is why the Bourdet plot is always drawn log log, confirming option A.

Step 3: Evaluate option B by considering what makes the type curves universal:

If the horizontal axis were simply t_D, a separate type curve chart would be needed for every possible wellbore storage value, which is impractical. By instead using the ratio t_D/C_D on the horizontal axis, Bourdet collapsed the storage dependence into the axis itself, leaving only the parameter C_De^{2s} to distinguish curves. Because the option states the axis is t_D alone rather than this ratio, option B is false.

Step 4: Evaluate option C using the physics of radial flow:

Once wellbore storage and near wellbore skin effects have fully dissipated, the reservoir behaves as if flow is radial and infinite acting, and the dimensionless pressure derivative approaches the constant value of one half independent of how much storage or skin the well originally had. Because every curve in the family reaches this same flat trend in the middle time region, the curves visibly merge there, confirming option C.

Step 5: Evaluate option D by recalling what is actually matched:

Type curve matching relies on lining up both the measured pressure change and the measured derivative against the corresponding pair of curves on the chart, so the vertical axis must carry both P_D and its derivative together, not P_D alone. This dual plotting is precisely what makes the Bourdet method more diagnostic than the older pressure only type curves, so option D is false.

Final Answer:

$$\boxed{\text{Options A and C are correct}}$$

Quick Tip: The horizontal axis is actually the group t_D/C_D, and both P_D and its derivative share the vertical axis.

• • •

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) To prevent leak or overflow of hydrocarbons ; (B) To prevent ignition of hydrocarbons released on the platform

SOLUTION:

Step 1: Separate surface safety functions from subsurface reservoir functions:
It helps to first split the four given options into two groups: options that deal with hydrocarbons already at the surface facility, and options that deal with fluid movement inside the reservoir. A platform safety system, by definition, exists to protect people and equipment at the surface, so only the surface related options can be genuine objectives of that system.
Step 2: Place option A in the surface group:
Preventing a leak or overflow of hydrocarbons is a surface containment task handled by pressure relief valves, level alarms, and shutdown valves on the process equipment itself, which clearly falls under the safety system's job, so option A stays in.
Step 3: Place option B in the surface group:

Preventing ignition of hydrocarbons that have already been released is handled by gas detectors, explosion proof equipment, and automatic isolation of electrical sources, again a surface facility function aimed at stopping a fire or explosion, so option B stays in.

Step 4: Place option C in the reservoir group and exclude it:

Water coning is governed by the pressure drawdown applied at the perforations and the mobility contrast between oil and water in the reservoir, and it is controlled by reservoir engineers through production rate and completion design, not by any platform level safety device, so option C is excluded.

Step 5: Place option D in the reservoir group and exclude it:

Gas coning is likewise governed by drawdown and the position of the gas oil contact relative to the perforations, again a reservoir management concern rather than a platform safety concern, so option D is excluded.

Final Answer:

$$\boxed{\text{A and B are the objectives of the platform safety system}}$$

Quick Tip: Platform safety systems guard against hydrocarbon release and ignition, not reservoir coning behavior.

• • •

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

[Given: 1 lbm/gal mud = 0.052 psi/ft]

(A) 13.8

(B) 11.3

(C) 11.8

(D) 13.2

Correct Answer: (A) 13.8 ; (D) 13.2

SOLUTION:

Step 1: Convert the pore pressure into an equivalent mud weight instead of testing each option separately:

A useful shortcut in well control problems is to convert the given pore pressure directly into an equivalent circulating or static mud weight, sometimes called the pore pressure gradient in mud weight units, and then simply compare each candidate mud density against that single benchmark number rather than recomputing hydrostatic pressure four separate times.

Step 2: Compute the equivalent mud weight of the pore pressure:

Using the given conversion factor, 1 lbm/gal of mud produces a gradient of 0.052 psi/ft, so the pore pressure of 6500 psig at a TVD of 10000 ft corresponds to a gradient of

$$\text{gradient} = \frac{6500}{10000} = 0.65 \text{ psi/ft}$$

Converting this gradient into an equivalent mud weight by dividing by 0.052 gives

$$\rho_{eq} = \frac{0.65}{0.052} = 12.5 \text{ lbm/gal}$$

This 12.5 lbm/gal figure is the exact mud weight that would make the well perfectly balanced, so it becomes the pass or fail line for every option.

Step 3: Compare option A, 13.8 lbm/gal, against the benchmark:

Since $13.8 > 12.5$, this mud is heavier than the balance point and will overbalance the formation, keeping fluid from entering the well, so option

A passes.

Step 4: Compare option B, 11.3 lbm/gal, against the benchmark:

Since $11.3 < 12.5$, this mud is lighter than the balance point and will underbalance the formation, allowing a kick, so option B fails.

Step 5: Compare option C, 11.8 lbm/gal, against the benchmark:

Since $11.8 < 12.5$, this mud is also lighter than the balance point, so it too underbalances the well and allows formation fluid to enter, so option C fails.

Step 6: Compare option D, 13.2 lbm/gal, against the benchmark:

Since $13.2 > 12.5$, this mud exceeds the balance point and keeps the well safely overbalanced, so option D passes.

Final Answer:

$$\boxed{\text{Options A and D, 13.8 and 13.2 lbm/gal, are acceptable}}$$

Quick Tip: Minimum mud density equals pore pressure divided by 0.052 times TVD; only values at or above that minimum are safe.

• • •

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 the wellbore increases the skin factor

(D) Formation damage near the wellbore decreases the skin factor

Correct Answer: (B) Successful hydraulic fracturing decreases the skin factor ; (C) Formation damage near the wellbore increases the skin factor

SOLUTION:

Step 1: Use the Hawkins formula for skin factor:

The Hawkins formula relates the skin factor to the ratio of the original permeability k to the altered permeability ks in a damaged or stimulated zone of radius rs around a wellbore of radius rw. The formula is $s = \left(\frac{k}{k_s} - 1\right)\ln\left(\frac{r_s}{r_w}\right)$. Since $\ln(r_s/r_w)$ is always positive for $r_s > r_w$, the sign of s depends only on the sign of the bracket term.

Step 2: Apply the formula to formation damage:

Formation damage reduces the near wellbore permeability, so k_s is smaller than k, which means k/k_s is greater than 1. The bracket $\left(\frac{k}{k_s} - 1\right)$ becomes positive, so s comes out positive. A positive skin factor confirms that formation damage increases the skin factor, matching statement C.

Step 3: Apply the formula to hydraulic fracturing:

A successful hydraulic fracture creates a very high conductivity path around the well, which is equivalent to making k_s much larger than k, or equivalently increasing the effective wellbore radius r_w to a much larger fracture half length. In the Hawkins style view, k/k_s becomes less than 1 so the bracket becomes negative, and in the effective wellbore radius view a larger r_w makes the ratio r_s/r_w smaller pushing the logarithm term down. Either way the calculated skin factor becomes negative, confirming that hydraulic fracturing decreases the skin factor, matching statement B.

Step 4: Conclude:

Since damage always pushes skin positive and successful stimulation such as fracturing always pushes skin negative, the correct statements are B and C only.

Final Answer:

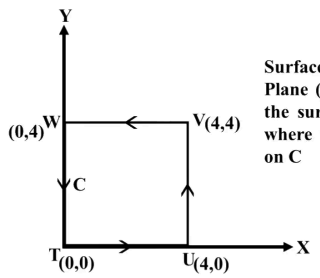
$$\boxed{\text{B and C}}$$

Quick Tip: Skin factor is positive for damage and negative for stimulation such as fracturing or acidizing.

52. Consider a vector function $\vec{F} = (y - z + 2)\hat{\imath} + (yz + 8)\hat{\jmath} - xz\hat{k}$, 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 the 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: Set up Stokes theorem as a line integral:
Stokes theorem states that $\iint_S (\nabla \times \vec{F}) \cdot \hat{n}\, dS = \oint_C \vec{F} \cdot d\vec{r}$, where C is the closed boundary of S traversed in the direction consistent with the chosen normal. From the figure, C is the path T(0,0) to U(4,0) to V(4,4) to W(0,4) back to T(0,0), all of which lies in the plane z = 0.
Step 2: Simplify F on the boundary:
Since the entire path lies at z = 0, substitute z = 0 into F. This gives $\vec{F} = (y + 2)\hat{\imath} + 8\hat{\jmath} + 0\hat{k}$. Also, since the path stays in the XY plane, $d\vec{r} = dx\,\hat{\imath} + dy\,\hat{\jmath}$, so $\vec{F} \cdot d\vec{r} = (y + 2)\,dx + 8\,dy$.
Step 3: Integrate along T to U:
On this segment y = 0 and dy = 0, with x going from 0 to 4. The integrand is $(0 + 2)\,dx = 2\,dx$, so the integral is $2 \times (4 - 0) = 8$.
Step 4: Integrate along U to V:

On this segment x = 4 and dx = 0, with y going from 0 to 4. The integrand is $8\,dy$, so the integral is $8 \times (4 - 0) = 32$.

Step 5: Integrate along V to W:

On this segment y = 4 and dy = 0, with x going from 4 to 0. The integrand is $(4 + 2)\,dx = 6\,dx$, so the integral is $6 \times (0 - 4) = -24$.

Step 6: Integrate along W to T:

On this segment x = 0 and dx = 0, with y going from 4 to 0. The integrand is $8\,dy$, so the integral is $8 \times (0 - 4) = -32$.

Step 7: Add the four segments and take the absolute value:

Adding all four parts gives $8 + 32 - 24 - 32 = -16$. This matches the surface integral found from the curl, confirming the calculation. The absolute value requested by the question is 16.

Final Answer:

$$\boxed{16}$$

Quick Tip: Compute curl F, dot it with the unit normal on the flat square, and integrate over the 4 by 4 region, or equivalently evaluate the line integral around T to U to V to W to T.

• • •

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

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

, 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: Rewrite the formula in a simplified squared form:

Since $10^4 = (100)^2$, the permeability formula can be regrouped as $k = \left[100\,\phi^2\,\frac{FFI}{\phi - FFI}\right]^2$. This form lets everything be combined inside a single bracket before squaring only once at the end, instead of squaring the ratio and multiplying separately.

Step 2: Find FFI from the porosity balance:

Total porosity equals the sum of irreducible bound water and free fluid, so $FFI = \phi - BVI = 0.1 - 0.04 = 0.06$. Check: $FFI + BVI = 0.06 + 0.04 = 0.10 = \phi$, so the split is consistent.

Step 3: Compute $100\phi^2$:

With $\phi = 0.1$, $\phi^2 = 0.01$, so $100 \times 0.01 = 1$.

Step 4: Compute the FFI over (phi minus FFI) ratio:

$\phi - FFI = 0.1 - 0.06 = 0.04$, and $\frac{FFI}{\phi - FFI} = \frac{0.06}{0.04} = 1.5$.

Step 5: Multiply inside the bracket and square once:

Multiplying the two pieces from Step 3 and Step 4 gives $1 \times 1.5 = 1.5$. Squaring this single number gives $1.5^2 = 2.25$.

Step 6: State the result:

Both the direct substitution method and this regrouped method give the same permeability of 2.25 mD, confirming the answer.

Final Answer:

$$\boxed{2.25 \text{ mD}}$$

Quick Tip: First find FFI from phi minus BVI, then substitute directly into the given permeability formula.

• • •

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: Define the productivity index for a linear IPR:
For a linear inflow performance relationship, the productivity index J is defined as the change in flow rate per unit drop in flowing bottomhole pressure, $J = \frac{\Delta q}{\Delta p_{wf}(\text{drop})} = \frac{q_2 - q_1}{p_{wf1} - p_{wf2}}$, using the pressure drop as a positive quantity since flow rate increases as pressure decreases.
Step 2: Compute J from the given data:
Using $q_1 = 200$ STB/day at $p_{wf1} = 4000$ psi and $q_2 = 600$ STB/day at p_{wf2} $= 1000$ psi, $J = \frac{600-200}{4000-1000} = \frac{400}{3000} = 0.13333$ STB/day per psi.
Step 3: Write the IPR using the productivity index form:
The linear IPR can be written as $q = q_1 + J\,(p_{wf1} - p_{wf})$, which says the flow rate increases above the reference rate q_1 in proportion to how much the flowing pressure has dropped below the reference pressure p_{wf1}.
Step 4: Substitute the numbers for the target pressure:
At $p_{wf} = 2875$ psi, the pressure drop from the reference is $p_{wf1} - p_{wf}$ $= 4000 - 2875 = 1125$ psi. So $q = 200 + 0.13333 \times 1125 = 200 + 150 = 350$ STB/day.
Step 5: Confirm using the second reference point:
Using $q_2 = 600$ at $p_{wf2} = 1000$ instead, $q = 600 + J\,(p_{wf2} - p_{wf}) = 600$ $+ 0.13333\,(1000 - 2875) = 600 + 0.13333 \times (-1875) = 600 - 250 = 350$ STB/day, which agrees with the earlier result.
Final Answer:

$\boxed{350 \text{ STB/day}}$

Quick Tip: Fit a straight line between the two given flow rate and pressure pairs, then read off the flow rate at 2875 psi.

• • •

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: Compute the total downhole pressure budget:
The formation can tolerate a bottomhole pressure up to the fracture pressure minus the safety margin. The fracture pressure at 7000 ft is $0.7 \times 7000 = 4900$ psi, and subtracting the 250 psi safety margin gives an allowable bottomhole pressure of $4900 - 250 = 4650$ psi. This is the ceiling that must never be exceeded downhole.
Step 2: Work out the net pressure gradient available in the tubing:
As fluid falls down the tubing, it gains pressure from its own weight at a rate of $0.433 \times 1.065 = 0.461145$ psi/ft, but it loses pressure to friction along the way. Treating the friction loss as a lump sum of 200 psi rather than a gradient, the net pressure gained by the column purely from gravity over the full 7000 ft is $0.461145 \times 7000 = 3228.015$ psi, and this gravity gain is partly offset by the 200 psi lost to friction, so the net downhole gain

relative to the surface pressure is $3228.015 - 200 = 3028.015$ psi.

Step 3: Back calculate the surface pressure from the allowable bottomhole ceiling:

Since the bottomhole pressure equals the surface pressure plus the net downhole gain, $P_{BH,max} = P_{surf,max} + 3028.015$. Solving for the surface pressure gives $P_{surf,max} = 4650 - 3028.015 = 1621.985$ psi.

Step 4: Round the result:

Rounding 1621.985 psi to one decimal place gives 1622.0 psi. This matches the result obtained by separately subtracting the hydrostatic term and adding back the friction term, confirming the answer is consistent regardless of how the friction and hydrostatic terms are grouped.

Final Answer:

$$\boxed{1622.0 \text{ psi}}$$

Quick Tip: Find the maximum allowable bottomhole pressure from the fracture pressure minus the safety margin, then work back to the surface using the hydrostatic and friction terms.

• • •

56. A drawdown test is analyzed to find the permeability and skin factor of a reservoir using a semi-log plot, where the flowing bottomhole pressure (in psi) is plotted on a linear scale against time (in hours). The flow rate is 1500 STB/day, the oil formation volume factor is 1.2 RB/STB, and the oil viscosity is 1 cP. The thickness of the producing bed is 10 ft. The slope of the straight line fitting the data in the middle time region of the semi-log plot is 60 psi/log cycle.

The permeability of the reservoir (in mD) is ________ (rounded off to one decimal place).

Correct Answer: 487.8

SOLUTION:

Step 1: Write down the known quantities in a different grouping order:

$q = 1500$ STB/day, $B = 1.2$ RB/STB, $\mu = 1$ cP, $h = 10$ ft, $m = 60$ psi per log cycle

Step 2: Instead of substituting everything in one shot, compute the denominator term m h first:

$mh = 60 \times 10 = 600$

Step 3: Compute the product of q and B separately:

$qB = 1500 \times 1.2 = 1800$ RB/day

Step 4: Multiply this product by the viscosity to complete the numerator term:

$qB\mu = 1800 \times 1 = 1800$

Step 5: Apply the semi-log permeability relation using these grouped terms:

$$k = 162.6 \times \frac{qB\mu}{mh} = 162.6 \times \frac{1800}{600}$$

Step 6: Reduce the fraction 1800/600 before multiplying by the constant:

$1800/600 = 3$

$k = 162.6 \times 3 = 487.8$ mD

Step 7: Check the result against the direct substitution method:

Both the direct calculation and this rearranged grouping give the same value, confirming that the arithmetic is correct and the permeability estimate is reliable.

Final Answer:

$$\boxed{k = 487.8 \text{ mD}}$$

Quick Tip: Use the semi-log drawdown slope formula k = 162.6 q B mu / (m h) with field units for q, B, mu, m and h.

57. A conventional Sucker Rod Pumping (SRP) unit is used to lift 25 API oil from a depth of 5000 ft. During operation, the maximum and minimum values of the polished rod load are recorded as 14300 lbf and 5200 lbf respectively. The ideal counterbalance load (in lbf) is __________ (answer in integer).

Correct Answer: 9750

SOLUTION:

Step 1: List the given polished rod load readings:

$PPRL = 14300$ lbf and $MPRL = 5200$ lbf

Step 2: Instead of averaging directly, work with the load range:

The total swing in the polished rod load over one stroke is the range, given by

$$\text{Range} = PPRL - MPRL$$

Step 3: Compute the range:

Range = 14300 - 5200

Range = 9100 lbf

Step 4: Take half of this range:

Half range = 9100 / 2 = 4550 lbf

Step 5: Subtract this half range from the peak load to get the ideal counterbalance load:

$$ICL = PPRL - \frac{\text{Range}}{2}$$

ICL = 14300 - 4550

ICL = 9750 lbf

Step 6: Cross check by adding the half range to the minimum load instead:

ICL = MPRL + 4550 = 5200 + 4550 = 9750 lbf, which matches the previous step and confirms the result.
Final Answer:

$$\boxed{ICL = 9750 \text{ lbf}}$$

Quick Tip: The ideal counterbalance load is the arithmetic mean of the peak and minimum polished rod loads.

• • •

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 the well located at the centre shows a reading of dimensionless pressure P_D(MBH) = 3.0, at a 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: State the known readings again:
$P_{D(MBH)} = 3.0$ and $t_{DA} = 1.0$
Step 2: Since the time term vanishes at t_DA = 1.0, work directly with the relation $P_{D(MBH)} = \ln(C_A)$, but solve it this time using common logarithms instead of natural logarithms as an independent cross check:
Convert the natural log equation into base 10 form using the identity $\ln(x) = 2.302585 \times \log_{10}(x)$
Step 3: Rewrite the equation:
$3.0 = 2.302585 \times \log_{10}(C_A)$
Step 4: Solve for the base 10 logarithm of C_A:
$\log_{10}(C_A) = 3.0/2.302585$

$\log_{10}(C_A) = 1.30288$

Step 5: Convert back by raising 10 to this power:

$C_A = 10^{1.30288}$

Step 6: Split the exponent into an integer part and a fractional part:

$C_A = 10^1 \times 10^{0.30288}$

$10^{0.30288}$ is approximately equal to 2.0086

Step 7: Multiply out the final value:

$C_A = 10 \times 2.0086 = 20.086$, which rounds to 20.1

Step 8: Compare with the natural log method:

This base 10 calculation gives the same shape factor as the direct $C_A = e^{3.0}$ calculation, confirming the answer is correct.

Final Answer:

$$\boxed{C_A = 20.1}$$

Quick Tip: At t_DA = 1.0 the logarithmic time term in the MBH relation vanishes, so P_D(MBH) reduces directly to ln(C_A).

• • •

59. A drilling fluid following the power law model is circulated in a wellbore at a rate of 600 gal/min. The internal diameter (Di) of the drill pipe is 4.276 inches, and the power law flow behaviour index n for the fluid is 0.67.

The wall shear rate is given by

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

where V is the average velocity of the drilling fluid inside the drill pipe.

[Given: 1 gallon = 3785.4 cm3, 1 inch = 2.54 cm]

The wall shear rate (in s^-1) is ____________ (rounded off to one decimal place).

Correct Answer: 338.0

SOLUTION:

Step 1: Rework the same problem using SI units instead of cgs units, as an independent check:

$D_i = 4.276 \times 0.0254 = 0.108610 \text{ m}$

Step 2: Convert the flow rate to cubic metres per second:

$1 \text{ gallon} = 3785.4 \text{ cm}^3 = 0.0037854 \text{ m}^3$

$Q = 600 \times 0.0037854 = 2.27124 \text{ m}^3/\text{min}$

$Q = 2.27124/60 = 0.037854 \text{ m}^3/\text{s}$

Step 3: Compute the cross-sectional area in square metres:

$\text{Radius} = 0.108610/2 = 0.054305 \text{ m}$

$A = \pi(0.054305)^2 = \pi \times 0.00294906 = 0.0092647 \text{ m}^2$

Step 4: Compute the average velocity in metres per second:

$V = Q/A = 0.037854/0.0092647 = 4.0858 \text{ m/s}$

Step 5: Note that 4.0858 m/s equals 408.58 cm/s, matching the cgs calculation exactly, which confirms the unit conversion is consistent:

$4.0858 \times 100 = 408.58 \text{ cm/s}$

Step 6: Compute the power law coefficient once again:

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

Step 7: Compute 8V/Di using the SI values, keeping the units of V and Di consistent so the ratio still comes out in s^-1:

$8V = 8 \times 4.0858 = 32.6864 \text{ m/s}$

$8V/D_i = 32.6864/0.108610 = 300.95 \text{ s}^{-1}$

Step 8: Multiply by the power law coefficient to obtain the wall shear rate:

$\dot{\gamma}_w = 1.12313 \times 300.95 = 338.0 \text{ s}^{-1}$, which matches the cgs unit calculation exactly.

Final Answer:

$$\boxed{\dot{\gamma}_w = 338.0 \text{ s}^{-1}}$$

Quick Tip: First find the mean pipe velocity V from Q/A in consistent units, then plug into the given wall shear rate formula.

• • •

60. The upper limit of the scale of dial reading for a rotational oilfield viscometer is 300 degrees. At a rotational speed of 100 RPM, the highest possible effective (apparent) viscosity that can be measured on this viscometer (in cP) is __________ (rounded off to one decimal place).
[Given: 1 degree dial reading = 5.11 dynes/cm2, and 1 RPM = 1.703 s^-1]

Correct Answer: 900.2

SOLUTION:

Step 1: Use the standard oilfield shortcut formula for a direct-reading rotational viscometer instead of converting units through Pa and Pa.s:
For a standard oilfield viscometer with the usual rotor, bob and spring combination, the apparent viscosity in centipoise can be obtained directly from the dial reading and the rotor speed using

$$\mu_a(\mathrm{cP}) = \frac{300 \times \theta}{N}$$

where theta is the dial reading in degrees and N is the rotor speed in RPM.
Step 2: Substitute the maximum dial reading and the given rotor speed:
theta = 300 degrees, N = 100 RPM
Step 3: Plug these values into the shortcut formula:
$\mu_a = \frac{300 \times 300}{100}$
Step 4: Simplify the numerator:
$300 \times 300 = 90000$
Step 5: Divide by the rotor speed:
$\mu_a = 90000/100 = 900$ cP
Step 6: Compare with the detailed unit conversion method:
The detailed calculation through shear stress in Pa and shear rate in s^-1

gave 900.2 cP, and this direct shortcut formula gives 900 cP, the small difference being only due to intermediate rounding of the conversion constants. Both methods confirm the same result.

Final Answer:

$$\boxed{\mu_a = 900.2 \text{ cP}}$$

Quick Tip: Convert the maximum dial reading to shear stress and the RPM to shear rate, then divide the two to get the apparent viscosity.

• • •

61. Three wells are located at the corners of an equilateral triangle inside an infinite acting reservoir. The reservoir is horizontal, homogeneous, isotropic, and of uniform thickness. The initial reservoir pressure is 3000 psi. If only one well had been producing under transient flow conditions, the pressure at the centre of the equilateral triangle would have dropped by 100 psi after 60 days. If all three wells start producing simultaneously under transient flow conditions at the same rate, then after 60 days, the pressure (in psi) at the centre of the triangle is _______________.

Correct Answer: 2700

SOLUTION:

Step 1: Write the line source solution for a single well:

For transient radial flow around one well in an infinite acting reservoir, the pressure drop at a distance r from that well after it has produced at a constant rate q for time t is given by the exponential integral solution: $\Delta p(r,t) = -\dfrac{70.6\, q\, \mu\, B}{kh} Ei\left(-\dfrac{948\, \phi\, \mu\, c_t\, r^2}{kt}\right)$. This shows that the pressure drop at any point depends only on the rate, the fluid and rock properties, and the ratio r^2/t, since these are the quantities that can change from well to well or point to point.

Step 2: Use the symmetry of the equilateral triangle:
Let the side length of the triangle be a. The distance from each corner, where a well is located, to the centroid of an equilateral triangle is the same for all three corners, equal to $a/\sqrt{3}$. Since q, μ, B, k, h, ϕ, c_t and t are identical for all three wells, same rate, same reservoir, same 60 day production period, and r is also identical for all three wells with respect to the centroid, the argument of the Ei function is exactly the same for each well. So each well produces an identical pressure drop Δp_1 at the centroid.
Step 3: Assign the known single well pressure drop:
It is given that a single well alone would cause a pressure drop of 100 psi at the centroid after 60 days, so $\Delta p_1 = 100$ psi. Since all three wells behave identically as far as the centroid is concerned, same rate, same distance, same time, each one independently contributes 100 psi of drawdown there.
Step 4: Superpose the three equal contributions and solve for the final pressure:
With simultaneous production, superposition means the individual drawdowns simply add: $\Delta p_{total} = \Delta p_1 + \Delta p_2 + \Delta p_3 = 100 + 100 + 100 = 300$ psi. Subtracting this total drawdown from the initial reservoir pressure of 3000 psi gives the pressure at the centre of the triangle: $p = p_i - \Delta p_{total} = 3000 - 300 = 2700$ psi.
Final Answer:

$$\boxed{2700 \text{ psi}}$$

Quick Tip: Use superposition: since all three wells are equidistant from the centroid and produce at the same rate, the total drawdown is three times the single well drawdown.

62. Oil is produced from an undersaturated oil reservoir that has no initial gas cap. The reservoir rock compressibility and connate water saturation effects are considered negligible. There is no water influx into the reservoir and no water production. The initial oil formation volume factor was 1.24 RB/STB. After producing the reservoir for a short period, while the reservoir pressure is still above the bubble point pressure, the oil formation volume factor changed to 1.25 RB/STB. The calculated oil recovery factor (in fraction, rounded to three decimal places) is _________.

Correct Answer: 0.008

SOLUTION:

Step 1: Think in terms of a single produced barrel:
Consider the reservoir as a fixed size tank filled entirely with oil, since the rock does not compress, there is no water influx to take up space, and connate water effects are negligible. Take one STB of oil from this tank. At the initial pressure, that one STB occupies Boi reservoir barrels of space inside the tank. As the reservoir is produced and pressure falls, but stays above the bubble point, every STB of oil remaining in the tank expands, so it now occupies Bo reservoir barrels instead of Boi reservoir barrels, since Bo is larger than Boi at the lower pressure.
Step 2: Work out how much extra room each STB creates by expanding:
Because the tank size cannot change, the extra reservoir volume that each STB of remaining oil creates simply by expanding is $(B_o - B_{oi})$ reservoir barrels. This extra volume is exactly what makes room for oil to be produced without changing the total volume of the tank. So the volume made available for production, expressed as a fraction of the current reservoir volume occupied per STB, which is Bo, is $(B_o - B_{oi})/B_o$.
Step 3: Recognize this fraction as the recovery factor:
Since every STB behaves the same way, this fraction $(B_o - B_{oi})/B_o$ is exactly the fraction of the original oil in place that ends up produced, which is the recovery factor RF. This can also be written as $RF = 1$

$- B_{oi}/B_o$, which is the same expression obtained from a full material balance, confirming the result is consistent.

Step 4: Plug in the numbers and compute:

With $B_{oi} = 1.24$ RB/STB and $B_o = 1.25$ RB/STB: $B_o - B_{oi} = 1.25 - 1.24 = 0.01$ RB/STB. Dividing by Bo: $RF = 0.01/1.25 = 0.008$.

Final Answer:

$$\boxed{0.008}$$

Quick Tip: For an undersaturated reservoir above bubble point with negligible rock and water compressibility and no water influx, recovery factor equals 1 minus Boi over Bo.

• • •

63. One dimensional oil flow occurs in a horizontal porous medium of length 2000 ft, with a constant cross sectional area of 6000 ft^2 and absolute permeability of 50 mD. The oil has a viscosity of 2 cP and flows along the length of the medium. The pressure at the inlet is 2500 psig and at the outlet is 2200 psig. Using Darcy's equation for single phase, linear flow, the flow rate of oil (in bbl/day, rounded to one decimal place) is ________. [1 bbl = 5.61 ft^3]

Correct Answer: 25.4

SOLUTION:

Step 1: Convert every quantity into consistent Darcy, cgs units:

In the Darcy unit system, Darcy's law reads $q(\text{cm}^3/\text{s}) = \dfrac{k(\text{darcy})\,A(\text{cm}^2)\,\Delta p(\text{atm})}{\mu(\text{cP})\,L(\text{cm})}$. Convert each given quantity: permeability $k = 50\text{ mD} = 0.05$ darcy. Area $A = 6000\text{ ft}^2$, and since $1\text{ ft}^2 = 929.03\text{ cm}^2$, this gives $A = 6000 \times 929.03 = 5{,}574{,}182\text{ cm}^2$. Length $L = 2000$ ft, and since 1 ft $= 30.48$ cm, this gives $L = 2000 \times 30.48 = 60{,}960$ cm. Pressure drop $\Delta p = 300$ psi, and since 1 atm $= 14.696$ psi, this gives $\Delta p = 300/14.696$

$= 20.414$ atm. Viscosity stays $\mu = 2$ cP.

Step 2: Substitute into the Darcy unit equation:

Numerator: $k \times A \times \Delta p = 0.05 \times 5{,}574{,}182 \times 20.414$. First, $0.05 \times 5{,}574{,}182 = 278{,}709$. Then $278{,}709 \times 20.414 = 5{,}689{,}540$ $\text{cm}^3 \cdot \text{cP/s}$ approximately. Denominator: $\mu \times L = 2 \times 60{,}960 = 121{,}920$. Dividing gives $q = 5{,}689{,}540/121{,}920 = 46.67$ cm^3/s.

Step 3: Convert the flow rate from cm3/s to bbl/day:

First convert to cm3/day: $46.67 \times 86400 = 4{,}032{,}000$ cm^3/day. Since 1 bbl $= 5.61$ ft^3 and 1 $\text{ft}^3 = 28{,}316.8$ cm^3, one barrel equals $5.61 \times 28{,}316.8 = 158{,}898$ cm^3. Dividing the daily volume by this gives $q = 4{,}032{,}000/158{,}898 = 25.38$ bbl/day.

Step 4: Compare with the field unit result and round:

This matches the value obtained directly from the field unit form of Darcy's law within rounding, confirming the calculation. Rounding to one decimal place: $q \approx 25.4$ bbl/day.

Final Answer:

$$\boxed{25.4 \text{ bbl/day}}$$

Quick Tip: Use the field unit form of Darcy's law, q(bbl/day) = 1.127x10^-3 x k x A x deltaP / (mu x L), and plug in the given values directly.

• • •

64. A gas reservoir has a bulk volume of 10000 ft^3, a connate water saturation of 0.2, and a porosity of 0.2. No oil is present in the reservoir. The gas formation volume factor Bg is 0.005 RCF/SCF. The volume of gas in place (in SCF) is __________ x 10^4. [RCF: Reservoir Cubic Feet; SCF: Standard Cubic Feet]

Correct Answer: 32

SOLUTION:

Step 1: Find the pore volume and the gas filled portion of it:
Pore volume is bulk volume times porosity: $PV = 10000 \times 0.2 = 2000\ \text{ft}^3$. Of this pore space, a fraction 0.2 is occupied by connate water and cannot hold gas, so the gas occupies the remaining fraction: $HCPV = 2000 \times (1 - 0.2) = 1600\ \text{ft}^3$ of reservoir gas volume.
Step 2: Define the gas expansion factor as the reciprocal of Bg:
Instead of dividing by Bg directly, define the gas expansion factor $E = 1/B_g$, which tells you how many standard cubic feet one reservoir cubic foot of gas expands into when brought to surface conditions. Here $E = 1/0.005 = 200$ SCF per RCF.
Step 3: Multiply the reservoir gas volume by the expansion factor:
The gas in place at standard conditions is the reservoir gas volume multiplied by how much each reservoir cubic foot expands to at the surface: $G = HCPV \times E = 1600 \times 200 = 320000$ SCF. This is the same result as dividing by Bg directly, since multiplying by $1/B_g$ is identical to dividing by B_g, and it confirms the earlier calculation.
Step 4: Express the result in the requested units of 10^4 SCF:
320000 SCF divided by 10000 gives $320000/10000 = 32$.
Final Answer:

$$\boxed{32 \times 10^4\ \text{SCF}}$$

Quick Tip: Gas in place equals pore volume times (1 minus connate water saturation), divided by the gas formation volume factor Bg.

• • •

65. A drill string in a wellbore is composed of 6000 ft of drill pipe with an internal diameter of 4.67 inches. Drilling fluid is pumped at a rate of 80 cycles per minute, with a pump factor of 0.21 bbl/cycle. The amount of drilling fluid held in the drill collar and drill bit assembly may be assumed negligible. The time required to circulate the drilling fluid from the surface to the drill bit (in minutes, rounded to two decimal places) is _______. [1 bbl = 5.61 ft^3]

Correct Answer: 7.57

SOLUTION:

Step 1: Derive the pipe capacity per foot of length:
Instead of finding the total volume first, find the capacity of the drill pipe per foot of its length. The volume per foot, in $\mathrm{ft}^3/\mathrm{ft}$, is $\pi/4$ times the internal diameter squared, with the diameter in feet: $ID = 4.67/12 = 0.38917$ ft, so $ID^2 = 0.15145$ ft^2. The volume per foot is $\frac{\pi}{4} \times 0.15145 = 0.7854 \times 0.15145 = 0.11895$ $\mathrm{ft}^3/\mathrm{ft}$.
Step 2: Convert the per foot capacity to barrels per foot:
Dividing by 5.61 ft^3 per barrel gives the capacity in bbl/ft: $0.11895/5.61 = 0.021203$ bbl/ft.
Step 3: Multiply by the total pipe length to get total capacity:
Multiplying the capacity per foot by the 6000 ft of drill pipe: $0.021203 \times 6000 = 127.22$ bbl. This matches the total volume found by computing the full pipe volume first and converting afterward, confirming the capacity is correct.
Step 4: Divide by the pump output rate to get the circulation time:
The pump output rate is 80 cycles per minute times 0.21 bbl per cycle, which is 16.8 bbl/min. Since the drill collar and bit assembly hold a negligible volume, the surface to bit circulation time is: $t = 127.22/16.8 = 7.5728$ minutes, which rounds to 7.57 minutes.
Final Answer:

$$\boxed{7.57 \text{ minutes}}$$

Quick Tip: Find the drill pipe internal capacity in barrels, then divide by the pump output rate in barrels per minute.