



XPertSTEM

XPertSTEM Competition 2026

Complete Two-Tier Solutions & Step-by-Step Point Allocation Guide

The XPertSTEM competitions consist of two stages: Qualification (held online or at local centers, typically requiring a score of 60–70% to advance to the finals, though the threshold varies by year) and the Elite Finals (held abroad). The final score is calculated from three components: the Individual Challenge (30 multiple-choice questions, 30%), the Theory Exam (step-by-step problem-solving, 50%), and the Team Challenge (up to 3 members, 20%).

The questions in this booklet are for the Theory Challenge. The Theory Challenge consists of 15 questions divided into three difficulty levels: **Normal**, **Hard**, and **Very Hard**. For each question, the first stage (multiple-choice) is always worth 2 points, while the second stage (reasoning/explanation) is worth 2, 4, or 8 points depending on the question's difficulty level. Accordingly, the total points per question are: Normal 4 points, Hard 6 points, and Very Hard 10 points. This system evaluates both the ability to select the correct answer and to demonstrate logical reasoning.

Difficulty Level	Stage 1 (Multiple-Choice)	Stage 2 (Explanation)	Total
Normal	2 points	2 points	4 points
Hard	2 points	4 points	6 points
Very Hard	2 points	8 points	10 points

 In this sample booklet, all questions have been evaluated on a 10-point scale.

1. Mathematics Solutions & Step-by-Step Scoring

1.1 Division 1 Mathematics

Question	Stage 1 Answer (2 Pts)	Stage 2 Reasoning Score	Total Score
Question 1 (Apples & Baskets)	A) 5 baskets	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 2 (Rectangle Perimeter)	B) 22 cm	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 3 (Equivalent Fractions)	B) 6/9	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 4 (Clock Angles)	D) Straight angle	8 / 8 Points (Step-by-step)	10 / 10 Points

Question 1: Sarah has 24 apples... Stage 2 Point Breakdown (8 Points Total):

- Define divisibility: To divide 24 apples evenly into baskets without leftovers, the number of baskets must be an exact integer factor of 24. **(2 points)**
- List all positive integer factors of 24: {1, 2, 3, 4, 6, 8, 12, 24}. **(2 points)**
- Test the given options: $24 \div 3 = 8$ (remainder 0), $24 \div 4 = 6$ (remainder 0), and $24 \div 6 = 4$ (remainder 0). **(2 points)**
- Calculate the remainder for 5 baskets: $24 \div 5 = 4$ with a remainder of 4. Conclude logically that 5 baskets is NOT possible because 4 apples would be left over. **(2 points)**

Question 2: A rectangle has a length of 8 cm and width of 3 cm... Stage 2 Point Breakdown (8 Points Total):

- State the geometric definition: The perimeter of a polygon is the total linear distance around its outer boundary. **(2 points)**
- Write the mathematical formula for the perimeter of a rectangle: $P = 2 \times (\text{Length} + \text{Width})$ or $P = 2l + 2w$. **(2 points)**
- Substitute the given dimensions into the formula: $P = 2 \times (8 \text{ cm} + 3 \text{ cm})$. **(2 points)**
- Execute step-by-step calculation: $P = 2 \times 11 \text{ cm} = 22 \text{ cm}$, and state the final unit correctly. **(2 points)**

Question 3: Which fraction is equivalent to $\frac{2}{3}$?... Stage 2 Point Breakdown (8 Points

Total):

- Define equivalent fractions: Fractions that represent the same numerical value or proportion of a whole, obtained by multiplying or dividing numerator and denominator by the same non-zero integer. **(2 points)**
- Set up the equivalence test by choosing a scaling factor of 3: Multiply both numerator (2) and denominator (3) by 3. **(2 points)**
- Perform the calculation: $(2 \times 3) / (3 \times 3) = 6 / 9$. **(2 points)**
- Verify other options to confirm they fail equivalence: $4/9 \neq 2/3$, $4/8 = 1/2 \neq 2/3$, $3/6 = 1/2 \neq 2/3$. Conclude that $6/9$ is the only equivalent fraction. **(2 points)**

Question 4: A clock shows exactly 6:00... Stage 2 Point Breakdown (8 Points Total):

- Describe hand positions at 6:00: The minute hand points directly upward toward the 12, and the hour hand points directly downward toward the 6. **(2 points)**
- Calculate geometric angular separation: The hands point in exactly opposite directions along a single continuous straight line, covering 6 out of 12 clock hours ($6/12 \times 360^\circ = 180^\circ$). **(2 points)**
- Define angle classification rules: Acute $< 90^\circ$, Right $= 90^\circ$, Obtuse is between 90° and 180° , and Straight $= 180^\circ$. **(2 points)**
- Conclude that since the angle between the hands is exactly 180° , it forms a straight angle. **(2 points)**

1.2 Division 2 Mathematics

Question	Stage 1 Answer (2 Pts)	Stage 2 Reasoning Score	Total Score
Question 1 (Percentages)	D) 50	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 2 (Proportions & Ratios)	B) 12	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 3 (Least	A) 24	8 / 8 Points (Step-by-	10 / 10 Points

Question	Stage 1 Answer (2 Pts)	Stage 2 Reasoning Score	Total Score
Common Multiple)		step)	
Question 4 (Triangle Interior Angles)	C) 70°	8 / 8 Points (Step-by-step)	10 / 10 Points

Question 1: What is 25% of 200?... Stage 2 Point Breakdown (8 Points Total):

- Explain Method 1 (Decimal Multiplication): Convert 25% to decimal form (0.25) and multiply: $0.25 \times 200 = 50$. **(2 points)**
- Explain Method 2 (Fraction Equivalent): Convert 25% to its simplest fraction form: $25/100 = 1/4$. **(2 points)**
- Execute Method 2 calculation: Divide 200 by 4: $200 / 4 = 50$. **(2 points)**
- Justify efficiency: Method 2 is computationally more efficient as dividing by 4 avoids decimal point manipulation and can be executed rapidly via mental arithmetic. **(2 points)**

Question 2: Ratio of boys to girls is 3:4, total 28 students... Stage 2 Point Breakdown (8 Points Total):

- Define proportional parts: A ratio of 3:4 means the class is divided into $3 + 4 = 7$ equal proportional parts. **(2 points)**
- Calculate the value of one part: Divide total students by total parts: $28 \text{ students} / 7 \text{ parts} = 4 \text{ students per part}$. **(2 points)**
- Calculate number of boys: Multiply the boys' ratio share (3) by the value of one part: $3 \times 4 = 12 \text{ boys}$. **(2 points)**
- Contextual verification: Girls = $4 \times 4 = 16$. Sum check: $12 \text{ boys} + 16 \text{ girls} = 28 \text{ total students}$; ratio $12/16$ simplifies exactly to $3/4$. **(2 points)**

Question 3: What is the least common multiple (LCM) of 6 and 8?... Stage 2 Point Breakdown (8 Points Total):

- List sequential positive multiples of 6: {6, 12, 18, 24, 30, 36, 42, 48, 54...}. **(2 points)**
- List sequential positive multiples of 8: {8, 16, 24, 32, 40, 48, 56...}. **(2 points)**
- Identify common multiples: Comparing both sets reveals common multiples at 24 and 48. **(2 points)**
- Apply LCM definition: The Least Common Multiple is the smallest positive integer divisible

by both numbers, which is 24. Larger numbers like 48 are common multiples but fail minimality. **(2 points)**

Question 4: Triangle angles 50° and 60°... Stage 2 Point Breakdown (8 Points Total):

- State fundamental geometric theorem: By the Triangle Angle-Sum Theorem, the sum of internal interior angles in any Euclidean triangle is invariably 180°. **(2 points)**
- Set up linear algebraic equation: $50^\circ + 60^\circ + x = 180^\circ$, where x is the unknown third angle. **(2 points)**
- Combine known angle terms: $110^\circ + x = 180^\circ$. **(2 points)**
- Isolate variable x : $x = 180^\circ - 110^\circ = 70^\circ$. Justify that geometric closure prohibits any other angle measure. **(2 points)**

1.3 Division 3 Mathematics

Question	Stage 1 Answer (2 Pts)	Stage 2 Reasoning Score	Total Score
Question 1 (Radical Simplification)	A) $6\sqrt{2}$	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 2 (Linear Equation)	C) $x = 7$	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 3 (Similar Triangles)	D) 10 cm	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 4 (Dice Probability)	B) $1/6$	8 / 8 Points (Step-by-step)	10 / 10 Points

Question 1: Simplify $\sqrt{72}$... Stage 2 Point Breakdown (8 Points Total):

- State radical simplification rule: To simplify a square root, find the largest perfect square integer factor of the radicand. **(2 points)**

- Factor 72 into its largest perfect square and remaining factor: $72 = 36 \times 2$. **(2 points)**
- Apply product property of square roots: $\sqrt{72} = \sqrt{(36 \times 2)} = \sqrt{36} \times \sqrt{2}$. **(2 points)**
- Evaluate the perfect square: $\sqrt{36} = 6$, yielding $6\sqrt{2}$. Justify that since 2 contains no square factors other than 1, $6\sqrt{2}$ is fully simplified. **(2 points)**

Question 2: Solve for x: $3x - 7 = 14$... Stage 2 Point Breakdown (8 Points Total):

- State algebraic principle: To isolate variable x, apply inverse operations to both sides of the equation to preserve equality balance. **(2 points)**
- Eliminate subtraction term: Add 7 to both sides of the equation: $3x - 7 + 7 = 14 + 7$. **(2 points)**
- Simplify both sides: $3x = 21$. **(2 points)**
- Eliminate multiplication coefficient: Divide both sides by 3: $3x / 3 = 21 / 3 \rightarrow x = 7$. **(2 points)**

Question 3: Similar triangles, sides 3, 4, 5 cm; second triangle shortest 6 cm... Stage 2 Point Breakdown (8 Points Total):

- Define similarity: Similar triangles have identical angle measures and corresponding side lengths that scale by a constant proportionality factor k. **(2 points)**
- Set up ratio of corresponding shortest sides to find scale factor: $k = \text{Shortest}_2 / \text{Shortest}_1 = 6 \text{ cm} / 3 \text{ cm}$. **(2 points)**
- Calculate scale factor: $k = 2$. **(2 points)**
- Calculate longest side of second triangle: Multiply corresponding longest side of first triangle (5 cm) by k: $5 \text{ cm} \times 2 = 10 \text{ cm}$. **(2 points)**

Question 4: Probability of rolling a sum of 7 with two standard dice... Stage 2 Point Breakdown (8 Points Total):

- Determine total sample space: Rolling two 6-sided dice yields $6 \times 6 = 36$ equally likely independent outcomes. **(2 points)**
- Enumerate favorable outcomes summing to 7: $\{(1,6), (2,5), (3,4), (4,3), (5,2), (6,1)\}$. **(2 points)**
- Count favorable outcomes: Exactly 6 distinct ordered pairs produce a sum of 7. **(2 points)**
- Calculate probability fraction: $P = \text{Favorable} / \text{Total} = 6 / 36$, which simplifies to $1 / 6$. **(2 points)**

1.4 Division 4 Mathematics

Question	Stage 1 Answer (2 Pts)	Stage 2 Reasoning Score	Total Score
Question 1 (Quadratic Factoring)	A) $x = 2, 3$	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 2 (Trigonometric Ratios)	B) $1/2$	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 3 (Coordinate Slope)	C) 2	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 4 (Distance Formula)	D) 5	8 / 8 Points (Step-by-step)	10 / 10 Points

Question 1: Solve quadratic equation $x^2 - 5x + 6 = 0$... Stage 2 Point Breakdown (8 Points Total):

- State factoring methodology: Find two integers whose product equals constant term (+6) and whose sum equals linear coefficient (-5). **(2 points)**
- Identify factors: The integers -2 and -3 satisfy conditions: $(-2)(-3) = 6$ and $(-2) + (-3) = -5$. **(2 points)**
- Factor equation and apply Zero Product Property: $(x - 2)(x - 3) = 0 \rightarrow x - 2 = 0$ or $x - 3 = 0$, yielding $x = 2$ and $x = 3$. **(2 points)**
- Verify solutions by substitution: $(2)^2 - 5(2) + 6 = 4 - 10 + 6 = 0$; $(3)^2 - 5(3) + 6 = 9 - 15 + 6 = 0$. Both identities hold. **(2 points)**

Question 2: What is the value of $\sin 30^\circ$?... Stage 2 Point Breakdown (8 Points Total):

- Define sine ratio in a right triangle: $\sin(\theta) = \text{Length of Opposite Side} / \text{Length of Hypotenuse}$. **(2 points)**
- Reference 30° - 60° - 90° special triangle properties: The side opposite the 30° angle is exactly half the length of the hypotenuse. **(2 points)**

- Calculate trigonometric ratio: $\sin(30^\circ) = (1/2 \times \text{Hypotenuse}) / \text{Hypotenuse} = 1/2$. **(2 points)**
- Justify scale invariance: Trigonometric values depend exclusively on angular separation, remaining constant regardless of physical triangle dimensions. **(2 points)**

Question 3: Slope through points (2, 3) and (6, 11)... Stage 2 Point Breakdown (8 Points Total):

- State linear slope formula: $m = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1}$ **(2 points)**
- Substitute coordinate values: $m = (11 - 3) / (6 - 2)$. **(2 points)**
- Simplify numerator and denominator: $m = 8 / 4 = 2$. **(2 points)**
- Interpret physical meaning: A slope of 2 represents a rate of change where vertical height increases by 2 units for every 1 unit of horizontal displacement. **(2 points)**

Question 4: Distance between points (1, 2) and (4, 6)... Stage 2 Point Breakdown (8 Points Total):

- State Euclidean distance formula derived from Pythagorean theorem:
 $d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$ **(2 points)**
- Substitute coordinates into formula: $d = \sqrt{[(4 - 1)^2 + (6 - 2)^2]}$. **(2 points)**
- Simplify coordinate differences and square: $d = \sqrt{[3^2 + 4^2]} = \sqrt{[9 + 16]}$. **(2 points)**
- Evaluate square root: $d = \sqrt{25} = 5$ units, forming a classic 3-4-5 Pythagorean triple. **(2 points)**

1.5 Division 5 Mathematics

Question	Stage 1 Answer (2 Pts)	Stage 2 Reasoning Score	Total Score
Question 1 (Polynomial Differentiation)	A) $12x^3 - 6x^2 + 1$	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 2 (Indefinite Integration)	B) $x^4 - x^2 + x + C$	8 / 8 Points (Step-by-step)	10 / 10 Points

Question	Stage 1 Answer (2 Pts)	Stage 2 Reasoning Score	Total Score
Question 3 (Limits of Continuous Functions)	C) 6	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 4 (Complex Number Powers)	D) -1	8 / 8 Points (Step-by-step)	10 / 10 Points

Question 1: Derivative of $f(x) = 3x^4 - 2x^3 + x - 7$... Stage 2 Point Breakdown (8 Points

Total):

- State differentiation rules: Apply linearity of differentiation and power rule $d/dx(x^n) = n \cdot x^{n-1}$. **(2 points)**
- Differentiate first two cubic/quartic terms: $d/dx(3x^4) = 12x^3$ and $d/dx(-2x^3) = -6x^2$. **(2 points)**
- Differentiate linear term: $d/dx(x^1) = 1 \cdot x^0 = 1$. **(2 points)**
- Differentiate constant term: $d/dx(-7) = 0$, because constants exhibit zero rate of change. Combine all terms to yield $12x^3 - 6x^2 + 1$. **(2 points)**

Question 2: Evaluate integral $\int (4x^3 - 2x + 1) dx$... Stage 2 Point Breakdown (8 Points Total):

- State integration power rule: $\int x^n dx = (x^{n+1})/(n+1) + C$ for $n \neq -1$. **(2 points)**
- Integrate polynomial terms term-by-term: $\int 4x^3 dx = 4(x^4/4) = x^4$; $\int -2x^1 dx = -2(x^2/2) = -x^2$; $\int 1 dx = x$. **(2 points)**
- Combine antiderivative terms: $x^4 - x^2 + x$. **(2 points)**
- Append constant of integration $+C$ and justify: Differentiation of any constant is zero; hence indefinite integration represents an infinite family of antiderivatives requiring $+C$. **(2 points)**

Question 3: Limit $\lim_{x \rightarrow 2} (x^2 + 3x - 4)$... Stage 2 Point Breakdown (8 Points Total):

- Analyze function continuity: The expression is a polynomial, and polynomials are continuous across all real numbers ($\mathbb{R}$). **(2 points)**
- State evaluation method: By definition of continuity, limits of continuous functions can be evaluated by direct substitution: $\lim_{x \rightarrow c} f(x) = f(c)$. **(2 points)**

- Substitute $x = 2$ into polynomial: $(2)^2 + 3(2) - 4$. **(2 points)**
- Execute arithmetic: $4 + 6 - 4 = 6$. **(2 points)**

Question 4: Value of i^{2020} where $i = \sqrt{-1}$... Stage 2 Point Breakdown (8 Points Total):

- State cyclic periodicity of imaginary unit: Powers of i repeat in cycles of 4: $i^1 = i$, $i^2 = -1$, $i^3 = -i$, $i^4 = 1$. **(2 points)**
- Divide exponent by cycle period 4: $2026 / 4 = 506$ with a remainder of 2 (since $4 \times 506 = 2024$). **(2 points)**
- Express exponent using remainder: $i^{2020} = (i^4)^{506} \times i^2 = (1)^{506} \times i^2$. **(2 points)**
- Simplify final expression: $1 \times (-1) = -1$. **(2 points)**

2. Natural Science Solutions & Step-by-Step Scoring

2.1 Division 1 Natural Science

Question	Stage 1 Answer (2 Pts)	Stage 2 Reasoning Score	Total Score
Question 1 (States of Matter)	A) Water	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 2 (Magnetic Poles & Domains)	B) Each piece becomes a separate magnet...	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 3 (Trophic Diet Classifications)	C) Cow	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 4 (Photosynthesis Energy Source)	D) Sunlight	8 / 8 Points (Step-by-step)	10 / 10 Points

Question 1: Which is a liquid at room temperature?... Stage 2 Point Breakdown (8 Points Total):

- Define physical states of matter: Solid (rigid shape/volume), Liquid (fixed volume, adaptable shape), Gas (expandable volume/shape). **(2 points)**
- Define room temperature standard: Standard room temperature is scientifically defined as approximately 20°C to 25°C (293 - 298 K) at 1 atm. **(2 points)**
- Evaluate water's phase transition points: Water freezes at 0°C and boils at 100°C; thus at 20°C-25°C, it exists stably in the liquid phase. **(2 points)**
- Eliminate other options: Ice is solid water (< 0°C), steam is gaseous water (> 100°C), and iron is a crystalline solid with a melting point of 1538°C. **(2 points)**

Question 2: Magnet cut into two pieces... Stage 2 Point Breakdown (8 Points Total):

- State dipole rule: All magnets exist as dipoles with inseparable North and South poles; magnetic monopoles do not exist in classical physics. **(2 points)**
- Explain internal magnetic domain structure: Permanent magnets consist of aligned atomic magnetic domains throughout their entire volume. **(2 points)**
- Analyze mechanical fracturing: Cutting a magnet across its length exposes new boundary surfaces where existing domain orientations instantly create complementary poles. **(2 points)**
- Conclude outcome: Each severed piece automatically becomes an independent, complete dipole magnet featuring both a North and a South pole. **(2 points)**

Question 3: Which animal is a herbivore?... Stage 2 Point Breakdown (8 Points Total):

- Define dietary classifications: Herbivores consume plant tissue exclusively; carnivores consume animal tissue; omnivores consume both. **(2 points)**
- Analyze cow digestive adaptation: A cow is a specialized ruminant herbivore adapted with multi-chambered stomachs to ferment and digest plant cellulose (grass). **(2 points)**
- Analyze predatory options: Lions and eagles are obligate carnivores adapted for hunting and consuming animal prey. **(2 points)**
- Analyze frog diet: Adult frogs are carnivorous/insectivorous amphibians feeding on invertebrates, confirming cow as the sole herbivore. **(2 points)**

Question 4: Main source of energy for plants... Stage 2 Point Breakdown (8 Points Total):

- Define photosynthesis: The endergonic biochemical process where photoautotrophs synthesize organic food (glucose) from inorganic molecules. **(2 points)**
- Identify light-absorbing pigments: Chlorophyll pigments within plant chloroplasts capture electromagnetic radiation. **(2 points)**

- Identify primary energy driver: Solar photons (sunlight) provide the essential excitation energy required to photolyze water and fixCO₂ **(2 points)**
- State overall chemical transformation: $6\text{CO}_2 + 6\text{H}_2\text{O} + \text{sunlight} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$ proving sunlight is the ultimate energy source. **(2 points)**

2.2 Division 2 Natural Science

Question	Stage 1 Answer (2 Pts)	Stage 2 Reasoning Score	Total Score
Question 1 (Cellular Powerhouse)	A) Mitochondria	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 2 (Food Chain Trophic Levels)	B) Rabbit	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 3 (Phase Transition Density)	C) Usually increases, but water's density decreases	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 4 (Simple Machines)	D) Lever	8 / 8 Points (Step-by-step)	10 / 10 Points

Question 1: Powerhouse of the cell... Stage 2 Point Breakdown (8 Points Total):

- Identify organelle function: Mitochondria are double-membraned eukaryotic organelles responsible for aerobic cellular respiration. **(2 points)**
- Describe biochemical pathway: They house the citric acid cycle (matrix) and electron transport chain (inner cristae) to oxidize glucose. **(2 points)**
- Explain energy conversion: This metabolic oxidation generates Adenosine Triphosphate

(ATP), the universal biochemical energy currency of cells. **(2 points)**

- Justify "powerhouse" label: Because they supply over 90% of cellular ATP required for metabolism and locomotion, mitochondria earn the powerhouse designation. **(2 points)**

Question 2: Primary consumer in a food chain... Stage 2 Point Breakdown (8 Points

Total):

- Define trophic hierarchy: Producers (autotrophs like grass) create biomass from solar energy at the base of the food chain. **(2 points)**
- Define primary consumers: Herbivores that feed directly upon photosynthetic producers occupy the second trophic level (primary consumers). **(2 points)**
- Classify given organisms: Grass is a producer; the rabbit is a herbivore feeding on grass; the fox is a carnivore (secondary consumer). **(2 points)**
- Conclude selection: Therefore, the rabbit correctly represents the primary consumer within this ecological web. **(2 points)**

Question 3: Density change when liquid freezes to solid... Stage 2 Point Breakdown (8

Points Total):

- State general thermodynamic rule: For most substances, solidification packs molecules into a tighter lattice, increasing mass per unit volume (density). **(2 points)**
- Identify water's anomaly: Water exhibits anomalous expansion upon freezing due to directional hydrogen bonding between H_2O molecules. **(2 points)**
- Explain ice crystal lattice: Hydrogen bonds force freezing water into an open, hexagonal crystalline structure containing significant void space. **(2 points)**
- Conclude density comparison: Consequently, solid ice is roughly 9% less dense than liquid water, causing ice to float. **(2 points)**

Question 4: Which is a simple machine?... Stage 2 Point Breakdown (8 Points Total):

- Define simple machine: An elementary mechanical device that changes the magnitude or direction of a force using mechanical advantage with minimal moving parts. **(2 points)**
- List classical examples: Lever, inclined plane, pulley, screw, wedge, and wheel-and-axle. **(2 points)**
- Analyze lever structure: A lever consists of a rigid beam pivoting around a fixed point called a fulcrum. **(2 points)**
- Contrast with complex systems: Bicycles, internal combustion engines, and computers are compound machines integrating numerous complex electromechanical parts. **(2 points)**

2.3 Division 3 Natural Science

Question	Stage 1 Answer (2 Pts)	Stage 2 Reasoning Score	Total Score
Question 1 (Gametogenesis & Meiosis)	A) Meiosis	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 2 (Newton's Second Law)	B) $F = ma$	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 3 (Chemical vs. Physical Change)	C) Rusting of iron	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 4 (Neutral pH Autoionization)	D) 7	8 / 8 Points (Step-by-step)	10 / 10 Points

Question 1: Cell division producing gametes... Stage 2 Point Breakdown (8 Points Total):

- Contrast mitosis vs. meiosis: Mitosis produces identical diploid ($2n$) somatic cells; Meiosis is a specialized reductional division occurring in germ cells. **(2 points)**
- Explain ploidy reduction: Meiosis involves two division rounds (Meiosis I & II) to yield four haploid (n) gametes (sperm and egg cells). **(2 points)**
- Justify biological necessity: Halving the chromosome number ensures that fertilization restores the normal diploid chromosome complement ($2n$) in offspring. **(2 points)**
- Explain genetic diversity: Meiosis introduces variation through homologous crossing over (Prophase I) and random independent assortment (Metaphase I). **(2 points)**

Question 2: Newton's second law equation... Stage 2 Point Breakdown (8 Points Total):

- Define physical law: Newton's Second Law states that the net force on an object is proportional to the rate of change of its linear momentum. **(2 points)**

- State formula for constant mass: When mass is invariant, this simplifies to Force equals mass multiplied by acceleration: $F = m \cdot a$. **(2 points)**
- Define variable symbols: F = Net vector force (Newtons), m = inertial mass (kg), a = resulting acceleration vector (m/s^2). **(2 points)**
- Explain physical relationship: Acceleration occurs in the exact direction of net force, scaled inversely by mass (inertia). **(2 points)**

Question 3: Example of a chemical change... Stage 2 Point Breakdown (8 Points Total):

- Define physical change: Alterations in macroscopic state or appearance without changing molecular chemical composition (e.g., melting, boiling, dissolving). **(2 points)**
- Define chemical change: Chemical reactions that break and reform intramolecular bonds to synthesize new substances with distinct chemical properties. **(2 points)**
- Analyze rusting mechanism: Rusting is an oxidation-reduction reaction where elemental metallic iron reacts with atmospheric oxygen and moisture. **(2 points)**
- Identify chemical product: This irreversibly forms hydrated iron(III) oxide $Fe_2O_3 \cdot nH_2O$ confirming rusting as a true chemical change. **(2 points)**

Question 4: pH value of pure water at 25°C... Stage 2 Point Breakdown (8 Points Total):

- Define pH scale formula: pH quantifies logarithmic hydronium ion activity:
- $pH = -\log_{10}[H^+]$. **(2 points)**
- Explain water autoionization: At 25°C, water self-ionizes $2H_2O \rightleftharpoons H_3O^+ + OH^-$ with equilibrium constant $K_1 = 1.0 \times 10^{-14}$. **(2 points)**
- Calculate ion concentrations: In pure water, hydronium exactly equals hydroxide concentration: $[H^+] = [OH^-] = 1.0 \times 10^{-7} \text{ M}$. **(2 points)**
- Calculate final pH: Substituting $[H^+]$ gives $pH = -\log_{10}(10^{-7}) = 7.0$ defining exact thermodynamic neutrality. **(2 points)**

3. Biology Solutions & Step-by-Step Scoring

3.1 Division 4 Biology

Question	Stage 1 Answer (2 Pts)	Stage 2 Reasoning Score	Total Score
Question 1 (Respiration Organelle)	A) Mitochondria	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 2 (Mendelian Genetics Genotype)	B) Tt	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 3 (Vascular Tissue Physiology)	C) Transport of water and minerals	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 4 (Polar Animal Adaptations)	D) Thick fur and blubber	8 / 8 Points (Step-by-step)	10 / 10 Points

Question 1: Organelle responsible for cellular respiration... Stage 2 Point Breakdown (8 Points Total):

- Define cellular respiration: The oxidative catabolic pathway breaking down organic molecules (glucose) to synthesize ATP energy. **(2 points)**
- Identify cellular locations: While initial glycolysis occurs in the cytoplasm, aerobic respiration stages occur inside the mitochondria. **(2 points)**
- Detail mitochondrial role: Mitochondria host the Krebs cycle in the matrix and oxidative phosphorylation across the inner cristae membranes. **(2 points)**
- Eliminate other organelles: Chloroplasts perform photosynthesis, ribosomes synthesize proteins, and the nucleus stores DNA. **(2 points)**

Question 2: Heterozygous tall pea plant genotype (T = tall, t = short)... Stage 2 Point Breakdown (8 Points Total):

- Define genetic terms: Genotype is an organism's underlying allelic composition; phenotype is the observable physical trait. **(2 points)**

- Define zygosity: Homozygous carries identical alleles (TT or tt); heterozygous carries two distinct alleles for the trait (Tt). **(2 points)**
- Apply Mendelian dominance: In pea plants, tall stem (T) exhibits complete dominant expression over short stem (t). **(2 points)**
- Conclude expression: In the Tt heterozygote, the single dominant T allele completely masks recessive t, producing a tall phenotype. **(2 points)**

Question 3: Function of xylem in plants... Stage 2 Point Breakdown (8 Points Total):

- Contrast plant vascular tissues: Phloem translocates bidirectional organic sugars; Xylem conducts inorganic transport. **(2 points)**
- State xylem function: Xylem is specifically responsible for the unidirectional upward transport of water and dissolved minerals from roots to shoots. **(2 points)**
- Describe xylem anatomy: Composed of dead, lignified tracheids and vessel elements forming hollow structural capillary tubes. **(2 points)**
- Explain transport mechanism: Driven upward against gravity by transpirational pull from leaf stomata and water cohesion-tension. **(2 points)**

Question 4: Animal adaptation for cold environments... Stage 2 Point Breakdown (8 Points Total):

- Define evolutionary adaptation: A hereditary trait evolved via natural selection enhancing survival and reproductive fitness in a specific biome. **(2 points)**
- Identify polar biome challenge: Freezing Arctic/Antarctic climates mandate aggressive physiological heat retention to prevent hypothermia. **(2 points)**
- Explain fur insulation: Thick fur/plumage traps a boundary layer of stagnant air, minimizing convective heat loss to the atmosphere. **(2 points)**
- Explain blubber function: Subcutaneous blubber provides a thick vascularized adipose layer acting as thermal insulation and caloric energy storage. **(2 points)**

3.2 Division 5 Biology

Question	Stage 1 Answer (2 Pts)	Stage 2 Reasoning Score	Total Score
Question 1 (tRNA in	A) Transports amino acids to the	8 / 8 Points (Step-by-	10 / 10 Points

Question	Stage 1 Answer (2 Pts)	Stage 2 Reasoning Score	Total Score
Translation)	ribosome	step)	
Question 2 (Hardy-Weinberg Equilibrium)	B) No mutation, no selection, large population size...	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 3 (Desert Ecosystem Abiotics)	C) Desert	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 4 (Endocrine Homeostasis)	D) Glucagon	8 / 8 Points (Step-by-step)	10 / 10 Points

Question 1: Role of tRNA in protein synthesis... Stage 2 Point Breakdown (8 Points Total):

- Identify translation phase: Protein synthesis involves translating mRNA nucleotide transcripts into polypeptides at ribosomal complexes. **(2 points)**
- Describe tRNA molecular anatomy: Transfer RNA features a cloverleaf secondary structure with an amino acid binding site and an anticodon loop. **(2 points)**
- Explain codon-anticodon pairing: The tRNA anticodon forms complementary hydrogen bonds with specific mRNA codons inside the ribosomal A-site. **(2 points)**
- State primary molecular function: tRNA acts as an adaptor, transporting the specific amino acid corresponding to the mRNA codon to extend the polypeptide chain. **(2 points)**

Question 2: Hardy-Weinberg principle assumptions... Stage 2 Point Breakdown (8 Points Total):

- Define genetic equilibrium: The Hardy-Weinberg principle proves allele frequencies remain constant across generations in the absence of evolutionary forces. **(2 points)**
- List demographic conditions: Requires an infinitely large population size (to prevent

genetic drift) and random mating across all genotypes. **(2 points)**

- List evolutionary conditions: Requires zero net mutation rates, zero gene flow (no immigration/emigration), and absence of natural selection. **(2 points)**
- Explain null hypothesis role: Serves as a mathematical baseline; when any condition is violated, microevolutionary change occurs. **(2 points)**

Question 3: Ecosystem with low rainfall, extreme temps, succulents... Stage 2 Point

Breakdown (8 Points Total):

- Identify abiotic moisture criteria: Classified by severe moisture deficit, receiving less than 250 mm of precipitation annually. **(2 points)**
- Identify temperature dynamics: Characterized by intense solar radiation and extreme diurnal temperature fluctuations between day and night. **(2 points)**
- Analyze plant adaptations: Xerophytic and succulent flora (e.g., Cactaceae) evolve thick waxy cuticles, reduced leaf surface area (spines), and water-storing parenchyma. **(2 points)**
- Analyze metabolic adaptations: Utilization of CAM photosynthesis opens stomata exclusively at cool nights to minimize evapotranspiration, defining a desert ecosystem. **(2 points)**

Question 4: Hormone increasing blood sugar levels... Stage 2 Point Breakdown (8 Points Total):

- Identify endocrine regulator: Blood glucose homeostasis is governed by the islets of Langerhans within the pancreas. **(2 points)**
- Contrast antagonistic hormones: Beta cells secrete insulin to lower blood sugar (promoting cellular uptake and glycogen synthesis). **(2 points)**
- Identify hyperglycemic hormone: Pancreatic alpha cells secrete glucagon in response to hypoglycemia (low blood glucose during fasting/exercise). **(2 points)**
- Explain mechanism of action: Glucagon targets hepatocytes to stimulate glycogenolysis (converting glycogen to glucose) and gluconeogenesis, elevating blood sugar. **(2 points)**

4. Chemistry Solutions & Step-by-Step Scoring

4.1 Division 4 Chemistry

Question	Stage 1 Answer (2 Pts)	Stage 2 Reasoning Score	Total Score
Question 1 (Covalent Bonding)	A) Covalent bond	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 2 (Stoichiometry & Mole Ratios)	B) 2 moles	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 3 (pH Calculation)	C) 5	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 4 (Atmospheric Composition)	D) Nitrogen	8 / 8 Points (Step-by-step)	10 / 10 Points

Question 1: Bond formed by sharing electrons... Stage 2 Point Breakdown (8 Points Total):

- Define chemical bonding motivation: Atoms bond to achieve stable valence octet electron configurations. **(2 points)**
- Contrast ionic bonding: Ionic bonds involve electrostatic electron transfer from metals to nonmetals, forming crystal lattices. **(2 points)**
- Define covalent bonding: Covalent bonds form when electronegative nonmetal atoms mutually share valence electron pairs. **(2 points)**
- Provide molecular example: In H_2O , central oxygen shares electron pairs with two hydrogen atoms via covalent bonds. **(2 points)**

Question 2: Moles of water produced from 2 moles of $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$

Stage 2 Point Breakdown (8 Points Total):

- Define stoichiometry: Stoichiometric coefficients in a balanced equation establish exact molar ratios between reactants and products. **(2 points)**

- Identify balanced chemical equation: $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$; O indicates 2 moles of hydrogen react with 1 mole of oxygen to yield 2 moles of water. **(2 points)**
- Establish mole ratio: The coefficient ratio between H_2 ; reactant and H_2O product is exactly 2:2, which simplifies to a 1:1 proportionality. **(2 points)**
- Calculate product yield: Therefore, complete consumption of 2 moles of H_2 ; in excess oxygen yields exactly 2 moles of H_2O . **(2 points)**

Question 3: pH of solution with $[\text{H}^+] = 1 \times 10^{-5} \text{ M}$... Stage 2 Point Breakdown (8 Points Total):

- State mathematical pH definition: pH represents the negative base-10 logarithm of hydronium concentration: $\text{pH} = -\log_{10}[\text{H}^+]$ **(2 points)**
- Substitute given concentration: $\text{pH} = -\log_{10}(1.0 \times 10^{-5} \text{ M})$ **(2 points)**
- Evaluate logarithmic term: Apply logarithm exponent property: $-(-5) = 5.0$. **(2 points)**
- Classify solution acidity: On the standard 0-14 aqueous scale at 25°C , $\text{pH} < 7$ confirms an acidic solution. **(2 points)**

Question 4: Most abundant gas in Earth's atmosphere... Stage 2 Point Breakdown (8 Points Total):

- List volumetric proportions of dry atmosphere: Nitrogen (~78.08%), Oxygen (~20.95%), Argon (~0.93%), and Carbon Dioxide (~0.04%). **(2 points)**
- Identify primary atmospheric component: Nitrogen gas (N_2) is overwhelmingly the most abundant constituent by volume and mass. **(2 points)**
- Explain molecular chemical stability: Diatomic nitrogen is bound by an exceptionally strong covalent triple bond ($\text{N}\equiv\text{N}$, dissociation energy ~945 kJ/mol). **(2 points)**
- Explain geological accumulation: Its extreme chemical inertness prevents rapid atmospheric reactions, allowing N_2 to accumulate over geological eras. **(2 points)**

4.2 Division 5 Chemistry

Question	Stage 1 Answer (2 Pts)	Stage 2 Reasoning Score	Total Score
Question 1 (Activation Energy &	A) The minimum energy required to	8 / 8 Points (Step-by-	10 / 10 Points

Question	Stage 1 Answer (2 Pts)	Stage 2 Reasoning Score	Total Score
Kinetics)	initiate...	step)	
Question 2 (Carboxylic Acid Structure)	B) -COOH (carboxyl)	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 3 (The Nernst Equation)	C) The cell potential under non-standard...	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 4 (Gibbs Free Energy Spontaneity)	D) $\Delta H < 0$ and $\Delta S > 0$	8 / 8 Points (Step-by-step)	10 / 10 Points

Question 1: What is the activation energy of a reaction?... Stage 2 Point Breakdown (8 Points Total):

- State collision theory requirements: Reacting molecules must collide with proper steric orientation and sufficient kinetic energy to break existing bonds. **(2 points)**
- Define activation energy (E_a): The minimum kinetic energy threshold required to elevate reactants to the unstable transition state (activated complex). **(2 points)**
- Explain transition state dynamics: Without achieving E_a , colliding molecules rebound elastically without undergoing chemical transformation. **(2 points)**
- Explain catalyst function: Catalysts accelerate reaction rates by providing an alternative mechanistic pathway with a lower E_a barrier without being consumed. **(2 points)**

Question 2: Functional group in a carboxylic acid... Stage 2 Point Breakdown (8 Points Total):

- Identify organic functional group: Carboxylic acids are defined by the carboxyl group (-COOH). **(2 points)**

- Describe internal structure: Consists of a carbonyl carbon (C=O) covalently bonded to a hydroxyl group (-OH). **(2 points)**
- Explain Brønsted-Lowry acidity: Carboxylic acids readily donate a proton (H⁺) from the hydroxyl group, exhibiting lower pK_a than alcohols. **(2 points)**
- Explain conjugate base stability: The resulting carboxylate anion (–COO[–]) is highly stabilized by resonance delocalizing negative charge across both oxygen atoms. **(2 points)**

Question 3: Nernst equation calculation purpose... Stage 2 Point Breakdown (8 Points Total):

- State standard electrochemical conditions: Standard cell potentials (E°) assume 1 M concentration, 1 atm pressure, and 298 K temperature. **(2 points)**
- State Nernst equation formula: $E = E^{\circ} - \frac{RT}{nF} \ln(Q)$ modeling real-world electrochemical behavior. **(2 points)**
- Define formula parameters: E = actual voltage, R = gas constant, T = Kelvin temperature, n = moles transferred electrons, F = Faraday constant, Q = reaction quotient. **(2 points)**
- Conclude analytical utility: Calculates exact electromotive force and cell potential under dynamic, non-standard chemical concentrations. **(2 points)**

Question 4: Spontaneity at all temperatures... Stage 2 Point Breakdown (8 Points Total):

- State Gibbs-Helmholtz equation: Thermodynamic spontaneity at constant T and P is governed by $\Delta G = \Delta H - T\Delta S$. **(2 points)**
- Define spontaneity criterion: A chemical process occurs spontaneously without external energy input only when free energy change is strictly negative ($\Delta G < 0$). **(2 points)**
- Analyze enthalpy and entropy signs: When enthalpy change $\Delta H < 0$ (exothermic heat release) and entropy change $\Delta S > 0$ (increasing molecular disorder). **(2 points)**
- Evaluate temperature dependence: Since absolute temperature T is always positive in Kelvin (>0 K), the term -TΔS is inherently negative, guaranteeing $\Delta G < 0$ at all temperatures. **(2 points)**

5. Physics Solutions & Step-by-Step Scoring

5.1 Division 4 Physics

Question	Stage 1 Answer (2 Pts)	Stage 2 Reasoning Score	Total Score
Question 1 (Force & Acceleration)	A) 4 m/s²	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 2 (Linear Kinetic Energy)	B) 9 J	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 3 (Ohm's Law Circuit)	C) 1.2 A	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 4 (Sound Wave Propagation)	D) Longitudinal wave	8 / 8 Points (Step-by-step)	10 / 10 Points

Question 1: Acceleration of 5 kg object with 20 N force... Stage 2 Point Breakdown (8 Points Total):

- State governing physical law: Newton's Second Law relates net applied force, inertial mass, and resulting linear acceleration: $F_{\text{net}} = m \cdot a$. **(2 points)**
- Rearrange formula to solve for acceleration: $a = F_{\text{net}} / m$. **(2 points)**
- Substitute numerical parameters: $a = 20 \text{ N} / 5 \text{ kg}$. **(2 points)**
- Calculate final value with SI unit verification: $1 \text{ N} = 1 \text{ kg} \cdot \text{m/s}^2$; thus $a = 4 \text{ N/kg} = 4 \text{ m/s}^2$. **(2 points)**

Question 2: Kinetic energy of 2 kg object at 3 m/s... Stage 2 Point Breakdown (8 Points Total):

- Define mechanical kinetic energy: Energy possessed by a body due to its translational motion, expressed by $KE = \frac{1}{2}mv^2$ **(2 points)**
- Substitute physical values into formula: $KE = (1/2) \cdot (2 \text{ kg}) \cdot (3 \text{ m/s})^2$. **(2 points)**
- Execute step-by-step arithmetic: $KE = (1 \text{ kg}) \cdot (9 \text{ m}^2/\text{s}^2) = 9 \text{ Joules (J)}$. **(2 points)**
- Analyze velocity scaling: Because velocity is squared, doubling speed quadruples kinetic

energy, proving quadratic sensitivity. **(2 points)**

Question 3: Current in 10 Ω resistor connected to 12 V battery... Stage 2 Point Breakdown (8 Points Total):

- State Ohm's Law: For ohmic DC circuits, voltage equals current multiplied by resistance: $V = I \cdot R$. **(2 points)**
- Rearrange equation to solve for current: $I = V / R$. **(2 points)**
- Substitute circuit parameters: $I = 12 \text{ V} / 10 \Omega$. **(2 points)**
- Calculate final current: $I = 1.2 \text{ Amperes (A)}$, representing a charge flow of 1.2 Coulombs per second. **(2 points)**

Question 4: Type of wave for sound... Stage 2 Point Breakdown (8 Points Total):

- Contrast wave classifications: Transverse waves oscillate perpendicular to propagation (e.g., light); Longitudinal waves oscillate parallel to propagation vector. **(2 points)**
- Identify sound wave medium requirement: Sound is a mechanical acoustic wave requiring a physical fluid or solid medium to travel. **(2 points)**
- Describe particle oscillation: Acoustic energy propagates via medium particles vibrating back and forth parallel to the wave travel direction. **(2 points)**
- Identify pressure zones: This parallel displacement creates alternating localized zones of high-pressure compressions and low-pressure rarefactions, defining a longitudinal wave. **(2 points)**

5.2 Division 5 Physics

Question	Stage 1 Answer (2 Pts)	Stage 2 Reasoning Score	Total Score
Question 1 (Rotational Dynamics)	A) 3 rad/s²	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 2 (Carnot Engine Efficiency)	B) 1 - T_c/T_h	8 / 8 Points (Step-by-step)	10 / 10 Points

Question	Stage 1 Answer (2 Pts)	Stage 2 Reasoning Score	Total Score
Question 3 (Relativistic Length Contraction)	C) Shorter than its proper length	8 / 8 Points (Step-by-step)	10 / 10 Points
Question 4 (Photon Quantum Energy)	D) $3.315 \times 10^{-15} \text{ J}$	8 / 8 Points (Step-by-step)	10 / 10 Points

Question 1: Wheel torque 6 Nm, moment of inertia 2 kg·m²... Stage 2 Point Breakdown (8 Points Total):

- Establish translational-rotational analogy: Torque (τ) replaces force, moment of inertia (I) replaces mass, and angular acceleration (α) replaces linear acceleration. **(2 points)**
- State rotational Newton's Second Law: $\tau = I \cdot \alpha$. **(2 points)**
- Rearrange to isolate angular acceleration: $\alpha = \tau / I$. **(2 points)**
- Substitute numerical values: $\alpha = 6 \text{ N}\cdot\text{m} / 2 \text{ kg}\cdot\text{m}^2 = 3 \text{ rad/s}^2$. **(2 points)**

Question 2: Carnot engine efficiency formula... Stage 2 Point Breakdown (8 Points Total):

- Define thermodynamic efficiency: Ratio of net work output to heat input from hot reservoir:

$$\eta = \frac{W}{Q_m} = \frac{Q_m - Q_h}{Q_m} = 1 - \frac{Q_h}{Q_m} \text{ (2 points)}$$
- Apply Carnot cycle reversibility: For an idealized reversible Carnot heat engine, heat transfer ratios scale strictly with absolute Kelvin reservoir temperatures: $Q_h / Q_m = T_h / T_m$. **(2 points)**
- Derive final efficiency formula: Substituting temperature ratio yields $\eta = 1 - (T_h / T_m)$. **(2 points)**
- State Second Law significance: Establishes upper theoretical efficiency limit; no real engine can exceed this due to inevitable entropy generation. **(2 points)**

Question 3: Spaceship length at 0.8c relative to Earth... Stage 2 Point Breakdown (8 Points Total):

- State Special Relativity principle: Spatial dimensions measured by a stationary observer contract parallel to relative velocity vector of moving reference frame. **(2 points)**

- State Lorentz length contraction formula: $L = L_t \sqrt{1 - v^2/c^2}$, where L_t is proper length measured in object's rest frame. **(2 points)**
- Substitute relative velocity $v = 0.8c$: $L = L_t \sqrt{1 - (0.8c)^2/c^2} = L_t \sqrt{1 - 0.64} = L_t \sqrt{0.36}$. **(2 points)**
- Calculate observed length fraction: $L = 0.6 \cdot L_t$. Conclude spaceship appears significantly shorter (60% of proper length) to Earth observer. **(2 points)**

Question 4: Photon energy at frequency 5×10^{14} Hz... Stage 2 Point Breakdown (8 Points Total):

- State quantum radiation principle: Electromagnetic radiation is quantized into discrete energy packets (photons). **(2 points)**
- State Planck-Einstein relation: Photon energy is directly proportional to wave frequency: $E = h \cdot f$, where $h = 6.63 \times 10^{-34}$ J·s. **(2 points)**
- Substitute given frequency: $E = (6.63 \times 10^{-34} \text{ J·s}) \times (5 \times 10^{14} \text{ s}^{-1})$. **(2 points)**
- Execute scientific notation arithmetic: $E = 33.15 \times 10^{-20} \text{ J} = 3.315 \times 10^{-15} \text{ Joules}$, confirming exact quantum energy. **(2 points)**

5. English Solutions & Step-by-Step Scoring

GRADE 3-4 SET

QUESTION 1

- **STAGE 1 - Correct Answer:** B) She was smart, independent, and loved reading.
(Points: 2)
- **STAGE 2 - Reasoning:**
 - Matilda's independence is shown by her teaching herself to read at age three and choosing to read despite her father's disapproval. (1 point)
 - Her father dislikes reading because he prefers shallow entertainment (television) and likely feels threatened by his daughter's intellect. (1 point)
 - To convince him: "Reading allows children to learn about the world, gain new perspectives, and develop problem-solving skills that television cannot provide."
(2 points)

QUESTION 2

- **STAGE 1 - Correct Answer:** B) He does not know any different, so he accepts it.
(Points: 2)

- **STAGE 2 - Reasoning:**

- The cupboard contains a small space, dust, and spiders. (1 point)
- Sleeping there would feel lonely, uncomfortable, and frightening. (1 point)
- "He never complained" shows that Harry is resilient, humble, and has been conditioned to believe that neglect is normal. (2 points)

QUESTION 3

- **STAGE 1 - Correct Answer:** C) She taught herself by reading books every day. (Points: 2)
- **STAGE 2 - Reasoning:**
 - Instead of caring for her, her parents neglect her and ignore her potential. (1 point)
 - Matilda reads books rather than watching television. (1 point)
 - Her constant practice and curiosity built her knowledge base. (1 point)
 - Her parents could have provided books, encouraged her questions, and spent time talking with her. (1 point)

QUESTION 4

- **STAGE 1 - Correct Answer:** B) Happy because a worry went away (Points: 2)
- **STAGE 2 - Reasoning:**
 - Before: Harry felt confused and isolated because no one believed him. (1 point)
 - After: He felt validated and hopeful. (1 point)
 - The change happened because Hagrid provided proof that Harry wasn't "crazy." (2 points)

QUESTION 5

- **STAGE 1 - Correct Answer:** B) She is a tall, angry person. (Points: 2)
- **STAGE 2 - Reasoning:**
 - Words: "Tall," "angry," "shouted," "frightened." (1 point)
 - These words create a sense of fear and intimidation in the reader. (1 point)
 - As a child, one would likely hide, stay very quiet, or try to avoid her attention. (2 points)

GRADE 5-6 SET

QUESTION 6

- **STAGE 1 - Correct Answer:** B) They are terrified of her. (Points: 2)
- **STAGE 2 - Reasoning:**
 - The Trunchbull uses fear, physical intimidation, and harsh words to control

children. (1 point)

- A teacher who never praises students lowers their self-esteem and makes them stop trying because they feel "nothing is good enough." (1 point)
- An ideal teacher is supportive, patient, and encourages students to grow through positive reinforcement. (2 points)

QUESTION 7

- **STAGE 1 - Correct Answer:** B) Because he feels free and like he finally belongs. (Points: 2)
- **STAGE 2 - Reasoning:**
 - At Hogwarts, Harry finds a talent he excels at, which contrasts with the Dursleys' house where he was treated as an outcast. (1 point)
 - Belonging provides a "safety net" that allows a person to take risks and build confidence. (3 points)

QUESTION 8

- **STAGE 1 - Correct Answer:** B) To show children that not all adults are good and to think critically. (Points: 2)
- **STAGE 2 - Reasoning:**
 - They act like "loving" parents online/publicly, but are neglectful in private. (1 point)
 - It is vital for children to realize that titles (like "parent") do not automatically guarantee good behavior, helping them set boundaries. (1 point)
 - If ignored, a child should seek help from a trusted teacher, relative, or counselor. (2 points)

QUESTION 9

- **STAGE 1 - Correct Answer:** B) Standing up to friends is sometimes harder than fighting enemies. (Points: 2)
- **STAGE 2 - Reasoning:**
 - It is hard because you risk losing the friendship or being socially rejected. (1 point)
 - This is true moral courage; it shows you value integrity over convenience. (3 points)

QUESTION 10

- **STAGE 1 - Correct Answer:** B) Reading is a personal choice that brings her joy. (Points: 2)

- **STAGE 2 - Reasoning:**
 - "Joy" is a deep, internal sense of happiness and satisfaction. (1 point)
 - Books allow escape, imagination, and learning. (1 point)
 - One word for Matilda: *Resilient*. She overcomes her environment through her own mind. (2 points)

GRADE 7-8 SET

QUESTION 11

- **STAGE 1 - Correct Answer:** B) Metaphor (Points: 2)
- **STAGE 2 - Reasoning:**
 - A simile uses "like" or "as"; a metaphor states one thing *is* another. (1 point)
 - "Crushed into dust" is a metaphor (implied comparison). (1 point)
 - It helps the reader feel the physical sensation of his extreme grief. (2 points)

QUESTION 12

- **STAGE 1 - Correct Answer:** B) Intelligence and courage help you overcome difficulties. (Points: 2)
- **STAGE 2 - Reasoning:**
 - "Mind is your power" means knowledge and critical thinking cannot be taken away by others. (1 point)
 - Intelligence helps you find solutions; courage helps you act on them. (1 point)
 - Examples: Standing up to a bully, or solving a difficult group project problem despite peer pressure. (2 points)

QUESTION 13

- **STAGE 1 - Correct Answer:** B) Harry's perspective (Points: 2)
- **STAGE 2 - Reasoning:**
 - We know Harry's feelings ("he felt proud and relieved") but only observe Malfoy's expression ("face was twisted"). (1 point)
 - Malfoy perspective: "I stared at the hat, my stomach churning with hatred as I watched Potter smirk. The arrogance of him!" (3 points)

QUESTION 14

- **STAGE 1 - Correct Answer:** C) She went from being scared to being determined to fight back. (Points: 2)
- **STAGE 2 - Reasoning:**
 - Stages: Fear (witnessing bullying) -> Anger (empathy for victims) -> Determination (deciding to use her brain). (2 points)

- Intelligence is better because it solves the root of the problem without needing violence. (2 points)

QUESTION 15

- **STAGE 1 - Correct Answer:** B) External conflict (The wizarding world intruding on Harry's normal life) (Points: 2)
- **STAGE 2 - Reasoning:**
 - This event forces Harry out of his mundane, suppressed life. (1 point)
 - It is a positive conflict because it offers him an identity and potential for freedom. (3 points)

GRADE 9-10 SET

QUESTION 16

- **STAGE 1 - Correct Answer:** B) Fairness and judging people by their character, not appearance (Points: 2)
- **STAGE 2 - Reasoning:**
 - The hat is "old and patched," but its value is "immense magic." (1 point)
 - Judging by appearance leads to bias; judging by character promotes fairness. (3 points)

QUESTION 17

- **STAGE 1 - Correct Answer:** B) Situational irony (Points: 2)
- **STAGE 2 - Reasoning:**
 - Irony: The father is proud of *failure* and ignores *success*, which is the opposite of expected parent behavior. (2 points)
 - It highlights how society/parents often value superficial things over real achievement. (2 points)

QUESTION 18

- **STAGE 1 - Correct Answer:** A) Harry will ignore the warning and discover a dangerous secret. (Points: 2)
- **STAGE 2 - Reasoning:**
 - Clues: "Strictly forbidden," "scratching," "something large/alive/waiting." (1 point)
 - Dumbledore warns them to create a test of character—to see who is curious enough to investigate. (1 point)
 - Prediction: A magical creature or guarded treasure. (2 points)

QUESTION 19

- **STAGE 1 - Correct Answer:** B) Multiple metaphors to create a terrifying image (Points:

2)

- **STAGE 2 - Reasoning:**

- Metaphors: "Hands were slabs of meat," "voice was a drill," "she was a tyrant." (2 points)
- Effect: It strips away her humanity and makes her seem like an unstoppable, hurting machine. (1 point)
- Kind teacher: "Her voice was a warm blanket on a cold morning." (1 point)

QUESTION 20

- **STAGE 1 - Correct Answer:** C) Harry is preparing for a future, dangerous challenge.

(Points: 2)

- **STAGE 2 - Reasoning:**

- Thinking about the future shows emotional growth and the transition from child to hero. (1 point)
- Brave: Feeling fear but doing it anyway. Prepared: Having the skills to survive the encounter. (3 points)