GATE 2026 Biotechnology (BT) Question Paper with Solutions

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

General Instructions

Read the following instructions very carefully and strictly follow them:

1. This question paper is divided into three sections:
   - **General Aptitude (GA):** 10 questions (5 questions × 1 mark + 5 questions × 2 marks) for a total of 15 marks.
   - **Engineering Mathematics:**
     - **Part A (Mandatory):** 36 questions (1 questions × 1 mark + 19 questions × 2 marks) for a total of 55 marks.
     - **Part B (Section 1):** Candidates can choose either Part B1 (Surveying and Mapping) or Part B2 (Section 2). Each part contains 16 questions (8 questions × 1 mark + 11 questions × 2 marks) for a total of 30 marks.
2. The total number of questions is **65**, carrying a maximum of **100 marks**.
3. The duration of the exam is **3 hours**.
4. Marking scheme:
   - For 1-mark MCQs, $\frac{1}{3}$ mark will be deducted for every incorrect response.
   - For 2-mark MCQs, $\frac{2}{3}$ mark will be deducted for every incorrect response.
   - No negative marking for numerical answer type (NAT) questions.
   - No marks will be awarded for unanswered questions.
5. Ensure you attempt questions only from the optional section (Part B1 or Part B2) you have selected.
6. Follow the instructions provided during the exam for submitting your answers.

1. "He often _____ the numbers. False claims are not going to help. Honesty _____ trust", said the manager.
Choose the option with the correct order of words to fill the blanks.

(A) exaggerates; engenders
(B) excels; encourages
(C) aggravates; alleviates
(D) diminishes; eliminates

Correct Answer: (A) exaggerates; engenders

Solution:
Step 1: Understanding the Concept:

The question tests vocabulary in context.
We need to find words that fit the negative connotation of "false claims" and the positive outcome of "honesty."

Step 2: Detailed Explanation:
In the first sentence, "False claims" suggests that the person is misrepresenting data.
The word "exaggerates" means to represent something as being larger or better than it really is, which fits the context of "numbers" and "false claims."
In the second sentence, the manager speaks about the result of "honesty."
The word "engenders" means to cause or give rise to a feeling or situation.
Therefore, "honesty engenders trust" is a logically sound and grammatically correct statement.
Other options like "aggravates" (makes a problem worse) or "diminishes" (reduces) do not fit the context of building trust through honesty.

Step 3: Final Answer:
The correct pair of words is "exaggerates" and "engenders."

Quick Tip

Always look for contextual clues like "false claims" to determine if the required word should have a positive or negative connotation.

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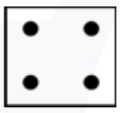
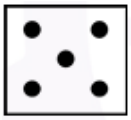
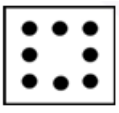
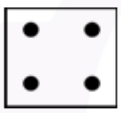
2. In the sequence of tiles shown below, the missing tile indicated by the question mark should be

(A) 

(B) 

(C) 

(D) 

Correct Answer: (A) 

Solution:
Step 1: Understanding the Concept:
This is a pattern recognition problem based on the number of dots in a sequence of tiles.

Step 2: Detailed Explanation:
Let us count the number of dots in each tile provided in the sequence:
Tile 1: 2 dots
Tile 2: 3 dots
Tile 3: ?
Tile 4: 6 dots
Tile 5: 9 dots
Let the number of dots be n_1, n_2, n_3, n_4, n_5.
The difference between terms is:
$n_2 - n_1 = 3 - 2 = 1$
$n_5 - n_4 = 9 - 6 = 3$
If we assume the increment itself increases by 0 or 1, let's test a sequence of increments:
If the increments are $+1, +1, +2, +3$:
$n_1 = 2$
$n_2 = 2 + 1 = 3$
$n_3 = 3 + 1 = 4$
$n_4 = 4 + 2 = 6$
$n_5 = 6 + 3 = 9$
This forms a consistent logical pattern where the increment follows a Fibonacci-style growth or a simple additive logic.
Comparing with the visual options provided in the original image, Option (A) shows 4 dots.

Step 3: Final Answer:
The missing tile must have 4 dots.

Quick Tip

In visual sequences, first check the numerical count of elements. Most patterns follow a simple arithmetic or geometric progression.

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3. A school has 100 students distributed among 1^{st} to 10^{th} standards. Based on this, which one of the following statements is always correct?

(A) There are at least 10 students who belong to the same standard.
(B) There is at least one student in each standard.

(C) There are at most 10 students in 10^{th} standard.
(D) The total number of students from 1^{st} to 5^{th} standards is at least 50.

Correct Answer: (A) There are at least 10 students who belong to the same standard.

Solution:
Step 1: Understanding the Concept:
This problem is a direct application of the Pigeonhole Principle.
If n items are put into m containers, then at least one container must contain at least $\lceil n/m \rceil$ items.

Step 2: Key Formula or Approach:
Number of students (pigeons), $n = 100$
Number of standards (pigeonholes), $m = 10$

Step 3: Detailed Explanation:
According to the principle, at least one standard must have at least:

$$\text{Minimum students} = \left\lceil \frac{100}{10} \right\rceil = 10$$

This confirms statement (A).
Let's check why others are incorrect:
- For (B): It is possible that all 100 students are in the 1^{st} standard, meaning others have 0.
- For (C): It is possible that all 100 students are in the 10^{th} standard.
- For (D): It is possible that all 100 students are in the 10^{th} standard, so the sum for 1^{st}–5^{th} is 0.

Step 4: Final Answer:
Statement (A) is the only one that is mathematically guaranteed in all scenarios.

> Quick Tip
>
> When a question asks which statement is "always" correct regarding distribution, check for the Pigeonhole Principle or extreme distribution cases (all items in one group).

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4. How many 3-digit numbers can be formed using three distinct single digit prime numbers?

(A) 64
(B) 24
(C) 12
(D) 4

Correct Answer: (B) 24

Solution:
Step 1: Understanding the Concept:
We need to identify single-digit prime numbers and calculate the number of permutations of 3 distinct values chosen from them.

Step 2: Key Formula or Approach:
Permutation formula: $P(n, r) = \frac{n!}{(n-r)!}$

Step 3: Detailed Explanation:
First, list the single-digit prime numbers: $\{2, 3, 5, 7\}$.
Note that 1 is not a prime number.
There are $n = 4$ such numbers.
We need to form 3-digit numbers using $r = 3$ distinct numbers from this set.
The number of ways to choose and arrange 3 distinct numbers out of 4 is:

$$P(4, 3) = \frac{4!}{(4-3)!} = \frac{4 \times 3 \times 2 \times 1}{1} = 24$$

Step 4: Final Answer:
There are 24 such numbers.

> Quick Tip
>
> Be careful with the definition of prime numbers. Always remember that 2 is the only even prime, and 1 is neither prime nor composite.

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5. In a group of students, 10 students like Mathematics, 12 students like English, 4 students like both Mathematics and English, and 6 students like neither Mathematics nor English. The number of students in the group is _____

(A) 18
(B) 20
(C) 24
(D) 32

Correct Answer: (C) 24

Solution:
Step 1: Understanding the Concept:
This is a set theory problem involving the principle of inclusion-exclusion for two sets.

Step 2: Key Formula or Approach:
Total students = $n(M \cup E) + n(\text{Neither})$

Where $n(M \cup E) = n(M) + n(E) - n(M \cap E)$.

Step 3: Detailed Explanation:
Given:
$n(M) = 10$
$n(E) = 12$
$n(M \cap E) = 4$
$n(\text{Neither}) = 6$
First, calculate the number of students who like at least one subject:

$$n(M \cup E) = 10 + 12 - 4 = 18$$

Now, add the students who like neither subject to find the total group size:

$$\text{Total students} = 18 + 6 = 24$$

Step 4: Final Answer:
The total number of students is 24.

> Quick Tip
>
> Using a Venn diagram can help visualize the subsets and ensure you don't double-count the intersection.

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6. Charity : P :: Retaliation : Q
Choose the appropriate pair of words P and Q that fit the analogy.

(A) P = Parsimonious; Q = Vengeful
(B) P = Altruistic; Q = Amicable
(C) P = Resentful; Q = Spiteful
(D) P = Magnanimous; Q = Vindictive

Correct Answer: (D) P = Magnanimous; Q = Vindictive

Solution:
Step 1: Understanding the Concept:
The analogy relates an action (noun) to the character trait (adjective) of a person performing that action.

Step 2: Detailed Explanation:
Charity is the act of giving. A person who performs charity is described as "Magnanimous" (generous and forgiving).
Retaliation is the act of harming someone in return for an injury. A person who performs

retaliation is described as "Vindictive" (having a strong desire for revenge).
Let's analyze other options:
- (A) Parsimonious means stingy, which is the opposite of being charitable.
- (B) Amicable means friendly, which contradicts the act of retaliation.
- (C) Resentful is a feeling, but it does not represent the trait associated with the act of charity.

Step 3: Final Answer:
The pair (D) fits the analogy perfectly as trait-action correspondences.

Quick Tip

In analogies, define the relationship in a sentence: "A [P] person performs [Charity]". This helps in testing options.

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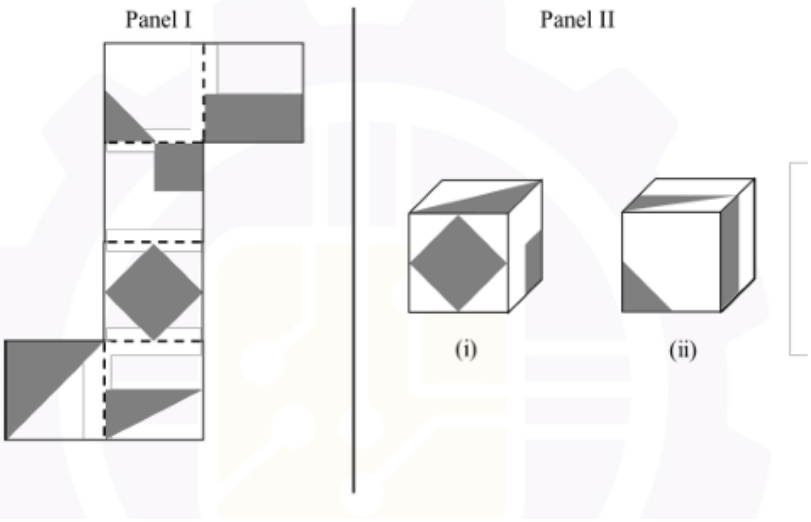
7. A paper shown in Panel I is folded along the dashed lines (- - -) to construct a cube. The shaded regions shown in Panel I appear on the outer surface of the cube. Referring to cubes shown in Panel II, which one of the options is correct?



(A) Only (i) can correspond to the unfolded cube in Panel I.
(B) Only (ii) can correspond to the unfolded cube in Panel I.
(C) Both (i) and (ii) can correspond to the unfolded cube in Panel I.
(D) Neither (i) nor (ii) can correspond to the unfolded cube in Panel I.

Correct Answer: (B) Only (ii) can correspond to the unfolded cube in Panel I.

Solution:
Step 1: Understanding the Concept:
This is a 3D visualization problem where a 2D net is folded into a 3D cube. Adjacency and orientation of shaded faces are key.

Step 2: Detailed Explanation:
Looking at the net (Panel I):
- The face with the central shaded diamond is adjacent to four other faces.
- The face above the diamond has a horizontal shaded bar at the top edge.
- When folded, the top edge of this bar will be far from the diamond face.
In cube (i): The shaded region (triangle) and the diamond are shown such that the shaded triangle touches the edge shared with the diamond. In the net, the triangle is on a face further away and does not touch the diamond face directly in that orientation.
In cube (ii): The faces shown are the top face with a shaded triangle and a side face with a shaded bar. By observing the folding pattern, these two shaded regions meet at a common edge in the manner shown.

Step 3: Final Answer:
Only orientation (ii) is possible given the layout of the net.

Quick Tip

Identify "opposite" faces in the net (separated by one square). These faces can never be adjacent in the final cube.

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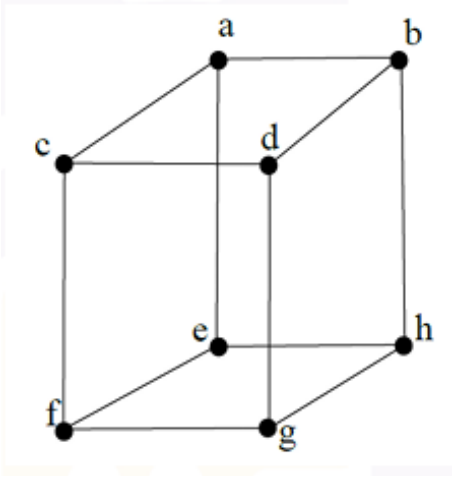
8. Consider the cube shown below with its 8 corners labelled a, b, c, d, e, f, g, and h. All corners are to be colored such that any two corners that are connected by an edge must be of different colors. The minimum number of colors required to achieve this is _____



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

Correct Answer: (D) 2

Solution:
Step 1: Understanding the Concept:
This is a graph coloring problem. We need to find the chromatic number of the graph represented by the edges of a cube.

Step 2: Detailed Explanation:
A graph can be colored with 2 colors if and only if it is bipartite.
A graph is bipartite if it contains no odd cycles (cycles of length 3, 5, 7, etc.).
A cube consists of 12 edges and 6 faces. Every cycle in a cube (like the boundaries of the faces) is of length 4 (an even number).
Since there are no odd cycles in a cube, it is a bipartite graph.
We can color the vertices as follows:
Color 1: a, d, f, g
Color 2: b, c, e, h
If we check the edges:
'a' is connected to 'b', 'c', 'e' (all Color 2).
'd' is connected to 'b', 'c', 'h' (all Color 2).
No two vertices of the same color share an edge.

Step 3: Final Answer:
The minimum number of colors required is 2.

Quick Tip

The chromatic number of any bipartite graph is 2. A cube, being a collection of even cycles, is always bipartite.

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9. Four hills H1, H2, H3, and H4 are present in an area. The following observations are made:
i. Neither H2 nor H3 is the easternmost hill.
ii. Neither H2 nor H3 is the westernmost hill.
iii. Neither the easternmost hill nor the westernmost hill is the southernmost hill.
iv. Two hills are located to the west of H2.
v. The southernmost hill has at least two hills to its east.
The southernmost hill is _____.

(A) H1
(B) H2
(C) H3
(D) H4

Correct Answer: (C) H3

Solution:
Step 1: Understanding the Concept:

This is a logical arrangement problem based on directional constraints.

Step 2: Detailed Explanation:
Let the positions from West to East be 1, 2, 3, 4.
From (iv): "Two hills are located to the west of H2." This means H2 is at position 3.
West [1] [2] [3: H2] [4] East.
From (i) and (ii): H2 and H3 are neither easternmost (4) nor westernmost (1).
Since H2 is at 3, H3 must be at position 2.
The hills at 1 and 4 must be H1 and H4 (in any order).
From (iii): The southernmost hill is neither at position 1 nor 4. So the southernmost hill must be H2 or H3.
From (v): "The southernmost hill has at least two hills to its east."
If H2 were southernmost, it has only 1 hill (pos 4) to its east. This fails.
If H3 were southernmost, it has 2 hills (pos 3 and 4) to its east. This fits.

Step 3: Final Answer:
Therefore, H3 is the southernmost hill.

Quick Tip

Draw a line and place the elements as you process each constraint. Start with fixed positions like "two hills to the west."

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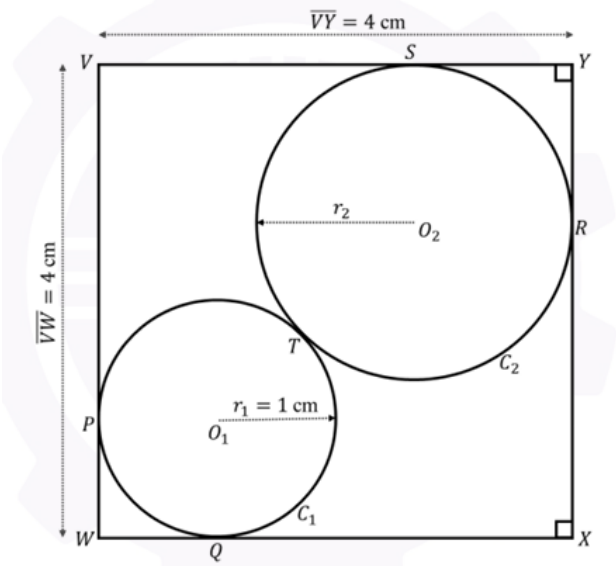
10. As shown in the figure, circle C_1 with center O_1 and radius r_1 touches the square $VWXY$ at points P and Q while circle C_2 with center O_2 and radius r_2 touches the square $VWXY$ at points R and S. The two circles touch each other at T. Given $r_1 = 1$ cm and $\overline{VY} = \overline{VW} = 4$ cm, $r_2 =$ _____ cm.



(A) $4 - 3\sqrt{2}$

(B) $1 + 2\sqrt{2}$
(C) $7 - 4\sqrt{2}$
(D) $5 + 3\sqrt{2}$

Correct Answer: (C) $7 - 4\sqrt{2}$

Solution:
Step 1: Understanding the Concept:
The circles are placed in a square of side 4 cm. Circle C_1 is in the bottom-left corner and circle C_2 is in the top-right corner. They touch each other.

Step 2: Key Formula or Approach:
Use a coordinate system where W is the origin (0, 0).
Then $V = (0, 4)$, $Y = (4, 4)$, $X = (4, 0)$.

Step 3: Detailed Explanation: Center of C_1, $O_1 = (r_1, r_1) = (1, 1)$.
Center of C_2, $O_2 = (4 - r_2, 4 - r_2)$.
Since the circles touch each other externally, the distance between centers is:

$$O_1O_2 = r_1 + r_2 = 1 + r_2$$

Using the distance formula:

$$\sqrt{(4 - r_2 - 1)^2 + (4 - r_2 - 1)^2} = 1 + r_2$$

$$\sqrt{2(3 - r_2)^2} = 1 + r_2$$

$$\sqrt{2}(3 - r_2) = 1 + r_2$$

$$3\sqrt{2} - \sqrt{2}r_2 = 1 + r_2$$

$$3\sqrt{2} - 1 = r_2(1 + \sqrt{2})$$

$$r_2 = \frac{3\sqrt{2} - 1}{\sqrt{2} + 1}$$

Rationalizing the denominator by multiplying with $(\sqrt{2} - 1)$:

$$r_2 = \frac{(3\sqrt{2} - 1)(\sqrt{2} - 1)}{(\sqrt{2} + 1)(\sqrt{2} - 1)}$$

$$r_2 = \frac{3(2) - 3\sqrt{2} - \sqrt{2} + 1}{2 - 1} = 6 - 4\sqrt{2} + 1 = 7 - 4\sqrt{2}$$

Step 4: Final Answer:
The radius r_2 is $7 - 4\sqrt{2}$ cm.

> Quick Tip
>
> For circles touching the sides of a square corner, the distance from the corner to the center is always $r\sqrt{2}$. The diagonal of the square connects the corners and passes through the centers of such circles.

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11. Consider the two functions $f_1(x) = \frac{x^2-4}{x-2}$ and $f_2(x) = x^2 - 2x + 2$. Which of the following is the value of $(f_1(x) + f_2(x))$ as $x \to 2$?

(A) 0
(B) 6
(C) 8
(D) ∞

Correct Answer: (B) 6

Solution:
Step 1: Understanding the Concept:
We need to find the limit of the sum of two functions as x approaches a specific value.

Step 2: Detailed Explanation:
First, evaluate $\lim_{x\to 2} f_1(x)$:

$$f_1(x) = \frac{x^2 - 4}{x - 2} = \frac{(x - 2)(x + 2)}{x - 2}$$

For $x \neq 2$, $f_1(x) = x + 2$.

$$\lim_{x\to 2} f_1(x) = 2 + 2 = 4$$

Next, evaluate $\lim_{x\to 2} f_2(x)$:

$$f_2(x) = x^2 - 2x + 2$$

Substituting $x = 2$:

$$f_2(2) = 2^2 - 2(2) + 2 = 4 - 4 + 2 = 2$$

The limit of the sum is the sum of the limits:

$$\lim_{x \to 2}(f_1(x) + f_2(x)) = 4 + 2 = 6$$

Step 3: Final Answer:
The value is 6.

> Quick Tip
>
> When evaluating limits of rational functions that result in 0/0, factor the numerator and denominator to cancel common terms.

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12. Which of the following is one of the eigenvalues for the matrix given below?

$$\begin{bmatrix} 3 & 4 \\ 4 & -3 \end{bmatrix}$$

(A) 1
(B) 3
(C) 5
(D) 7

Correct Answer: (C) 5

Solution:
Step 1: Understanding the Concept:
The eigenvalues of a matrix are the roots of the characteristic equation $\det(A - \lambda I) = 0$.

Step 2: Key Formula or Approach: For a 2×2 matrix $A = \begin{bmatrix} a & b \\ c & d \end{bmatrix}$, the characteristic equation is:

$$\lambda^2 - (\text{trace})\lambda + (\text{determinant}) = 0$$

Step 3: Detailed Explanation:
Trace $= 3 + (-3) = 0$
Determinant $= (3)(-3) - (4)(4) = -9 - 16 = -25$

The characteristic equation is:

$$\lambda^2 - 0\lambda - 25 = 0$$

$$\lambda^2 = 25$$

$$\lambda = \pm 5$$

The eigenvalues are 5 and -5.

Step 4: Final Answer:
One of the eigenvalues is 5.

> Quick Tip
>
> For a symmetric matrix where the trace is zero, the eigenvalues are always of the form $\pm k$. This simplifies the calculation significantly.

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13. Which of the following functions has the highest area under the curve between $x = 0$ and $x = 10$?

(A) $y = x + 8$
(B) $y = 3x$
(C) $y = 2x + 1$
(D) $y = x + 2$

Correct Answer: (B) $y = 3x$

Solution:
Step 1: Understanding the Concept:
The area under a curve $y = f(x)$ from $x = a$ to $x = b$ is calculated using the definite integral $\int_a^b f(x)dx$.

Step 2: Detailed Explanation:
Calculate the area for each function:
(A) $\int_0^{10}(x + 8)dx = [\frac{x^2}{2} + 8x]_0^{10} = 50 + 80 = 130$
(B) $\int_0^{10} 3xdx = [\frac{3x^2}{2}]_0^{10} = \frac{300}{2} = 150$
(C) $\int_0^{10}(2x + 1)dx = [x^2 + x]_0^{10} = 100 + 10 = 110$
(D) $\int_0^{10}(x + 2)dx = [\frac{x^2}{2} + 2x]_0^{10} = 50 + 20 = 70$
Comparing the values: $150 > 130 > 110 > 70$.

Step 3: Final Answer:
Function (B) has the highest area.

Quick Tip

For linear functions $y = mx + c$, the area can also be found as the area of a trapezoid: Area = width $\times$ average height $= 10 \times \frac{f(0)+f(10)}{2}$.

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14. Cancer cells display a high level of heterogeneity in the expression of TP53 protein. Which of the following techniques can be directly used to determine the intra-tumoral heterogeneity of TP53 expression in a given tumor sample, without resorting to additional cell separation techniques?

(A) Immunoblotting
(B) Flow cytometry
(C) ELISA
(D) Quantitative RT-PCR

Correct Answer: (B) Flow cytometry

Solution:
Step 1: Understanding the Concept:
Heterogeneity refers to cell-to-cell variations within a sample. Determining this requires a "single-cell analysis" technique.

Step 2: Detailed Explanation:
- Immunoblotting (Western Blot) and ELISA are "bulk" techniques. They require lysing all cells together, giving only the average protein expression of the entire population.
- Quantitative RT-PCR measures mRNA levels in bulk, providing an average transcriptional level.
- Flow cytometry analyzes individual cells one by one as they flow past a laser. By using fluorescently labeled antibodies against TP53, it can quantify the protein level in each individual cell. This distribution of values directly reveals the heterogeneity of the population.

Step 3: Final Answer:
Flow cytometry is the standard technique for assessing individual cell expression profiles in a heterogeneous population.

Quick Tip

If a question mentions "heterogeneity" or "single-cell variation," the answer is likely Flow Cytometry, Immunohistochemistry, or Single-cell Sequencing.

15. The transfer function of a Proportional-Integral (PI) controller $G_C(s)$ is given by

$$G_C(s) = K_C\left(1 + \frac{1}{\tau_I s}\right)$$

where K_C is the controller gain, τ_I is the controller integral time constant and s is the Laplace variable. The role of the integral component of the controller is to _____.

(A) integrate the difference between the process and manipulated variable
(B) integrate the difference between the set point and disturbance variable
(C) integrate the difference between the set point and the measured variable
(D) integrate the difference between the input and output variable

Correct Answer: (C) integrate the difference between the set point and the measured variable

Solution:
Step 1: Understanding the Concept:
A PI controller combines proportional and integral control actions.
The input to any controller in a feedback loop is the error signal $e(t)$, which is defined as the difference between the set point (SP) and the measured process variable (PV).

Step 2: Key Formula or Approach:
The control law in the time domain is given by:

$$u(t) = K_C e(t) + \frac{K_C}{\tau_I}\int_0^t e(t)dt$$

Where $e(t) = SP(t) - PV(t)$.

Step 3: Detailed Explanation:
The transfer function $G_C(s) = K_C(1 + \frac{1}{\tau_I s})$ represents the relationship between the error and the controller output in the Laplace domain.
The term $\frac{1}{\tau_I s}$ corresponds to the integral operation in the time domain.
Specifically, the integral component integrates the error signal over time.
As the error is the difference between the set point and the measured variable, the integral action serves to eliminate the steady-state offset by continuously accumulating this difference.

Step 4: Final Answer:
Therefore, the integral component integrates the difference between the set point and the measured variable.

Quick Tip

Integral action is known as "Reset Action" because it resets the error to zero, effectively eliminating steady-state offset in a stable control system.

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16. Which of the following enzyme is involved in the protection of cells from reactive oxygen species?

(A) Hexokinase
(B) Glucose 6-phosphate dehydrogenase
(C) Enolase
(D) Pyruvate kinase

Correct Answer: (B) Glucose 6-phosphate dehydrogenase

Solution:
Step 1: Understanding the Concept:
Protection against Reactive Oxygen Species (ROS) like superoxide and hydrogen peroxide requires reducing power, primarily in the form of NADPH.

Step 2: Detailed Explanation:
Glucose 6-phosphate dehydrogenase (G6PD) is the rate-limiting enzyme of the oxidative phase of the Pentose Phosphate Pathway (PPP).
The primary function of G6PD is to produce NADPH.
NADPH is a vital cofactor used by the enzyme Glutathione Reductase to maintain a pool of reduced glutathione (GSH).
Reduced glutathione is essential for the neutralization of ROS by Glutathione Peroxidase.
In the absence or deficiency of G6PD, cells (especially erythrocytes) cannot maintain sufficient levels of GSH, leading to oxidative damage and hemolysis.
Hexokinase, Enolase, and Pyruvate kinase are enzymes of the Glycolytic pathway and are not directly involved in NADPH production for ROS protection.

Step 3: Final Answer:
Glucose 6-phosphate dehydrogenase is the enzyme crucial for providing the reducing power needed to protect cells from ROS.

Quick Tip

Remember: PPP = NADPH production. NADPH = ROS protection. G6PD deficiency is the most common enzyme deficiency in humans, leading to neonatal jaundice or hemolytic anemia under oxidative stress.

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17. In nitrogen fixation, to reduce nitrogen to ammonia, which one of the following shows the correct order of electron flow?

(A) Ferredoxin → reductase → nitrogenase
(B) NADH → reductase → nitrogenase
(C) Ferredoxin → nitrogenase → reductase
(D) Reductase → NADH → nitrogenase

Correct Answer: (A) Ferredoxin → reductase → nitrogenase

Solution:
Step 1: Understanding the Concept:
Biological nitrogen fixation is catalyzed by the nitrogenase enzyme complex found in prokaryotes like *Rhizobium* or *Azotobacter*.

Step 2: Detailed Explanation:
The nitrogenase complex consists of two main components:
1. Dinitrogenase reductase (Fe-protein): This component accepts electrons from an external carrier.
2. Dinitrogenase (MoFe-protein, often just called Nitrogenase): This component receives electrons from the reductase and uses them to reduce N_2 to NH_3.
The initial source of electrons is usually reduced Ferredoxin or Flavodoxin.
The order of electron flow is:

Ferredoxin (Source) → Dinitrogenase reductase (Fe-protein) → Dinitrogenase (MoFe-protein)

This matches Option (A).

Step 3: Final Answer:
The correct order of electron flow is Ferredoxin → reductase → nitrogenase.

Quick Tip

Nitrogen fixation is an extremely energy-expensive process requiring at least 16 ATP molecules to reduce one molecule of nitrogen to two molecules of ammonia.

---

18. For monoclonal antibody production, hypoxanthine _____.

(A) allows DNA synthesis in the absence of *de novo* dTMP synthesis
(B) allows purine synthesis in cells containing HGPRT
(C) induces cell fusion
(D) prevents *de novo* nucleotide synthesis

Correct Answer: (B) allows purine synthesis in cells containing HGPRT

Solution:
Step 1: Understanding the Concept:
Hybridoma technology for monoclonal antibody production utilizes the HAT selection medium. HAT stands for Hypoxanthine, Aminopterin, and Thymidine.

Step 2: Detailed Explanation:
Aminopterin in the medium blocks the *de novo* pathway for nucleotide synthesis.
As a result, cells must rely on the "Salvage Pathway" to produce nucleotides and survive.
Hypoxanthine is a specific precursor for the salvage synthesis of purine nucleotides (IMP, GMP, AMP).
The enzyme Hypoxanthine-guanine phosphoribosyltransferase (HGPRT) is required to utilize hypoxanthine.
In the HAT selection process, myeloma cells are HGPRT-deficient and die because they cannot use the salvage pathway when the *de novo* pathway is blocked.
The hybridoma cells (fusion of B-cell and Myeloma) inherit the functional HGPRT gene from the primary B-cell, allowing them to use hypoxanthine for purine synthesis and thus survive.

Step 3: Final Answer:
Hypoxanthine allows purine synthesis in cells that possess the HGPRT enzyme via the salvage pathway.

Quick Tip

HAT selection depends on:
1. Aminopterin: Blocks *de novo* synthesis.
2. Hypoxanthine and Thymidine: Provide precursors for the salvage pathway.
3. HGPRT and Thymidine Kinase: Enzymes required to utilize salvage precursors.

---

19. Which one of the following proteins would elute third in gel filtration chromatography from a mixture of four proteins given below?

(A) Insulin (6 kDa)
(B) Myoglobin (17 kDa)
(C) Thrombin (37 kDa)
(D) Albumin (66 kDa)

Correct Answer: (B) Myoglobin (17 kDa)

Solution:
Step 1: Understanding the Concept:
Gel filtration chromatography, also known as Size Exclusion Chromatography (SEC), separates proteins based on their molecular weight or hydrodynamic volume.

Step 2: Key Formula or Approach:
In SEC, larger molecules are excluded from the pores of the stationary phase beads and elute

first.
Smaller molecules enter the pores, travel a longer path, and elute later.
Elution order: Largest MW $\rightarrow$ Smallest MW.

Step 3: Detailed Explanation:
Let's list the proteins in descending order of their molecular weights:
1. Albumin (66 kDa) - Largest, elutes 1st.
2. Thrombin (37 kDa) - 2nd largest, elutes 2nd.
3. Myoglobin (17 kDa) - 3rd largest, elutes 3rd.
4. Insulin (6 kDa) - Smallest, elutes 4th.
The question asks for the protein that elutes third.

Step 4: Final Answer:
Myoglobin, with a molecular weight of 17 kDa, will elute third.

Quick Tip

Mnemonic for SEC: Big proteins "slip" past the beads (fast), Small proteins "visit" every bead (slow). MW is inversely proportional to elution time.

---

20. Which one of the following antibiotics blocks protein chain elongation by preventing the action of peptidyl transferase?

(A) Bleomycin
(B) Rifampicin
(C) Chloramphenicol
(D) Tetracycline

Correct Answer: (C) Chloramphenicol

Solution:
Step 1: Understanding the Concept:
Different antibiotics target specific steps in the bacterial translation process.

Step 2: Detailed Explanation:
- **Chloramphenicol:** Binds to the 50S ribosomal subunit and specifically inhibits the peptidyl transferase activity, thereby preventing the formation of peptide bonds during elongation.
- **Tetracycline:** Binds to the 30S subunit and prevents the attachment of aminoacyl-tRNA to the A site.
- **Rifampicin:** Inhibits RNA polymerase, thus blocking transcription, not translation.
- **Bleomycin:** A glycopeptide antibiotic that causes DNA strand breaks and is primarily used in cancer chemotherapy.

Step 3: Final Answer:
Chloramphenicol is the antibiotic that inhibits peptidyl transferase.

Quick Tip

Remember:
Chloramphenicol → Peptidyl transferase (50S).
Macrolides (Erythromycin) → Translocation (50S).
Aminoglycosides (Streptomycin) → Initiation/Mireading (30S).
Tetracycline → tRNA binding (30S).

---

21. The catalytic efficiency of an enzyme following Michaelis-Menten kinetics is defined by

(A) k_{cat}
(B) V_{max}/k_{cat}
(C) k_{cat}/K_M
(D) k_{cat}/V_{max}

Correct Answer: (C) k_{cat}/K_M

Solution:
Step 1: Understanding the Concept:
In enzyme kinetics, separate parameters describe turnover and affinity.

Step 2: Key Formula or Approach:
1. k_{cat} (Turnover Number): Measures the number of substrate molecules converted to product per enzyme active site per unit time when the enzyme is saturated.
2. K_M (Michaelis Constant): Reflects the affinity of the enzyme for its substrate (lower K_M means higher affinity).

Step 3: Detailed Explanation:
Catalytic efficiency evaluates how "perfect" an enzyme is.
It takes into account both the speed of the reaction at saturation (k_{cat}) and the ability of the enzyme to bind substrate even at low concentrations ($1/K_M$).
Mathematically, it is defined as the ratio of the turnover number to the Michaelis constant:

$$\text{Catalytic Efficiency} = \frac{k_{cat}}{K_M}$$

This ratio is useful for comparing the preference of an enzyme for different substrates.

Step 4: Final Answer:
The catalytic efficiency is defined by k_{cat}/K_M.

Quick Tip

The upper limit for k_{cat}/K_M is roughly 10^8 to 10^9 $M^{-1}s^{-1}$, which corresponds to the rate of diffusion. Such enzymes are called "catalytically perfect."

---

22. The RNA primer synthesized during bacterial DNA replication is removed by _____.

(A) DNA gyrase
(B) DNA Polymerase I
(C) Primase
(D) DNA Polymerase III

Correct Answer: (B) DNA Polymerase I

Solution:
Step 1: Understanding the Concept:
DNA replication requires short RNA primers to provide a 3'-OH group for DNA polymerases. Once replication of a segment (like an Okazaki fragment) is complete, these RNA primers must be replaced with DNA.

Step 2: Detailed Explanation:
In bacteria like *E. coli*, DNA Polymerase I is specifically equipped for this task.
Unlike DNA Polymerase III (the main replicative enzyme), DNA Polymerase I possesses a unique 5' to 3' exonuclease activity.
This activity allows it to remove ribonucleotides from the RNA primer at the 5' end while simultaneously adding deoxyribonucleotides to the 3' end of the adjacent DNA strand (a process known as nick translation).
- DNA gyrase is involved in relieving torsional strain.
- Primase synthesizes the primer.
- DNA Polymerase III performs the bulk of synthesis but lacks 5' to 3' exonuclease activity.

Step 3: Final Answer:
The RNA primer is removed by DNA Polymerase I.

Quick Tip

DNA Pol I has three activities:
1. 5' to 3' Polymerase.
2. 3' to 5' Exonuclease (Proofreading).
3. 5' to 3' Exonuclease (Primer removal).

---

23. Match the carbohydrates in Column I with the correct glycosidic linkages involved in Column II.

Column I	Column II
P. Amylose	1. β (1→ 4)
Q. Sucrose	2. α (1→ 4)
R. Amylopectin	3. α1→ β2
S. Cellulose	4. α (1→ 4), α (1→ 6)

(A) P-4; Q-3; R-2; S-1
(B) P-2; Q-1; R-4; S-3
(C) P-2; Q-3; R-4; S-1
(D) P-1; Q-3; R-4; S-2

Correct Answer: (C) P-2; Q-3; R-4; S-1

Solution:
Step 1: Understanding the Concept:
Carbohydrates are classified based on the type of monosaccharide units and the glycosidic linkages that join them.

Step 2: Detailed Explanation:
- **P. Amylose:** A linear polymer of glucose units linked by $\alpha(1 \to 4)$ glycosidic bonds. (Matches 2)
- **Q. Sucrose:** A non-reducing disaccharide composed of glucose and fructose linked by an $\alpha 1 \to \beta 2$ glycosidic bond. (Matches 3)
- **R. Amylopectin:** A branched polymer of glucose. The linear chains are linked by $\alpha(1 \to 4)$ bonds, and the branch points are created by $\alpha(1 \to 6)$ bonds. (Matches 4)
- **S. Cellulose:** A linear structural polysaccharide composed of glucose units linked by $\beta(1 \to 4)$ glycosidic bonds. (Matches 1)
Matching summary: P-2, Q-3, R-4, S-1.

Step 3: Final Answer:
The correct matching sequence is P-2; Q-3; R-4; S-1.

Quick Tip

Remember: "Amylose is a Line" ($\alpha 1 \to 4$), "Amylopectin is a Tree" (both $\alpha 1 \to 4$ and $\alpha 1 \to 6$). Cellulose uses "B"eta for "B"uilding walls ($\beta 1 \to 4$).

---

24. The correct sequence of the four steps involved in anaerobic production of biogas from complex organics is:

(A) Hydrolysis → Acidogenesis → Acetogenesis → Methanogenesis
(B) Methanogenesis → Acetogenesis → Acidogenesis → Hydrolysis
(C) Acidogenesis → Hydrolysis → Methanogenesis → Acetogenesis
(D) Hydrolysis → Methanogenesis → Acidogenesis → Acetogenesis

Correct Answer: (A) Hydrolysis → Acidogenesis → Acetogenesis → Methanogenesis

Solution:
Step 1: Understanding the Concept:
Anaerobic digestion is a biological process that breaks down organic materials in the absence of oxygen to produce biogas.

Step 2: Detailed Explanation:
The process follows a strictly hierarchical sequence:
1. **Hydrolysis:** Large, insoluble organic polymers (carbohydrates, proteins, fats) are broken down into soluble monomers (sugars, amino acids, fatty acids).
2. **Acidogenesis:** These monomers are converted into volatile fatty acids (VFAs), alcohols, H_2, and CO_2 by acidogenic bacteria.
3. **Acetogenesis:** VFAs and alcohols are further oxidized into acetate, H_2, and CO_2 by acetogenic bacteria.
4. **Methanogenesis:** Finally, methanogens convert acetate or H_2/CO_2 into methane (CH_4) and CO_2.

Step 3: Final Answer:
The correct sequence is Hydrolysis → Acidogenesis → Acetogenesis → Methanogenesis.

Quick Tip

Mnemonic: "H.A.A.M" (Hydrolysis, Acidogenesis, Acetogenesis, Methanogenesis).
Note that Methanogenesis is the most sensitive step to pH and temperature.

---

25. Which one of the following options represents the products of light reactions of photosynthesis in plants?

(A) O_2/NADH/H_2
(B) $O_2/NADP^+/CO_2$
(C) O_2/NADPH/ATP
(D) $O_2/NADP^+$/ATP

Correct Answer: (C) O_2/NADPH/ATP

Solution:
Step 1: Understanding the Concept:
Photosynthesis consists of two stages: Light-dependent reactions (in the thylakoid membranes)

and Light-independent reactions (Calvin cycle in the stroma).

Step 2: Detailed Explanation:
During the light reactions:
1. Light energy is captured by chlorophyll.
2. Photolysis of water occurs, releasing oxygen (O_2) as a byproduct.
3. The electron transport chain generates a proton gradient that drives the synthesis of ATP (Photophosphorylation).
4. Electrons are ultimately transferred to $NADP^+$ along with protons to form reduced NADPH.
These two molecules, ATP and NADPH, carry chemical energy to the Calvin cycle to fix CO_2 into glucose.
Option (C) correctly lists oxygen, NADPH, and ATP.

Step 3: Final Answer:
The products of the light reactions are O_2, NADPH, and ATP.

> Quick Tip
>
> Remember the "inputs" and "outputs":
> Light Reactions: In (Light, H_2O, ADP, $NADP^+$) $\rightarrow$ Out (O_2, ATP, NADPH).
> Dark Reactions: In (CO_2, ATP, NADPH) $\rightarrow$ Out (Sugar, ADP, $NADP^+$).

---

26. Which component of the CRISPR/Cas9 gene editing system is NOT of natural origin?

(A) CAS9 protein
(B) CRISPR repeats
(C) PAM sequence
(D) sgRNA

Correct Answer: (D) sgRNA

Solution:
Step 1: Understanding the Concept:
The CRISPR/Cas9 system is an adaptive immune system found naturally in bacteria and archaea to defend against viral infections.
While most components are derived directly from the biological pathway, some have been engineered for laboratory use.

Step 2: Detailed Explanation:
1. **CAS9 protein (Option A):** This is a natural RNA-guided DNA endonuclease enzyme found in bacteria like *Streptococcus pyogenes*.
2. **CRISPR repeats (Option B):** These are short segments of DNA containing palindromic

repetitions that are part of the natural CRISPR locus in the bacterial genome.
3. **PAM sequence (Option C):** The Protospacer Adjacent Motif (PAM) is a short DNA sequence (typically NGG) found naturally in the target DNA (viral genome) that is required for Cas9 to bind and cleave.
4. **sgRNA (Option D):** In nature, the system requires two separate RNA molecules: CRISPR RNA (crRNA) and trans-activating CRISPR RNA (tracrRNA).
For gene editing applications, scientists engineered a single molecule by fusing these two together with a linker loop. This "single guide RNA" (sgRNA) is a synthetic construct of non-natural origin.

Step 3: Final Answer:
The sgRNA is the component of the CRISPR/Cas9 system that is not of natural origin.

Quick Tip

Remember that "sg" in sgRNA stands for "single guide," which signifies the bioengineered fusion of the naturally separate crRNA and tracrRNA.

---

27. The equation $\frac{d^2y}{dx^2} - y = 0$ has a solution of the form $y = e^{Ax}$. The value(s) of A satisfying this is/are:

(A) 0
(B) 1
(C) -1
(D) -∞

Correct Answer: (B) 1, (C) -1

Solution:
Step 1: Understanding the Concept:
This is a second-order linear homogeneous differential equation with constant coefficients.
If $y = e^{Ax}$ is a solution, it must satisfy the differential equation when substituted.

Step 2: Key Formula or Approach:
For a given function $y = e^{Ax}$:
The first derivative is $\frac{dy}{dx} = Ae^{Ax}$.
The second derivative is $\frac{d^2y}{dx^2} = A^2e^{Ax}$.

Step 3: Detailed Explanation:
Substitute y and $\frac{d^2y}{dx^2}$ into the given equation:

$$A^2e^{Ax} - e^{Ax} = 0$$

Factoring out e^{Ax}:

$$e^{Ax}(A^2 - 1) = 0$$

Since the exponential function e^{Ax} is never zero for any finite x, we must have:

$$A^2 - 1 = 0$$

$$A^2 = 1$$

$$A = \pm 1$$

Thus, $A = 1$ and $A = -1$ are the values that satisfy the equation.

Step 4: Final Answer:
The values of A are 1 and -1.

> Quick Tip
>
> For equations of the form $ay'' + by' + cy = 0$, the values of A in the trial solution e^{Ax} are simply the roots of the characteristic equation $aA^2 + bA + c = 0$.

---

28. Which of the following drugs inhibit(s) ATP-ADP translocase?

(A) Oligomycin
(B) Atractyloside
(C) Amytal
(D) Bongkrekic acid

Correct Answer: (B) Atractyloside, (D) Bongkrekic acid

Solution:
Step 1: Understanding the Concept:
ATP-ADP translocase (Adenine Nucleotide Translocator) is a transport protein located in the inner mitochondrial membrane that exchanges mitochondrial ATP for cytosolic ADP.

Step 2: Detailed Explanation:
Different drugs target various parts of the mitochondrial respiratory chain and oxidative phosphorylation:
1. **Atractyloside (Option B):** This is a toxic glycoside that binds to the translocase when its binding site faces the intermembrane space (cytoplasmic side), inhibiting the exchange.
2. **Bongkrekic acid (Option D):** This antibiotic binds to the translocase when its binding

site faces the mitochondrial matrix, locking it in a state that prevents further transport.
3. **Oligomycin (Option A):** This drug inhibits ATP synthase (Complex V) directly by blocking the F_O subunit, not the translocase.
4. **Amytal (Option C):** This is a barbiturate that inhibits Complex I (NADH-Q oxidoreductase) of the Electron Transport Chain.

Step 3: Final Answer:
The drugs that specifically inhibit ATP-ADP translocase are Atractyloside and Bongkrekic acid.

Quick Tip

Remember: Atractyloside locks the translocase from the outside (Intermembrane space), while Bongkrekic acid locks it from the inside (Matrix). Both halt ATP production indirectly by stopping the fuel (ADP) from entering.

---

29. Which of the following is/are extra-cellular matrix protein(s)?

(A) Myosin
(B) Fibronectin
(C) Lamin
(D) Collagen

Correct Answer: (B) Fibronectin, (D) Collagen

Solution:
Step 1: Understanding the Concept:
The extracellular matrix (ECM) is a complex network of proteins and carbohydrates secreted by cells that provide structural and biochemical support to surrounding cells.

Step 2: Detailed Explanation:
1. **Collagen (Option D):** This is the most abundant protein in the ECM. It provides structural strength and resilience to tissues.
2. **Fibronectin (Option B):** This is a glycoprotein found in the ECM that binds to integrins (cell surface receptors) and other ECM components like collagen, helping cells adhere to the matrix.
3. **Myosin (Option A):** This is an **intracellular** motor protein found in the cytoplasm (specifically in muscle fibers) involved in contraction. It is not part of the ECM.
4. **Lamin (Option C):** These are fibrous proteins found in the **nuclear lamina** (inside the nucleus), providing structural support to the nuclear envelope. They are not secreted into the ECM.

Step 3: Final Answer:
The extracellular matrix proteins among the choices are Fibronectin and Collagen.

Quick Tip

Common ECM proteins include Collagen, Elastin, Fibronectin, and Laminin. Do not confuse **Laminin** (an ECM protein) with **Lamin** (a nuclear protein).

---

30. BLAST and its extensions can be used to determine similarity of a query protein sequence with which of the following database(s)?

(A) A database of translated nucleotide sequences
(B) A database of binding ligands and small translated peptides
(C) A database of protein structures
(D) A database of binding, linking and self-assembling proteins

Correct Answer: (A) A database of translated nucleotide sequences

Solution:
Step 1: Understanding the Concept:
BLAST (Basic Local Alignment Search Tool) is a suite of algorithms used to compare primary biological sequence information, such as the amino-acid sequences of proteins or the nucleotides of DNA sequences.

Step 2: Detailed Explanation:
The BLAST tool has several "extensions" or variants depending on the query and the database:
1. **BLASTp:** Compares a protein query against a protein database.
2. **tBLASTn:** This specific extension compares a **protein query** against a **nucleotide database** that is dynamically **translated** into all six reading frames. This allows researchers to find coding regions in genomic DNA that match a known protein.
3. **BLASTx:** Compares a translated nucleotide query against a protein database.
Option (A) specifically describes the target of the tBLASTn extension.
Options (B), (C), and (D) involve specialized functional or structural databases that are not the standard target of primary sequence-based BLAST alignments.

Step 3: Final Answer:
BLAST can be used to compare a protein sequence with a database of translated nucleotide sequences via the tBLASTn extension.

Quick Tip

Remember the logic of BLAST suffixes:
- **p**: protein
- **n**: nucleotide
- **x**: translated query
- **t...n**: translated database.

---

31. The mean of the following series is _____. (rounded off to three decimal places)
0.01, 0.02, 0.03, . . . , 1

Correct Answer: 0.505

Solution:
Step 1: Understanding the Concept:
The given series is an Arithmetic Progression (AP) where the first term is a, the common difference is d, and the last term is l.
The mean of an arithmetic series is calculated as the sum of all terms divided by the total number of terms.

Step 2: Key Formula or Approach:
Number of terms (n) in an AP is given by:

$$n = \frac{l - a}{d} + 1$$

The sum of n terms (S_n) is:

$$S_n = \frac{n}{2}(a + l)$$

The mean is:

$$\text{Mean} = \frac{S_n}{n} = \frac{a + l}{2}$$

Step 3: Detailed Explanation:
Given:
First term (a) = 0.01
Last term (l) = 1
Common difference (d) = 0.02 - 0.01 = 0.01
Calculation for n:

$$n = \frac{1 - 0.01}{0.01} + 1 = \frac{0.99}{0.01} + 1 = 99 + 1 = 100$$

Calculation for Mean:

$$\text{Mean} = \frac{0.01 + 1}{2} = \frac{1.01}{2} = 0.505$$

Step 4: Final Answer:
The mean of the series is 0.505.

Quick Tip

For any arithmetic series, the mean is always simply the average of the first and the last term.

---

32. You are characterizing a new enzyme isolated and purified in the laboratory. If the maximum velocity of the enzyme is 1800 μmoles L^{-1} min^{-1} and the total concentration of the enzyme in the reaction mixture is 1.5 μM, then the turnover number of the enzyme is _____ s^{-1}. (answer in integer)

Correct Answer: 20

Solution:
Step 1: Understanding the Concept:
The turnover number (k_{cat}) of an enzyme is the maximum number of chemical conversions of substrate molecules per second that a single catalytic site will execute for a given enzyme concentration.

Step 2: Key Formula or Approach:
The relationship between V_{max}, turnover number (k_{cat}), and total enzyme concentration ($[E]_t$) is:

$$V_{max} = k_{cat} \cdot [E]_t \implies k_{cat} = \frac{V_{max}}{[E]_t}$$

Step 3: Detailed Explanation:
Given data:
$V_{max} = 1800\mu\text{moles L}^{-1}\ \text{min}^{-1} = 1800\mu\text{M min}^{-1}$
$[E]_t = 1.5\mu\text{M}$
Calculation for k_{cat} in min^{-1}:

$$k_{cat} = \frac{1800\mu\text{M min}^{-1}}{1.5\mu\text{M}} = 1200\ \text{min}^{-1}$$

Converting to s^{-1}:

$$k_{cat} = \frac{1200}{60}\ \text{s}^{-1} = 20\ \text{s}^{-1}$$

Step 4: Final Answer:
The turnover number is 20 s^{-1}.

Quick Tip

Always check the units. Since 1μmole/L is equivalent to 1μM, the concentration units cancel out directly, but the time must be converted from minutes to seconds.

---

33. To determine the viable cell count of a bacterial culture, you have plated 50 μL of a 100-fold diluted sample of the culture on a nutrient agar plate and obtained 20 colonies after overnight incubation. The viable cell count of the culture is _____ CFU mL^{-1}. (answer in integer)

Correct Answer: 40000

Solution:
Step 1: Understanding the Concept:
The viable count is measured in Colony Forming Units per mL (CFU/mL). It accounts for the dilution factor and the volume of the sample plated.

Step 2: Key Formula or Approach:

$$\text{CFU/mL} = \frac{\text{Colony Count} \times \text{Dilution Factor}}{\text{Volume Plated (in mL)}}$$

Step 3: Detailed Explanation:
Given:
Colony Count = 20
Dilution Factor = 100 (as the sample was 100-fold diluted)
Volume Plated = 50 μL = 0.05 mL
Calculation:

$$\text{CFU/mL} = \frac{20 \times 100}{0.05}$$

$$\text{CFU/mL} = \frac{2000}{0.05} = 40000$$

Step 4: Final Answer:
The viable cell count is 40,000 CFU mL^{-1}.

Quick Tip

Be extremely careful with volume conversions. 1000μL = 1 mL, so 50μL = 0.05 mL. Dividing by 0.05 is the same as multiplying by 20.

34. Given below is the Gibbs free energy change (ΔG) in kilo Joules per electron equivalent (kJ e^-eq^{-1}) at pH 7.0, of organic and inorganic half reactions.
Acetate synthesis:
$\frac{1}{8}\mathbf{CO_2} + \frac{1}{8}\mathbf{HCO_3^-} + \mathbf{H^+} + e^- \rightarrow \frac{1}{8}\mathbf{CH_3COO^-} + \frac{3}{8}\mathbf{H_2O} \qquad \Delta G = 27.4$ **kJ** $\mathbf{e^-eq^{-1}}$
Reduction reaction:
$\frac{1}{4}\mathbf{O_2} + \mathbf{H^+} + e^- \rightarrow \frac{1}{2}\mathbf{H_2O} \qquad \Delta G = -78.72$ **kJ** $\mathbf{e^-eq^{-1}}$
The free energy change of acetate oxidation to CO_2, H_2O and HCO_3^- is _____ kJ e^-eq^{-1}. (rounded off to two decimal places)

Correct Answer: -106.12

Solution:
Step 1: Understanding the Concept:
Acetate oxidation involves the transfer of electrons from acetate to an electron acceptor (in this case, presumably oxygen, based on the provided reduction half-reaction).
The overall ΔG for a redox reaction is the sum of the ΔG of the oxidation half-reaction and the reduction half-reaction.

Step 2: Key Formula or Approach:
1. Reverse the synthesis reaction to get the oxidation half-reaction. Reversing changes the sign of ΔG.
2. Sum the ΔG values of the oxidation and reduction half-reactions.

Step 3: Detailed Explanation:
Oxidation half-reaction:

$$\frac{1}{8}\mathrm{CH_3COO^-} + \frac{3}{8}\mathrm{H_2O} \rightarrow \frac{1}{8}\mathrm{CO_2} + \frac{1}{8}\mathrm{HCO_3^-} + \mathrm{H^+} + e^-$$

$$\Delta G_{\text{oxidation}} = -27.4 \text{ kJ } \mathrm{e^-eq^{-1}}$$

Reduction half-reaction:

$$\frac{1}{4}\mathrm{O_2} + \mathrm{H^+} + e^- \rightarrow \frac{1}{2}\mathrm{H_2O}$$

$$\Delta G_{\text{reduction}} = -78.72 \text{ kJ } \mathrm{e^-eq^{-1}}$$

Total free energy change:

$$\Delta G_{\text{total}} = \Delta G_{\text{oxidation}} + \Delta G_{\text{reduction}}$$

$$\Delta G_{\text{total}} = -27.4 + (-78.72) = -106.12 \text{ kJ } \mathrm{e^-eq^{-1}}$$

Step 4: Final Answer:
The free energy change is -106.12 kJ $e^{-}eq^{-1}$.

> Quick Tip
>
> Oxidation is the reverse of synthesis. Always remember to flip the sign of ΔG when you reverse the reaction direction.

---

35. You have purified an enzyme using a series of chromatographic methods. It was observed that a 10 μg mL^{-1} of this purified enzyme converted 10 mM substrate per hour at 25°C and pH 7. Its specific activity is _____ IU μg^{-1}. (rounded off to three decimal places)

Correct Answer: 16.667

Solution:

Step 1: Understanding the Concept:
The International Unit (IU) measures the catalytic activity of an enzyme.
Specific activity represents the purity or efficiency of an enzyme and is expressed as the enzyme activity (IU) per unit mass of protein (usually mg or μg).
1 IU = 1 μmol of substrate converted per minute.

Step 2: Key Formula or Approach:
1. Convert the reaction rate from mM/hr to μmol/mL/min (Activity per mL).
2. Use the formula for Specific Activity:

$$\text{Specific Activity} = \frac{\text{Enzyme Activity (IU/mL)}}{\text{Enzyme Concentration } (\mu\text{g/mL})}$$

Step 3: Detailed Explanation:
1. Convert Reaction Rate to Activity per mL:
Given Rate = 10 mM/hr.
This means 10 mmol/L/hr.
Convert mmol to μmol:

$$10 \text{ mmol/L/hr} = 10 \times 10^3 \mu\text{mol/L/hr} = 10,000 \mu\text{mol/L/hr}$$

Convert hours to minutes:

$$\frac{10,000 \mu\text{mol/L}}{60 \text{ min}} \approx 166.667 \mu\text{mol/L/min}$$

Convert Liters to milliliters (mL) to match the enzyme concentration units:

$$\frac{166.667\mu\text{mol/L/min}}{1000} = 0.16667\mu\text{mol/mL/min}$$

Since 1 μmol/min = 1 IU, the activity is 0.16667 IU/mL.

2. Calculate Specific Activity:
Given Enzyme Concentration = 10μg/mL.

$$\text{Specific Activity} = \frac{0.16667 \text{ IU/mL}}{10\mu\text{g/mL}}$$

$$\text{Specific Activity} = 0.016667 \text{ IU}/\mu\text{g}$$

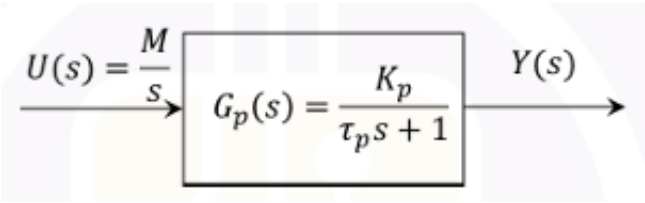
Rounding to four decimal places, we get 0.0167 IU/μg.

Step 4: Final Answer:
The specific activity of the enzyme is 0.0167 IU μg^{-1}.

> Quick Tip
>
> Always standardize your units to μmoles and minutes first to find IU, then simply divide by the mass.

---

36. In the open-loop process shown in the figure, the input $U(s)$, the transfer function $G_p(s)$ and the output $Y(s)$ are given in the Laplace domain in terms of the Laplace variable s. For this process, which of the following is true?
(where M, τ_p, K_p, are the magnitude of the input, the characteristic time and the gain for the process, respectively)



(A) $y(t) = K_p(1 - e^{-t/\tau_p})$
(B) $y(t) = MK_p(1 - e^{-t/\tau_p})$
(C) $y(t) = K_p(M - e^{-t/\tau_p})$
(D) $y(t) = K_p(1 - Me^{-t/\tau_p})$

Correct Answer: (B) $y(t) = MK_p(1 - e^{-t/\tau_p})$

Solution:

Step 1: Understanding the Concept:

In control systems, the output in the Laplace domain $Y(s)$ is the product of the input $U(s)$ and the transfer function $G_p(s)$. To find the time-domain response $y(t)$, we take the inverse Laplace transform.

Step 2: Detailed Explanation:

Given:

$$U(s) = \frac{M}{s}$$

$$G_p(s) = \frac{K_p}{\tau_p s + 1}$$

The output $Y(s)$ is:

$$Y(s) = U(s) \cdot G_p(s) = \frac{M}{s} \cdot \frac{K_p}{\tau_p s + 1} = \frac{MK_p}{s(\tau_p s + 1)}$$

To find $y(t)$, we use partial fraction decomposition:

$$\frac{MK_p}{s(\tau_p s + 1)} = MK_p \left[\frac{1}{s} - \frac{\tau_p}{\tau_p s + 1}\right] = MK_p \left[\frac{1}{s} - \frac{1}{s + 1/\tau_p}\right]$$

Taking the inverse Laplace transform:

$$y(t) = \mathcal{L}^{-1} \left\{ MK_p \left[\frac{1}{s} - \frac{1}{s + 1/\tau_p}\right] \right\}$$

$$y(t) = MK_p(1 - e^{-t/\tau_p})$$

Step 3: Final Answer:

The correct time-domain expression is $y(t) = MK_p(1 - e^{-t/\tau_p})$.

> **Quick Tip**
>
> The expression $(1 - e^{-t/\tau})$ is the standard step response of a first-order system. The final steady-state value is always the product of the step magnitude M and the system gain K_p.

---

37. Match the immunological terms in Column I with their function/description in Column II

Column I	Column II
P. J gene	1. Suppresses immune system by blocking calcineurin
Q. Cyclosporin	2. Antibody binding site on a large molecule
R. Epitope	3. Small foreign molecule which elicits an immune response only when combined with a carrier molecule
S. Hapten	4. Contributes to antibody diversity

(A) P-3; Q-4; R-2; S-1
(B) P-2; Q-4; R-1; S-3
(C) P-4; Q-1; R-2; S-3
(D) P-1; Q-3; R-4; S-2

Correct Answer: (C) P-4; Q-1; R-2; S-3

Solution:
Step 1: Understanding the Concept:
This question requires matching basic immunological components and pharmacological agents with their biological roles.

Step 2: Detailed Explanation:
P. J gene: The Joining (J) gene segments, along with V (Variable) and D (Diversity) segments, undergo somatic recombination to produce diverse antibody heavy and light chains. Thus, it contributes to antibody diversity. (P-4)
Q. Cyclosporin: This is an immunosuppressant drug used to prevent organ rejection. It works by inhibiting calcineurin, which in turn prevents the activation of T-cells. (Q-1)
R. Epitope: An epitope, or antigenic determinant, is the specific part of an antigen (usually a large protein molecule) to which an antibody binds. (R-2)
S. Hapten: A hapten is a small molecule that can elicit an immune response only when attached to a larger carrier protein. On its own, it is not immunogenic. (S-3)

Step 3: Final Answer:
The correct matching is P-4, Q-1, R-2, and S-3.

Quick Tip

Remember: Hapten = "Half" an antigen (needs a carrier). Epitope = The specific "site" on the antigen.

38. Match the genetic disorders in Column I to the corresponding underlying cause in Column II

Column I	Column II
P. Klinefelter Syndrome	1. X-chromosome insufficiency
Q. Turner syndrome	2. DNA helicase mutations
R. Bloom syndrome	3. Nucleotide excision repair defects
S. Xeroderma pigmentosum	4. Extra X chromosome(s) in a male

(A) P-1; Q-3; R-4; S-2
(B) P-4; Q-1; R-2; S-3
(C) P-4; Q-2; R-3; S-1
(D) P-3; Q-2; R-4; S-1

Correct Answer: (B) P-4; Q-1; R-2; S-3

Solution:
Step 1: Understanding the Concept:
Genetic disorders can arise from chromosomal abnormalities (aneuploidy) or specific mutations in DNA repair enzymes.

Step 2: Detailed Explanation:
P. Klinefelter Syndrome: This occurs in males who have an extra X chromosome, typically having a 47,XXY karyotype. (P-4)
Q. Turner Syndrome: This occurs in females who have only one functional X chromosome (monosomy X), represented as 45,X. This is an X-chromosome insufficiency. (Q-1)
R. Bloom Syndrome: This is a rare disorder characterized by genomic instability and is caused by mutations in the *BLM* gene, which encodes a member of the RecQ DNA helicase family. (R-2)
S. Xeroderma Pigmentosum: This is an autosomal recessive genetic disorder in which the ability to repair damage caused by ultraviolet (UV) light is deficient due to defects in the nucleotide excision repair (NER) pathway. (S-3)

Step 3: Final Answer:
The correct matching is P-4, Q-1, R-2, and S-3.

Quick Tip

Klinefelter = XXY (Male), Turner = XO (Female). XP is always associated with the inability to repair UV damage via NER.

39. Match the biomolecules in Column I with their function given in Column II

Column I		Column II
P.	Lectins	1. Acts as ATP dependent pump to efflux out small molecules
Q.	P-glycoprotein	2. Targets lysosomal enzymes to their destination
R.	Digitoxigenin	3. Specific carbohydrate binding proteins
S.	Mannose 6-phosphate	4. Inhibits Na^+-K^+ pump

(A) P-3; Q-2; R-1; S-4
(B) P-1; Q-3; R-4; S-2
(C) P-2; Q-1; R-3; S-4
(D) P-3; Q-1; R-4; S-2

Correct Answer: (D) P-3; Q-1; R-4; S-2

Solution:
Step 1: Understanding the Concept:
This question involves identifying the specific biochemical functions or biological roles of various proteins and small molecules.

Step 2: Detailed Explanation:
P. Lectins: Lectins are a group of proteins that bind specifically to carbohydrate groups on proteins or cell surfaces. (P-3)
Q. P-glycoprotein: Also known as Multidrug Resistance Protein 1 (MDR1), it is an ATP-dependent efflux pump that moves small molecules (including many drugs) out of the cell. (Q-1)
R. Digitoxigenin: This is a cardiac glycoside aglycone that inhibits the Na^+-K^+ ATPase pump, used in treating heart failure. (R-4)
S. Mannose 6-phosphate: This sugar tag is added to lysosomal enzymes in the Golgi apparatus to target them to the lysosome. (S-2)

Step 3: Final Answer:
The correct matching is P-3, Q-1, R-4, and S-2.

Quick Tip

Mannose 6-Phosphate is the "address label" for the lysosome. Lectins are the "Velcro" that binds specific sugars.

40. By elemental analysis of a biomass sample, it was found that the cells in the given sample are composed of (by weight) C=50%, H=8%, O=20%, N=10% and ash content=12%. Which of the following is the correct empirical formula of the ash-free cells, normalized with respect to Nitrogen?

(A) $C_{5.8}H_{11.2}O_{1.7}N$
(B) $C_{5.0}H_{10.2}O_{1.1}N$
(C) $C_{6.8}H_{12.2}O_{2.1}N$
(D) $C_{4.8}H_{9.2}O_{3.1}N$

Correct Answer: (A) $C_{5.8}H_{11.2}O_{1.7}N$

Solution:
Step 1: Understanding the Concept:
To find the empirical formula, we calculate the number of moles of each element in a given weight and then normalize the ratios by dividing by the moles of the reference element (Nitrogen).

Step 2: Key Formula or Approach:

$$\text{Moles of element} = \frac{\text{Weight \%}}{\text{Atomic weight}}$$

Normalize by dividing each by the moles of Nitrogen.

Step 3: Detailed Explanation:
Assume 100g of dry biomass. Ash-free mass = 100 - 12 = 88g.
Weight percentages within this 88g for the formula calculation:
Weight C = 50g
Weight H = 8g
Weight O = 20g
Weight N = 10g
(Note: Using ash-free cells means we use the percentages given relative to the total, but since the result is a normalized ratio, the absolute weight doesn't matter as long as the ratios are preserved).
Moles of C = $50/12 = 4.167$
Moles of H = $8/1 = 8.0$
Moles of O = $20/16 = 1.25$
Moles of N = $10/14 = 0.714$
Normalizing with respect to N:
C-ratio = $4.167/0.714 \approx 5.83$
H-ratio = $8.0/0.714 \approx 11.20$
O-ratio = $1.25/0.714 \approx 1.75$
Formula = $C_{5.83}H_{11.2}O_{1.75}N$
This matches Option (A) most closely.

Step 4: Final Answer:
The empirical formula is $C_{5.8}H_{11.2}O_{1.7}N$.

Quick Tip

When normalizing a formula, the ash content is irrelevant because the stoichiometric ratio between C, H, O, and N remains the same regardless of the ash present in the sample.

---

41. For the given matrix, which of the statements given below is/are true?

$$\begin{bmatrix} 3 & 1 & 5 \\ 2 & -1 & 0 \\ 5 & 2 & 9 \end{bmatrix}$$

(A) The matrix is full rank
(B) The matrix is invertible
(C) The matrix has a determinant
(D) The matrix has a transpose

Correct Answer: (C) The matrix has a determinant, (D) The matrix has a transpose

Solution:
Step 1: Understanding the Concept:
Rank and invertibility depend on whether the determinant of the matrix is non-zero. A square matrix always has a determinant and a transpose.

Step 2: Detailed Explanation:
Let's calculate the determinant of matrix A:

$$\det(A) = 3[(-1)(9) - (2)(0)] - 1[(2)(9) - (5)(0)] + 5[(2)(2) - (5)(-1)]$$

$$\det(A) = 3[-9] - 1[18] + 5[4 + 5]$$

$$\det(A) = -27 - 18 + 5[9] = -45 + 45 = 0$$

Since the determinant is 0:
- The matrix is **singular** and **not invertible**. (Option B is false)
- The matrix is **not full rank** (Rank < 3). (Option A is false)
- Every square matrix **has a determinant** (even if it's zero). (Option C is true)
- Every matrix **has a transpose**. (Option D is true)

Step 3: Final Answer:
The true statements are (C) and (D).

> Quick Tip
>
> Always check if rows or columns are linearly dependent. Notice that Row 1 + Row 2 = [5, 0, 5], which is not Row 3. However, if det = 0, the rank must be less than the number of rows.

---

42. Messenger RNAs (mRNAs) translate to generate polypeptides and the translation terminates at the UGA, UAG or UAA stop codons. The AGA codon acts as additional stop codon in the mitochondria. The longest possible polypeptide(s) that can be hypothetically translated in the cytosol and/or mitochondria, from the given full length mRNA sequence (36 nucleotides) is/are
5'-AACACCAUGACCCAGUGGCGAGACGGUAGUUAAAA- 3'

(A) 7 amino acids long in the cytosol
(B) 5 amino acids long in the mitochondria
(C) 6 amino acids long in the mitochondria
(D) 8 amino acids long in the cytosol

Correct Answer: (A) 7 amino acids long in the cytosol, (B) 5 amino acids long in the mitochondria

Solution:
Step 1: Understanding the Concept:
Translation begins at the start codon (AUG) and continues until a stop codon is reached. Different biological systems (cytosol vs. mitochondria) may have different stop codon assignments.

Step 2: Detailed Explanation:
First, find the start codon (AUG) in the sequence:
5'-AAC ACC **AUG** ACC CAU GUG GCG AGA CGG UAG UUA AAA- 3'
The coding starts at the 7th nucleotide.
Codons in the cytosol:
1: AUG (Met)
2: ACC (Thr)
3: CAU (His)
4: GUG (Val)
5: GCG (Ala)
6: AGA (Arg)
7: CGG (Arg)
8: UAG (**STOP**)
In the cytosol, the polypeptide is 7 amino acids long. (Option A is correct)
Codons in the mitochondria:
1: AUG

2: ACC
3: CAU
4: GUG
5: GCG
6: AGA (**STOP** in mitochondria, as given in question)
In the mitochondria, translation stops at the 6th codon, resulting in a polypeptide 5 amino acids long. (Option B is correct)

Step 3: Final Answer:
The correct options are (A) and (B).

Quick Tip

Count amino acids carefully: they are the total number of codons **before** the stop codon. The stop codon itself does not encode an amino acid.

---

43. The RNA sequence below depicts the part of a 330 nucleotides long mRNA and it encodes the C-terminal portion of a protein.
5'-... ... ... AAC ACC ACG ACC CAU GUG GCG AGA CGG UAG- 3'
A mutation was identified in this RNA denoted as 322A → U. This nucleotide change is represented by which of the following class(es) of mutation?

(A) Missense mutation
(B) Non-sense mutation
(C) Transversion mutation
(D) Silent mutation

Correct Answer: (B) Non-sense mutation, (C) Transversion mutation

Solution:
Step 1: Understanding the Concept:
Mutations are classified by the change in the DNA base (transition/transversion) and the resulting effect on the protein sequence (missense/nonsense/silent).

Step 2: Detailed Explanation:
Sequence end: ...AGA CGG UAG-3'.
The length is 330. Let's count back from the end:
330(G), 329(A), 328(U) -¿ STOP (UAG)
327(G), 326(G), 325(C) -¿ CGG
324(A), 323(G), 322(A) -¿ AGA (Arginine)
Wait, the numbering is usually 5' to 3'.
If 322A is the first A of codon 322-324 (AGA):
Original codon: AGA (Arg)
Mutated codon (322A → U): UGA
UGA is a **STOP codon**. A mutation that creates a premature stop codon is a **Nonsense**

mutation. (Option B is correct)
Base change: A (Purine) to U (Pyrimidine). A change from a purine to a pyrimidine (or vice versa) is a **Transversion**. (Option C is correct)

Step 3: Final Answer:
The mutation is both a nonsense mutation and a transversion.

Quick Tip

Transition: Purine → Purine or Pyrimidine → Pyrimidine.
Transversion: Purine ↔ Pyrimidine.
Non-sense: New Stop codon. Missense: Different amino acid. Silent: Same amino acid.

---

44. A microbial culture is being grown in a bioreactor with continuous aeration. The dissolved oxygen probe provided with the system shows a reading of zero. In this context, which of the following inferences is/are correct?

(A) The culture has died due to absence of oxygen
(B) The culture has run out of carbon source
(C) The culture growth becomes oxygen limited
(D) The culture growth is independent of dissolved oxygen

Correct Answer: (C) The culture growth becomes oxygen limited

Solution:
Step 1: Understanding the Concept:
Dissolved oxygen (DO) levels in a bioreactor reflect the balance between oxygen supply (aeration) and oxygen demand (cellular respiration).

Step 2: Detailed Explanation:
- If the DO reading is zero, it means the rate of oxygen consumption by the microbes is exactly equal to or greater than the maximum rate of oxygen supply provided by the system.
- This signifies that the microbes are consuming oxygen as fast as it is supplied, and the growth rate is now limited by how fast oxygen can be transferred into the medium. This is the definition of **oxygen limitation**. (Option C is correct)
- Option A is incorrect because a zero DO reading means cells are actively breathing and consuming oxygen. If they were dead, they wouldn't consume oxygen, and DO would likely rise.
- Option B is incorrect because if the carbon source ran out, respiration would stop, and DO would rise to saturation.
- Option D is incorrect; aerobic growth depends heavily on DO.

Step 4: Final Answer:
The correct inference is (C).

Quick Tip

In aerobic fermentations, a zero DO reading is a classic signal of oxygen mass-transfer limitation ($OUR = OTR_{\max}$).

---

45. For a Newtonian fluid, a plot of shear stress (on Y axis) against shear rate (on X axis) will result in a straight line _____.

(A) parallel to the X axis
(B) parallel to the Y axis
(C) with a negative slope
(D) with a positive slope

Correct Answer: (D) with a positive slope

Solution:
Step 1: Understanding the Concept:
The rheological behavior of a Newtonian fluid is defined by Newton's law of viscosity.

Step 2: Key Formula or Approach:
Newton's law:

$$\tau = \mu\gamma$$

where τ is shear stress, γ is shear rate, and μ is viscosity (a constant for Newtonian fluids).

Step 3: Detailed Explanation:
The equation $\tau = \mu\gamma$ is in the form $y = mx$, which represents a straight line passing through the origin.
The slope of the line is the viscosity μ.
Since viscosity μ is a physical property and always positive for real fluids, the slope is positive.

Step 4: Final Answer:
The plot results in a straight line with a positive slope.

Quick Tip

For Newtonian fluids, the slope (viscosity) is constant. For non-Newtonian fluids (like Pseudoplastic or Dilatant), the plot would be a curve because the "apparent viscosity" changes with shear rate.

---

46. In an aerobic fermentation with air sparging, which of the following options can be used to increase the volumetric mass transfer coefficient for oxygen transfer?

(A) Using pure oxygen in place of air
(B) Increasing the volumetric flow rate of air
(C) Reducing the bubble diameter
(D) Decreasing the agitation rate

Correct Answer: (B) Increasing the volumetric flow rate of air, (C) Reducing the bubble diameter

Solution:
Step 1: Understanding the Concept:
The volumetric mass transfer coefficient (k_La) depends on the liquid film mass transfer coefficient (k_L) and the specific interfacial area (a).

Step 2: Detailed Explanation:
- **Option B:** Increasing air flow rate increases gas holdup and turbulence, which directly increases the interfacial area a and thus k_La. (Correct)
- **Option C:** Reducing bubble diameter significantly increases the specific interfacial area ($a = 6\epsilon/d_b$). Smaller bubbles provide more surface area for the same volume of gas. (Correct)
- Option A: Pure oxygen increases the **driving force** ($C^* - C_L$), not the mass transfer **coefficient** k_La itself.
- Option D: Decreasing agitation would decrease bubble breakage and turbulence, thus decreasing k_La.

Step 3: Final Answer: The correct methods are (B) and (C).

Quick Tip

Mass transfer rate $= k_La(C^* - C_L)$.
k_La relates to the efficiency of the machine/mixing.
$(C^* - C_L)$ relates to the chemistry/gas composition.

---

47. For a liquid flowing in a circular cross section pipe, the transition from laminar to turbulent flow will NOT depend on which of the following factor(s)?

(A) The diameter of the pipe
(B) The length of the pipe
(C) The linear velocity of the liquid
(D) The viscosity of the liquid

Correct Answer: (B) The length of the pipe

Solution:
Step 1: Understanding the Concept:
The transition from laminar to turbulent flow is determined by the dimensionless Reynolds number (Re).

Step 2: Key Formula or Approach:

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

where ρ is density, v is velocity, D is diameter, and μ is viscosity.

Step 3: Detailed Explanation:
The flow becomes turbulent when Re exceeds a critical value (typically 2100 for pipe flow).
Looking at the formula:
- It depends on diameter D. (Option A)
- It depends on velocity v. (Option C)
- It depends on viscosity μ. (Option D)
The length of the pipe does not appear in the Reynolds number formula and does not affect the inherent nature of the flow regime in a fully developed flow.

Step 4: Final Answer:
The transition does not depend on (B).

Quick Tip

The Reynolds number is a ratio of inertial forces to viscous forces. Length only affects the pressure drop (head loss), not the flow regime (Re).

---

48. Which of the following is/are posttranslational modification(s) involved in epigenetic control of gene expression?

(A) Arginine methylation
(B) Lysine acetylation
(C) Cytosine methylation
(D) Cytosine deamination

Correct Answer: (A) Arginine methylation, (B) Lysine acetylation

Solution:
Step 1: Understanding the Concept:
Epigenetic control involves modifications to DNA or histone proteins that affect gene expression without changing the DNA sequence. Posttranslational modifications (PTMs) specifically refer to modifications of **proteins** after they have been synthesized.

Step 2: Detailed Explanation:
- **Arginine methylation (Option A):** This is a common PTM on histone tails that regulates chromatin structure and gene access. (Correct)
- **Lysine acetylation (Option B):** This PTM on histones (neutralizing positive charge) typically opens chromatin (euchromatin) and activates gene expression. (Correct)
- **Cytosine methylation (Option C):** While this is a critical epigenetic mechanism, it is a **DNA modification**, not a protein modification. Therefore, it is not a "posttranslational" modification.
- **Cytosine deamination (Option D):** This is a chemical change/damage to DNA bases, not a protein modification.

Step 3: Final Answer:
The posttranslational modifications are (A) and (B).

Quick Tip

Distinguish carefully between **histone modifications** (Posttranslational) and **DNA modifications** (Epigenetic, but not posttranslational).

---

49. For an ideal plug flow reactor, which of the following statements is/are true?

(A) It can be approximated by a large number of ideal continuous stirred tank reactors connected in series
(B) It has significant back mixing
(C) It has significant axial mixing
(D) It has a uniform velocity profile across any cross section

Correct Answer: (A, D) It can be approximated by a large number of ideal continuous stirred tank reactors connected in series; It has a uniform velocity profile across any cross section

Solution:

Step 1: Understanding the Concept:
An ideal Plug Flow Reactor (PFR) is a simplified model of a chemical reactor in which the fluid is assumed to travel as a series of coherent "plugs" or "pistons" through the reactor.
The core assumption is that there is no mixing in the direction of flow (axial direction), but perfect mixing in the direction perpendicular to flow (radial direction).

Step 2: Key Formula or Approach:
The performance of a PFR can be compared to a series of Continuous Stirred Tank Reactors (CSTRs) using the Tanks-in-Series model.
As the number of equal-sized CSTRs in series (N) increases, the flow behavior transitions from

fully back-mixed to plug flow.

$$\lim_{N\to\infty} (\text{Series of CSTRs}) = \text{Ideal PFR}$$

Step 3: Detailed Explanation:
1. **Approximation by CSTRs in Series:** Statement (A) is correct because a series of infinite CSTRs perfectly mimics the residence time distribution of a PFR.
Each CSTR acts like a tiny slice of the PFR where mixing occurs locally, but overall axial dispersion is minimized as N increases.

2. **Mixing Characteristics:** Statements (B) and (C) are incorrect because an "ideal" PFR is defined by the absolute absence of axial mixing and back-mixing.
Any significant mixing in the axial direction would lead to deviations from ideal plug flow behavior, such as non-uniform residence times for fluid elements.

3. **Velocity Profile:** Statement (D) is correct because the ideal plug flow model assumes a "flat" or uniform velocity profile.
This means every fluid element across any cross-section moves at the exact same velocity, ensuring they all have the same residence time in the reactor.

Step 4: Final Answer:
Therefore, the true statements for an ideal plug flow reactor are (A) and (D).

Quick Tip

In reactor design, remember that "Plug Flow" implies zero axial dispersion. If a question mentions "is/are true" in a competitive exam like GATE, always check if multiple statements satisfy the theoretical definitions of the ideal model.

---

50. An enzyme-catalyzed reaction is found to have $\Delta G = -100$ kJ mol^{-1}. Which of the following statements about this reaction is/are true?

(A) The rate of the reaction cannot be predicted
(B) The rate of the reaction is high
(C) The rate of the reaction is low
(D) The reaction is irreversible

Correct Answer: (A, D) The rate of the reaction cannot be predicted; The reaction is irreversible

Solution:

Step 1: Understanding the Concept:
This question distinguishes between thermodynamics and kinetics.
Gibbs free energy change (ΔG) determines the spontaneity and equilibrium state of a reaction, while the reaction rate is a kinetic property determined by activation energy (E_a).

Step 2: Key Formula or Approach:
The relationship between the equilibrium constant (K_{eq}) and standard Gibbs free energy is:

$$\Delta G = -RT \ln K_{eq}$$

Or rearranged:

$$K_{eq} = e^{-\Delta G/RT}$$

Step 3: Detailed Explanation:
1. **Predicting the Rate:** Statement (A) is correct because thermodynamics does not provide information about the speed of a reaction.
A large negative ΔG indicates that the reaction is energetically favorable (spontaneous), but it says nothing about the height of the energy barrier (activation energy).
A reaction can be highly spontaneous but extremely slow (e.g., diamond turning into graphite) or very fast. Thus, the rate cannot be predicted.

2. **Irreversibility:** Statement (D) is correct in a practical and biochemical context.
For $\Delta G = -100$ kJ mol^{-1}, the equilibrium constant K_{eq} at 298 K is:

$$K_{eq} = e^{100000/(8.314\times298)} \approx e^{40.36} \approx 3.3 \times 10^{17}$$

Such a massive equilibrium constant means the reaction proceeds almost entirely to the product side, and the reverse reaction is negligible. In enzymology, reactions with $\Delta G < -20$ kJ mol^{-1} are typically considered physiologically irreversible.

3. **Incorrect Options:** Statements (B) and (C) are incorrect because they make assumptions about the rate based solely on thermodynamic data, which is logically flawed.

Step 4: Final Answer:
The statements (A) and (D) are both scientifically accurate in the context of this thermodynamic value.

Quick Tip

Thermodynamics tells you the "What" (is it possible?) and "How far" (equilibrium), while Kinetics tells you the "How fast" (rate). A very large negative ΔG essentially means the door is wide open, but the rate depends on how narrow the hallway (activation energy) is!

---

51. Consider the equation $\frac{dy}{dx} = \frac{1}{x}$. The value of the integral $\int_1^2 dy$ using trapezoidal method and interval $h = 0.25$ is _____. (rounded off to two decimal places)

Correct Answer: 0.70

Solution:
Step 1: Understanding the Concept:
The problem asks for the numerical evaluation of a definite integral using the Trapezoidal Rule. Given the differential equation $\frac{dy}{dx} = \frac{1}{x}$, we are evaluating $\int_1^2 \frac{1}{x} dx$.

Step 2: Key Formula or Approach:
The Trapezoidal Rule for a step size h is given by:

$$I \approx \frac{h}{2} \left[y_0 + y_n + 2(y_1 + y_2 + \cdots + y_{n-1}) \right]$$

where $y_i = f(x_i) = \frac{1}{x_i}$.

Step 3: Detailed Explanation:
Interval is $[1, 2]$ with step size $h = 0.25$.
The grid points are:
$x_0 = 1.00 \implies y_0 = \frac{1}{1} = 1.0000$
$x_1 = 1.25 \implies y_1 = \frac{1}{1.25} = 0.8000$
$x_2 = 1.50 \implies y_2 = \frac{1}{1.50} \approx 0.6667$
$x_3 = 1.75 \implies y_3 = \frac{1}{1.75} \approx 0.5714$
$x_4 = 2.00 \implies y_4 = \frac{1}{2} = 0.5000$
Applying the Trapezoidal Rule:

$$I \approx \frac{0.25}{2} \left[1.0000 + 0.5000 + 2(0.8000 + 0.6667 + 0.5714) \right]$$

$$I \approx 0.125 \left[1.5000 + 2(2.0381) \right]$$

$$I \approx 0.125 \left[1.5000 + 4.0762 \right]$$

$$I \approx 0.125 \times 5.5762 \approx 0.6970$$

Rounding to two decimal places, we get 0.70.

Step 4: Final Answer:
The value of the integral is 0.70.

> Quick Tip
>
> Numerical integration results vary based on step size; smaller h leads to more accurate results.
> The exact value of $\int_1^2 \frac{1}{x} dx$ is $\ln(2) \approx 0.6931$.

---

52. If the straight lines given by the following two equations are parallel to each other, the value of a is _____. (answer in integer)
$4x + 7y = 6; \quad 3ax + 42y = 24$

Correct Answer: 8

Solution:
Step 1: Understanding the Concept:
Two lines in the form $A_1x + B_1y = C_1$ and $A_2x + B_2y = C_2$ are parallel if their slopes are equal.

Step 2: Key Formula or Approach:
For two lines to be parallel:

$$\frac{A_1}{A_2} = \frac{B_1}{B_2} \neq \frac{C_1}{C_2}$$

Alternatively, Slope $m = -\frac{A}{B}$.

Step 3: Detailed Explanation:
From the first equation $4x + 7y = 6$:
$A_1 = 4, B_1 = 7$.
From the second equation $3ax + 42y = 24$:
$A_2 = 3a, B_2 = 42$.
Applying the condition for parallelism:

$$\frac{4}{3a} = \frac{7}{42}$$

Simplify the right side:

$$\frac{4}{3a} = \frac{1}{6}$$

Cross-multiply:

$$3a = 4 \times 6$$

$$3a = 24$$

$$a = 8$$

Check if $\frac{6}{24}$ is different: $\frac{4}{24} = 1/4$, $\frac{7}{42} = 1/6$, and $\frac{6}{24} = 1/4$.
Since $\frac{4}{24} = \frac{6}{24}$, the lines are actually coincident if $a = 8$.
However, in standard competitive exams, the proportionality of x and y coefficients is used to define parallel or coincident lines.

Step 4: Final Answer:
The value of a is 8.

> Quick Tip
>
> Lines are parallel if the ratio of coefficients of x and y are equal.

---

53. A straight line $y = x - 1$ intersects a circle with center at $x = 1, y = 1$ and radius of magnitude 1 at two points. The length of the chord formed by this intersection is _____. (rounded off to three decimal places)

Correct Answer: 1.414

Solution:
Step 1: Understanding the Concept:
We need to find the distance between the two points where the line $y = x - 1$ intersects the circle $(x - 1)^2 + (y - 1)^2 = 1$.

Step 2: Key Formula or Approach:
1. Find intersection points by substitution.
2. Use the distance formula $d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$.

Step 3: Detailed Explanation:
Equation of the circle: $(x - 1)^2 + (y - 1)^2 = 1$.

Equation of the line: $y = x - 1$.
Substitute $y = x - 1$ into the circle equation:

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

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

$$x^2 - 2x + 1 + x^2 - 4x + 4 = 1$$

$$2x^2 - 6x + 4 = 0$$

Divide by 2:

$$x^2 - 3x + 2 = 0$$

Factoring:

$$(x-1)(x-2) = 0$$

So, $x_1 = 1$ and $x_2 = 2$.
Find corresponding y values:
For $x_1 = 1$: $y_1 = 1 - 1 = 0$.
For $x_2 = 2$: $y_2 = 2 - 1 = 1$.
The intersection points are $(1, 0)$ and $(2, 1)$.
Calculate the distance (chord length):

$$\text{Length} = \sqrt{(2-1)^2 + (1-0)^2} = \sqrt{1^2 + 1^2} = \sqrt{2}$$

$\sqrt{2} \approx 1.414$.

Step 4: Final Answer:
The length of the chord is 1.414.

> **Quick Tip**
>
> Chord length $= 2\sqrt{r^2 - d^2}$, where d is the perpendicular distance from the center to the line.

---

54. A heat exchanger during operation in a bioprocess has a steady temperature of 90 °C. After completion of its operation, it was shut down and it was observed that the rate of decrease of temperature at any time was directly proportional to the difference $T(t) - 30$ °C, where $T(t)$ denotes temperature at time t. It was observed that it took 30 min for the temperature to drop to 70 °C. The temperature after 51.5 min will be _____ °C. (rounded off to the nearest integer)

Correct Answer: 60

Solution:
Step 1: Understanding the Concept:
This problem follows Newton's Law of Cooling, which states that the rate of change of temperature is proportional to the difference between the object's temperature and the surrounding temperature.

Step 2: Key Formula or Approach:
Differential equation: $\frac{dT}{dt} = -k(T - T_s)$.
General solution: $T(t) = T_s + (T_0 - T_s)e^{-kt}$.

Step 3: Detailed Explanation:
Given: $T_0 = 90$ °C, $T_s = 30$ °C.
Equation: $T(t) = 30 + (90 - 30)e^{-kt} = 30 + 60e^{-kt}$.
At $t = 30$ min, $T = 70$ °C:

$$70 = 30 + 60e^{-30k} \implies 40 = 60e^{-30k} \implies e^{-30k} = \frac{2}{3}$$

We need to find T at $t = 51.5$ min:

$$T(51.5) = 30 + 60e^{-51.5k}$$

Rewrite $e^{-51.5k}$ in terms of e^{-30k}:

$$e^{-51.5k} = (e^{-30k})^{51.5/30} = \left(\frac{2}{3}\right)^{1.7167}$$

Calculate $(0.6667)^{1.7167} \approx 0.4988$.

$$T(51.5) = 30 + 60(0.4988) = 30 + 29.928 = 59.928$$

Rounding to the nearest integer gives 60.

Step 4: Final Answer:
The temperature after 51.5 min will be 60 °C.

Quick Tip

You can use the logarithmic ratio form: $\frac{T_1-T_s}{T_0-T_s} = \left(\frac{T_2-T_s}{T_1-T_s}\right)^{\Delta t_2/\Delta t_1}$ to skip calculating k explicitly.

---

55. A microbial culture (following Monod model for growth) has a maximum specific growth rate of 0.1 $\mathbf{h^{-1}}$, Monod constant of 1 $\mathbf{mg\ L^{-1}}$ and endogenous decay rate of 0.1 $\mathbf{day^{-1}}$. At limiting substrate concentration of 23 $\mathbf{g\ L^{-1}}$, the net specific growth rate will be _____ $\mathbf{day^{-1}}$. (rounded off to one decimal place)

Correct Answer: 2.3

Solution:
Step 1: Understanding the Concept:
The net specific growth rate (μ_{net}) is the difference between the specific growth rate (μ) and the endogenous decay rate (k_d).

Step 2: Key Formula or Approach:
Specific growth rate: $\mu = \mu_{\max}\frac{S}{K_s+S}$.
Net growth rate: $\mu_{\text{net}} = \mu - k_d$.

Step 3: Detailed Explanation:
First, harmonize units to day^{-1}:
$\mu_{\max} = 0.1\ \text{h}^{-1} \times 24\ \text{h/day} = 2.4\ \text{day}^{-1}$.
$k_d = 0.1\ \text{day}^{-1}$.
Now evaluate μ at $S = 23$ g/L:
Given $K_s = 1$ mg/L $= 0.001$ g/L.
Since $S \gg K_s$ (23 g/L $\gg$ 0.001 g/L), the term $\frac{S}{K_s+S} \approx 1$.

$$\mu = 2.4 \times \frac{23}{0.001 + 23} \approx 2.4\ \text{day}^{-1}$$

Calculate μ_{net}:

$$\mu_{\text{net}} = 2.4 - 0.1 = 2.3\ \text{day}^{-1}$$

Step 4: Final Answer:
The net specific growth rate is $2.3\ \text{day}^{-1}$.

Quick Tip

When the substrate concentration is much larger than the Monod constant, the specific growth rate effectively equals the maximum specific growth rate.

---

56. A CSTR with a volume of 100 $\mathbf{m^3}$ is operated in cell recycle mode. At a volumetric flow rate of 10 $\mathbf{m^3\ day^{-1}}$ and effluent biomass of 20 $\mathbf{mg\ L^{-1}}$, the steady state biomass concentration is 200 $\mathbf{mg\ L^{-1}}$. The mean cell retention time in the reactor is _____ days. (answer in integer)

Correct Answer: 100

Solution:
Step 1: Understanding the Concept:
Mean Cell Retention Time (MCRT), often denoted as θ_c, is the average time biomass stays in the system. It is defined as the total biomass in the reactor divided by the rate of biomass loss in the effluent.

Step 2: Key Formula or Approach:

$$\theta_c = \frac{VX}{QX_e}$$

where V is volume, X is reactor biomass concentration, Q is flow rate, and X_e is effluent biomass concentration.

Step 3: Detailed Explanation:
Given values:
$V = 100\ \text{m}^3$
$Q = 10\ \text{m}^3/\text{day}$
$X = 200\ \text{mg/L}$
$X_e = 20\ \text{mg/L}$
Substitute into the formula:

$$\theta_c = \frac{100 \times 200}{10 \times 20}$$

$$\theta_c = \frac{20000}{200} = 100\ \text{days}$$

Step 4: Final Answer:
The mean cell retention time is 100 days.

Quick Tip

In systems with cell recycle, the MCRT is always greater than the hydraulic retention time ($\theta = V/Q$). Here $\theta = 10$ days while $\theta_c = 100$ days.

---

57. The electron equivalent per liter ($e^-eq\ L^{-1}$) of acetate ion solution of concentration 10 g L^{-1} is _____ $e^-eq\ L^{-1}$. (rounded off to one decimal place)

Correct Answer: 1.4

Solution:
Step 1: Understanding the Concept:
Electron equivalents represent the number of moles of electrons transferred during the complete oxidation of a substance.

Step 2: Key Formula or Approach:
1. Identify the oxidation half-reaction for acetate.
2. Calculate the number of electrons per mole of acetate.
3. Calculate the concentration in mol/L.

Step 3: Detailed Explanation:
Acetate oxidation half-reaction:

$$CH_3COO^- + 2H_2O \rightarrow 2CO_2 + 7H^+ + 8e^-$$

One mole of acetate provides 8 electron equivalents.
Molar mass of acetate (CH_3COO^-):
MW $= 2(12) + 3(1) + 2(16) = 24 + 3 + 32 = 59$ g/mol.
Concentration in mol/L:

$$C_{\text{mol}} = \frac{10 \text{ g/L}}{59 \text{ g/mol}} \approx 0.1695 \text{ mol/L}$$

Calculate electron equivalents per liter:

$$e^-eq/L = 0.1695 \text{ mol/L} \times 8 \text{ } e^-eq/mol \approx 1.356$$

Rounding to one decimal place, we get 1.4.

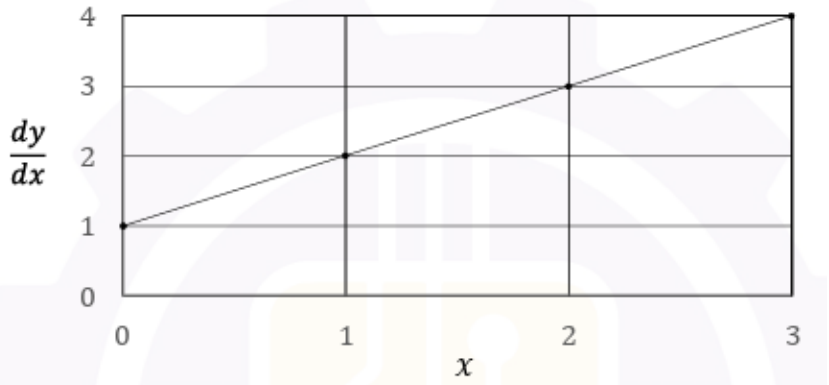
Step 4: Final Answer:
The electron equivalent per liter is 1.4.

Quick Tip

The number of electrons for a carbon source can often be determined using the oxidation states or standard biochemical half-reactions. For acetate (C_2), both carbons go from a combined average of 0 to +4.

---

58. From the following plot of $\frac{dy}{dx}$ versus x and if $y(2) = 5$, the value of $y(3)$ is _____. (rounded off to one decimal place)



Correct Answer: 8.5

Solution:
Step 1: Understanding the Concept:
The problem relates the derivative $\frac{dy}{dx}$ to the change in y using the Fundamental Theorem of Calculus.

Step 2: Key Formula or Approach:

$$y(x_2) = y(x_1) + \int_{x_1}^{x_2} \left(\frac{dy}{dx}\right) dx$$

The integral represents the area under the curve of the provided plot.

Step 3: Detailed Explanation:
From the plot, the relationship for $\frac{dy}{dx}$ is a straight line:
Passing through $(0, 1)$ and $(2, 3)$, the slope is $\frac{3-1}{2-0} = 1$.
Intercept is 1. So, $\frac{dy}{dx} = x + 1$.
To find $y(3)$ given $y(2) = 5$:

$$y(3) = y(2) + \int_2^3 (x + 1)dx$$

$$y(3) = 5 + \left[\frac{x^2}{2} + x\right]_2^3$$

$$y(3) = 5 + \left(\left(\frac{9}{2} + 3\right) - \left(\frac{4}{2} + 2\right)\right)$$

$$y(3) = 5 + (7.5 - 4) = 5 + 3.5 = 8.5$$

Step 4: Final Answer:
The value of $y(3)$ is 8.5.

Quick Tip

For a linear plot, the change in y is simply the area of the trapezoid under the curve between the two x-coordinates. Area = Width $\times$ $\frac{\text{Height}_1+\text{Height}_2}{2}$.

---

59. A batch sterilizer is being operated at 121 °C for sterilizing a medium containing microbial cells. Assume that the thermal deactivation of cells is a first order process with a death rate constant of 0.69 min^{-1} at 121 °C. If the initial concentration of microbes in the medium is 10^{10} cells m^{-3}, the time taken to reduce the microbial load to a final concentration of 10 cells m^{-3} is _____ min. (rounded off to the nearest integer)

Correct Answer: 30

Solution:
Step 1: Understanding the Concept:
First-order kinetics describes a process where the rate of change of a quantity is proportional to the quantity itself. For microbial death: $\frac{dN}{dt} = -kN$.

Step 2: Key Formula or Approach:
Integrated first-order rate equation:

$$t = \frac{\ln(N_0/N)}{k}$$

Step 3: Detailed Explanation:
Given values:
$N_0 = 10^{10}$ cells m^{-3}

$N = 10$ cells m^{-3}
$k = 0.69$ min^{-1}
Calculate the ratio:

$$\frac{N_0}{N} = \frac{10^{10}}{10} = 10^9$$

Substitute into the formula:

$$t = \frac{\ln(10^9)}{0.69}$$

Using $\ln(10^9) = 9\ln(10) \approx 9 \times 2.3026 \approx 20.723$:

$$t = \frac{20.723}{0.69} \approx 30.03 \text{ min}$$

Rounding to the nearest integer, we get 30.

Step 4: Final Answer:
The time taken is 30 min.

Quick Tip

Note that $\ln(2) \approx 0.693$. Since $k = 0.69$, it is approximately $\ln(2)$. The calculation simplifies to $9 \times \frac{\ln(10)}{\ln(2)} = 9 \times \log_2(10)$.

---

60. A substrate is consumed in a zero order reaction such that its concentration falls from 42 g L^{-1} to 14 g L^{-1} in 4 hours. The total time taken for complete utilization of substrate will be _____ hours. (answer in integer)

Correct Answer: 6

Solution:
Step 1: Understanding the Concept:
In a zero-order reaction, the rate of reaction is constant and independent of the concentration of the substrate.

Step 2: Key Formula or Approach:
Zero-order rate equation:

$$C_t = C_0 - kt \implies k = \frac{C_0 - C_t}{t}$$

Step 3: Detailed Explanation:
First, find the rate constant k:
$C_0 = 42$ g/L, $C_t = 14$ g/L, $t = 4$ h.

$$k = \frac{42 - 14}{4} = \frac{28}{4} = 7 \text{ g L}^{-1} \text{ h}^{-1}$$

Now, find the time for complete utilization ($C_{\text{final}} = 0$):

$$0 = 42 - 7 \times t_{\text{total}}$$

$$7 \times t_{\text{total}} = 42$$

$$t_{\text{total}} = 6 \text{ hours}$$

Step 4: Final Answer:
The total time taken is 6 hours.

> **Quick Tip**
>
> For zero-order reactions, concentration decreases linearly with time. You can use simple proportions: if 28 g/L is consumed in 4 h, then 42 g/L is consumed in $4 \times \frac{42}{28} = 6$ h.

---

61. A microbe that follows Monod growth kinetics on a limiting substrate (maximum specific growth rate of 0.5 h^{-1} and Monod constant of 0.1 g L^{-1}) is cultivated in a continuous reactor for microbial growth (chemostat) with sterile feed. Given that the chemostat volume is 5 L and inlet concentration of limiting substrate is 10 g L^{-1}, the minimum inlet feed flow rate for chemostat washout is _____ L h^{-1}. (rounded off to one decimal place)

Correct Answer: 2.5

Solution:
Step 1: Understanding the Concept:
Washout occurs in a chemostat when the dilution rate ($D = F/V$) exceeds the specific growth rate of the cells. The maximum dilution rate before washout is approximately equal to the maximum specific growth rate μ achievable at the inlet substrate concentration.

Step 2: Key Formula or Approach:
Dilution rate at washout: $D_{\text{washout}} = \mu_{\max} \frac{S_0}{K_s + S_0}$.

Flow rate: $F_{\text{washout}} = V \times D_{\text{washout}}$.

Step 3: Detailed Explanation:
Given:
$\mu_{\max} = 0.5\ \text{h}^{-1}$
$K_s = 0.1\ \text{g/L}$
$S_0 = 10\ \text{g/L}$
$V = 5\ \text{L}$
Calculate D_{washout}:

$$D_{\text{washout}} = 0.5 \times \frac{10}{0.1 + 10} = 0.5 \times \frac{10}{10.1} \approx 0.495\ \text{h}^{-1}$$

Calculate F_{washout}:

$$F_{\text{washout}} = 5\ \text{L} \times 0.495\ \text{h}^{-1} \approx 2.475\ \text{L/h}$$

Rounding to one decimal place gives 2.5.

Step 4: Final Answer:
The minimum inlet feed flow rate for washout is 2.5 L h^{-1}.

Quick Tip

Since $S_0 \gg K_s$, the critical dilution rate is very close to $\mu_{\max}$. $F \approx V \times \mu_{\max} = 5 \times 0.5 = 2.5$ L/h.

---

62. It is desired to cultivate 150 mg (dry weight) microbial cells with an empirical formula of $C_5H_7O_2N$. If the phosphorus requirement for the cells is 20% of the nitrogen requirement (on a weight/weight basis), the minimum amount of phosphorous required to be added to the cultivation medium is _____ mg. (rounded off to one decimal place)

Correct Answer: 3.7

Solution:
Step 1: Understanding the Concept:
The amount of an element required for biomass cultivation is determined by its mass fraction in the total biomass weight.

Step 2: Key Formula or Approach:
1. Find mass of nitrogen in 150 mg cells.
2. Calculate phosphorus as 20% of nitrogen mass.

Step 3: Detailed Explanation:
Calculate formula weight of $C_5H_7O_2N$:
MW $= 5(12) + 7(1) + 2(16) + 1(14) = 60 + 7 + 32 + 14 = 113$.
Mass fraction of Nitrogen: $\frac{14}{113}$.
Mass of Nitrogen in 150 mg cells:

$$\text{Mass}_N = 150 \times \frac{14}{113} \approx 18.584 \text{ mg}$$

Phosphorus requirement is 20% of Nitrogen requirement:

$$\text{Mass}_P = 0.20 \times 18.584 \approx 3.7168 \text{ mg}$$

Rounding to one decimal place gives 3.7.

Step 4: Final Answer:
The minimum amount of phosphorus required is 3.7 mg.

> **Quick Tip**
>
> Biomass composition is typically given as a stoichiometric formula. Convert the formula to weight percentages to solve nutritional requirement problems.

---

63. In the process of generating a clonal mammalian cell line, a single cell was seeded in a well of a cell culture plate. After the first 48 hours, one of the progeny cells underwent apoptosis due to a new mutation. If the doubling time of the cells is 24 hours and no more cell death occurs, the total number of cells after a total of 7 days from seeding will be _____. (answer in integer)

Correct Answer: 96

Solution:
Step 1: Understanding the Concept:
Cell population growth is an exponential process where each doubling increases the population by a factor of 2. Cell death must be subtracted at the exact time it occurs.

Step 2: Key Formula or Approach:
Growth equation: $N = N_0 \times 2^n$, where n is the number of doublings.

Step 3: Detailed Explanation:
Doubling time $t_d = 24$ h $= 1$ day.
Timeline:
Day 0: 1 cell.
Day 1 (24 h): 2 cells.

Day 2 (48 h): 4 cells.
At the end of 48 h, 1 cell dies: $4 - 1 = 3$ cells remaining.
Total time is 7 days. Time remaining after the death event is $7 - 2 = 5$ days.
Number of doublings in remaining time: $n = 5$ days/1 day/doubling $= 5$.
Final cell count:

$$N = 3 \times 2^5 = 3 \times 32 = 96 \text{ cells}$$

Step 4: Final Answer:
The total number of cells after 7 days is 96.

> Quick Tip
>
> Always break down discrete events like cell death before continuing the exponential calculation from that point forward.

---

64. A disease-associated allele shows X-linked recessive inheritance. If the mother is a carrier of the disease, the father is genetically normal and the child born is a son, then the probability that he is born with the disease is _____. (rounded off to one decimal place)

Correct Answer: 0.5

Solution:
Step 1: Understanding the Concept:
X-linked recessive inheritance means the gene is on the X chromosome. Males (XY) express the trait if their single X is affected. Females (XX) only express it if both are affected.

Step 2: Key Formula or Approach:
Use a Punnett Square to find the genotype ratios of the offspring.

Step 3: Detailed Explanation:
Mother is a carrier: X^DX (where X^D is the diseased allele).
Father is normal: XY.
Gametes:
Mother: X^D, X.
Father: X, Y.
Offspring possibilities:
1. X^DX (Carrier Daughter)
2. X^DY (Diseased Son)
3. XX (Normal Daughter)
4. XY (Normal Son)

The question states the child born is a son. The possible genotypes for sons are X^DY and XY. Out of these 2 equal possibilities, only 1 is diseased.
Probability $= 1/2 = 0.5$.

Step 4: Final Answer:
The probability is 0.5.

> Quick Tip
>
> In X-linked recessive traits, a carrier mother passes the disease to 50% of her sons regardless of the father's genotype.

---

65. A packed bed bioreactor with length 1 m and inside diameter 10 cm has liquid flowing at an interstitial velocity of 1 cm s^{-1}. Given a volumetric flow rate of 0.025 L s^{-1}, the void fraction of the packed bed is _____. (rounded off to two decimal places)

Correct Answer: 0.32

Solution:
Step 1: Understanding the Concept:
The void fraction (ε) relates the superficial velocity (u) to the interstitial velocity (v). Interstitial velocity is the actual velocity of the fluid in the gaps between particles.

Step 2: Key Formula or Approach:

$$v = \frac{u}{\varepsilon} \implies \varepsilon = \frac{u}{v}$$

Superficial velocity $u = \frac{Q}{A}$.

Step 3: Detailed Explanation:
1. Calculate the cross-sectional area A:
Diameter $D = 10$ cm.

$$A = \frac{\pi D^2}{4} = \frac{\pi \times 100}{4} = 25\pi \text{ cm}^2 \approx 78.54 \text{ cm}^2$$

2. Calculate superficial velocity u:
$Q = 0.025$ L/s $= 25$ cm^3/s.

$$u = \frac{25 \text{ cm}^3/\text{s}}{25\pi \text{ cm}^2} = \frac{1}{\pi} \text{ cm/s} \approx 0.3183 \text{ cm/s}$$

3. Calculate void fraction ε:

$v = 1$ cm/s.

$$\varepsilon = \frac{u}{v} = \frac{0.3183}{1} = 0.3183$$

Rounding to two decimal places gives 0.32.

Step 4: Final Answer:
The void fraction of the packed bed is 0.32.

> Quick Tip
>
> Superficial velocity is the velocity the fluid would have if the bed were empty. Since the gaps are smaller than the whole pipe, interstitial velocity is always higher than superficial velocity ($v > u$).
