

# TIFR GS Science Education

## Sample Paper – 4

Duration: 180 Minutes

Maximum Marks: 100

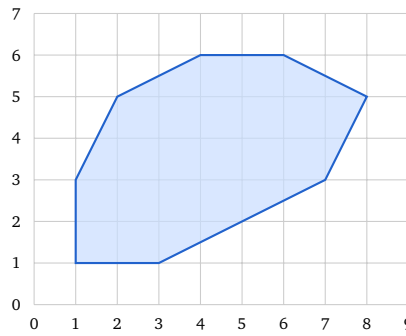
### Instructions

- This paper contains **80 Multiple Choice Questions** modelled on the **TIFR GS Science Education** (HBCSE PhD) entrance examination.
- You may attempt **any 50 questions** from this section. If more than 50 are attempted, the score will be normalized to 50 questions.
- Each correct answer earns **+2 marks**. There is **no negative marking**; unattempted and wrong answers earn 0.
- Distribution: Q1–25 (Quantitative Reasoning & Scientific Literacy) | Q26–40 (Social, Cognitive Sciences & Education) | Q41–50 (Biology) | Q51–60 (Chemistry) | Q61–70 (Mathematics) | Q71–80 (Physics).
- Only **one** option is correct per question. Read all options before marking.
- Syllabus: Quantitative reasoning, scientific literacy; science education research, learning theories, curriculum, assessment; Biology, Chemistry, Mathematics, Physics at CBSE Class XII level.
- Personal calculators, mobile phones, and electronic gadgets are strictly prohibited. Rough sheets are provided.

### Part A: Quantitative Reasoning & Scientific Literacy (Q1–25)

- Q1. The figure below shows an irregular closed shape drawn on a centimetre-square grid. Each small square has an area of  $1 \text{ cm}^2$ . Using the “count full squares plus half boundary squares” rule, estimate the area of the shaded region.





- (A)  $16 \text{ cm}^2$
- (B)  $22 \text{ cm}^2$
- (C)  $28 \text{ cm}^2$
- (D)  $34 \text{ cm}^2$

**Q2.** A shopkeeper reduces the price of an article from ₹1,250 to ₹875. What is the percentage decrease in price?

- (A) 20%
- (B) 25%
- (C) 30%
- (D) 35%

**Q3.** Consider the two premises: “No mammals are reptiles” and “All snakes are reptiles.” Which conclusion follows **necessarily**?

- (A) All reptiles are snakes.
- (B) Some mammals are snakes.
- (C) No reptiles are mammals.
- (D) No snakes are mammals.

**Q4.** Read the following passage and answer the question below.

*“When a bus suddenly brakes, passengers lurch forward. When it suddenly accelerates, they are thrown backward. A ball on the floor of a smoothly moving train stays at rest relative to the train, but the moment the train turns a curve, the ball rolls outward. These everyday phenomena are not mysterious: they are direct consequences of inertia, the tendency of any ob-*



*ject to resist changes in its state of motion — precisely what Newton encoded in his First Law.”*

In a uniformly moving lift (elevator) travelling upward, a person stands on a weighing scale. Compared to the reading when the lift is stationary, the scale reading is:

- (A) Equal to the stationary reading, because the lift moves at constant velocity.
- (B) Greater, because upward motion adds to apparent weight.
- (C) Less, because upward motion reduces effective gravity.
- (D) Zero, because the person is in free motion.

**Q5.** In a class, 20 students scored an average of 45 marks and 30 students scored an average of 60 marks. What is the weighted mean of the entire class?

- (A) 50.0
- (B) 54.0
- (C) 52.5
- (D) 56.0

**Q6.** Pipe A can fill a tank in 12 hours and Pipe B can fill it in 18 hours. If both pipes are opened simultaneously, how long will it take to fill the tank?

- (A) 6 hours
- (B) 6.5 hours
- (C) 7.2 hours
- (D) 8 hours

**Q7.** A fair coin is tossed 3 times. What is the probability of getting **at least one head**?

- (A)  $\frac{1}{2}$
- (B)  $\frac{3}{4}$
- (C)  $\frac{6}{8}$



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

Q8. Calculate  $(3.2 \times 10^4) \times (2.5 \times 10^{-2})$ .

- (A)  $8.0 \times 10^2$   
(B)  $8.0 \times 10^3$   
(C)  $5.7 \times 10^2$   
(D)  $8.0 \times 10^{-8}$

Q9. A clinical study reports the following data on drug efficacy across age groups:

| Age Group | Recovered (%) | Not Recovered (%) |
|-----------|---------------|-------------------|
| Under 30  | 85            | 15                |
| 30–60     | 70            | 30                |
| Over 60   | 50            | 50                |

Which of the following conclusions is **best supported** by the data?

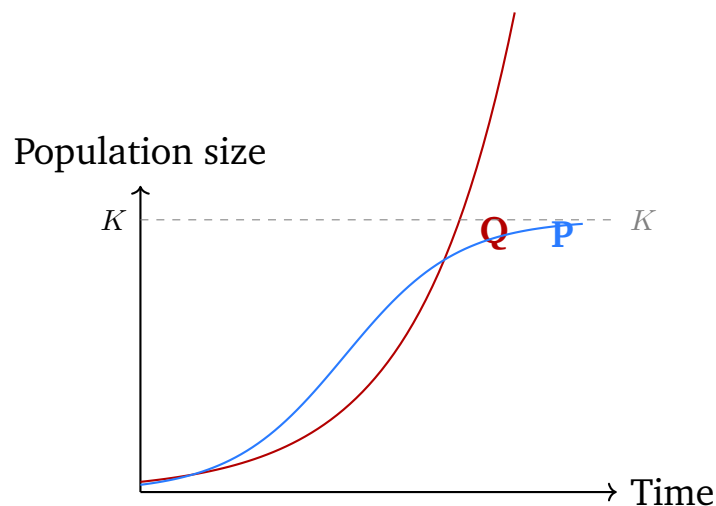
- (A) The drug is equally effective for all age groups.  
(B) Recovery rate decreases with increasing age.  
(C) The drug is ineffective for the over-60 group.  
(D) The drug causes harm in younger patients.
- Q10. A student wants to investigate how the concentration of fertiliser affects plant height. She designs an experiment where she changes both the concentration and the amount of water given daily across different plant pots. A science teacher remarks that the design violates a fundamental principle of experimentation. Which principle is being violated?
- (A) Replication  
(B) Randomisation  
(C) Control of variables (OFAT — One Factor At a Time)  
(D) Blinding



**Q11.** In a coding scheme, the word TIGER is coded as REGIT (the word is reversed and then each letter is replaced by its mirror image letter in the English alphabet, where  $A \leftrightarrow Z$ ,  $B \leftrightarrow Y$ , ...). Using the same scheme, what is the code for SPARK?

- (A) KAPSH
- (B) KZIIP
- (C) ZIIPK
- (D) ZIIKP

**Q12.** The graph below shows two population growth curves (P and Q) plotted against time.



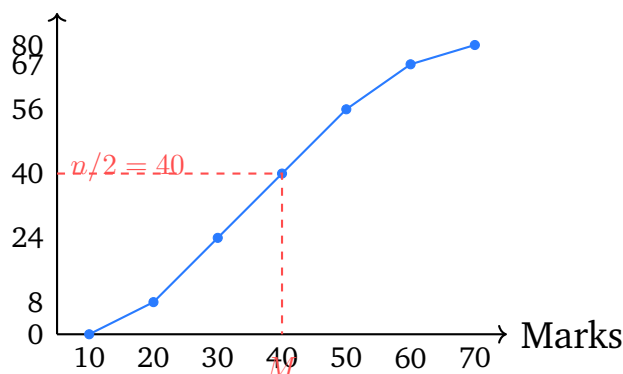
Which statement correctly distinguishes the two curves?

- (A) Curve P is logistic growth (approaches carrying capacity  $K$ ); Curve Q is exponential growth (no upper limit).
- (B) Curve P is exponential; Curve Q is logistic.
- (C) Both curves are logistic but with different  $K$  values.
- (D) Both curves are exponential but with different growth rates.

**Q13.** The cumulative frequency (ogive) graph below represents the marks of 80 students.



Cumulative Frequency



From the ogive, the median marks of the class is:

- (A) 35
- (B) 40
- (C) 45
- (D) 50

**Q14.** Evaluate the truth of the biconditional  $P \leftrightarrow Q$  (“ $P$  if and only if  $Q$ ”) when  $P$  is **False** and  $Q$  is **True**.

- (A) True, because  $P \rightarrow Q$  holds when  $P$  is false.
- (B) True, because  $Q \rightarrow P$  holds when  $Q$  is true.
- (C) False, because  $P$  and  $Q$  have different truth values.
- (D) True, because the biconditional is always true.

**Q15.** The average distance from the Sun to the Earth is approximately  $1.5 \times 10^{11}$  m. Given that the speed of light is  $3.0 \times 10^8$  m/s, how long (in minutes) does sunlight take to reach Earth?

- (A) 4.2 minutes
- (B) 6.0 minutes
- (C) 7.5 minutes
- (D) 8.3 minutes

**Q16.** A scientist observes that 200 randomly selected crows are all black, and concludes “All crows are black.” What type of reasoning is being used, and why is it epistemically limited?



- (A) Inductive reasoning; the conclusion is probable but not guaranteed because unobserved instances could differ.
- (B) Deductive reasoning; the argument is valid but the premise could be false.
- (C) Abductive reasoning; it selects the simplest explanation.
- (D) Analogical reasoning; it draws parallels between crow populations.

**Q17.** For the data set  $\{4, 6, 8, 10, 12\}$ , the mean is 8. What is the **variance**?

- (A) 6
- (B) 8
- (C) 10
- (D) 12

**Q18.** A solid 3D object looks like a capital letter “L” when viewed from the front. If this object is rotated  $90^\circ$  clockwise about its vertical axis, the resulting front view will look like:

- (A) A capital letter “T”
- (B) A capital letter “L” (unchanged)
- (C) A capital letter “T” (inverted-L)
- (D) A capital letter “I”

**Q19.** Read the passage and answer the question below.

*“Short-wave solar radiation easily penetrates the atmosphere and is absorbed by Earth’s surface. The warmed surface re-emits energy as long-wave (infrared) radiation. Unlike short-wave radiation, this long-wave radiation is readily absorbed by greenhouse gases such as water vapour, carbon dioxide, and methane in the troposphere. The absorbed energy is re-emitted in all directions, including back towards Earth, raising its equilibrium surface temperature. Without this natural greenhouse effect, Earth’s average surface temperature would be approximately  $-18^\circ\text{C}$  instead of the present  $+15^\circ\text{C}$ .”*

Which statement about the greenhouse effect is **NOT** supported by the passage?



- (A) Solar radiation absorbed by Earth's surface is re-emitted as infrared radiation.
- (B) Greenhouse gases absorb long-wave radiation, not short-wave radiation.
- (C) Without greenhouse gases, Earth's surface temperature would be about  $-18^{\circ}\text{C}$ .
- (D) Human emissions of  $\text{CO}_2$  are the primary driver of the greenhouse effect.

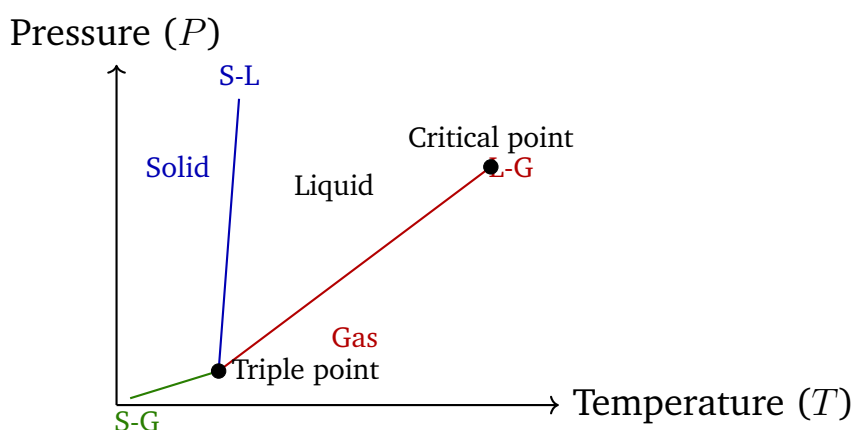
**Q20.** A mixture is made by blending 20 litres of a 40% acid solution with 30 litres of a 60% acid solution. What is the percentage concentration of acid in the resulting mixture?

- (A) 52%
- (B) 50%
- (C) 48%
- (D) 54%

**Q21.** Find the geometric mean of 4, 8, and 32.

- (A) 6
- (B) 8
- (C) 10
- (D) 12

**Q22.** The pressure-temperature (P-T) phase diagram of a pure substance is shown below.





If a sample is initially in the gas phase and the pressure is increased isothermally at a temperature **below** the triple-point temperature, the sample will:

- (A) Undergo gas  $\rightarrow$  liquid  $\rightarrow$  solid transitions.
- (B) Remain as gas regardless of pressure.
- (C) Undergo gas  $\rightarrow$  solid transition (sublimation boundary crossed in reverse).
- (D) Undergo gas  $\rightarrow$  liquid transition only.

**Q23.** A researcher presents data showing that a new teaching method improves student outcomes. A critic responds: “We should not trust these results because the researcher received funding from the company that sells this teaching method.” What type of logical fallacy does the critic commit?

- (A) Straw man fallacy
- (B) False dichotomy
- (C) Slippery slope
- (D) Ad hominem fallacy

**Q24.** A gas occupies 4.0 L at a pressure of 2.5 atm. If the temperature is kept constant, what pressure is needed to compress the gas to 2.0 L?

- (A) 5.0 atm
- (B) 4.0 atm
- (C) 3.5 atm
- (D) 2.0 atm

**Q25.** Read the passage and answer the question below.

*“In 1928, Alexander Fleming noticed that a Petri dish containing Staphylococcus colonies had become contaminated with a mould, Penicillium notatum. Around the mould, the bacterial colonies were absent — a clear zone of inhibition. Fleming deduced that the mould was secreting a substance lethal to the bacteria. He named this substance penicillin. However, it was not until the early 1940s that Howard Florey, Ernst Chain, and their colleagues at*



*Oxford purified and tested penicillin clinically, enabling it to save countless lives during World War II.”*

Which of the following best describes the nature of Fleming’s discovery?

- (A) A purely hypothetical prediction confirmed by Florey and Chain.
- (B) A serendipitous observation that led to a scientifically significant inference.
- (C) A deliberate experiment designed to test bacterial inhibition.
- (D) An accidental discovery that had no practical use until the 21st century.

**Part B: Social & Cognitive Sciences & Education (Q26–40)**

- Q26. According to **social constructivism**, how is knowledge constructed?
- (A) Individually, through private discovery independent of culture and context.
  - (B) By direct instruction from an expert who transmits pre-formed knowledge.
  - (C) Through social interaction, cultural tools, and mediated experiences shared with others.
  - (D) Exclusively through sensory experience without language or social input.
- Q27. Daniel Kahneman’s **dual-process theory** distinguishes between System 1 (fast, intuitive) and System 2 (slow, deliberate) thinking. Which classroom implication follows most directly from this theory?
- (A) Students should always rely on fast intuition to solve scientific problems.
  - (B) Lectures should be shortened to less than 10 minutes to match System 1 attention span.
  - (C) Homework should eliminate all open-ended problems to reduce cognitive load.



(D) Science instruction should deliberately engage System 2 by prompting students to question their intuitive (System 1) responses.

**Q28.** Which of the following best characterises **direct instruction** as a pedagogical strategy?

- (A) Teacher-led, structured delivery of content with clear objectives, modelled examples, and guided practice.
- (B) Students construct knowledge independently through open inquiry with minimal teacher input.
- (C) Learning occurs primarily through peer interaction in collaborative group tasks.
- (D) Instruction is mediated entirely by digital tools without live teacher interaction.

**Q29.** In the **revised Bloom’s taxonomy** (Anderson & Krathwohl, 2001), which verb is associated with the “**Creating**” level?

- (A) Identify
- (B) Design
- (C) Compare
- (D) Demonstrate

**Q30.** A common student misconception is that **evolution is goal-directed** (e.g., “giraffes evolved long necks because they needed to reach leaves”). Which type of conceptual change strategy is **most appropriate** to address this misconception?

- (A) Simply re-teaching the correct definition more loudly and repeatedly.
- (B) Ignoring the misconception and providing correct information.
- (C) Creating cognitive conflict by presenting evidence that contradicts the goal-directed view, then scaffolding the correct mechanism (variation, selection, inheritance).
- (D) Asking students to memorise the five steps of natural selection without discussion.



- Q31. Portfolio assessment** is characterised by a collection of a student's work over time. What does it primarily reveal that a single test score cannot?
- (A) The student's exact rank compared to peers.
  - (B) The student's performance on standardised content.
  - (C) The speed at which a student completes tasks under pressure.
  - (D) The student's growth, self-reflection, and diversity of competencies over time.
- Q32.** Mary Budd Rowe's research on **wait time** (think time) in classroom questioning found that increasing the pause after a teacher's question from under 1 second to 3–5 seconds leads to which outcome?
- (A) Longer, more accurate student responses and greater participation from more students.
  - (B) Shorter responses because students lose their train of thought.
  - (C) Increased teacher anxiety, leading to worse questioning quality.
  - (D) No measurable change in student response quality.
- Q33.** In the context of **multicultural science education**, what is meant by "Eurocentric bias" in the science curriculum?
- (A) Teaching only European languages in science classrooms.
  - (B) Presenting the history and practice of science as if it were exclusively a product of European/Western tradition, marginalising contributions from other cultures and knowledge systems.
  - (C) Requiring students to study only European scientists as role models.
  - (D) Prohibiting non-Western students from studying certain science topics.
- Q34.** How does **activity-based learning** differ from merely **hands-on learning**?
- (A) Activity-based learning requires expensive laboratory equipment; hands-on does not.



- (B) Hands-on learning is cognitive; activity-based learning is purely physical.
- (C) Activity-based learning emphasises purposeful cognitive engagement with the activity (minds-on), not just physical manipulation.
- (D) They are identical in educational literature.

**Q35.** Research on **gesture and embodied cognition in science learning** suggests that:

- (A) Gestures are distracting and should be discouraged in science classrooms.
- (B) Only tactile manipulation (touching objects) contributes to conceptual understanding.
- (C) Verbal explanation alone is superior to any form of bodily representation.
- (D) Gestures can express and scaffold understanding of scientific concepts, sometimes conveying ideas that speech does not yet fully articulate.

**Q36.** Manu Kapur's research on **productive failure** found that:

- (A) Students who first struggle with a novel problem (even if they fail) and then receive instruction outperform those who receive direct instruction first, because prior failure activates relevant prior knowledge and highlights knowledge gaps.
- (B) Student failure always indicates poor teaching and should be prevented entirely.
- (C) Productive failure is only applicable in mathematics, not in science.
- (D) Students who fail consistently develop learned helplessness regardless of later support.

**Q37.** In the “science as practice” framework (NRC, 2012), **epistemic practices** refer to:

- (A) Memorising scientific facts and vocabulary as an epistemic foundation.



- (B) The ways scientists generate, justify, evaluate, and refine knowledge claims, such as argumentation, model construction, and critique.
- (C) The ethical guidelines that govern scientific conduct in research institutions.
- (D) Laboratory safety protocols that form the procedural basis of science.

**Q38. Gamification** in education refers to the use of game elements (points, badges, leaderboards) in non-game contexts. Which statement best captures both an affordance **and** a limitation of gamification in science learning?

- (A) Affordance: guaranteed learning gains; Limitation: high cost.
- (B) Affordance: eliminates all assessment; Limitation: students refuse to participate.
- (C) Affordance: increases motivation and engagement through extrinsic rewards; Limitation: may undermine intrinsic motivation if rewards are removed or overshadow deep content learning.
- (D) Affordance: replaces the teacher entirely; Limitation: requires internet access.

**Q39.** Regarding the integration of **AI tools** (such as large language model chatbots) in science education, which option accurately states a key potential **and** a key concern?

- (A) Potential: AI guarantees scientifically accurate answers; Concern: AI is too slow for classroom use.
- (B) Potential: AI eliminates the need for teachers; Concern: teachers will become unemployed.
- (C) Potential: AI provides instant personalised feedback; Concern: AI generates electricity costs.
- (D) Potential: AI can provide personalised tutoring and explain concepts in multiple ways; Concern: AI can generate plausible-sounding but factually incorrect information (“hallucinations”) that students may uncritically accept.



**Q40.** What distinguishes an **analytic rubric** from a **holistic rubric**?

- (A) An analytic rubric evaluates each criterion separately with its own performance scale, enabling detailed diagnostic feedback; a holistic rubric assigns a single overall score based on a global impression.
- (B) A holistic rubric evaluates each criterion separately; an analytic rubric gives one overall score.
- (C) Analytic rubrics are only used in English; holistic rubrics are used in science.
- (D) Analytic rubrics are simpler and faster to use than holistic rubrics.

**Part C: Biology (Q41–50)**

**Q41.** In cellular signal transduction, **cyclic AMP (cAMP)** is a classic second messenger. Which sequence correctly describes how a hormone signal is amplified via cAMP?

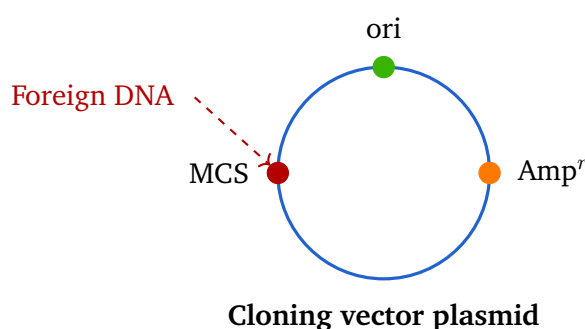
- (A) Hormone → nucleus → cAMP synthesis → receptor activation.
- (B) Hormone binds surface receptor → G-protein activates adenylyl cyclase → ATP converted to cAMP → cAMP activates protein kinase A → cellular response.
- (C) cAMP binds DNA directly to regulate gene expression without a receptor.
- (D) Hormone enters cell → binds cAMP → cAMP enters nucleus → transcription.

**Q42.** Which cytoskeletal component is primarily responsible for maintaining the **biconcave disc shape of red blood cells** and providing mechanical flexibility as they squeeze through narrow capillaries?

- (A) Microtubules
- (B) Intermediate filaments
- (C) Spectrin (a peripheral membrane protein linked to actin in a cortical network)
- (D) Myosin filaments



- Q43.** What is the primary role of **gibberellins** in seed germination?
- (A) They inhibit water uptake to prevent premature germination.
  - (B) They break seed dormancy by degrading abscisic acid directly.
  - (C) They promote stomatal opening to supply carbon dioxide.
  - (D) They stimulate the aleurone layer to produce  $\alpha$ -amylase, which digests starch reserves to supply the embryo with sugars.
- Q44.** In recombinant DNA technology, the figure below shows a simplified plasmid used as a cloning vector.



What is the primary role of the **plasmid** in gene cloning?

- (A) It acts as a vector to carry and replicate the foreign gene inside host cells.
  - (B) It synthesises the protein product of the foreign gene directly.
  - (C) It cleaves DNA at restriction sites to excise the target gene.
  - (D) It degrades the host cell's own DNA to make room for the foreign gene.
- Q45.** Which of the following is the best example of **mutualism**?
- (A) A tapeworm living in the intestine of a mammal.
  - (B) Rhizobium bacteria in root nodules of leguminous plants, where the bacteria fix nitrogen for the plant and the plant supplies organic carbon to the bacteria.
  - (C) An orchid growing on a tree branch without harming or benefiting the tree.
  - (D) A cuckoo laying eggs in a warbler's nest.





- Q46.** In agarose gel electrophoresis, DNA fragments migrate **toward the positive electrode (anode)**. The best explanation for this is:
- (A) DNA has a net positive charge due to its nitrogenous bases.
  - (B) The anode releases reagents that attract DNA.
  - (C) DNA is negatively charged (due to phosphate backbone) and is attracted to the positive electrode.
  - (D) DNA migrates because of osmotic pressure differences across the gel.
- Q47.** In the human digestive system, where does the majority of **fat absorption** occur?
- (A) Stomach
  - (B) Large intestine
  - (C) Duodenum
  - (D) Jejunum (small intestine lacteals)
- Q48.** Which organism is primarily responsible for **biological nitrogen fixation** in terrestrial ecosystems?
- (A) Rhizobium (a prokaryote possessing nitrogenase enzyme)
  - (B) Aspergillus (a soil fungus)
  - (C) Nitrosomonas (a nitrifying bacterium)
  - (D) Pseudomonas (a denitrifying bacterium)
- Q49.** **Polyploidy** (having more than two sets of homologous chromosomes) is most commonly found in which kingdom?
- (A) Animalia
  - (B) Plantae
  - (C) Fungi
  - (D) Monera
- Q50.** The **hybridoma technique** used to produce monoclonal antibodies involves:



- (A) Inserting antibody genes into bacterial plasmids for mass expression.
- (B) Harvesting antibodies directly from the blood serum of immunised donors.
- (C) Fusing antigen-stimulated B-lymphocytes with immortal myeloma cells to create cells that both produce a specific antibody and divide indefinitely.
- (D) Chemically synthesising antibodies from their amino acid sequence in vitro.

Part D: Chemistry (Q51–60)

- Q51. For a binary electrolyte AB that completely dissociates into  $A^+$  and  $B^-$  in solution, what is the **van't Hoff factor** ( $i$ )?
- (A) 0
  - (B) 0.5
  - (C) 1
  - (D) 2
- Q52. Given  $E^\circ(\text{Zn}^{2+}/\text{Zn}) = -0.76 \text{ V}$  and  $E^\circ(\text{Cu}^{2+}/\text{Cu}) = +0.34 \text{ V}$ , the standard EMF of the electrochemical cell  $\text{Zn} \mid \text{Zn}^{2+} \parallel \text{Cu}^{2+} \mid \text{Cu}$  is:
- (A) +1.10 V
  - (B) -1.10 V
  - (C) +0.42 V
  - (D) -0.42 V
- Q53. A **pseudo first-order reaction** is observed when:
- (A) The reaction involves only one reactant that is radioactive.
  - (B) One reactant is present in such large excess that its concentration remains effectively constant, making the rate depend only on the other reactant.
  - (C) The reaction is first-order at high temperature but second-order at low temperature.



(D) The rate constant and the rate are numerically equal.

**Q54.** A **Schottky defect** arises when equal numbers of cations and anions are missing from lattice sites. What is its effect on the **density** of the crystal?

(A) Density increases because the lattice contracts.

(B) Density remains unchanged because missing ions are replaced internally.

(C) Density decreases because the mass decreases while the volume stays nearly the same.

(D) Density increases because vacancies trap heavy impurities.

**Q55.** According to **Markovnikov's rule**, when HBr adds to propene ( $\text{CH}_3\text{CH}=\text{CH}_2$ ), the major product is:

(A)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$  (1-bromopropane)

(B)  $\text{CH}_3\text{CHBrCH}_3$  and  $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$  in equal amounts

(C)  $\text{CH}_2\text{BrCH}_2\text{CH}_3$  (1-bromopropane)

(D)  $\text{CH}_3\text{CHBrCH}_3$  (2-bromopropane)

**Q56.** Square planar geometry is most commonly adopted by complexes with which *d*-electron configuration (in a strong-field ligand environment)?

(A)  $d^8$

(B)  $d^6$

(C)  $d^4$

(D)  $d^{10}$

**Q57.** Which statement correctly compares **actinide contraction** with **lanthanide contraction**?

(A) Actinide contraction is smaller in magnitude than lanthanide contraction because 5f orbitals penetrate the core more.

(B) Actinide contraction is larger in magnitude than lanthanide contraction because 5f electrons are more poorly shielded than 4f electrons.



- (C) Both contractions are identical because  $f$ -orbitals have the same shielding regardless of principal quantum number.
- (D) Lanthanide contraction does not affect ionic radii, but actinide contraction does.

**Q58.** The **Rosenmund reduction** converts an acyl chloride ( $\text{RCOCl}$ ) to:

- (A) A carboxylic acid ( $\text{RCOOH}$ )
- (B) A primary alcohol ( $\text{RCH}_2\text{OH}$ )
- (C) An aldehyde ( $\text{RCHO}$ ), using  $\text{H}_2$  over palladium-on- $\text{BaSO}_4$  catalyst
- (D) A ketone ( $\text{RCOR'}$ )

**Q59.** At its **isoelectric point (pI)**, an amino acid carries:

- (A) A net positive charge because the amine group is protonated.
- (B) A net negative charge because the carboxyl group is deprotonated.
- (C) No ionisable groups at all.
- (D) A zero net charge (zwitterion form:  $-\text{NH}_3^+$  and  $-\text{COO}^-$  cancel).

**Q60.** The **ebullioscopic constant** ( $K_b$ ) of a solvent depends on which intrinsic property of the solvent?

- (A) The molar enthalpy of vaporisation and the boiling point of the pure solvent ( $K_b = \frac{RT_b^2 M}{1000 \Delta H_{\text{vap}}}$ ).
- (B) The molar mass of the solute dissolved in it.
- (C) The concentration of the solute in molality units.
- (D) The density of the solvent at room temperature.

### Part E: Mathematics (Q61–70)

**Q61.** A binary operation  $*$  is defined on  $\mathbb{R}$  by  $a * b = a + b - ab$ . Is  $*$  **associative**? Evaluate  $(1 * 2) * 3$  and  $1 * (2 * 3)$  to decide.

- (A) No, because  $(1 * 2) * 3 = 0$  and  $1 * (2 * 3) = 2$ .
- (B) Yes, because  $(1 * 2) * 3 = -2$  and  $1 * (2 * 3) = -2$ .
- (C) No, because  $(1 * 2) * 3 = 5$  and  $1 * (2 * 3) = 3$ .



(D) Yes, because  $(1 * 2) * 3 = 6$  and  $1 * (2 * 3) = 6$ .

Q62. Evaluate  $\int_0^{\pi/2} \cos x \, dx$ .

(A) 0

(B)  $\frac{\pi}{2}$

(C) 1

(D)  $-1$

Q63. A fair coin is tossed 5 times. Using the binomial distribution, what is the probability of getting **exactly 3 heads**?

(A)  $\frac{3}{16}$

(B)  $\frac{1}{4}$

(C)  $\frac{3}{8}$

(D)  $\frac{5}{16}$

Q64. Find the unit vector along  $\vec{v} = 3\hat{i} - 4\hat{j}$ .

(A)  $\frac{3}{5}\hat{i} - \frac{4}{5}\hat{j}$

(B)  $3\hat{i} - 4\hat{j}$

(C)  $\frac{3}{7}\hat{i} - \frac{4}{7}\hat{j}$

(D)  $\frac{1}{\sqrt{7}}(3\hat{i} - 4\hat{j})$

Q65. The equation  $M \, dx + N \, dy = 0$  is an **exact differential equation** if and only if:

(A)  $\frac{\partial M}{\partial x} = \frac{\partial N}{\partial y}$

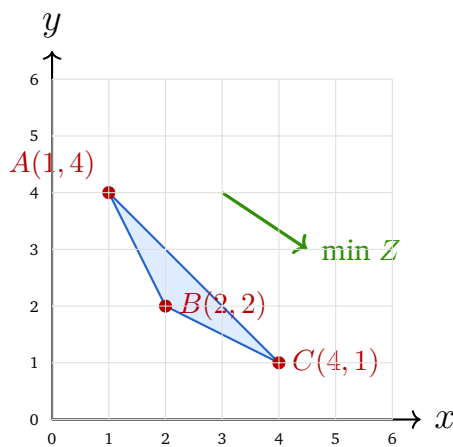
(B)  $\frac{\partial M}{\partial y} = \frac{\partial N}{\partial x}$

(C)  $M = N$  everywhere

(D)  $M + N = 0$  for all  $(x, y)$



- Q66.** The **Intermediate Value Theorem (IVT)** guarantees the existence of a root  $c \in (a, b)$  for a continuous function  $f$  when:
- (A)  $f(a) = f(b) = 0$
  - (B)  $f(a) > 0$  and  $f(b) > 0$
  - (C)  $f(a)$  and  $f(b)$  have opposite signs (i.e.,  $f(a) \cdot f(b) < 0$ )
  - (D)  $f$  is differentiable on  $[a, b]$
- Q67.** Cramer's rule guarantees a **unique solution** to a system of linear equations  $Ax = b$  when:
- (A)  $\det(A) = 0$  and  $b = 0$
  - (B) All entries of  $A$  are non-zero.
  - (C) The system is homogeneous ( $b = 0$ ).
  - (D)  $\det(A) \neq 0$
- Q68.** The figure below shows the feasible region (shaded) for a linear programming minimisation problem.



- If the objective function is  $Z = x + 2y$ , which corner point gives the **minimum** value of  $Z$ ?
- (A)  $C(4, 1)$ , giving  $Z = 6$
  - (B)  $B(2, 2)$ , giving  $Z = 6$
  - (C)  $A(1, 4)$ , giving  $Z = 9$
  - (D)  $B(2, 2)$ , giving  $Z = 4$



**Q69.** The **domain** of the function  $f(x) = \arcsin(x)$  is:

- (A)  $(-\infty, +\infty)$
- (B)  $[-1, 1]$
- (C)  $[0, \pi]$
- (D)  $(0, 1)$

**Q70.** Let  $f : \mathbb{R} \rightarrow \mathbb{R}$  be defined by  $f(x) = 2x + 5$ . Find  $f^{-1}(x)$ .

- (A)  $2x - 5$
- (B)  $\frac{x}{2} + 5$
- (C)  $\frac{x - 5}{2}$
- (D)  $\frac{x + 5}{2}$

### Part F: Physics (Q71–80)

**Q71.** The electric potential energy of two point charges  $q_1$  and  $q_2$  separated by a distance  $r$  in vacuum is given by:

- (A)  $U = \frac{q_1 q_2}{4\pi\epsilon_0 r^2}$
- (B)  $U = \frac{q_1 + q_2}{4\pi\epsilon_0 r}$
- (C)  $U = \frac{q_1 q_2}{r}$
- (D)  $U = \frac{q_1 q_2}{4\pi\epsilon_0 r}$

**Q72.** A resistor has four colour bands: **Yellow, Violet, Orange, Gold** (from left to right). Using the standard colour code table (Black=0, Brown=1, Red=2, Orange=3, Yellow=4, Green=5, Blue=6, Violet=7, Grey=8, White=9; Gold tolerance= $\pm 5\%$ ), what is the resistance?



- (A)  $47 \text{ k}\Omega \pm 5\%$
- (B)  $47 \Omega \pm 5\%$



- (C)  $470 \Omega \pm 5\%$
- (D)  $4.7 \text{ M}\Omega \pm 5\%$

**Q73. Eddy currents** are utilised in electromagnetic braking systems. Which of the following correctly explains how eddy-current braking works?

- (A) The rotating metal disc is magnetised by the brake coil, attracting a stationary magnet.
- (B) A changing magnetic field induces circulating currents in a moving conductor; these currents dissipate kinetic energy as heat (Joule heating), opposing the motion (Lenz's law).
- (C) The magnetic field directly exerts a torque on the axle, slowing it mechanically.
- (D) High-frequency AC current in the disc creates a back-EMF that opposes the supply voltage.

**Q74. In the lens-maker's equation**  $\frac{1}{f} = (n - 1) \left( \frac{1}{R_1} - \frac{1}{R_2} \right)$ , what does  $n$  represent?

- (A) The number of surfaces of the lens.
- (B) The refractive index of the medium surrounding the lens.
- (C) The refractive index of the lens material relative to the surrounding medium.
- (D) The ratio of image distance to object distance.

**Q75. Bragg's law for X-ray diffraction** is expressed as  $n\lambda = 2d \sin \theta$ . What do  $d$  and  $\theta$  represent?

- (A)  $d$  = diameter of the X-ray beam;  $\theta$  = angle of incidence to crystal face.
- (B)  $d$  = depth of the crystal;  $\theta$  = diffraction angle measured from the normal.
- (C)  $d$  = X-ray wavelength;  $\theta$  = Bragg angle.
- (D)  $d$  = interplanar spacing of the crystal lattice;  $\theta$  = glancing angle (angle between incident ray and the reflecting planes).

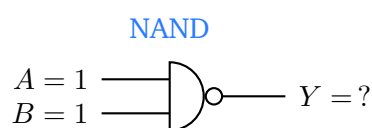




**Q76.** The mass defect of a nucleus is  $\Delta m = 0.03 \text{ u}$ . Given that  $1 \text{ u} = 931.5 \text{ MeV}/c^2$ , the **binding energy** of the nucleus is:

- (A) 27.945 MeV
- (B) 31.05 MeV
- (C) 0.03 MeV
- (D) 9.315 MeV

**Q77.** The figure below shows a NAND gate with inputs  $A = 1$  and  $B = 1$ . What is the output  $Y$ ?



- (A)  $Y = 1$
- (B)  $Y = 0$
- (C)  $Y = \text{undefined}$  (NAND requires exactly one input)
- (D)  $Y = A \cdot B = 1$

**Q78.** For a series RLC circuit, the total **impedance**  $Z$  is:

- (A)  $Z = R + X_L + X_C$
- (B)  $Z = R + X_L - X_C$
- (C)  $Z = \sqrt{R^2 + (X_L - X_C)^2}$
- (D)  $Z = \sqrt{R^2 - (X_L - X_C)^2}$

**Q79.** Using the Biot-Savart law, the magnetic field at the **centre of a circular loop** of radius  $R$  carrying current  $I$  is:

- (A)  $B = \frac{\mu_0 I}{2R^2}$
- (B)  $B = \frac{\mu_0 I}{4\pi R}$
- (C)  $B = \mu_0 I R$
- (D)  $B = \frac{\mu_0 I}{2R}$



**Q80.** A point charge  $+Q$  is placed at one **corner** of a cube of side  $a$ . By symmetry arguments and Gauss's law, the total electric flux through the entire surface of the cube is:

- (A)  $\frac{Q}{8\varepsilon_0}$  (the charge is shared equally among 8 equivalent cubes)
- (B)  $\frac{Q}{\varepsilon_0}$
- (C)  $\frac{Q}{6\varepsilon_0}$
- (D)  $\frac{Q}{4\varepsilon_0}$

