TIFR GS Science Education

Sample Paper – 1

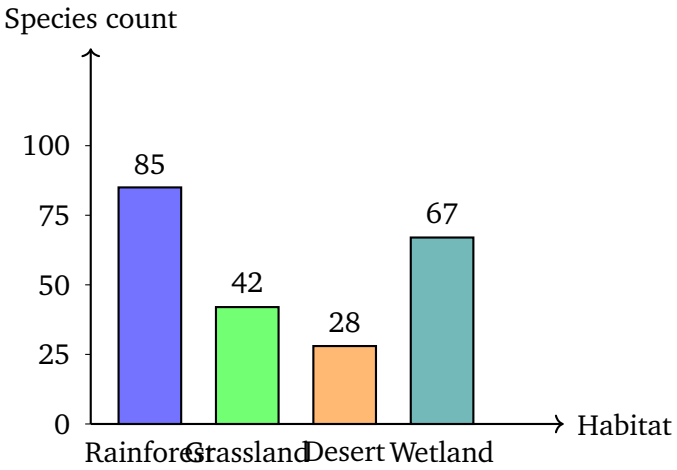
Duration: 180 Minutes **Maximum Marks: 100**

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–Q25 | +2 marks each | No negative marking)

Q0. A biodiversity survey recorded the number of species found in four habitat types. The bar chart below displays the results. Which habitat has the **second-highest** species richness?



(A) Rainforest

(B) Wetland

(C) Grassland

(D) Desert

Q1. A city had a population of 4,00,000 people. Over the next five years, the population grew by 15%. What is the new population after five years?

(A) 4,60,000

(B) 4,20,000

(C) 4,50,000

(D) 4,80,000

Q2. Consider the following statements:

Statement 1: All scientists are curious.

Statement 2: Ravi is curious.

Which of the following conclusions is **logically valid**?

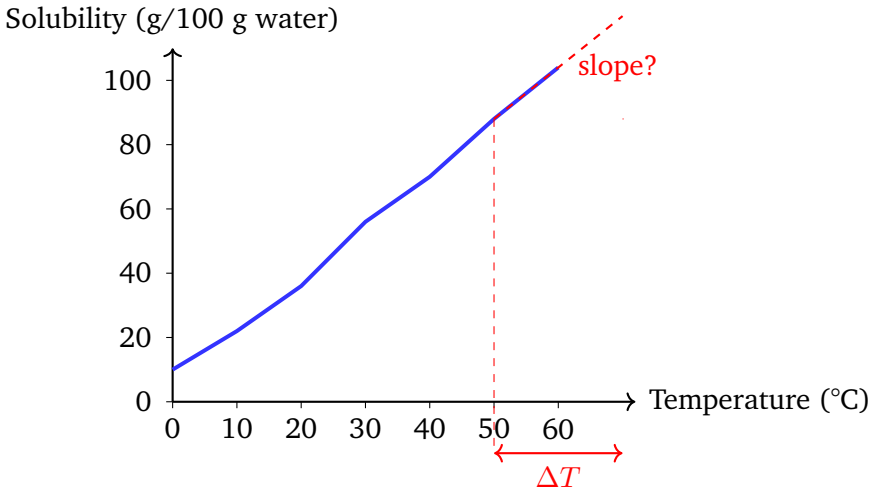
(A) Ravi is definitely a scientist.

(B) All curious people are scientists.

(C) Ravi may or may not be a scientist; the conclusion cannot be determined.

(D) Ravi is not a scientist.

Q3. The graph below shows the solubility of KNO_3 in water (in g per 100 g water) as a function of temperature. Estimate the rate of change of solubility (slope) at the interval between 50°C and 70°C.



(A) 0.5 g per °C

(B) 1.0 g per °C

(C) 1.5 g per °C

(D) 2.0 g per °C

Q4. In a survey of 100 students: 65 enjoy reading, 50 enjoy coding, and 35 enjoy art. Among these, 25 enjoy both reading and coding, 15 enjoy both reading and art, 10 enjoy both coding and art, and 5 enjoy all three. How many students enjoy **only reading** (and neither coding nor art)?

(A) 25

(B) 30

(C) 20

(D) 35

Q5. A train 150 m long travels at a uniform speed of 60 km/h. How long (in seconds) does the train take to completely cross a bridge 300 m long?

(A) 27 seconds

(B) 30 seconds

(C) 18 seconds

(D) 45 seconds

Q6. A bag contains 4 red balls, 3 blue balls, and 3 green balls. One ball is drawn at random. What is the probability that the ball drawn is **not red**?

(A) $\frac{2}{5}$

(B) $\frac{1}{2}$

(C) $\frac{3}{5}$

(D) $\frac{7}{10}$

Q7. Green light has a wavelength of 532 nm, and a photon of red light carries energy of 2.5 eV. Express these quantities in SI base units. (Given: 1 eV $= 1.6 \times 10^{-19}$ J)

(A) 5.32×10^{-6} m; 4.0×10^{-18} J

(B) 5.32×10^{-7} m; 4.0×10^{-18} J

(C) 5.32×10^{-6} m; 4.0×10^{-19} J

(D) 5.32×10^{-7} m; 4.0×10^{-19} J

Q8. Read the following passage and answer the question:

"In enzyme-catalysed reactions, the Michaelis–Menten model describes how reaction velocity (v) varies with substrate concentration ($[S]$). The parameter K_m, called the Michaelis constant, is a key characteristic of an enzyme. V_{max} is the maximum reaction velocity achieved when the enzyme is saturated with substrate."

According to the passage, what does K_m **represent** in the Michaelis–Menten model?

(A) The substrate concentration at which the reaction velocity is half of V_{max}

(B) The maximum reaction velocity of the enzyme

(C) The minimum enzyme concentration required for catalysis

(D) The product inhibition constant of the enzyme

Q9. A researcher grows two sets of plants. Set A receives a measured dose of a new fertiliser; Set B receives no fertiliser but is otherwise kept under identical conditions. The researcher measures plant height after four weeks. Which group is the **control group**?

(A) Set A (plants that received the fertiliser)

(B) Set B (plants that received no fertiliser)

(C) Both sets together form the control group

(D) The soil used in the experiment

Q10. Identify the **missing term** in the following sequence:

$2,\ 3,\ 5,\ 8,\ 13,\ 21,\ ?,\ 55$

(A) 32

(B) 31

(C) 34

(D) 36

Q11. A data analyst observes that as ice cream sales increase during summer months, the number of drowning incidents also increases. The analyst concludes that eating ice cream causes drowning. Which statement **best describes** the flaw in this reasoning?

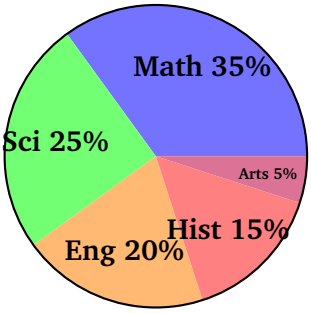
(A) The data set is too small to draw any conclusion.

(B) Drowning incidents cause people to buy more ice cream.

(C) The analyst should have used a different statistical test.

(D) The correlation is due to a confounding variable (hot weather increases both ice cream sales and outdoor swimming).

Q12. The pie chart below shows the subject preferences of 200 school students. What **percentage** of students prefer **Science or History**?



(A) 40%

(B) 50%

(C) 45%

(D) 35%

Q13. In a population of 200 adults: 80 have been diagnosed with hypertension (set P), 60 have been diagnosed with diabetes (set Q), and 25 have both conditions. How many adults have **neither** hypertension nor diabetes?

(A) 75

(B) 85

(C) 90

(D) 80

Q14. Pressure is defined as force per unit area. Which of the following formulae has **correct dimensions** for pressure?

(A) $P = Fv$ (force $\times$ velocity)

(B) $P = F^2/A$

(C) $P = F/A$

(D) $P = F \cdot A$

Q15. A researcher states: *"Students who study more tend to score higher on tests. Meena scored the highest in the class; therefore, Meena must have studied the most."* What is the **logical flaw** in this argument?

(A) The sample size used in the original study is too small.

(B) No control group was included in the study.

(C) The study used inappropriate statistical tests.

(D) The argument affirms the consequent — high scores do not necessarily imply maximum study time.

Q16. The heights (in cm) of seven students are: 152, 158, 160, 165, 168, 170, and 175. What is the **mean** height?

(A) 164 cm

(B) 166 cm

(C) 168 cm

(D) 160 cm

Q17. Four flat nets (A, B, C, D) are described below. Only one of them can be folded to form a closed cube. Which is it?

(A) A T-shaped arrangement of 6 squares with two squares sharing only a corner.

(B) A cross-shaped (plus sign) arrangement of 4 squares in a column with one square attached to each side of the second square from top.

(C) A straight line of 6 squares in a single row.

(D) An L-shaped arrangement of 4 squares with two squares stacked on the right end.

Q18. Read the passage and answer:

"Climate scientists study feedback loops to understand how the Earth's climate system responds to perturbations. A feedback loop can either amplify or dampen an initial change. When the feedback amplifies the original change, it is called a positive feedback; when it reduces the original change, it is called a negative feedback."

According to the passage, a **positive feedback loop** in climate science means:

(A) The feedback has beneficial or desirable effects on the climate.

(B) The feedback reduces or dampens the original perturbation.

(C) The feedback amplifies or reinforces the original change.

(D) The feedback only occurs at temperatures above 0°C.

Q19. An alloy is made of copper and zinc in the ratio 3 : 2 by mass. If 500 g of the alloy is prepared, what is the **mass of zinc** in the alloy?

(A) 150 g

(B) 250 g

(C) 100 g

(D) 200 g

Q20. The following sequence represents integers written in **binary (base-2)** notation:

$1,\ 10,\ 11,\ 100,\ 101,\ 110,\ 111,\ ?$

What is the **next term** in the sequence?

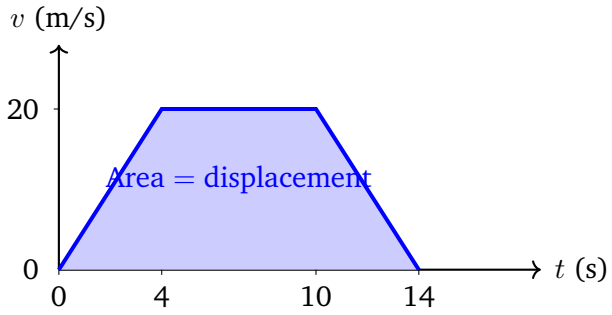
(A) 1000

(B) 1001

(C) 1100

(D) 1010

Q21. The velocity–time (v–t) graph of an object is shown below. The object accelerates from rest to 20 m/s in the first 4 s, maintains 20 m/s for the next 6 s, and then decelerates uniformly back to rest in 4 s. What is the **total displacement** of the object?



(A) 180 m

(B) 200 m

(C) 160 m

(D) 220 m

Q22. The table below shows the activity of an enzyme at various pH values. At which pH is the enzyme activity at its **optimum**?

pH	Enzyme Activity (units)
4	10
5	45
6	80
7	100
8	75
9	30
10	5

(A) pH 6

(B) pH 8

(C) pH 7

(D) pH 5

Q23. Given the conditional statement: *"If it rains, then the ground gets wet."*

Suppose you observe that **the ground is not wet**. What can you **logically conclude**?

(A) It rained.

(B) It may have rained but the ground dried quickly.

(C) No conclusion can be drawn about whether it rained.

(D) It did not rain.

Q24. Read the following passage and answer the question:

"CRISPR-Cas9 is a revolutionary genome-editing tool. The Cas9 protein acts as molecular scissors that cut double-stranded DNA at specific locations. A short synthetic RNA, called the guide RNA (gRNA), directs Cas9 to

the precise target sequence in the genome. Once the gRNA base-pairs with the target DNA, Cas9 induces a double-strand break, which the cell then repairs."

According to the passage, the Cas9 protein is directed to the target DNA by:

(A) A guide RNA (gRNA) that base-pairs with the target sequence

(B) Restriction endonucleases that recognize specific sequences

(C) DNA ligase that seals nicks in the DNA backbone

(D) DNA polymerase that replicates the target region

PART B — Social & Cognitive Sciences, Science Education (Q26–Q40 | +2 marks each | No negative marking)

Q24. Piaget conducted his famous **conservation of liquid** experiment by pouring equal amounts of water from two identical wide beakers into a tall, narrow beaker and a short, wide beaker. A child in which of Piaget's stages of cognitive development typically **fails** to conserve (i.e., believes the tall beaker has more water)?

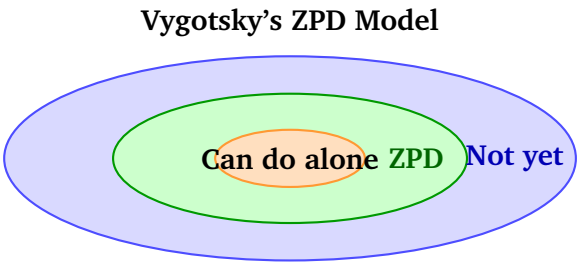
(A) Formal operational stage (12 years and above)

(B) Preoperational stage (2–7 years)

(C) Concrete operational stage (7–11 years)

(D) Sensorimotor stage (0–2 years)

Q25. The diagram below illustrates Vygotsky's concept of the **Zone of Proximal Development (ZPD)**. According to Vygotsky, the ZPD is best described as:



(A) The absolute upper limit of a learner's potential ability

(B) The region where a student can work entirely independently without any help

(C) The gap between what a learner can do independently and what the learner can achieve with guidance from a more knowledgeable other

(D) The zone of skills already mastered in a learner's past

Q26. A science teacher asks students to design and conduct their own experiment to test whether the type of soil affects seed germination rate. This classroom activity is **most consistent** with which educational philosophy?

(A) Behaviourism — stimulus–response conditioning

(B) Cognitivism — direct instruction and schema building

(C) Social learning theory — observational modelling

(D) Constructivism — students actively construct knowledge through investigation

Q27. A teacher asks students to *"Design an original experiment to investigate the effect of light intensity on the rate of photosynthesis."* According to the **revised Bloom's Taxonomy**, this task primarily belongs to which cognitive level?

(A) Create (highest level — generating new plans or products)

(B) Evaluate (judging the quality of work using criteria)

(C) Analyse (breaking information into component parts)

(D) Apply (using knowledge in a new situation)

Q28. Research on student misconceptions in physics shows that many students hold a persistent naive belief about motion. Which of the following **best describes** this common misconception?

(A) Students believe that heavier objects always fall faster than lighter objects.

(B) Students believe that a continuously applied force is necessary to keep an object moving at constant velocity.

(C) Students believe that energy and force are the same physical quantity.

(D) Students believe that all objects in free fall have the same acceleration regardless of mass.

Q29. A science teacher regularly gives short quizzes, asks questions during class, and reviews student notebooks to adjust her teaching. She uses the information gathered to modify her explanations and provide targeted feedback. This practice is **best described** as:

(A) Summative assessment — used to assign final grades at the end of a unit

(B) Normative assessment — used to rank students against one another

(C) Formative assessment — used to monitor and support ongoing learning

(D) Criterion-referenced assessment — used to certify mastery of fixed standards

Q30. According to **Ausubel's assimilation theory**, *meaningful learning* is distinguished from *rote learning* by which key feature?

(A) Meaningful learning relies primarily on repetition and drill for retention.

(B) Meaningful learning occurs faster than rote learning in all situations.

(C) Meaningful learning requires the presence of a social group for co-construction.

(D) Meaningful learning involves deliberately linking new information to existing cognitive structures (advance organisers).

Q31. In educational sociology, the term **"hidden curriculum"** refers to:

(A) The implicit values, norms, and social expectations transmitted through schooling beyond the formal academic content

(B) Advanced course content not listed in the official syllabus

(C) The set of extracurricular activities offered by a school

(D) Private tutoring or coaching provided outside school hours

Q32. The principle of **"Science for All"**, as articulated in international science education documents such as AAAS Project 2061, primarily implies:

(A) All students must enrol in advanced science courses regardless of ability or interest.

(B) Science education should be made accessible, relevant, and meaningful to all students, regardless of gender, socioeconomic background, or ability.

(C) Only science subjects should be taught in schools; arts and humanities are secondary.

(D) Science teachers must hold doctoral degrees to ensure quality instruction.

Q33. In science education research, **external representations** (such as diagrams, graphs, and models) are considered important pedagogical tools. What is their **primary cognitive role** in science learning?

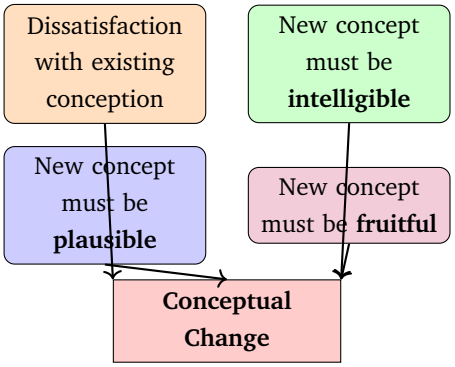
(A) They replace verbal explanations entirely in advanced science courses.

(B) They have been shown to confuse learners who are novices in the domain.

(C) They support the construction and communication of mental models by offloading cognitive effort.

(D) They are used only for decorative purposes in textbooks and slides.

Q34. Posner et al.'s **conceptual change theory** proposes that students replace their naive conceptions with scientifically correct ones only when certain conditions are met. The diagram below represents these conditions. Which answer correctly identifies **all four conditions**?



(A) Repetition, reward, punishment, and social reinforcement

(B) Memorisation, association, retrieval, and transfer

(C) Observation, imitation, modelling, and reinforcement

(D) Dissatisfaction, intelligibility, plausibility, and fruitfulness

Q35. A student pauses during a problem-solving task and thinks: *"I am not sure I understand this concept — I need to re-read the section before continuing."* This internal self-monitoring process is an example of:

(A) Metacognition — awareness and regulation of one's own learning processes

(B) Elaborative rehearsal — connecting new information with long-term memory

(C) Distributed practice — spacing learning sessions over time

(D) Social scaffolding — receiving support from a peer

Q36. Which of the following **best characterises** inquiry-based science learning?

(A) The teacher demonstrates an experiment while students take notes and reproduce the steps exactly.

(B) Students pose questions, plan investigations, collect and analyse data, and draw conclusions based on evidence.

(C) Students memorise scientific facts and definitions for subsequent recall on assessments.

(D) Assessment drives all learning; students study only what will be tested.

Q37. According to **Vygotsky's sociocultural theory**, learning is fundamentally:

(A) An individual mental process of schema construction, independent of social context

(B) A biological maturation process determined primarily by the child's stage of neural development

(C) A socially mediated process in which cultural tools, language, and interaction with knowledgeable others shape cognition

(D) A conditioned response to environmental stimuli shaped by reinforcement and punishment

Q38. In educational assessment research, "**assessment for learning**" and "**assessment of learning**" serve different purposes. Which statement **most accurately** distinguishes the two?

(A) They are different labels for the same process and serve identical functions.

(B) Assessment of learning is formative; assessment for learning is summative.

(C) Both types measure final learning outcomes and assign grades.

(D) Assessment for learning provides feedback during instruction to improve learning; assessment of learning evaluates achievement at the end of an instructional period.

PART C — Biology (CBSE Class XII Level) (Q41–Q50 | +2 marks each | No negative marking)

Q38. A dihybrid cross is performed between two pea plants both heterozygous for seed colour (A = yellow, a = green) and seed shape (B = round, b = wrinkled): **AaBb** × **AaBb**. A simplified Punnett square is shown below. What **fraction** of the offspring will show the **dominant phenotype for both traits** (yellow and round seeds)?

	AB	Ab	aB	ab
AB	AABB	AABb	AaBB	AaBb
Ab	AABb	AAbb	AaBb	Aabb
aB	AaBB	AaBb	aaBB	aaBb
ab	AaBb	Aabb	aaBb	aabb

(A) $\frac{9}{16}$

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

(C) $\frac{1}{16}$

(D) $\frac{6}{16}$

Q39. During **DNA replication** in eukaryotes, the double helix must first be unwound before the DNA polymerase can act. Which enzyme is **primarily responsible** for unwinding the DNA double helix at the replication fork?

(A) DNA polymerase III

(B) Helicase

(C) Primase

(D) DNA ligase

Q40. The **light-dependent reactions** of photosynthesis (Z-scheme) occur in the thylakoid membranes. Which of the following correctly lists the **direct products** of the light reactions?

(A) Glucose and oxygen only

(B) Carbon dioxide and water

(C) ATP, NADPH, and oxygen (O_2)

(D) ADP, $NADP^+$, and carbon dioxide

Q41. The **cell cycle** consists of interphase (G1, S, G2) and mitotic phase (M). In most actively dividing somatic cells, which phase occupies the **greatest proportion** of the total cell cycle time?

(A) S phase (DNA synthesis phase)

(B) M phase (mitosis and cytokinesis)

(C) G2 phase (post-synthesis gap phase)

(D) G1 phase (first gap/growth phase)

Q42. In the **ABO blood group system** combined with the Rh factor, which blood group is considered the **universal donor** for red blood cell transfusions?

(A) O negative (O^-)

(B) AB positive (AB^+)

(C) A positive (A^+)

(D) B negative (B^-)

Q43. In angiosperms, **double fertilization** involves two fusion events. One sperm cell fuses with the egg cell to form the zygote. The **second** sperm cell fuses with:

(A) The two synergid cells to form the embryo sac

(B) The two polar nuclei (secondary nucleus) to form the primary endosperm nucleus (3n)

(C) The three antipodal cells to reinforce the endosperm

(D) The integuments to form the seed coat (testa)

Q44. The human immune system comprises multiple layers of defence. What constitutes the **first line of defence** against pathogens?

(A) T lymphocytes (cytotoxic T cells and helper T cells)

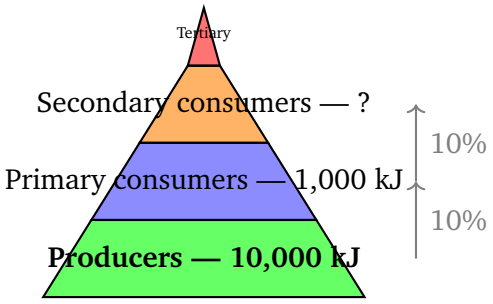
(B) Circulating antibodies produced by plasma cells

(C) Skin, mucous membranes, and secretions such as mucus, saliva, and tears

(D) B lymphocytes and memory cells

Q45. In a terrestrial food chain, only about **10%** of the energy at one trophic level is transferred to the next. The energy pyramid below illustrates

this. If the **producers** in this ecosystem contain **10,000 kJ** of energy, how much energy is available to the **secondary consumers**?



(A) 1,000 kJ

(B) 10 kJ

(C) 1 kJ

(D) 100 kJ

Q46. **Down syndrome** is a chromosomal disorder in humans. What is the **most common cytogenetic cause** of Down syndrome?

(A) Trisomy 21 — three copies of chromosome 21 due to non-disjunction during meiosis

(B) Deletion of a portion of chromosome 21

(C) Inversion of chromosome 21

(D) Trisomy 18 (Edwards syndrome)

Q47. The production of **vinegar** (acetic acid) from ethanol is a microbial process used in the food industry. Which microorganism is **primarily responsible** for this conversion?

(A) *Saccharomyces cerevisiae*

(B) *Acetobacter aceti*

(C) *Lactobacillus acidophilus*

(D) *Rhizobium leguminosarum*

PART D — Chemistry (CBSE Class XII Level)
(Q51–Q60 | +2 marks each | No negative marking)

Q47. A non-volatile, non-electrolyte solute is dissolved in a pure liquid solvent. According to **Raoult's law**, how does the **vapour pressure of the solution** ($P_{solution}$) compare with the vapour pressure of the **pure solvent** ($P^{\circ}_{solvent}$)?

(A) $P_{solution} = P^{\circ}_{solvent}$ (vapour pressure is unchanged by dissolving a solute)

(B) $P_{solution} > P^{\circ}_{solvent}$ (the solute increases the vapour pressure)

(C) $P_{solution} < P^{\circ}_{solvent}$ (solute molecules reduce the mole fraction of solvent, lowering vapour pressure)

(D) $P_{solution}$ is independent of mole fractions and depends only on temperature

Q48. The **Standard Hydrogen Electrode (SHE)** is used as the universal reference for measuring standard electrode potentials. By international convention, the standard electrode potential assigned to the SHE is:

(A) $+1.23$ V (same as the standard reduction potential of oxygen)

(B) -0.76 V (same as the standard reduction potential of zinc)

(C) $+0.34$ V (same as the standard reduction potential of copper)

(D) 0.00 V (defined as exactly zero by convention)

Q49. For a **first-order** chemical reaction, the half-life ($t_{1/2}$) is expressed in terms of the rate constant k as:

(A) $t_{1/2} = \dfrac{0.693}{k}$ (independent of initial concentration)

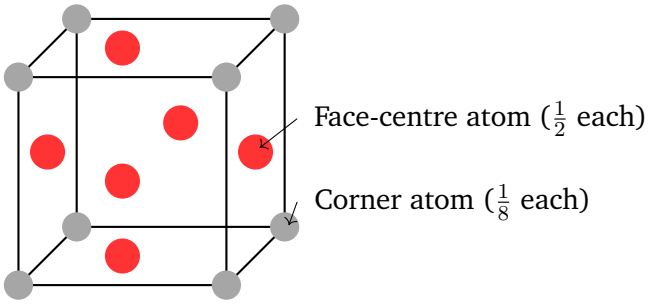
(B) $t_{1/2} = \dfrac{1}{k[A]_0}$ (inversely proportional to initial concentration)

(C) $t_{1/2} = \dfrac{2}{k[A]_0}$ (inversely proportional to initial concentration)

(D) $t_{1/2} = k[A]_0$ (directly proportional to initial concentration)

Q50. A **face-centred cubic (FCC)** unit cell is shown in the diagram below. Atoms (grey) sit at the 8 corners and atoms (red) sit at the centre of each of the 6 faces. Accounting for the fraction of each atom shared

between unit cells, what is the **total number of atoms** per FCC unit cell?



(A) 1 atom per unit cell

(B) 4 atoms per unit cell

(C) 2 atoms per unit cell

(D) 6 atoms per unit cell

Q51. The **Lucas test** (anhydrous $ZnCl_2$ in concentrated HCl) is used to distinguish between primary, secondary, and tertiary alcohols. Which type of alcohol gives an **immediate** turbidity (cloudiness) at room temperature?

(A) Primary alcohol (turbidity after boiling only)

(B) Secondary alcohol (turbidity after about 5 minutes)

(C) Tertiary alcohol (immediate turbidity)

(D) All alcohols react at the same rate with the Lucas reagent

Q52. What is the **correct IUPAC name** of the coordination compound $[Cu(NH_3)_4]SO_4$?

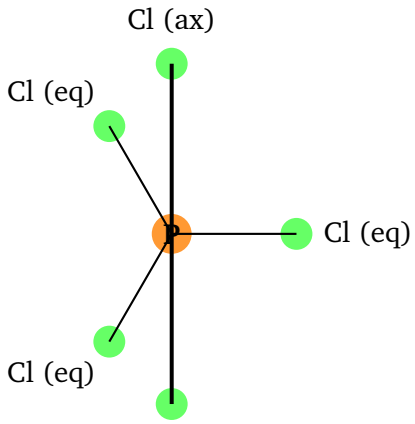
(A) Tetraminecopper(I) sulphate

(B) Copper tetraamine sulphate

(C) Tetraamminecopper(I) sulphate

(D) Tetraamminecopper(II) sulphate

Q53. The geometry and hybridisation of PCl_5 are depicted below. What is the correct hybridisation of the central phosphorus atom in PCl_5?



Trigonal bipyramidal geometry

(A) sp^3d (trigonal bipyramidal)

(B) sp^3d^2 (octahedral)

(C) sp^3 (tetrahedral)

(D) sp^2 (trigonal planar)

Q54. In electrophilic aromatic substitution, the hydroxyl group ($-$**OH**) in phenol acts as an **activating, ortho/para-directing** group. This is primarily because:

(A) The $-$OH group withdraws electron density from the ring by induction, stabilising the ring.

(B) The $-$OH group donates electron density to the ring by resonance, increasing electron density at the ortho and para positions.

(C) The $-$OH group is a meta-director because of its steric bulk.

(D) The $-$OH group increases the ionisation energy of the ring, making it less reactive.

Q55. Which of the following amino acids has a **non-polar (hydrophobic) side chain** at physiological pH (7.4)?

(A) Aspartic acid (Asp) — acidic, charged side chain

(B) Lysine (Lys) — basic, positively charged side chain

(C) Glycine (Gly) — side chain is a hydrogen atom (non-polar)

(D) Serine (Ser) — polar uncharged side chain ($-CH_2OH$)

Q56. Which of the following statements **best defines** the term **"colligative properties"** of solutions?

(A) Only the boiling point elevation of a solution is a colligative property.

(B) Only the osmotic pressure of a solution is a colligative property.

(C) Only the freezing point depression is a colligative property.

(D) Colligative properties (vapour pressure lowering, boiling point elevation, freezing point depression, osmotic pressure) all depend on the **number** of solute particles, not their chemical identity.

PART E — Mathematics (CBSE Class XII Level)
(Q61–Q70 | +2 marks each | No negative marking)

Q56. Let $A = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$ and $B = \begin{bmatrix} 5 & 6 \\ 7 & 8 \end{bmatrix}$. The diagram below shows the product AB. What is the element in **row 1, column 2** of $(AB)^T$?

A | B | AB

1	2	×	5	6	=	19	22
3	4		7	8		43	50

$(AB)_{21} \rightarrow (AB)^T_{12}$

(A) 43

(B) 22

(C) 50

(D) 19

Q57. Evaluate the indefinite integral $\int x\, e^x\, dx$ using the method of **integration by parts**.

(A) $x\, e^x + C$

(B) $e^x(x - 1) + C$

(C) $e^x(x + 1) + C$

(D) $\dfrac{x^2\, e^x}{2} + C$

Q58. For two events A and B: $P(A) = 0.4$, $P(B) = 0.5$, and $P(A \cap B) = 0.2$. Find the **conditional probability** $P(A \mid B)$.

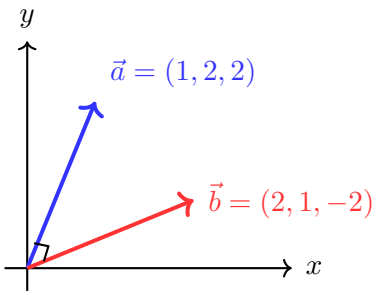
(A) 0.20

(B) 0.50

(C) 0.40

(D) 0.80

Q59. Two vectors $\vec{a} = (1, 2, 2)$ and $\vec{b} = (2, 1, -2)$ are shown schematically below. Calculate the **angle** between $\vec{a}$ and $\vec{b}$.



$$\vec{a} \cdot \vec{b} = 1(2) + 2(1) + 2(-2) = 0$$

(A) 0 (vectors are parallel)

(B) 45

(C) 60

(D) 90 (vectors are perpendicular since $\vec{a} \cdot \vec{b} = 0$)

Q60. Solve the **separable** differential equation $\dfrac{dy}{dx} = \dfrac{y}{x}$, where $y > 0$ and $x > 0$.

(A) $y = Cx$ (family of lines through the origin)

(B) $y = Ce^x$

(C) $y = Cx^2$

(D) $y = \dfrac{C}{x}$

Q61. A function is defined as:

$$f(x) = \begin{cases} x^2 - 4, & x < 2 \\ k, & x = 2 \\ 3x - 6, & x > 2 \end{cases}$$

For $f(x)$ to be **continuous at** $x = 2$, the value of k must be:

(A) $k = 2$

(B) $k = 0$

(C) $k = 4$

(D) $k = -2$

Q62. Evaluate the **determinant** of the following 3×3 matrix:

$$\begin{vmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{vmatrix}$$

(A) -6

(B) 6

(C) 0

(D) 18

Q63. Maximise $Z = 5x + 3y$ subject to the constraints: $x + y \leq 4$, $x \geq 0$, $y \geq 0$. Using the **corner-point method**, the **maximum value** of Z is:

(A) 12

(B) 15

(C) 18

(D) 20

Q64. Evaluate: $\sin^{-1}\left(\frac{1}{2}\right) + \cos^{-1}\left(\frac{1}{2}\right)$

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

(B) π

(C) $\dfrac{\pi}{3}$

(D) $\dfrac{2\pi}{3}$

Q65. Let $f(x) = 2x + 1$ and $g(x) = x^2 - 1$. Find $(f \circ g)(x)$, i.e., $f(g(x))$.

(A) $2x^2 + 1$

(B) $2x^2 - 1$

(C) $4x^2 - 1$

(D) $2x^2 + 2$

PART F — Physics (CBSE Class XII Level) (Q71–Q80 | +2 marks each | No negative marking)

Q65. Two point charges q_1 and q_2 are separated by a distance r and exert a force F on each other (Coulomb's law). If the distance between the charges is **halved** (to $r/2$) while the charges remain the same, the new force is:

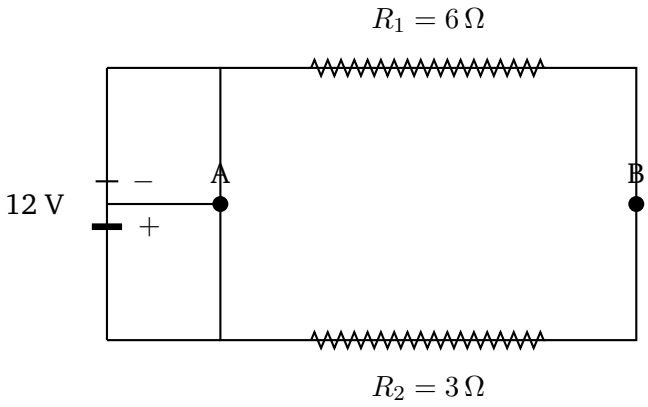
(A) $F/4$

(B) $F/2$

(C) $4F$

(D) $2F$

Q66. In the circuit below, resistors $R_1 = 6\,\Omega$ and $R_2 = 3\,\Omega$ are connected in **parallel** across a 12 V battery (internal resistance neglected). Using Kirchhoff's current law, find the **current through** R_2.



(A) 1 A

(B) 2 A

(C) 3 A

(D) 4 A

Q67. According to **Faraday's law of electromagnetic induction**, the magnitude of the induced EMF (ε) in a coil equals the rate of change of magnetic flux. If the magnetic flux through a coil changes from 0.50 Wb to 0.10 Wb in 0.20 s, what is the magnitude of the **induced EMF**?

(A) 2.0 V

(B) 0.8 V

(C) 4.0 V

(D) 0.2 V

Q68. A ray of light travels from a denser medium (refractive index $n = 1.5$) towards a less dense medium (air, $n = 1.0$). Using Snell's law, the **critical angle** θ_c for total internal reflection is:

(A) 30.0

(B) $41.8\ \left(\sin^{-1}\frac{2}{3}\right)$

(C) 45.0

(D) 60.0

Q69. In the **photoelectric effect**, a metal surface emits electrons only when the incident light has a sufficient frequency. Which of the following **cor-**

rectly explains why no electrons are emitted when the light frequency is below a certain value?

(A) The intensity of the incident light is too low to dislodge electrons.

(B) The metal is too thin to absorb the incident photons.

(C) Each photon must have energy hf exceeding the work function ϕ of the metal; below the threshold frequency, individual photon energies are insufficient.

(D) The applied voltage is not high enough to accelerate the photoelectrons.

Q70. **Rutherford's gold-foil scattering experiment** (1909) led to a revolutionary model of the atom. What was the **most significant conclusion** drawn from the observation that some α-particles were deflected at large angles (even back-scattered)?

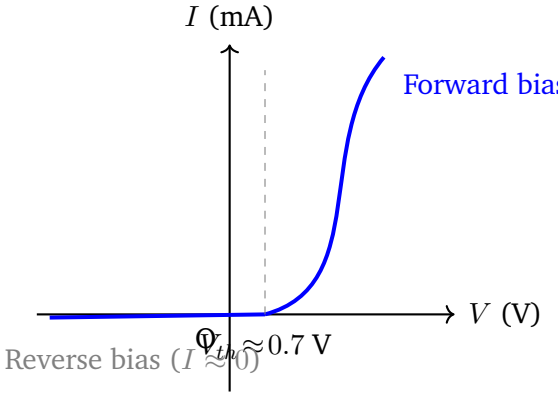
(A) Electrons are embedded uniformly throughout the atom (Thomson plum-pudding model confirmed).

(B) The entire positive charge is spread diffusely through the atom.

(C) Electrons orbit the nucleus in fixed, quantised energy levels (Bohr model).

(D) The atom has a tiny, extremely dense, positively charged nucleus, with electrons occupying mostly empty space around it.

Q71. The current–voltage (I–V) characteristic of a **p-n junction diode** is shown below. In the forward-bias region, the current behaviour is **best described** as:



(A) Current increases rapidly (approximately exponentially) with applied voltage once the threshold voltage is exceeded.

(B) Current decreases as forward voltage is increased.

(C) No current flows in forward bias until breakdown voltage is reached.

(D) Current is constant (independent of voltage) in forward bias.

Q72. An LC circuit consists of an inductor $L = 10$ mH and a capacitor $C = 100\,\mu$F connected in series. The **resonant frequency** f_0 of this circuit is given by $f_0 = \dfrac{1}{2\pi\sqrt{LC}}$. Calculate f_0.

(A) 100 Hz

(B) 159 Hz (approximately $\frac{1000}{2\pi}$ Hz)

(C) 250 Hz

(D) 318 Hz

Q73. A straight conductor of length $L = 0.20$ m carrying a current $I = 4.0$ A is placed perpendicular to a uniform magnetic field $B = 0.50$ T. The **magnitude of the magnetic force** on the conductor is:

(A) 0.2 N

(B) 0.1 N

(C) 0.4 N

(D) 0.8 N

Q74. A parallel-plate capacitor has a capacitance of $C = 4\,\mu$F and is charged to a potential difference of $V = 100$ V. The **energy stored** in the capacitor is given by $U = \frac{1}{2}CV^2$. Calculate U.

(A) 40 mJ

(B) 10 mJ

(C) 5 mJ

(D) 20 mJ