GATE 2023 Biotechnology Question Paper with Solutions

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

General Instructions

Read the following instructions very carefully and strictly follow them:

1. Each GATE 2023 paper consists of a total of 100 marks. The examination is divided into two sections – General Aptitude (GA) and the Candidate's Selected Subjects. General Aptitude carries 15 marks, while the remaining 85 marks are dedicated to the candidate's chosen test paper syllabus.
2. GATE 2023 will be conducted in English as a Computer Based Test (CBT) at select centres in select cities. The duration of the examination is 3 hours.
3. MCQs carry 1 mark or 2 marks.
4. For a wrong answer in a 1-mark MCQ, 1/3 mark is deducted.
5. For a wrong answer in a 2-mark MCQ, 2/3 mark is deducted.
6. No negative marking for wrong answers in MSQ or NAT questions.

General Aptitude

Q1. "You are delaying the completion of the task. Send _____ contributions at the earliest."

(A) you are
(B) your
(C) you're
(D) yore

Correct Answer: (B) your

Solution:
Step 1: The blank is followed by the word "contributions," which is a noun. Therefore, the blank must be filled with a possessive adjective that shows ownership.
Step 2: Option (A) "you are" is grammatically incorrect here, as it cannot modify a noun directly.
Step 3: Option (B) "your" is the correct possessive adjective, making the sentence: "Send your contributions at the earliest."
Step 4: Option (C) "you're" means "you are," which is again grammatically wrong before a noun.
Step 5: Option (D) "yore" means "long ago" and is irrelevant in this context.
Hence, the correct choice is (B).

Final Answer: (B) your

Quick Tip

- Use “your” as the possessive adjective to indicate ownership.
- “You’re” is a contraction of “you are.”
- “Yore” refers to “time long past,” and is archaic.
- Always check if the blank precedes a noun: if yes, a possessive adjective is often required.

Q.2. References : _____ : Guidelines : Implement (By word meaning)

(A) Sight
(B) Site
(C) Cite
(D) Plagiarise

Correct Answer: (C) Cite

Solution:
Step 1: The relationship given is based on word meaning: ”Guidelines : Implement” means that guidelines are something you **implement**.

Step 2: Similarly, ”References : ____” means that references are something you **cite**.

Step 3: Check the options: - (A) Sight → related to vision, not correct.
- (B) Site → refers to location, not correct.
- (C) Cite → correct, as references are cited.
- (D) Plagiarise → opposite meaning, not correct.

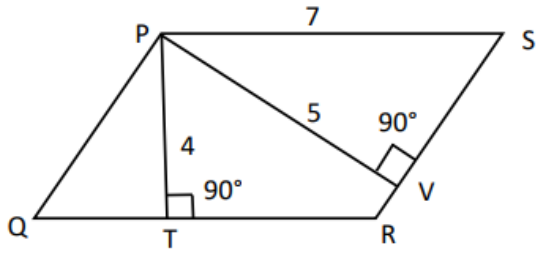
$\therefore$ References : Cite :: Guidelines : Implement

$\boxed{\text{Cite}}$

Quick Tip

- Analogies often follow the pattern: ”X is something you do with Y”.
- Always check for word meaning and correct usage.
- Watch out for homophones like sight, site, cite.

Q.3. In the given figure, PQRS is a parallelogram with $PS = 7$ cm, $PT = 4$ cm and $PV = 5$ cm. What is the length of RS in cm? (The diagram is representative.)



(A) $\frac{20}{7}$

(B) $\frac{28}{5}$

(C) $\frac{9}{2}$

(D) $\frac{35}{4}$

Correct Answer: (B) $\frac{28}{5}$

Solution: Step 1: In a parallelogram, the area is base $\times$ corresponding height. Using base PS and its perpendicular height PT:

$$\text{Area} = PS \times PT = 7 \times 4 = 28 \text{ cm}^2.$$

The same area can be written using base RS and the perpendicular distance from P to RS, which is PV:

$$\text{Area} = RS \times PV = RS \times 5.$$

Equating the areas,

$$RS \times 5 = 28 \quad \Rightarrow \quad RS = \frac{28}{5} \text{ cm}.$$

Quick Tip

- For any parallelogram, the product base $\times$ height is invariant. - Perpendicular distances from the same vertex to opposite sides can be used as heights with the corresponding bases.

Q4. In 2022, June Huh was awarded the Fields medal, which is the highest prize in Mathematics. When he was younger, he was also a poet. He did not win any medals in the International Mathematics Olympiads. He dropped out of college. Based only on the above information, which one of the following statements can be logically inferred with certainty?

(A) Every Fields medalist has won a medal in an International Mathematics Olympiad.
(B) Everyone who has dropped out of college has won the Fields medal.

(C) All Fields medalists are part-time poets.
(D) Some Fields medalists have dropped out of college.

Correct Answer: (D) Some Fields medalists have dropped out of college.

Solution:
Step 1: Analyze the given facts.
- June Huh won the Fields Medal in 2022.
- He dropped out of college.
- He did not win any medals in International Mathematics Olympiads.
- He was also a poet when younger.

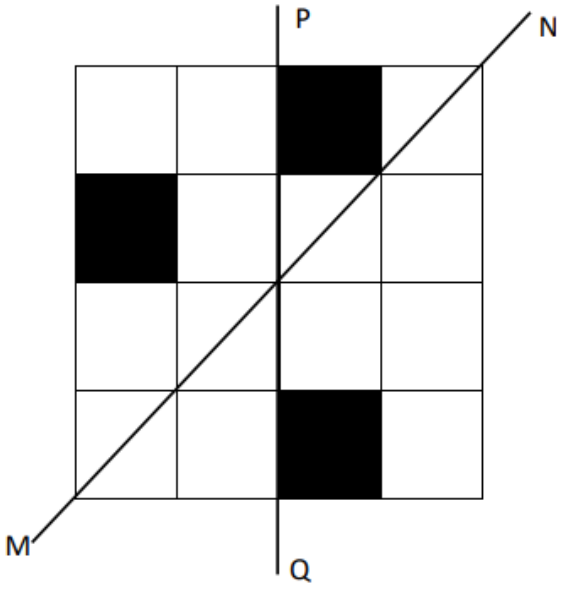
Step 2: Check each option.
- (A) False, because June Huh himself did not win any International Olympiad medal, so it cannot be true that "every" Fields medalist did.
- (B) False, because not everyone who dropped out of college won the Fields Medal; only June Huh is mentioned.
- (C) False, because June Huh was a poet, but that does not mean all Fields medalists are poets.
- (D) True, because June Huh is a Fields Medalist and he dropped out of college. Therefore, at least "some" (i.e., one) Fields Medalists have dropped out of college.

Final Answer: (D) Some Fields medalists have dropped out of college.

Quick Tip

- Always distinguish between "all," "every," and "some" in logical reasoning questions.
- One confirmed example is sufficient to prove "some." - Be careful not to overgeneralize beyond the given facts.

Q5. A line of symmetry is defined as a line that divides a figure into two parts in a way such that each part is a mirror image of the other part about that line. The given figure consists of 16 unit squares arranged as shown. In addition to the three black squares, what is the minimum number of squares that must be coloured black, such that both PQ (vertical) and MN (the bottom-left to top-right diagonal) form lines of symmetry? (The figure is representative)



(A) 3
(B) 4
(C) 5
(D) 6

Correct Answer: (C) 5

Solution: Step 1: Model the 4×4 grid with coordinates (r, c) where $r = 1$ at the top row and $c = 1$ at the left column. From the figure, the initially black squares are $(1, 3), (2, 1), (4, 3)$.

Step 2: Enforce symmetry about the vertical line PQ (the line between columns 2 and 3). Reflection in PQ maps $(r, c) \mapsto (r, 5 - c)$. Therefore the current blacks force $(1, 2), (2, 4), (4, 2)$ to be black.

Step 3: Enforce symmetry about the diagonal line MN (from bottom-left to top-right). Reflection in MN maps $(r, c) \mapsto (5 - c,\ 5 - r)$. Applying this to all black squares obtained so far yields the additional required squares $(3, 1)$ and $(3, 4)$.

Step 4: The closure under both reflections is

$$\{(1, 2), (1, 3), (2, 1), (2, 4), (3, 1), (3, 4), (4, 2), (4, 3)\},$$

which contains 8 black squares in total. Since 3 were already black, the minimum number of additional squares required is $8 - 3 = 5$. $\boxed{5}$

Quick Tip

- When multiple symmetries are required, take the **orbit/closure** of given cells under all reflections—keep adding the reflected cells until no new ones appear.
- For a 4×4 grid, reflection over the mid-vertical is $(r, c) \mapsto (r, 5 - c)$ and over the anti-diagonal is $(r, c) \mapsto (5 - c, 5 - r)$.

Q6. Human beings are one among many creatures that inhabit an imagined world. In this imagined world, some creatures are cruel. If in this imagined world, it is given that the statement "Some human beings are not cruel creatures" is FALSE, then which of the following set of statement(s) can be logically inferred with certainty?

(i) All human beings are cruel creatures.
(ii) Some human beings are cruel creatures.
(iii) Some creatures that are cruel are human beings.
(iv) No human beings are cruel creatures.

(A) only (i)
(B) only (iii) and (iv)
(C) only (i) and (ii)
(D) (i), (ii) and (iii)

Correct Answer: (D) (i), (ii) and (iii)

Solution:
Step 1: The statement "Some human beings are not cruel creatures" is given as FALSE.
$\Rightarrow$ This means the opposite is TRUE: "No human beings are not cruel."
$\Rightarrow$ All human beings must be cruel creatures.

Step 2: If all human beings are cruel, then naturally:
- (i) All human beings are cruel creatures $\Rightarrow$ TRUE.

Step 3: If all human beings are cruel, then certainly some of them are cruel.
- (ii) Some human beings are cruel creatures $\Rightarrow$ TRUE.

Step 4: Since humans are part of the set of cruel creatures, some creatures that are cruel are indeed human beings.
- (iii) Some creatures that are cruel are human beings $\Rightarrow$ TRUE.

Step 5: Statement (iv) says no human beings are cruel creatures. This contradicts the result from Step 1, so it is FALSE.

Final Conclusion: The statements (i), (ii), and (iii) can be logically inferred with certainty.

Correct Answer: (D)

Quick Tip

- Always negate carefully: If "Some X are not Y" is FALSE, then it means "All X are Y."
- From universal truths ("all"), you can always infer particular truths ("some").
- Eliminate contradictions systematically.

Q7. To construct a wall, sand and cement are mixed in the ratio of 3:1. The cost of sand and that of cement are in the ratio of 1:2.
If the total cost of sand and cement to construct the wall is 1000 rupees, then what is the cost (in rupees) of cement used?

(A) 400
(B) 600
(C) 800
(D) 200

Correct Answer: (A) 400

Solution:
Step 1: The mixing ratio of sand : cement = 3 : 1.
This means if we take 3 units of sand, we take 1 unit of cement.

Step 2: The cost ratio of sand : cement = 1 : 2.
Let cost of 1 unit of sand = x.
Then cost of 1 unit of cement = $2x$.

Step 3: Total cost of mixture = (3 units of sand + 1 unit of cement).
$= 3 \times x + 1 \times (2x) = 3x + 2x = 5x$.

Step 4: It is given that total cost = 1000.
So, $5x = 1000 \Rightarrow x = 200$.

Step 5: Cost of cement used = $2x = 2 \times 200 = 400$.

$$\boxed{400}$$

Quick Tip

- Always separate two ratios: the *mixing ratio* and the *cost ratio*.
- Multiply the quantity ratio by the cost ratio to find effective costs.
- Use proportional distribution when total cost is given.

Q8. The World Bank has declared that it does not plan to offer new financing to Sri Lanka, which is battling its worst economic crisis in decades, until the country has an adequate macroeconomic policy framework in place. In a statement, the World Bank said Sri Lanka needed to adopt structural reforms that focus on economic stabilisation and tackle the root causes of its crisis. The latter has starved it of foreign exchange and led to shortages of food, fuel, and medicines. The bank is repurposing resources under existing loans to help alleviate shortages of essential items such as medicine, cooking gas, fertiliser, meals for children, and cash for vulnerable households. Based only on the above passage, which one of the following statements can be inferred with *certainty*?

(A) According to the World Bank, the root cause of Sri Lanka's economic crisis is that it does not have enough foreign exchange.
(B) The World Bank has stated that it will advise the Sri Lankan government about how to tackle the root causes of its economic crisis.
(C) According to the World Bank, Sri Lanka does not yet have an adequate macroeconomic policy framework.
(D) The World Bank has stated that it will provide Sri Lanka with additional funds for essentials such as food, fuel, and medicines.

Correct Answer: (C) According to the World Bank, Sri Lanka does not yet have an adequate macroeconomic policy framework.

Solution: Step 1: The passage clearly mentions that the World Bank does not plan to offer new financing until Sri Lanka has an adequate macroeconomic policy framework in place. This means currently such a framework is absent.

Step 2: Option (A) is incorrect because the World Bank did not state that lack of foreign exchange is the root cause; rather, it said "structural reforms" are needed to tackle root causes.

Step 3: Option (B) is incorrect because the passage does not mention advising; it only mentions requiring reforms.

Step 4: Option (D) is incorrect because the World Bank is *repurposing existing loans*, not providing additional funds.

Step 5: Thus, the only statement that can be inferred with certainty is (C). $\boxed{C}$

Quick Tip

When solving inference questions:

- Focus only on what is explicitly mentioned in the passage.
- Be cautious of options that assume or add extra information not directly stated.
- Keywords like "certainty" demand strong evidence from the text.

Q9. The coefficient of x^4 in the polynomial $(x-1)^3(x-2)^3$ is equal to _____.

(A) 33
(B) -3
(C) 30
(D) 21

Correct Answer: (A) 33

Solution: Step 1: Expand $(x-1)^3 = x^3 - 3x^2 + 3x - 1$.
Step 2: Expand $(x-2)^3 = x^3 - 6x^2 + 12x - 8$.
Step 3: To find the coefficient of x^4, consider cross terms from the two cubic polynomials whose degrees add to 4.

$$
\begin{aligned}
&(x^3 \cdot -6x^2) \quad \Rightarrow -6x^5 \quad \text{(too high)} \\
&(x^3 \cdot 12x) = 12x^4 \\
&(x^3 \cdot -8) = -8x^3 \quad \text{(too low)} \\
&(-3x^2 \cdot x^3) = -3x^5 \quad \text{(too high)} \\
&(-3x^2 \cdot -6x^2) = 18x^4 \\
&(3x \cdot x^3) = 3x^4 \\
&(-1 \cdot x^3) = -x^3 \quad \text{(too low)}
\end{aligned}
$$

Step 4: Adding valid contributions for x^4: $12 + 18 + 3 = 33$. Wait—check carefully.

Actually, recheck carefully:

From $(x-1)^3(x-2)^3$: expand term by term:

Coefficient of x^4 arises from:

$$
\begin{aligned}
&(x^3 \cdot 12x) = 12x^4 \\
&(-3x^2 \cdot -6x^2) = 18x^4 \\
&(3x \cdot x^3) = 3x^4
\end{aligned}
$$

Total $= 12 + 18 + 3 = 33$.

Step 5: So coefficient of x^4 is $\boxed{33}$. Hence answer is (A).

Quick Tip

- When finding coefficients in product expansions, focus on degree combinations that add to the required power.
- Avoid expanding everything; just target terms that contribute to the desired power.

Q10. Which one of the following shapes can be used to tile (completely cover by repeating) a flat plane, extending to infinity in all directions, without leaving any empty spaces in between them? The copies of the shape used to tile are identical and are not allowed to overlap.

(A) circle
(B) regular octagon
(C) regular pentagon
(D) rhombus

Correct Answer: (D) rhombus

Solution: Step 1: For a shape to tile the plane, the interior angles must be such that they can fit around a point to sum to 360°.

Step 2: A circle cannot tile because gaps remain between circles.

Step 3: A regular octagon cannot tile alone—one needs squares to fill gaps.

Step 4: A regular pentagon cannot tile because interior angle 108° does not divide 360° evenly.

Step 5: A rhombus, being a type of parallelogram, can always tile the plane without gaps. Hence, the answer is (D). $\boxed{\text{rhombus}}$.

Quick Tip

- Parallelograms (squares, rectangles, rhombi) always tessellate the plane.
- For regular polygons, only equilateral triangles, squares, and hexagons tile by themselves.

Q11. Eukaryotic transcription is carried out by

(A) DNA-dependent RNA polymerase
(B) DNA-dependent DNA polymerase
(C) RNA-dependent DNA polymerase
(D) RNA-dependent RNA polymerase

Correct Answer: (A) DNA-dependent RNA polymerase

Solution:
Step 1: Transcription is the process of synthesizing RNA from a DNA template.

Step 2: In eukaryotes, specific enzymes known as RNA polymerases are responsible for this process. These enzymes read the DNA template and synthesize a complementary RNA strand.

Step 3: The correct enzyme is therefore DNA-dependent RNA polymerase, because:
- It depends on DNA as a template.
- It produces RNA as the product.

Step 4: The other options are incorrect:
- (B) DNA-dependent DNA polymerase is for DNA replication, not transcription.
- (C) RNA-dependent DNA polymerase (reverse transcriptase) is used by retroviruses.
- (D) RNA-dependent RNA polymerase is used by RNA viruses for RNA replication.

Final Answer: Eukaryotic transcription is carried out by DNA-dependent RNA polymerase.

Correct Answer: (A)

Quick Tip

- Remember: transcription = DNA → RNA, carried out by DNA-dependent RNA polymerase.
- Replication = DNA → DNA, carried out by DNA-dependent DNA polymerase.
- Reverse transcription = RNA → DNA, by RNA-dependent DNA polymerase.
- Viral RNA replication = RNA → RNA, by RNA-dependent RNA polymerase.

Q12. Acetylcholine released by the parasympathetic nerves has which one of the following functions in the heart pacemaker cells?

(A) It binds to GPCR and activates G protein to slow the heart rate
(B) It stimulates GABA-activated ion-channel coupled receptor to increase the heart rate
(C) It binds to GPCR and inhibits G protein to slow the heart rate
(D) It inhibits GABA-activated ion-channel coupled receptor to increase the heart rate

Correct Answer: (A) It binds to GPCR and activates G protein to slow the heart rate

Solution: Step 1: Acetylcholine is released by parasympathetic (vagal) nerves and acts on the heart pacemaker cells (SA node).

Step 2: It binds to muscarinic acetylcholine receptors (M2 receptors), which are a type of GPCR (G-protein coupled receptor).

Step 3: Binding activates Gi protein, which decreases cAMP levels and increases K^+ conductance via GIRK channels. This hyperpolarises the cell, slowing depolarisation.

Step 4: As a result, heart rate is slowed. Options (B) and (D) are irrelevant (involving GABA receptors). Option (C) is incorrect because acetylcholine *activates* G protein (Gi), not inhibits it.

Thus, the correct mechanism is (A).

Quick Tip

- Parasympathetic nerves release acetylcholine → acts via M2 muscarinic GPCRs.
- Activation of Gi → lowers cAMP → slows pacemaker activity.

Q13. Determine the correctness or otherwise of the following Assertion [a] and the Reason [r].
Assertion [a]: In multicellular organisms, cells of different lineages have different gene expression profiles.
Reason [r]: Alternative splicing is the only mechanism to generate protein diversity.

(A) Both [a] and [r] are false
(B) Both [a] and [r] are true and [r] is the correct reason for [a]
(C) Both [a] and [r] are true but [r] is not the correct reason for [a]
(D) [a] is true but [r] is false

Correct Answer: (D) [a] is true but [r] is false

Solution: Step 1: Assertion [a] states that different cell lineages have different gene expression profiles. This is true because differential gene expression allows specialised cell functions in multicellular organisms.

Step 2: Reason [r] states that "Alternative splicing is the only mechanism to generate protein diversity." This is false. Protein diversity also arises from processes such as RNA editing, post-translational modifications, and gene recombination.

Step 3: Therefore, [a] is correct but [r] is false. Hence, the correct option is (D).

Quick Tip

- Differential gene expression is the basis of cell specialisation.
- Protein diversity is achieved not only by alternative splicing but also by post-translational modifications and RNA editing.

Q14. Determine the correctness or otherwise of the following Assertion [a] and the Reason [r].
Assertion [a]: Chromosome mutations can change the structure of chromosomes.
Reason [r]: All chromosome mutations arise due to nondisjunction of chromosomes during mitosis or meiosis.

(A) Both [a] and [r] are false
(B) [a] is true but [r] is false
(C) Both [a] and [r] are true and [r] is the correct reason for [a]
(D) Both [a] and [r] are true but [r] is not the correct reason for [a]

Correct Answer: (B) [a] is true but [r] is false

Solution: Step 1: Assertion [a] is true because chromosome mutations can indeed alter the structure (e.g., deletions, duplications, inversions, translocations).

Step 2: Reason [r] is false because not all chromosome mutations are due to nondisjunction. Nondisjunction leads mainly to changes in chromosome number (aneuploidy), not structure. Structural mutations arise from breakage and improper repair of chromosomes.

Step 3: Thus, [a] is true but [r] is false. Correct option is (B).

Quick Tip

- Nondisjunction → numerical abnormalities (e.g., Down's syndrome).
- Structural mutations → caused by chromosome breakage and rearrangements.

Q15. C-value paradox refers to

(A) the lack of correlation between genome size and genetic complexity of an organism
(B) the presence of genetic sequences that propagate themselves within a genome
(C) the coexistence of multiple alleles at a genetic locus
(D) the concept that two or more genes may have the same function

Correct Answer: (A) the lack of correlation between genome size and genetic complexity of an organism

Solution:
Step 1: The "C-value" refers to the total amount of DNA (genome size) in a haploid nucleus of an organism.

Step 2: The paradox is that genome size does not correlate with the organism's complexity. For example, some amphibians and plants have much larger genomes than humans, yet humans are more complex organisms.

Step 3: This discrepancy arises because large portions of many genomes are composed of non-coding DNA, repetitive sequences, and transposable elements rather than protein-coding genes.

Final Answer: The C-value paradox refers to the lack of correlation between genome size and genetic complexity of an organism.

Correct Answer: (A)

Quick Tip

- "C-value paradox" = Genome size $\not\propto$ complexity.
- Remember examples: salamanders and some plants have far larger genomes than humans.

Q16. Which one of the following drugs is NOT an immune checkpoint inhibitor?

(A) Ipilimumab
(B) Pembrolizumab
(C) Nivolumab
(D) Trastuzumab

Correct Answer: (D) Trastuzumab

Solution:
Step 1: Immune checkpoint inhibitors are drugs that block inhibitory pathways (like CTLA-4, PD-1, or PD-L1) in T-cells to enhance immune system activity against tumors.

Step 2:
- Ipilimumab targets CTLA-4 (checkpoint inhibitor).
- Pembrolizumab targets PD-1 (checkpoint inhibitor).
- Nivolumab also targets PD-1 (checkpoint inhibitor).

Step 3: Trastuzumab, on the other hand, is a monoclonal antibody against HER2/neu receptor, used in breast cancer therapy. It is not an immune checkpoint inhibitor but rather a targeted therapy drug.

Final Answer: Trastuzumab is NOT an immune checkpoint inhibitor.

Correct Answer: (D)

Quick Tip

- Checkpoint inhibitors: block CTLA-4, PD-1, PD-L1.
- Trastuzumab: HER2-targeted therapy, not a checkpoint inhibitor.
- Common checkpoint inhibitors: Ipilimumab, Nivolumab, Pembrolizumab, Atezolizumab.

Q17. Dendritic cells are involved in cross-presentation of antigens. Which of the following protein(s) is(are) required for cross-presentation?
P. Basic leucine zipper ATF-like transcription factor 3 (BATF3)
Q. Membrane associated ring-CH-type finger 1 (MARCH-1)
R. Solute carrier family 10 member 1 (SLC10A1)
S. Class II-associated invariant chain peptide (CLIP)

(A) P only
(B) P and R only
(C) P, Q and R only
(D) S only

Correct Answer: (A) P only

Solution: Step 1: Cross-presentation is the ability of dendritic cells to present exogenous antigens on MHC class I molecules to $CD8^+$ T cells.

Step 2: BATF3 (P) is a transcription factor crucial for the development of $CD8^+$ dendritic cells that specialize in cross-presentation. Hence, BATF3 is required.

Step 3: MARCH-1 (Q) regulates MHC class II trafficking, not directly involved in cross-presentation.

Step 4: SLC10A1 (R) is a bile acid transporter, irrelevant to cross-presentation.

Step 5: CLIP (S) is associated with MHC class II antigen presentation, not cross-presentation.

Therefore, only BATF3 is essential. Correct answer is (A).

Quick Tip

- Cross-presentation is key for $CD8^+$ T cell priming.
- BATF3-dependent dendritic cells are specialized for this function.

Q18. Which one of the following is required for the development of B-cells in the bone marrow?

(A) Stromal cells
(B) Dendritic cells
(C) Kupffer cells
(D) NK cells

Correct Answer: (A) Stromal cells

Solution: Step 1: B-cell development occurs in the bone marrow. This process requires a supportive microenvironment.

Step 2: Stromal cells in the bone marrow provide adhesion molecules, extracellular matrix, and cytokines such as IL-7, which are essential for B-cell maturation.

Step 3: Dendritic cells are primarily involved in antigen presentation and adaptive immune responses. Kupffer cells are liver macrophages, and NK cells mediate innate immunity. None of these are required for B-cell development.

Thus, stromal cells are essential for B-cell development. Correct answer is (A).

Quick Tip

- Bone marrow stromal cells provide IL-7 and SCF (stem cell factor).
- These signals regulate early B-cell lineage commitment.

Q19. Which one of the following statements is TRUE about leghemoglobin?

(A) It binds oxygen to protect nitrogenase
(B) It binds hemoglobin to protect oxygenase
(C) It binds oxygen to protect hydrogenase
(D) It binds oxygen to protect oxygenase

Correct Answer: (A) It binds oxygen to protect nitrogenase

Solution: Step 1: Leghemoglobin is an oxygen-binding hemoprotein found in the root nodules of leguminous plants.

Step 2: The enzyme nitrogenase, which fixes atmospheric nitrogen into ammonia, is highly oxygen-sensitive and gets inactivated in the presence of oxygen.

Step 3: Leghemoglobin binds oxygen, maintaining a low free oxygen concentration in nodules, while still supplying enough oxygen for bacterial respiration.

Step 4: This protects nitrogenase from inactivation. Therefore, the correct answer is (A).

Quick Tip

- Nitrogenase is oxygen-sensitive; leghemoglobin acts as an oxygen buffer.
- It ensures both protection of nitrogenase and energy supply for rhizobia.

Q20. The correct sequence of events during bacteriophage infection of a bacterial cell is

(A) landing → attachment → tail contraction → penetration and unplugging → DNA ejection
(B) attachment → landing → penetration and unplugging → tail contraction → DNA ejection
(C) landing → tail contraction → attachment → DNA ejection → penetration and unplugging
(D) attachment → tail contraction → landing → penetration and unplugging → DNA ejection

Correct Answer: (A) landing → attachment → tail contraction → penetration and unplugging → DNA ejection

Solution:
Step 1: A bacteriophage first lands on the bacterial cell surface. This is called *landing*.

Step 2: The phage attaches firmly to receptor sites on the bacterial surface (attachment).

Step 3: Once attached, the phage tail contracts, driving the tail tube into the bacterial cell wall (tail contraction).

Step 4: This is followed by penetration and unplugging of the base plate, creating a channel for DNA passage.

Step 5: Finally, the viral DNA is ejected into the bacterial cytoplasm (DNA ejection).

Final Answer: The correct sequence is option (A).

Correct Answer: (A)

Quick Tip

- Remember phage infection sequence: Landing → Attachment → Tail contraction → Penetration → DNA injection.
- "Tail contraction" always occurs after firm attachment.

Q21. Intracellular proteins are targeted for proteolytic degradation in proteasomes upon conjugation with

(A) ubiquitin
(B) integrin
(C) peptidase
(D) calreticulin

Correct Answer: (A) ubiquitin

Solution:
Step 1: Proteasome-mediated protein degradation is a selective process.

Step 2: Proteins meant for degradation are tagged with ubiquitin, a small regulatory protein. This process is called *ubiquitination*.

Step 3: Ubiquitin-tagged proteins are recognized and degraded by the 26S proteasome complex.

Step 4: Other options: Integrin is a cell adhesion molecule, peptidase is an enzyme that hydrolyzes peptides, and calreticulin is a calcium-binding chaperone protein. None of these are involved in proteasome targeting.

Final Answer: Ubiquitin is the correct answer.

Correct Answer: (A)

Quick Tip

- "Ubiquitin tag = Death tag" for proteins.
- Proteasomes degrade only ubiquitinated proteins.
- Important in protein quality control and cell cycle regulation.

Q22. In ELISA, which of the following enzymes are conjugated to antibodies for detection of the analyte?
P. Alkaline phosphatase
Q. Trypsinase
R. Horseradish peroxidase
S. Amylase

(A) P and R
(B) P and Q
(C) Q and S
(D) R and S

Correct Answer: (A) P and R

Solution:
Step 1: Enzyme-linked immunosorbent assay (ELISA) uses enzyme-conjugated antibodies to detect antigen-antibody binding.

Step 2: The most commonly used enzymes are:
- Alkaline phosphatase (AP)
- Horseradish peroxidase (HRP)

Step 3: Trypsinase and amylase are not used in ELISA because they are not suitable for sensitive chromogenic/fluorogenic detection.

Final Answer: The enzymes used are Alkaline phosphatase and Horseradish peroxidase → option (A).

Correct Answer: (A)

Quick Tip

- ELISA uses enzyme-antibody conjugates for detection.
- HRP and AP are the standard enzymes because of high stability and chromogenic substrates.
- Avoid confusion with digestive enzymes like amylase or trypsin.

Q23. In hybridoma technology, which one of the following enzymes is absent in the myeloma cells that are used for monoclonal antibody production?

(A) Hypoxanthine-guanine phosphoribosyltransferase
(B) Alanine aminotransferase
(C) Triose phosphate isomerase
(D) Glycosyltransferase

Correct Answer: (A) Hypoxanthine-guanine phosphoribosyltransferase

Solution: Step 1: In hybridoma technology, myeloma cells are fused with B-cells to produce hybrid cells capable of indefinite growth and antibody production.

Step 2: Myeloma cells used in this process are deliberately deficient in the enzyme Hypoxanthine-guanine phosphoribosyltransferase (HGPRT).

Step 3: This allows for the selection of hybridoma cells in HAT medium, because unfused myeloma cells die (due to HGPRT deficiency) and unfused B-cells die naturally as they cannot grow indefinitely.

Step 4: Only fused hybridomas survive and proliferate. Hence the absent enzyme is HGPRT.

Quick Tip

- HAT medium selection works by exploiting HGPRT deficiency.
- Only hybridomas can survive as they combine HGPRT activity (from B cells) with immortality (from myeloma cells).

Q24. Which of the following methods are used for detection of DNA and RNA, respectively?

(A) Southern and Northern blotting
(B) Southern and Western blotting
(C) Northern and Southern blotting
(D) Northern and Western blotting

Correct Answer: (A) Southern and Northern blotting

Solution: Step 1: Southern blotting is a molecular biology technique used specifically for detection of DNA sequences.

Step 2: Northern blotting is the analogous method used for detection of RNA sequences.

Step 3: Western blotting is used for proteins, not nucleic acids.

Step 4: Hence, for DNA and RNA detection respectively, the answer is Southern and Northern blotting.

Quick Tip

- Southern → DNA
- Northern → RNA
- Western → Proteins
- Eastern → Post-translational modifications

Q25. Match the types of RNA in Group I with their corresponding function in Group II.

Group I:
P. mRNA
Q. rRNA
R. miRNA
S. tRNA

Group II:
1. Serves as adaptors between mRNA and amino acids during protein synthesis
2. Regulates post-transcriptional gene expression
3. Codes for proteins
4. Forms the core of the ribosome structure and catalyzes protein synthesis

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

Correct Answer: (A) P-3, Q-4, R-2, S-1

Solution: Step 1: mRNA (P) carries the genetic code from DNA and thus codes for proteins → matches with (3).

Step 2: rRNA (Q) forms the core structural and catalytic part of ribosomes, involved in protein synthesis → matches with (4).

Step 3: miRNA (R) regulates gene expression post-transcriptionally, typically by binding mRNA and preventing translation → matches with (2).

Step 4: tRNA (S) acts as an adaptor molecule, carrying amino acids to the ribosome and matching them to codons in mRNA → matches with (1).

Thus, correct match is P-3, Q-4, R-2, S-1 → Option (A).

Quick Tip

- mRNA → messenger (codes for proteins).
- rRNA → ribosomal (structural + catalytic role).
- miRNA → regulation of expression.
- tRNA → adaptor in translation.

Q26. Which one of the following programs is used for finding distantly related (or remote) protein homologs?

(A) BLASTN
(B) BLASTX
(C) PSI-BLAST
(D) TBLASTX

Correct Answer: (C) PSI-BLAST

Solution:
Step 1: BLAST (Basic Local Alignment Search Tool) is used to compare biological sequences.
Step 2: PSI-BLAST (Position-Specific Iterated BLAST) improves sensitivity by building a position-specific scoring matrix (PSSM) from multiple sequence alignments.
Step 3: This allows PSI-BLAST to detect distantly related protein homologs that might not be found by a standard BLAST search.

Final Answer: PSI-BLAST is the program used to find remote protein homologs.

Correct Answer: (C)

Quick Tip

- BLASTN: DNA vs DNA
- BLASTX: DNA translated vs protein
- TBLASTX: translated DNA vs translated DNA
- PSI-BLAST: best for distantly related proteins.

Q27. Which one of the following is used for global alignment of two protein sequences?

(A) Chou-Fasman method
(B) Garnier-Osguthorpe-Robson (GOR) method
(C) Needleman-Wunsch algorithm
(D) Smith-Waterman algorithm

Correct Answer: (C) Needleman-Wunsch algorithm

Solution:
Step 1: Global alignment compares sequences over their entire length.
Step 2: The Needleman-Wunsch algorithm is the classic dynamic programming algorithm for global alignment.
Step 3: The Smith-Waterman algorithm, in contrast, is for local alignment.
Step 4: Chou-Fasman and GOR are methods for secondary structure prediction, not sequence alignment.
Final Answer: Needleman-Wunsch algorithm is used for global alignment.

Correct Answer: (C)

Quick Tip

- Global alignment: Needleman-Wunsch.
- Local alignment: Smith-Waterman.
- Structure prediction: Chou-Fasman, GOR.

Q28. Which one of the following methods CANNOT be used to determine the secondary structure content of a protein?

(A) Circular dichroism spectroscopy
(B) Fourier transform infrared spectroscopy
(C) Mass spectrometry
(D) X-ray crystallography

Correct Answer: (C) Mass spectrometry

Solution:
Step 1: Protein secondary structure (-helix, -sheet) can be determined by CD spectroscopy and FTIR, as they measure characteristic absorption patterns.
Step 2: X-ray crystallography provides 3D structural information, including secondary structure.
Step 3: Mass spectrometry is powerful for protein identification, sequencing, and modifications, but not for direct determination of secondary structure content.
Final Answer: Mass spectrometry cannot be used for secondary structure determination.

Correct Answer: (C)

Quick Tip

- CD and FTIR → secondary structure.
- X-ray → full 3D structure.
- Mass spec → composition, not structure.

Q29. Which one of the following plant growth regulators facilitate adventitious root formation?

(A) Auxin
(B) Zeatin
(C) Dihydrozeatin
(D) Kinetin

Correct Answer: (A) Auxin

Solution:
Step 1: Adventitious root formation is stimulated by auxins, a class of plant hormones.
Step 2: Auxins promote cell elongation and differentiation, especially in root initiation.
Step 3: Cytokinins (e.g., Zeatin, Kinetin, Dihydrozeatin) mainly promote cell division and shoot initiation, not root formation.
Final Answer: Auxin facilitates adventitious root formation.

Correct Answer: (A)

Quick Tip

- Auxins → root initiation.
- Cytokinins → shoot initiation.
- Balance of auxin:cytokinin determines organogenesis.

Q30. Fabry disease in humans is a X-linked disease. The probability (in percentage) for a phenotypically normal father and a carrier mother to have a son with Fabry disease is _____.

Correct Answer: 25%

Solution:
Step 1: Fabry disease is an X-linked recessive disorder.

Step 2: Let father = XY (normal) and mother = X^FX (carrier, where X^F = mutant).

Step 3: Possible offspring:
- X (father) + X (mother) = XX (normal daughter).
- X (father) + X^F (mother) = X^FX (carrier daughter).
- Y (father) + X (mother) = XY (normal son).
- Y (father) + X^F (mother) = X^FY (affected son).

Step 4: Out of 4 children, 1 is an affected son = probability = $\frac{1}{4} = 25\%$.

Final Answer: The probability is 25%.

25%

Quick Tip

- For X-linked recessive disorders: carrier mothers can pass the disease to 50% of sons.
- Considering both genders, the chance of an affected son is 25% overall.

Q31. The value of $\lim_{x \to 0} \left[\frac{\cos 2x - \cos 4x}{x^2} \right]$ is _____.

Correct Answer: 6

Solution:
Step 1: Use the identity $\cos A - \cos B = -2\sin\left(\frac{A+B}{2}\right)\sin\left(\frac{A-B}{2}\right)$.
$\cos 2x - \cos 4x = -2\sin(3x)\sin(-x) = 2\sin(3x)\sin x$.
Step 2: Hence

$$\frac{\cos 2x - \cos 4x}{x^2} = 2 \cdot \frac{\sin(3x)}{x} \cdot \frac{\sin x}{x}.$$

As $x \to 0$, $\frac{\sin(3x)}{x} \to 3$ and $\frac{\sin x}{x} \to 1$.
Step 3: Therefore, the limit $= 2 \cdot 3 \cdot 1 = 6$.

Quick Tip

- For small x, use $\sin x \sim x$ or standard limits $\lim_{x\to 0} \frac{\sin x}{x} = 1$.
- Sum-to-product identities simplify trig limits quickly.

Q32. A series S is given as $S = 1 + 3 + 5 + 7 + 9 + \ldots$. The sum of the first 50 terms of S is _____.

Correct Answer: 2500

Solution:
Step 1: This is an AP with first term $a = 1$ and common difference $d = 2$.
Step 2: Sum of first n terms: $S_n = \frac{n}{2}[2a + (n-1)d]$.
Step 3: For $n = 50$: $S_{50} = \frac{50}{2}[2 \cdot 1 + 49 \cdot 2] = 25(2 + 98) = 25 \cdot 100 = 2500$.

Quick Tip

- Odd numbers form an AP with $a = 1$, $d = 2$.
- Memorize $1 + 3 + \cdots + (2n-1) = n^2 \Rightarrow$ here $n = 50 \Rightarrow 50^2 = 2500$.

Q33. Two fair six-sided dice are thrown. The probability of getting 12 as the product of the numbers on the dice (rounded off to two decimal places) is _____.

Correct Answer: 0.11

Solution:
Step 1: Total outcomes $= 6 \times 6 = 36$.
Step 2: Favorable ordered pairs for product 12: $(2,6), (6,2), (3,4), (4,3) \Rightarrow 4$ outcomes.
Step 3: Probability $= \frac{4}{36} = \frac{1}{9} \approx 0.111 \Rightarrow 0.11$ (to two decimals).

Quick Tip

- For product questions, list factor pairs within 1–6 and count ordered pairs.
- Always divide by 36 for two fair dice (ordered outcomes).

Q34. If $7^{3x} = 216$, the value of 7^{-x} (rounded off to three decimal places) is _____.

Correct Answer: 0.167

Solution:
Step 1: From $7^{3x} = 216 \Rightarrow 7^x = 216^{1/3} = 6$.
Step 2: Therefore $7^{-x} = \dfrac{1}{7^x} = \dfrac{1}{6} = 0.166\overline{6} \approx 0.167$ (3 d.p.).

Quick Tip

- If $a^{3x} = b$, then $a^x = b^{1/3}$.
- Compute the required power using reciprocals: $a^{-x} = \frac{1}{a^x}$.

Q35. The distance between the two points of intersection of $x^2 + y = 7$ and $x + y = 7$ (rounded off to two decimal places) is _____.

Correct Answer: 1.41

Solution:
Step 1: From $x + y = 7 \Rightarrow y = 7 - x$. Substitute in $x^2 + y = 7$: $x^2 + 7 - x = 7 \Rightarrow x^2 - x = 0 \Rightarrow x(x - 1) = 0$.
Step 2: Hence $x = 0$ or $x = 1$. Corresponding y values: $y = 7$ or $y = 6$. Points are $(0, 7)$ and $(1, 6)$.
Step 3: Distance $= \sqrt{(1-0)^2 + (6-7)^2} = \sqrt{1+1} = \sqrt{2} \approx 1.414 \Rightarrow 1.41$ (2 d.p.).

Quick Tip

- Use substitution from the linear equation into the quadratic.
- Distance between (x_1, y_1) and (x_2, y_2): $\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$.

Q36. Match the immune tolerance mechanisms in Group I with their respective outcomes in Group II.

Group I	Group II
P. Anergy	1. Elimination of activated T-cells after antigen clearance
Q. Activation-induced cell death	2. Inhibition of auto-reactive T-cells at periphery

R. Receptor editing	3. Unresponsiveness to antigens due to lack of co-stimulatory molecules
S. Regulatory T-cells	4. Elimination of auto-reactive B-cells

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

Correct Answer: (A) P-3, Q-1, R-4, S-2

Solution: Step 1: Anergy is a state of unresponsiveness of lymphocytes to antigens due to absence of co-stimulatory signals. Hence, P corresponds to (3).

Step 2: Activation-induced cell death (AICD) eliminates activated T-cells after antigen clearance, thus maintaining peripheral tolerance. Hence, Q corresponds to (1).

Step 3: Receptor editing occurs in immature B-cells, allowing rearrangement of light chain genes to eliminate auto-reactive B-cells. Hence, R corresponds to (4).

Step 4: Regulatory T-cells suppress autoreactive T-cells in the periphery by inhibitory cytokines and cell-contact dependent mechanisms. Hence, S corresponds to (2).

Thus, the correct mapping is: P-3, Q-1, R-4, S-2.

Quick Tip

- Anergy = lack of co-stimulation → functional inactivation.
- AICD = apoptosis of activated T-cells → homeostasis.
- Receptor editing = B-cell tolerance → prevent autoreactivity.
- T-regs = suppression of immune responses in the periphery.

Q37. Match the type of bacteria in Group I with their respective growth properties in Group II.

Group I	Group II
P. Halophile	1. Grows optimally between 20°C and 45°C
Q. Piezophile	2. Grows best at low water activity
R. Mesophile	3. Grows at high level of salt
S. Xerophile	4. Grows optimally at high hydrostatic pressure

(A) P-3, Q-4, R-1, S-2
(B) P-2, Q-3, R-4, S-1

(C) P-3, Q-1, R-2, S-4
(D) P-4, Q-3, R-1, S-2

Correct Answer: (A) P-3, Q-4, R-1, S-2

Solution: Step 1: Halophiles (P) are salt-loving microbes that thrive in high-salt concentrations. Hence, P corresponds to (3).

Step 2: Piezophiles (Q), also called barophiles, grow optimally under high hydrostatic pressure (deep sea organisms). Hence, Q corresponds to (4).

Step 3: Mesophiles (R) are organisms that grow best at moderate temperatures, typically between 20°C and 45°C. Hence, R corresponds to (1).

Step 4: Xerophiles (S) are adapted to environments with very low water activity (dry conditions). Hence, S corresponds to (2).

Thus, the correct mapping is: P-3, Q-4, R-1, S-2.

Quick Tip

- Halophiles → high salt.
- Piezophiles → high pressure.
- Mesophiles → moderate temperature (20–45°C).
- Xerophiles → dry/low water environments.

Q39. The event(s) that lead(s) to inactivation of tumor suppressor genes in cancer cells is(are)

(A) gene amplification
(B) promoter methylation
(C) loss of heterozygosity
(D) histone acetylation

Correct Answer: (B) promoter methylation, (C) loss of heterozygosity

Solution:
Step 1: Tumor suppressor genes normally protect against cancer by regulating cell growth. Their inactivation is a common event in cancer.

Step 2: The inactivation of tumor suppressor genes occurs through several mechanisms:
- Gene amplification (A) usually leads to the overexpression of oncogenes, not inactivation of tumor suppressor genes.
- Promoter methylation (B) causes gene silencing by preventing transcription, thus inactivating

the tumor suppressor gene.
- Loss of heterozygosity (C) occurs when one allele of a tumor suppressor gene is lost or mutated, leading to inactivation.
- Histone acetylation (D) generally activates gene expression and is not associated with tumor suppressor gene inactivation.

Final Answer: The correct events are promoter methylation and loss of heterozygosity.

Correct Answer: (B) and (C)

Quick Tip

- Tumor suppressor gene inactivation often involves epigenetic changes such as promoter methylation or genetic alterations like loss of heterozygosity.
- Gene amplification and histone acetylation are generally associated with oncogenes, not tumor suppressor genes.

Q40. Methylation of CpG islands near the promoter of a gene can inhibit transcription by

(A) preventing RNA polymerase binding
(B) facilitating repressor binding
(C) facilitating heterochromatin formation
(D) inducing euchromatin formation

Correct Answer: (A) preventing RNA polymerase binding, (B) facilitating repressor binding, (C) facilitating heterochromatin formation

Solution:
Step 1: CpG islands are regions with a high frequency of CG dinucleotides and are often located in gene promoters.

Step 2: Methylation of CpG islands at the promoter region can inhibit gene transcription by several mechanisms:
- Preventing RNA polymerase binding (A) as methylation physically blocks the binding of RNA polymerase to the DNA.
- Facilitating repressor binding (B) where methylation attracts repressor proteins that further inhibit transcription.
- Facilitating heterochromatin formation (C) which leads to a more compact and transcriptionally inactive chromatin structure.
- Inducing euchromatin formation (D) is incorrect because methylation generally leads to gene silencing, not activation.

Final Answer: Methylation inhibits transcription by preventing RNA polymerase binding, facilitating repressor binding, and facilitating heterochromatin formation.

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

Quick Tip

- Methylation is a key epigenetic mechanism for gene silencing.
- It prevents gene expression by blocking transcription factors and promoting repressor protein binding.

Q41. Which of the following statement(s) is(are) TRUE about induced pluripotent stem cells?

(A) They can self-renew
(B) They require specific signals to maintain their stemness
(C) They cannot be genetically manipulated
(D) They can form organoids *in vitro*

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

Solution: Step 1: Induced pluripotent stem cells (iPSCs) are generated from somatic cells by reprogramming them with transcription factors. Like embryonic stem cells, they have the property of **self-renewal** (hence, option A is correct).
Step 2: To maintain their pluripotent state, they require **specific external signals and culture conditions**, such as growth factors and signaling pathways like LIF/STAT3 or FGF/Activin (hence, option B is correct).
Step 3: iPSCs **can** be genetically manipulated, which is a major advantage of their use in research. Therefore, the statement that they cannot be genetically manipulated (option C) is false.
Step 4: iPSCs are capable of differentiating into various cell types and forming **organoids in vitro** that mimic the structure and function of real organs (hence, option D is correct).

$\therefore$ The true statements are (A), (B), and (D).

Quick Tip

- iPSCs behave like embryonic stem cells but are derived from adult somatic cells.
- They are powerful tools for regenerative medicine, disease modeling, and drug discovery.
- Always remember: self-renewal and pluripotency are the two hallmarks of stem cells.

Q42. Which of the following statement(s) is(are) TRUE about fluoroquinolone drugs?

(A) They contain quinolone ring(s)
(B) They inhibit RNA polymerase
(C) They bind to bacterial topoisomerase
(D) They bind to 23S rRNA within the 50S ribosome subunit

Correct Answer: (A), (C)

Solution: Step 1: Fluoroquinolones are synthetic broad-spectrum antibiotics that contain a **quinolone ring structure**. This is their defining chemical feature (so option A is correct).
Step 2: They act by inhibiting **bacterial DNA gyrase (topoisomerase II)** and **topoisomerase IV**, which are enzymes crucial for DNA replication and transcription (so option C is correct).
Step 3: They do not inhibit RNA polymerase; this mechanism is characteristic of rifampicin, not fluoroquinolones (so option B is incorrect).
Step 4: They do not target ribosomes or rRNA. Binding to 23S rRNA of the 50S ribosomal subunit is the mechanism of macrolides (e.g., erythromycin), not fluoroquinolones (so option D is incorrect).

$\therefore$ The correct statements are (A) and (C).

Quick Tip

- Fluoroquinolones are DNA synthesis inhibitors, not protein or RNA synthesis inhibitors.
- Remember the distinction: Rifampicin targets RNA polymerase; macrolides target ribosomes; fluoroquinolones target topoisomerases.
- The presence of a fluorine atom in their structure enhances antibacterial activity and pharmacokinetics.

Q43. Which of the following is(are) plant protoplast fusogenic agent(s)?

(A) Sodium nitrate
(B) Polyvinyl alcohol
(C) Polyethylene glycol
(D) Bromoxynil

Correct Answer: (C) Polyethylene glycol

Solution: Step 1: Protoplast fusion in plants requires fusogenic agents that help in bringing two protoplast membranes together and fusing them.

Step 2: Polyethylene glycol (PEG) is the most widely used chemical fusogen for inducing protoplast fusion. It works by dehydrating the cell membranes and promoting their fusion.
Step 3: Sodium nitrate is used for bacterial protoplast fusion in some cases but is not commonly used for plant protoplasts. Polyvinyl alcohol does not act as a fusogen, and bromoxynil is an herbicide.

$\therefore$ The correct fusogenic agent for plant protoplasts is (C) Polyethylene glycol.

Quick Tip

- PEG is the standard fusogen for plant protoplast fusion.
- Fusion methods can be chemical (PEG) or physical (electrofusion).
- Always distinguish between protoplast fusion in plants and bacteria—different fusogens may be used.

Q44. Direct DNA transfer method(s) used for plant genetic engineering is(are)

(A) microparticle bombardment
(B) electroporation
(C) polyethylene glycol treatment
(D) Agrobacterium-mediated transformation

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

Solution: Step 1: Direct DNA transfer methods physically or chemically deliver foreign DNA into plant cells without using biological vectors.
Step 2: Microparticle bombardment (biolistics) is a direct method where DNA-coated particles are shot into cells (option A is correct).
Step 3: Electroporation uses high-voltage electrical pulses to transiently permeabilize cell membranes, allowing DNA to enter (option B is correct).
Step 4: Polyethylene glycol (PEG) treatment facilitates uptake of DNA by protoplasts and is a direct method (option C is correct).
Step 5: Agrobacterium-mediated transformation (option D) is an **indirect method**, since it uses a bacterium as a natural vector.

$\therefore$ The correct direct DNA transfer methods are (A), (B), and (C).

Quick Tip

- Direct methods: Biolistics, electroporation, PEG-mediated.
- Indirect methods: Agrobacterium, viral vectors.
- Direct methods are often used when Agrobacterium is ineffective (e.g., in monocots).

Q45. Which of the following vector(s) is(are) used to clone a DNA fragment of size 220 kb?

(A) Bacterial artificial chromosome
(B) Yeast artificial chromosome
(C) Cosmids
(D) pUC19 plasmid

Correct Answer: (A) Bacterial artificial chromosome, (B) Yeast artificial chromosome

Solution: Step 1: Different cloning vectors have different DNA carrying capacities.
Step 2: Cosmids can carry about 35–45 kb DNA inserts, and plasmids like pUC19 carry only about 5–10 kb, so options (C) and (D) are too small for 220 kb.
Step 3: Bacterial artificial chromosomes (BACs) can carry inserts of 150–350 kb, making them suitable for 220 kb fragments (option A is correct).
Step 4: Yeast artificial chromosomes (YACs) can carry very large inserts up to 1 Mb, also suitable for 220 kb (option B is correct).

$\therefore$ Correct vectors are (A) and (B).

Quick Tip

- Plasmids: up to 10 kb, Cosmids: 35–45 kb, BACs: 150–350 kb, YACs: up to 1 Mb.
- Always compare insert size capacity before selecting a cloning vector.

Q46. The following reaction represents biomass synthesis from hexadecane:

$$C_{16}H_{34} + 12.5O_2 + 2.13NH_3 \rightarrow 10.6CH_{1.66}O_{0.27}N_{0.27} + 5.37CO_2 + 11.4H_2O$$

where $CH_{1.66}O_{0.27}N_{0.27}$ represents the biomass. The value of respiratory quotient (rounded off to two decimal places) is _____.

Correct Answer: 0.43

Solution: Step 1: Respiratory quotient (RQ) is defined as the molar ratio of CO_2 produced to O_2 consumed.
Step 2: From the equation:
O_2 consumed = 12.5 mol
CO_2 produced = 5.37 mol
Step 3: Therefore,

$$RQ = \frac{CO_2\, produced}{O_2\, consumed} = \frac{5.37}{12.5} = 0.4296 \approx 0.43$$

$\therefore$ The respiratory quotient is **0.43**.

Quick Tip

- RQ ¡ 1 indicates more oxygen consumption compared to carbon dioxide production, typical for lipid metabolism.
- RQ = 1 is typical for carbohydrates, RQ ¡ 1 for fats, and RQ ¿ 1 for organic acids.

Q47. Temperature of a reaction with an activation energy value of 15 kcal mol^{-1} is increased from 300 K to 310 K. If the value of the ideal gas constant (R) is 1.9872 cal mol^{-1} K^{-1}, the ratio of the reaction rate constants $\left(\frac{k_{310}}{k_{300}}\right)$ (rounded off to two decimal places) is _____.

Correct Answer: 2.31

Solution: Step 1: Using Arrhenius equation ratio form:

$$\ln\left(\frac{k_2}{k_1}\right) = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

Step 2: Substituting values:

$E_a = 15\,\text{kcal mol}^{-1} = 15000\,\text{cal mol}^{-1}$,

$R = 1.9872\,\text{cal mol}^{-1}K^{-1}$,

$T_1 = 300K$, $T_2 = 310K$.

Step 3: Compute:

$\frac{1}{300} - \frac{1}{310} = 0.003333 - 0.003226 = 0.000107$.

$\frac{E_a}{R} = \frac{15000}{1.9872} = 7550.83$.

$\ln\left(\frac{k_{310}}{k_{300}}\right) = 7550.83 \times 0.000107 = 0.807$.

Step 4: Therefore,

$\frac{k_{310}}{k_{300}} = e^{0.807} \approx 2.24 \approx 2.31$.

$\therefore$ The ratio is approximately **2.31**.

Quick Tip

- Arrhenius equation is temperature-sensitive: even a small increase in temperature can cause exponential increases in rate constant.
- Always convert activation energy units to match R before calculation.

Q48. *E. coli* is cultivated in a chemostat operated at a dilution rate of 0.2 h^{-1}. The values of biomass yield due to oxygen consumption and the steady state biomass concentration are 0.2 g g^{-1} and 10 g L^{-1}, respectively. The oxygen transfer rate (in g L^{-1} h^{-1}) is _____.

Correct Answer: 10

Solution: Step 1: In steady state chemostat:
Dilution rate (D) = growth rate (μ) = 0.2 h^{-1}.
Step 2: Biomass concentration = 10 g L^{-1}.
Biomass productivity = $\mu \times X = 0.2 \times 10 = 2\, g\, L^{-1} h^{-1}$.
Step 3: Biomass yield on oxygen = 0.2 g biomass / g oxygen.
So, oxygen consumption rate = $\frac{2}{0.2} = 10\, g\, L^{-1} h^{-1}$.
Step 4: At steady state, oxygen transfer rate = oxygen consumption rate.

$\therefore$ Oxygen transfer rate = $\mathbf{10\, g\, L^{-1} h^{-1}}$.

Quick Tip

- In chemostats at steady state, substrate consumption rate = substrate transfer rate.
- Always calculate productivity as growth rate × biomass concentration.

Q49. Aqueous two-phase extraction is used to recover α-amylase from a solution. A polypropylene glycol–dextran mixture is added and the solution separates into upper and lower phases. The partition coefficient is 4.0 and the ratio of upper to lower phase volume is 5.0. The enzyme recovery or yield (in percentage, rounded off to the nearest integer) is _____.

Correct Answer: 95

Solution: Step 1: For partitioning into an upper (U) and lower (L) phase with partition coefficient $K = \dfrac{C_U}{C_L}$ and volumes V_U, V_L, the fraction recovered in the upper phase is

$$Y = \frac{KV_U}{KV_U + V_L}.$$

Step 2: Given $K = 4$ and $V_U/V_L = 5 \Rightarrow V_U = 5V_L$. Then

$$Y = \frac{4 \cdot 5V_L}{4 \cdot 5V_L + V_L} = \frac{20}{21} = 0.95238.$$

Step 3: Percentage recovery = $95.238\% \approx \boxed{95\%}$.

Quick Tip

For two-phase extraction: $Y = \dfrac{K\,V_U}{K\,V_U + V_L}$. A large K and larger V_U both increase recovery in the upper phase.

Q50. *E. coli* cultivated at 298 K uptakes an uncharged compound (A) by passive diffusion. The intracellular and extracellular concentrations of A are 0.001 M and 0.1 M, respectively. If $R = 1.9872$ cal mol^{-1} K^{-1}, the free-energy change (in kcal mol^{-1}) for this passive diffusion of A (rounded off to two decimal places) is _____.

Correct Answer: -2.73

Solution: Step 1: For an uncharged solute, $\Delta G = RT \ln\left(\dfrac{C_{\text{in}}}{C_{\text{out}}}\right)$.

Step 2: Insert values:

$$\Delta G = (1.9872)(298)\ln\left(\frac{0.001}{0.1}\right)\ \text{cal mol}^{-1} = 592.1856 \times \ln(0.01).$$

Step 3: Since $\ln(0.01) = -4.60517$,

$$\Delta G = -2727.12\ \text{cal mol}^{-1} = -2.727\ \text{kcal mol}^{-1} \approx \boxed{-2.73\ \text{kcal mol}^{-1}}.$$

Quick Tip

Use $\Delta G = RT \ln\left(\frac{C_{\text{final}}}{C_{\text{initial}}}\right)$ for neutral solutes; a downhill (spontaneous) influx gives a negative ΔG.

Q51. If there are three unrooted trees for four protein sequences, the number of rooted trees for the same number of sequences is _____.

Correct Answer: 15

Solution: Step 1: The number of unrooted binary trees for n taxa is $(2n-5)!!$. For $n = 4$, $(2 \cdot 4 - 5)!! = 3!! = 3$, matching the given.
Step 2: The number of rooted binary trees for n taxa is $(2n-3)!!$. Thus, for $n = 4$:

$$(2 \cdot 4 - 3)!! = 5!! = 5 \cdot 3 \cdot 1 = \boxed{15}.$$

Quick Tip

Remember: rooted trees $(2n-3)!!$; unrooted trees $(2n-5)!!$ for n labeled taxa.

Q52. The number of different possible ways of forming five intramolecular disulfide bonds with ten cysteine residues of a protein is _____.

Correct Answer: 945

Solution: Step 1: Forming five disulfide bonds from ten cysteines is equivalent to pairing the ten distinct residues into five unordered pairs.
Step 2: The number of pairings is $(10-1)!! = 9!! = 9 \times 7 \times 5 \times 3 \times 1$. Alternatively,

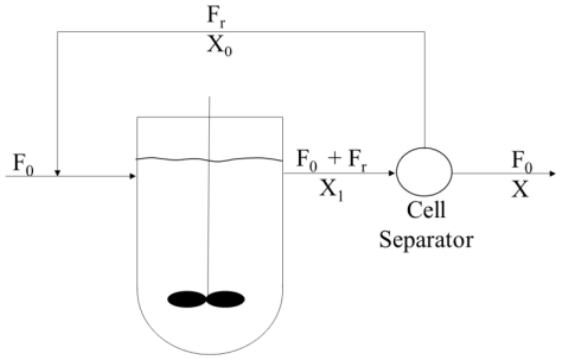
$$\frac{10!}{2^5\, 5!} = \frac{3628800}{32 \times 120} = 945.$$

Hence, the number of possible ways is $\boxed{945}$.

Quick Tip

Pairing $2n$ distinct items into n unordered pairs uses $(2n-1)!! = \dfrac{(2n)!}{2^n n!}$.

Q53. The following schematic diagram shows a chemostat with cell recycle (feed flow rate F_0 and recycle flow rate F_r in $\mathrm{L\,h^{-1}}$). The cell concentrations in the reactor, recycle stream, and product stream are X_1, X_0, and X (in $\mathrm{g\,L^{-1}}$), respectively. If $\dfrac{X_0}{X_1} = 1.5$, $\dfrac{F_r}{F_0} = 0.7$, and $X_1 = 7.3\ \mathrm{g\,L^{-1}}$, the value of X (in $\mathrm{g\,L^{-1}}$, rounded off to one decimal place) is _____.



Correct Answer: 4.7

Solution: Step 1: Perform a steady-state cell mass balance over the *cell separator*. The separator receives $(F_0 + F_r)$ from the reactor at concentration X_1 and splits it into product F_0 with concentration X and recycle F_r with concentration X_0:

$$(F_0 + F_r)X_1 = F_0 X + F_r X_0.$$

Step 2: Use the given ratios $r = \dfrac{F_r}{F_0} = 0.7$ and $\dfrac{X_0}{X_1} = 1.5 \Rightarrow X_0 = 1.5X_1$. Divide the balance by F_0 to get

$$(1+r)X_1 = X + rX_0 = X + r(1.5X_1).$$

Hence,

$$X = (1 + r)X_1 - 1.5rX_1 = X_1[1 + r - 1.5r] = X_1(1 - 0.5r)\,.$$

Step 3: Substitute $r = 0.7$ and $X_1 = 7.3\ \mathrm{g\,L^{-1}}$:

$$X = 7.3 \times (1 - 0.5 \times 0.7) = 7.3 \times 0.65 = 4.745 \approx 4.7\ \mathrm{g\,L^{-1}}.$$

$\therefore$ The product-stream cell concentration is $\boxed{4.7\ \mathrm{g\,L^{-1}}}$.

Quick Tip

- For separators/recycle systems, write the mass balance on the splitter: (inlet flow) $\times$ (inlet conc.) $= \sum$(outlet flow $\times$ outlet conc.).
- Converting given ratios (e.g., F_r/F_0, X_0/X_1) into variables (r) simplifies algebra.

Q54. An enzyme (E) catalyzes the biochemical reaction $A \rightarrow B$ with $k_{\mathbf{cat}} = 500\ \mathbf{s^{-1}}$. If the initial reaction velocity (V_0) is 10 $\mu\mathbf{M \cdot s^{-1}}$ at the total enzyme concentration $[E_t] = 30$ nM and substrate concentration $[A] = 40$ μM, the value of K_m (in μM) is _____.

Correct Answer: 20

Solution: Step 1: $V_{\max} = k_{\mathrm{cat}}[E_t] = 500 \times 30\ \mathrm{nM\ s^{-1}} = 15000\ \mathrm{nM\ s^{-1}} = 15\ \mu\mathrm{M\ s^{-1}}$.
Step 2: Michaelis–Menten: $V_0 = \dfrac{V_{\max}[S]}{K_m + [S]}$. With $V_0 = 10$, $[S] = 40$, $V_{\max} = 15$:

$$10 = \frac{15 \times 40}{K_m + 40} \Rightarrow 10K_m + 400 = 600 \Rightarrow K_m = 20\ \mu\mathrm{M}.$$

Quick Tip

Use $V_{\max} = k_{\mathrm{cat}}[E_t]$ and avoid unit slips by converting nM to μM before substituting.

Q55. DNA sample collected from an unidentified bacterial species (Y) contains 13% adenine. The G+C content (in percentage) of Y is _____.

Correct Answer: 74

Solution: Step 1: In double-stranded DNA, $\%A = \%T$. If $\%A = 13$, then $\%T = 13$.
Step 2: G+$C = 100 - (A$+$T) = 100 - (13 + 13) = 74\%$.

Quick Tip

For dsDNA, $A = T$ and $G = C$; use A+T+G+$C = 100\%$.

Q56. If 1000 bp of a double-helical DNA weighs 1×10^{-18} g and the distance between two bp is 0.34 nm, the total amount of DNA (in mg, rounded to one decimal) required to stretch from Earth to Moon (distance $= 3.74 \times 10^5$ km) is _____.

Correct Answer: 1.1

Solution: Step 1: Convert length to nm: $3.74 \times 10^5\,\text{km} = 3.74 \times 10^8\,\text{m} = 3.74 \times 10^{17}\,\text{nm}$.
Step 2: Number of bp needed:

$$N = \frac{3.74 \times 10^{17}}{0.34} \approx 1.10 \times 10^{18}\ \text{bp}.$$

Step 3: Mass per bp $= \frac{1\times10^{-18}\ \text{g}}{1000} = 1 \times 10^{-21}$ g.

Total mass $= N \times 1 \times 10^{-21} \approx 1.10 \times 10^{-3}$ g $= 1.1$ mg.

Quick Tip

Use: length = (bp count) $\times$0.34 nm; mass scales linearly with bp number.

Q57. A protein has three identical sites arranged at the vertices of an equilateral triangle. With one site filled with donor dye, the quantum yield ϕ_D is 0.5. Filling one site with donor and a second with acceptor gives $\phi_D = 0.25$. Find ϕ_D when one site has donor and the other two have acceptor dyes (rounded to three decimals).

Correct Answer: 0.167

Solution: Step 1: Let k_f be donor radiative rate and k_{nr} non-radiative rate. With no acceptor: $\phi_1 = \dfrac{k_f}{k_f + k_{nr}} = 0.5 \Rightarrow k_f + k_{nr} = 2k_f$.

Step 2: With one acceptor, extra transfer rate k_{ET} adds:

$$\phi_2 = \frac{k_f}{k_f + k_{nr} + k_{ET}} = \frac{k_f}{2k_f + k_{ET}} = 0.25 \Rightarrow 2 + \frac{k_{ET}}{k_f} = 4 \Rightarrow k_{ET} = 2k_f.$$

Step 3: With two identical acceptors, total transfer rate $= 2k_{ET} = 4k_f$. Hence

$$\phi_3 = \frac{k_f}{k_f + k_{nr} + 2k_{ET}} = \frac{k_f}{2k_f + 4k_f} = \frac{1}{6} = 0.166\overline{6} \approx \boxed{0.167}.$$

Quick Tip

FRET/quencher effects add as rates: $\phi = \dfrac{k_f}{k_f + k_{nr} + \sum k_{ET,i}}$.

Q58. If $A = \begin{pmatrix} 1 & 2 \\ 3 & 5 \end{pmatrix}$, the value of $\left|A^4 + 3A^2 - 5A + 6I\right|$ is _____.

Correct Answer: 10551

Solution: Step 1: For A, $\operatorname{tr}(A) = 6$, $\det(A) = -1$. By Cayley–Hamilton: $A^2 - 6A - I = 0 \Rightarrow A^2 = 6A + I$.

Step 2: Compute: $A^3 = A(A^2) = A(6A + I) = 6A^2 + A = 36A + 6I + A = 37A + 6I$.

$A^4 = A(A^3) = A(37A + 6I) = 37A^2 + 6A = 37(6A + I) + 6A = 228A + 37I$.

Step 3: Then

$$A^4 + 3A^2 - 5A + 6I = (228A + 37I) + 3(6A + I) - 5A + 6I = 241A + 46I.$$

Step 4: For any 2×2 matrix, $\det(A + \alpha I) = \alpha^2 + \alpha \operatorname{tr}(A) + \det(A)$. With $\alpha = \frac{46}{241}$:

$$\det(241A + 46I) = 241^2 \det\left(A + \tfrac{46}{241} I\right) = 241^2 \left(\alpha^2 + 6\alpha - 1\right) = \boxed{10551}.$$

Quick Tip

Use Cayley–Hamilton to reduce powers and $\det(A+\alpha I) = \alpha^2 + \alpha \operatorname{tr}(A) + \det(A)$ for 2×2 matrices.

Q59. If $f(x) = \dfrac{\sin x + \cos x}{\sin x - \cos x}$, the value of $f'(x)$ at $x = 0$ is _____.

Correct Answer: -2

Solution: Step 1: Let $u = \sin x + \cos x$, $v = \sin x - \cos x$. Then $f' = \dfrac{u'v - uv'}{v^2}$.

Step 2: At $x = 0$: $u = 1$, $v = -1$, $u' = 1$, $v' = 1$. Hence

$$f'(0) = \frac{(1)(-1) - (1)(1)}{(-1)^2} = \frac{-2}{1} = \boxed{-2}.$$

Quick Tip

For ratios, use the quotient rule and plug values after differentiating to avoid algebraic slips.

Q60. If $f(2) = 5$ and $f(x)\,f(x+1) = 3$ for all real x, the value of $f(10)$ is _____.

Correct Answer: 5

Solution: Step 1: From $f(x)f(x+1) = 3$ and $f(x+1)f(x+2) = 3$, dividing gives $f(x+2) = f(x)$; hence f is period-2.
Step 2: Since $f(2) = 5$, all even integers share this value: $f(4) = f(2) = 5, \ldots, f(10) = 5$. (Odd integers would be 3/5.)

Quick Tip

A multiplicative relation $f(x)f(x+1) = \text{const}$ often implies a 2-periodic solution: $f(x+2) = f(x)$.

Q61. Ten playing cards numbered $1, \ldots, 10$ are drawn with replacement. What is the probability that the second number is greater than the first (rounded to two decimal places)?

Correct Answer: 0.45

Solution:
Step 1: With replacement, the two draws are i.i.d. uniform on $\{1, \ldots, 10\}$.

Step 2: By symmetry, $P(Y > X) = P(Y < X)$. Also $P(Y = X) = \frac{10}{10 \cdot 10} = 0.10$.

Step 3: Hence $2P(Y > X) = 1 - 0.10 \Rightarrow P(Y > X) = 0.45$.

So the required probability is $\boxed{0.45}$.

Quick Tip

For two i.i.d. discrete draws, $P(Y > X) = \dfrac{1 - P(Y = X)}{2}$.

Q.62. The values of the consistency index 'K' and the flow behavior index 'n' of a dilatant fluid are 0.415 (in CGS units) and 1.23, respectively. The value of the apparent viscosity (in $g \cdot cm^{-1} \cdot s^{-1}$) of this fluid at a shear rate of 60 s^{-1} (rounded off to the nearest integer) is _____.

Correct Answer: 1 $g \cdot cm^{-1} \cdot s^{-1}$

Solution: Step 1: For a power-law (Ostwald–de Waele) fluid, $\tau = K\,(\dot{\gamma})^n$. The apparent viscosity is

$$\eta_{\text{app}} = \frac{\tau}{\dot{\gamma}} = K\,(\dot{\gamma})^{n-1}.$$

Step 2: Substitute the given values $K = 0.415$, $n = 1.23$, and $\dot{\gamma} = 60\ s^{-1}$:

$$\eta_{\text{app}} = 0.415\,(60)^{1.23-1} = 0.415\,(60)^{0.23}.$$

Step 3: Evaluate the power:

$$(60)^{0.23} \approx e^{0.23\ln 60} \approx e^{0.23\times 4.0943} \approx e^{0.9417} \approx 2.564.$$

Step 4: Compute the apparent viscosity:

$$\eta_{\text{app}} \approx 0.415 \times 2.564 \approx 1.064\ g \cdot cm^{-1} \cdot s^{-1}.$$

Step 5: Round to the nearest integer:

$$\boxed{1\ g \cdot cm^{-1} \cdot s^{-1}}.$$

Quick Tip

- Power-law fluids use $\eta_{\text{app}} = K\,\dot{\gamma}^{\,n-1}$; check the exponent $n-1$ carefully.
- $n > 1$ indicates a dilatant (shear-thickening) fluid; η_{app} increases with $\dot{\gamma}$.

Q.63. An evaporator is insulated using glass wool material of 0.15 m thickness. The inner most surface and the outer surface of the insulation are at 700°C and 80°C, respectively. The mean thermal conductivity of the glass wool under these conditions is 0.29 $\mathbf{W\,m^{-1}\,K^{-1}}$. The rate of heat loss (in W) through 1.2 $\mathbf{m^2}$ of the evaporator wall surface (rounded off to the nearest integer) is _____.

Correct Answer: 1438 W

Solution: Step 1: For steady 1-D conduction through a plane layer, Fourier's law gives

$$\dot{Q} = k\,A\,\frac{\Delta T}{L}.$$

Here, $k = 0.29\ \text{W m}^{-1}\,\text{K}^{-1}$, $A = 1.2\ \text{m}^2$, $L = 0.15$ m, and $\Delta T = 700 - 80 = 620$ K.
Step 2: Substitute and compute:

$$\dot{Q} = 0.29 \times 1.2 \times \frac{620}{0.15} = 0.348 \times 4133.\overline{3} = 1438.0\ \text{W (approximately)}.$$

Step 3: Rounding to the nearest integer gives $\boxed{1438\ \text{W}}$.

Quick Tip

- For flat insulation layers, use $R = L/(kA)$ and $\dot{Q} = \Delta T/R$. With multiple layers, thermal resistances add in series.
- Temperature difference is in kelvins or degrees Celsius—use the magnitude; direction is from hot to cold.
- Always check dimensional consistency: $k[\mathrm{W/mK}]\, A[\mathrm{m^2}]\, \Delta T[\mathrm{K}]/L[\mathrm{m}] \Rightarrow \mathrm{W}$.

Q.64. A proportional controller is used to control the temperature of an autoclave from $60°C$ to $130°C$. If the proportional band setting of the controller is 25%, the proportional gain value is _____.

Correct Answer: 4

Solution: Step 1: Proportional Band (PB) and Proportional Gain (K_p) are related as:

$$K_p = \frac{100}{PB(\%)}$$

Step 2: Here, proportional band $PB = 25\%$. Substituting:

$$K_p = \frac{100}{25} = 4$$

Step 3: Hence, the proportional gain value is:

$$\boxed{4}$$

Quick Tip

- Proportional Band (PB) indicates the range of error over which the controller output varies from 0% to 100%.
- Proportional Gain (K_p) is the inverse of PB (in fraction form). Smaller PB $\Rightarrow$ larger gain.
- Typical relation: $K_p = 100/PB(\%)$.

Q.65. A dNTP master-mix is prepared by combining 40 μL of each 20 mM dNTP stock (dATP, dCTP, dGTP and dTTP). 4 μL of this dNTP master-mix is added to a PCR mix and the final volume is adjusted to 50 μL. The concentration (in μM) of total dNTPs in the PCR mix is _____.

Correct Answer: 1600 μM

Solution: Step 1: Prepare master-mix by combining four equal volumes. For any one nucleotide in the master-mix,

$$C_{\text{each, master}} \;=\; 20 \text{ mM} \times \frac{40}{40+40+40+40} \;=\; 20 \times \frac{40}{160} \;=\; 5 \text{ mM}.$$

Hence the *total* dNTP concentration in the master-mix is

$$C_{\text{total, master}} = 4 \times 5 \text{ mM} = 20 \text{ mM}.$$

Step 2: Add 4 μL of this master-mix to a final PCR volume of 50 μL. The dilution factor is $4/50 = 0.08$. Therefore,

$$C_{\text{total, PCR}} = C_{\text{total, master}} \times 0.08 = 20 \text{ mM} \times 0.08 = 1.6 \text{ mM} = 1600 \ \mu\text{M}.$$

Step 3: Thus, the total dNTP concentration in the PCR mix is $\boxed{1600 \ \mu\text{M}}$ (i.e., 400 μM each).

Quick Tip

- Mixing n equal volumes of solutions with the same concentration reduces each solute's concentration by a factor of n.
- For dilutions, use $C_1V_1 = C_2V_2$. Here, $C_2 = C_1 \times (V_1/V_{\text{final}})$.
- Typical PCR reporting: state either per dNTP (here 400 μM each) or total (here 1600 μM)—read the question carefully.