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KMU PESHAWAR

KMU Peshawar MDCAT 2025 Official Paper

Official Annual Full-Length Practice Examination (FLP) · Complete Solved Paper

📌 Official Admitting Board: Khyber Medical University Peshawar 📌 Archive Code: BEAMBE-FLP-KMU-2025 ⌚ Duration: 210 Minutes (3h 30m)

180

TOTAL QUESTIONS

210m

OFFICIAL DURATION

+1 / 0.00

ZERO NEGATIVE MARKING

180

MAXIMUM MARKS

📄 EXAMINATION BLUEPRINT & SUBJECT WEIGHTAGE

Biology**81 MCQs**

45.0% weight

Chemistry**45 MCQs**

25.0% weight

Physics**36 MCQs**

20.0% weight

English**9 MCQs**

5.0% weight

Logical Reasoning**9 MCQs**

5.0% weight

BIO SECTION: BIOLOGY

Questions 1 to 81 (81 MCQs)

Q1. BIO

Intrinsic factor secreted by parietal cells is essential for:

- (A) Activation of pepsinogen to pepsin
- (B) Absorption of vitamin B12 in the intestine
- (C) Emulsification of dietary fats
- (D) Neutralization of stomach acid in the duodenum

Q2. BIO

The delta cells in the islets of Langerhans secrete:

- (A) Insulin
- (B) Somatostatin
- (C) Glucagon
- (D) Pancreatic polypeptide

Q3. BIO

Identify the main function of the duodenum:

- (A) Bile storage
- (B) Absorption of water
- (C) Digestion of food
- (D) Waste storage

Q4. BIO

Which stage of the swallowing process prevents food or liquid from being aspirated into the lungs?

- (A) Oral stage
- (B) Pharyngeal stage
- (C) Esophageal stage
- (D) Peristalsis

Q5. BIO

Which type of nephron is responsible for the development of osmotic gradients in the renal medulla?

- (A) Glomerular
- (B) Cortical
- (C) Juxtamedullary
- (D) Medullary

Q6. BIO

Which of the following best describes how the distal convoluted tubule contributes to regulation of blood pH in the body?

- (A) Selective reabsorption of glucose
- (B) Active secretion of hydrogen ions into the filtrate
- (C) Active secretion of sodium from the glomerular filtration
- (D) Tubular reabsorption of potassium ions

Q7. BIO

The sodium–potassium pumps in the distal convoluted tubule are activated by:

- (A) Aldosterone
- (B) Antidiuretic hormone
- (C) Anti-natriuretic peptide
- (D) Renin

Q8. BIO

If a person drinks an excessive amount of water, how does the kidney respond to maintain osmoregulation?

- (A) Increase ADH release and water reabsorption
- (B) Increase aldosterone release and reabsorb more sodium
- (C) Decrease ADH release and increase water excretion
- (D) Decrease renin secretion and retain more water

Q9. BIO

The primary function of glomerular capillaries is:

- (A) Reabsorption of water and solutes from the renal tubules
- (B) Secretion of waste products from peritubular blood into the tubules
- (C) Filtration of blood to form glomerular filtrate
- (D) Supply of nutrients and oxygen to the kidney tissue

Q10. BIO

In a heat stroke the hypothalamus will detect an increase in core body temperature, which of the following response is triggered?

- (A) Vasoconstriction and shivering
- (B) Vasodilation and sweating
- (C) Increased metabolic rate
- (D) Release of thyroxine

Q11. BIO

Which nitrogenous waste has the lowest solubility in water?

- (A) Urea
- (B) Ammonia
- (C) Uric acid
- (D) Nitrite

Q12. BIO

By nature, human excretory system is:

- (A) Ammoniotelic
- (B) Uricotelic
- (C) Ureotelic
- (D) Aminotelic

Q13. BIO

Hyperparathyroidism may lead to the formation of:

- (A) Calcium phosphate stones
- (B) Uric acid stones
- (C) Cystine stones
- (D) Struvite stones

Q14. BIO

In somatic cell hybridization, which two cells are fused to produce monoclonal antibodies?

- (A) T-cells and nerve cells
- (B) B-lymphocytes and spleen cells
- (C) T-cells and liver cells
- (D) B-lymphocytes and macrophages

Q15. BIO

In molecular diagnostics, the primary function of DNA/RNA probes is to:

- (A) Replace malfunctioning genes in affected cells
- (B) Bind to specific DNA or RNA sequences for identification
- (C) Cut genetic material at precise locations
- (D) Stimulate immune responses against disease-causing organisms

Q16. BIO

A set of uniform proteins generated by genetically identical immune cells, which are:

- (A) Therapeutic proteins
- (B) Immunoglobulins
- (C) Monoclonal antibodies
- (D) Recombinant proteins

Q17. BIO

Which biotechnological product is used to replace an abnormal gene in a patient's cells?

- (A) Antibiotic
- (B) Vaccine
- (C) Vector
- (D) Interferon

Q18. BIO

In Watson and Crick's DNA model, which of the following pairs with Cytosine?

- (A) Adenine
- (B) Guanine
- (C) Thymine
- (D) Uracil

Q19. BIO

Fats are considered as a very efficient source of energy because they:

- (A) Produce ATP directly and without requiring respiration
- (B) Enter into glycolysis without any modification
- (C) Are highly oxidized compounds
- (D) Generate multiple acetyl groups that produce more ATP

Q20. BIO

The junction between two consecutive neurons where information is transmitted from one neuron to the next is called:

- (A) Node of Ranvier
- (B) Synapse
- (C) Axon terminal
- (D) Dendrite cleft

Q21. BIO

All of the following are the functions of Golgi bodies EXCEPT:

- (A) Processing of protein
- (B) Plasma membrane formation
- (C) Cellular respiration
- (D) Lysosome formation

Q22. BIO

Which ion is tenfold higher in concentration outside the membrane of neuron during resting potential?

- (A) Potassium
- (B) Sodium
- (C) Calcium
- (D) Hydrogen

Q23. BIO

All of the following are the modes of transmission of AIDS, EXCEPT:

- (A) Transfusion of infected blood
- (B) Sharing infected needles
- (C) Shaking hands with infected person
- (D) Sexual contact with infected person

Q24. BIO

Which organelle of the cell is involved in the detoxification of toxins and poisonous compounds?

- (A) Lysosomes
- (B) Smooth Endoplasmic Reticulum
- (C) Ribosomes
- (D) Mitochondria

Q25. BIO

The active site is important in enzyme action because:

- (A) It binds to the substrate
- (B) It maintains the pH of reaction
- (C) It provides energy for reaction
- (D) It changes the shape of the enzyme

Q26. BIO

The idea that acquired characters are inherited is part of:

- (A) Darwinism
- (B) Neo Darwinism
- (C) Lamarckism
- (D) Biogenesis

Q27. BIO

Which disease is caused by syncytial virus?

- (A) Leaf curl disease of cotton
- (B) Polio
- (C) Hepatitis A
- (D) Respiratory syncytial virus infection

Q28. BIO

The glycoproteins are commonly found in:

- (A) Mitochondria
- (B) Chloroplasts
- (C) Ribosomes
- (D) Plasma membrane

Q29. BIO

Which structure enables the exchange of material between nucleus and cytoplasm?

- (A) Plasma membrane
- (B) Nuclear pores
- (C) Lysosomes
- (D) Mitochondria

Q30. BIO

The high specific heat capacity of water is due to:

- (A) Ionic bonding
- (B) Hydrogen bonding
- (C) Covalent bonding
- (D) Hydrophilic bonding

Q31. BIO

The contracted region of a chromosome that attaches to spindle fiber is called:

- (A) Telomere
- (B) Chromatin
- (C) Centromere
- (D) Nucleosomes

Q32. BIO

Touching a sharp object stimulates pain receptors. This information is carried to the central nervous system by the?

- (A) Motor neuron
- (B) Sensory neuron
- (C) Associative neuron
- (D) Effector neuron

Q33. BIO

The number of chromosomes in a haploid cell are:

- (A) Half the chromosomes in a normal body cell
- (B) Double the chromosomes in a normal body cell
- (C) Quarter the chromosomes in a normal body cell
- (D) Equal to the chromosomes in a normal body cell

Q34. BIO

Which of the following is a branched polysaccharide found in animals:

- (A) Cellulose
- (B) Glycogen
- (C) Amylose
- (D) Chitin

Q35. BIO

A substance that binds to an enzyme, but NOT at the active site and reduces the enzyme activity is called a:

- (A) Competitive inhibitor
- (B) Substrate
- (C) Non-Competitive inhibitor
- (D) Cofactor

Q36. BIO

On the basis of morphological classification, influenza virus is an example of:

- (A) Helical capsid virus
- (B) Polyhedral capsid virus
- (C) Enveloped capsid virus
- (D) Non-enveloped capsid virus

Q37. BIO

Which of the following is NOT a globular protein?

- (A) Enzyme
- (B) Albumen
- (C) Hemoglobin
- (D) Collagen

Q38. BIO

The state, when a neuron is NOT conducting an impulse during resting membrane potential is called;

- (A) Polarized
- (B) Depolarized
- (C) Repolarized
- (D) Hyperpolarized

Q39. BIO

Which of the following waves travel along a neuron during nerve impulse conduction?

- (A) Thermal waves
- (B) Magnetic waves
- (C) Electromagnetic waves
- (D) Electrochemical waves

Q40. BIO

The reticular formation in the brain runs through which specific regions?

- (A) Forebrain and Midbrain
- (B) Hindbrain and Midbrain
- (C) Cerebellum and Forebrain
- (D) Telencephalon and Cerebellum

Q41. BIO

Enzymes increase the rate of reaction by:

- (A) Increasing activation energy
- (B) Lowering activation energy
- (C) Increasing pH
- (D) Decreasing pH

Q42. BIO

A diabetic patient is advised to avoid both sucrose and lactose, because they both:

- (A) Are structural carbohydrates
- (B) Increase blood glucose after hydrolysis
- (C) Cannot be digested in human
- (D) Act as non-caloric sweeteners

Q43. BIO

Match the CORRECT structure of the brain with its function:

- (A) Medulla: Breathing
- (B) Pons: Memory
- (C) Cerebellum: Dreaming
- (D) Midbrain: Balance

Q44. BIO

Living cells Do NOT directly acquire energy released from the breakdown of food molecules because:

- (A) Glucose cannot be broken down inside the cells
- (B) Energy released is too small to be used by the cells
- (C) Glucose molecules do not store any energy
- (D) The energy released is too large, leading to heating and wastage

Q45. BIO

Which properties of water enable it to circulate in living bodies and act as transport medium?

- (A) Ionization and low density
- (B) Cohesion and ionization
- (C) Ionization and adhesion
- (D) Adhesion and cohesion

Q46. BIO

How are the phospholipid molecules arranged in the plasma membrane?

- (A) Hydrophilic heads face inwards and hydrophobic tails face outwards
- (B) Both hydrophilic heads face each other in the interior of the membrane
- (C) Hydrophilic heads face outwards and hydrophobic tails face inwards
- (D) Hydrophilic heads and hydrophobic tails are randomly distributed

Q47. BIO

The structure of RNA is distinguished from DNA by the:

- (A) Presence of a double polynucleotide strand
- (B) Presence of deoxyribose sugar
- (C) Presence of five different types of nucleotides
- (D) Presence of base uracil instead of thymine

Q48. BIO

The constant diameter of DNA is maintained by pairing:

- (A) Purine towards pyrimidine
- (B) Pyrimidine towards pyrimidine
- (C) Purine towards purine
- (D) Sugar towards phosphate

Q49. BIO

Identify the CORRECT option that matches the sugar with its carbon number and functional group:

- (A) Glyceraldehyde: Triose, ketone group
- (B) Ribose: Pentose, aldehyde group
- (C) Ribulose: Pentose, aldehyde group
- (D) Galactose: Hexose, ketone group

Q50. BIO

The CORRECT sequence of events in a reflex arc is:

- (A) Receptor, associative neuron, sensory neuron, motor neuron, effector
- (B) Receptor, motor neuron, associative neuron, sensory neuron, effector
- (C) Receptor, sensory neuron, associative neuron, motor neuron, effector
- (D) Receptor, sensory neuron, motor neuron, associative neuron, effector

Q51. BIO

Fertilization normally occurs in the:

- (A) Uterus
- (B) Ovary
- (C) Vagina
- (D) Fallopian tubes

Q52. BIO

Which cells of the fallopian tube moisten and nourish the ovum?

- (A) Ciliated epithelial cells
- (B) Non Ciliated epithelial cells
- (C) Germ cells
- (D) Endometrial cells

Q53. BIO

Which of the following is NOT an accessory gland of the human male reproductive system?

- (A) Bulbourethral gland
- (B) Seminal vesicle
- (C) Prostate gland
- (D) Testes

Q54. BIO

Syphilis is caused by what kind of bacteria?

- (A) Spirochaete
- (B) Cocci
- (C) Bacillus
- (D) Vibrio

Q55. BIO

What is FALSE about cartilages?

- (A) Cells are called chondrocytes
- (B) Consist of Type II collagen
- (C) Heal very slowly
- (D) Have an extensive blood supply

Q56. BIO

Bones provide a rigid framework with an inorganic matrix of:

- (A) 35%
- (B) 45%
- (C) 55%
- (D) 65%

Q57. BIO

An important feature of bone remodeling is bone breakdown. Which cell carries out this function?

- (A) Chondrocyte
- (B) Osteocyte
- (C) Osteoclast
- (D) Osteoblast

Q58. BIO

Myofibrils consist of small contractile units called:

- (A) Sarcoplasm
- (B) Sarcolemma
- (C) Sarcomere
- (D) Sarcoplasmic reticulum

Q59. BIO

Which muscle type is under conscious control and is multinucleated?

- (A) Smooth muscle
- (B) Skeletal muscle
- (C) Cardiac muscle
- (D) Ciliary muscle

Q60. BIO

Which part of the sarcomere contain both actin and myosin filament?

- (A) I-band
- (B) Z-line
- (C) A-band
- (D) H-zone

Q61. BIO

The primary role of calcium ions in muscle contraction is to:

- (A) Produce energy
- (B) Bind with troponin
- (C) Carry nerve impulses
- (D) Breakdown ATP

Q62. BIO

Which of the following is an example of a fibrous joint?

- (A) Shoulder joint
- (B) Elbow joint
- (C) Intervertebral discs
- (D) Skull sutures

Q63. BIO

Which of Mendel's laws can best explain why a child may inherit brown eyes even if one parent has blue eyes?

- (A) Law of Dominance
- (B) Law of Segregation
- (C) Law of Independent Assortment
- (D) Law of Recombination

Q64. BIO

What is the significance of the 9:3:3:1 ratio in a dihybrid cross?

- (A) It proves that all genes are linked
- (B) It demonstrates that traits assort independently
- (C) It indicates co-dominance between alleles
- (D) It confirms that mutations have occurred

Q65. BIO

In crossing over, an exchange of maternal and paternal chromatid parts occurs while homologous chromosomes are paired during stage of meiosis:

- (A) Metaphase I
- (B) Prophase I
- (C) Anaphase II
- (D) Telophase I

Q66. BIO

Linked genes DO NOT follow Mendel's Law of Independent Assortment because:

- (A) They are located on different chromosomes
- (B) They always undergo crossing over
- (C) They are physically close together on the same chromosome
- (D) They rarely separate during meiosis

Q67. BIO

A carrier female for an X-linked recessive disorder:

- (A) Expresses the disorder fully
- (B) Cannot pass the disorder to offspring
- (C) Can pass the disorder to her sons
- (D) Only passes the disorder to daughters

Q68. BIO

Which of the following is an X-linked recessive disorder in humans?

- (A) Cystic fibrosis
- (B) Thalassemia
- (C) Hemophilia
- (D) Sickle cell anemia

Q69. BIO

Which of the following CORRECTLY describes the expected outcome of children from a carrier mother for haemophilia ($X^H X^h$) and a normal father ($X^H Y$)?

- (A) All sons will have hemophilia
- (B) All daughters will be carriers
- (C) 50% of sons will have hemophilia, and 50% of daughters will be carriers
- (D) All offspring will be unaffected

Q70. BIO

The heart is surrounded by a tough, inelastic double membranous covering called:

- (A) Pleura
- (B) Peritoneum
- (C) Pericardium
- (D) Meninges

Q71. BIO

The primary effect of smoking on the respiratory system:

- (A) Increased lung function due to presence of nicotine
- (B) Reduced risk of lung cancer due to tolerance
- (C) Damage to alveoli reducing gaseous exchange
- (D) Improves oxygenation of the blood by activating hemoglobin

Q72. BIO

What happens when the external intercostal muscles contract during inhalation in humans?

- (A) The ribcage compresses
- (B) The ribs move outward
- (C) The sternum moves inwards
- (D) The diaphragm muscles relax

Q73. BIO

During gaseous exchange in human respiration, enzyme carbonic anhydrase is directly involved in the:

- (A) Release of oxygen from hemoglobin
- (B) Combination of water with carbon dioxide
- (C) Breakdown of oxyhemoglobin
- (D) Binding of oxygen to myoglobin

Q74. BIO

Which of the following best describes Inspiratory Reserve Volume (IRV)?

- (A) Volume of air inhaled during normal breathing
- (B) Maximum volume of air that can be inhaled after a normal inhalation
- (C) Volume of air remaining in lungs after normal exhalation
- (D) Maximum volume of air that can be exhaled after a normal exhalation

Q75. BIO

Identify the primary component of the T cell's defense.

- (A) Complement system and interferons
- (B) Physical component of skin defense
- (C) Specific recognition and memory of pathogens
- (D) General inflammation at the site of infection

Q76. BIO

The primary role of helper T-cells in immune response is:

- (A) Secreting perforins to destroy target cells
- (B) Assisting B-cells and other T-cells in their function
- (C) Inhibiting over activity of the immune system
- (D) Engulfing and digesting pathogens

Q77. BIO

What is the primary function of lymphatic vessels?

- (A) Transport oxygenated blood
- (B) Drain excess interstitial fluid
- (C) Produce antibodies
- (D) Store metabolic waste

Q78. BIO

Which phase of the cardiac cycle is characterized by the opening of semilunar valves?

- (A) Atrial systole
- (B) Atrial diastole
- (C) Ventricular systole
- (D) Ventricular diastole

Q79. BIO

Which part of the heart's conducting system delays the impulse from atria to the ventricles?

- (A) Sino-atrial node
- (B) Atrio-ventricular node
- (C) Purkinje fibers
- (D) Atrio-ventricular valves

Q80. BIO

The heartbeat sound "LUB" is produced on closure of:

- (A) Aortic valve
- (B) Atrio-ventricular valves
- (C) Pulmonary valves
- (D) Semilunar valves

Q81. BIO

Which disease is caused by syncytial virus?

- (A) Leaf curl disease of cotton
- (B) Polio
- (C) Hepatitis A
- (D) Respiratory syncytial virus infection

CHEM SECTION: CHEMISTRY

Questions 82 to 126 (45 MCQs)

Q82. CHEM

In a molecule of phenol, the carbon atom which is attached to OH group is:

- (A) sp hybridized
- (B) sp² hybridized
- (C) sp³ hybridized
- (D) unhybridized

Q83. CHEM

The value of R in atm·dm³·mol⁻¹·K⁻¹ is:

- (A) 0.0821
- (B) 0.821
- (C) 62.4
- (D) 8.314

Q84. CHEM

Which one of the following is a planar molecule?

- (A) NH₃
- (B) H₂O
- (C) BF₃
- (D) CH₄

Q85. CHEM

The rate of a chemical reaction changes with:

- (A) Concentration of reactant molecules
- (B) Concentration of product molecules
- (C) Concentration of both reactant and product
- (D) Rate constant

Q86. CHEM

According to Planck's quantum theory, if the frequency of photon is doubled, the value of 'h' will be?

- (A) Doubled
- (B) Increased 3 times
- (C) Increased 4 times
- (D) Unchanged

Q87. CHEM

The specific rate constant (k) of a reaction is related to the concentration of reactants:

- (A) Directly
- (B) Inversely
- (C) Exponentially
- (D) Independently

Q88. CHEM

Which of the following is NOT a postulate of kinetic molecular theory of gases?

- (A) Gas molecules undergo elastic collision
- (B) Gas molecules are in continuous random motion
- (C) Gas molecules do not exert pressure when molecules collide with wall of container
- (D) Gas molecules are far away from each other

Q89. CHEM

Spectral series for hydrogen spectrum are:

- (A) 2
- (B) 3
- (C) 5
- (D) 7

Q90. CHEM

The most electronegative element in periodic table is:

- (A) F
- (B) Cl
- (C) N
- (D) O

Q91. CHEM

An experiment shows that heating a protein disrupts its alpha-helix structure. Which level of protein structure is primarily affected?

- (A) Primary
- (B) Secondary
- (C) Tertiary
- (D) Quaternary

Q92. CHEM

Which of the following hydrogen halides has the highest bond energy?

- (A) HCl
- (B) HI
- (C) HF
- (D) HBr

Q93. CHEM

In which case does a chemical reaction proceed nearly to completion?

- (A) When K_c is large but positive
- (B) When K_c is small but positive
- (C) When K_c is approximately equal to 1
- (D) When K_c is negative

Q94. CHEM

The addition of water to propene in the presence of sulfuric acid produces:

- (A) Propanol
- (B) Propan-2-ol
- (C) Butanol
- (D) Ethanol

Q95. CHEM

Consider the chlorination of methane to methyl chloride. The attack of the chlorine free radical on methane occurs in which phase?

- (A) Before initiation
- (B) Initiation
- (C) Propagation
- (D) Termination

Q96. CHEM

A patient with pancreatic insufficiency shows reduced activity of an enzyme that hydrolyzes the peptide bond at the carboxyl end of proteins and peptides. Which enzyme is deficient?

- (A) Elastase
- (B) Pepsin
- (C) Carboxypeptidase
- (D) Collagenase

Q97. CHEM

The intermolecular force of attraction resulting from temporary instantaneous dipoles is:

- (A) Dipole-dipole
- (B) Dispersion force
- (C) Debye force
- (D) Ion dipole force

Q98. CHEM

A student adds bromine water to ethene and observes decolourisation. What makes ethene more reactive than ethane in this reaction?

- (A) Ethene has a higher molecular mass
- (B) Ethene contains a weak and exposed pi bond
- (C) Ethane contains fewer sigma bonds
- (D) Ethene undergoes substitution more readily

Q99. CHEM

What best describes the overall reaction in electrophilic aromatic substitution in benzene?

- (A) Addition of an electrophile across a double bond
- (B) Substitution of a halogen by a nucleophile
- (C) Substitution of a proton (H+) by an electrophile on the aromatic ring
- (D) Substitution of a methyl group by a nucleophile

Q100. CHEM

Real gases DO NOT reach absolute zero in practice because:

- (A) Molecular collisions become inelastic due to increased kinetic energy
- (B) Intermolecular forces become negligible and molecules disperse
- (C) Kinetic energy of molecules increases due to compression
- (D) Intermolecular forces exceed kinetic energy of molecules

Q101. CHEM

The IUPAC name of the compound $\text{CH}_3\text{CH}_2\text{CH}_2\text{C} \equiv \text{CH}$ is:

- (A) Hex-1-yne
- (B) Pent-2-yne
- (C) Pent-4-yne
- (D) Pent-1-yne

Q102. CHEM

If 10 moles of magnesium react with an excess of oxygen, calculate the theoretical yield of magnesium oxide (MgO). (Molar mass of Magnesium = 24 g/mol, Oxygen = 16 g/mol)

- (A) 160 g
- (B) 240 g
- (C) 320 g
- (D) 400 g

Q103. CHEM

The IUPAC name of the compound $\text{Br} - \text{CH}_2 - \text{CH}_2 - \text{CO} - \text{CH}_3$ is:

- (A) 1-bromobutan-1-one
- (B) 4-bromobutan-2-one
- (C) 1-bromobutan-3-one
- (D) 1-bromobutan-4-one

Q104. CHEM

Consider the reaction: $2\text{Na} + \text{Cl}_2 \rightarrow 2\text{NaCl}$. If 4 moles of Na and 2 moles of Cl_2 are reacted, how much Cl_2 will remain unreacted?

- (A) 0 mol
- (B) 0.5 mol
- (C) 1 mol
- (D) 1.5 mol

Q105. CHEM

According to Le Chatelier's Principle, when the pressure of a gaseous equilibrium system is increased, the equilibrium shifts towards:

- (A) No change in equilibrium position
- (B) The side with greater volume
- (C) The side with lower volume
- (D) The side with more moles of gas

Q106. CHEM

If 4 g of H_2 reacts with 2 moles of O_2 to form water, which reagent is in excess?

- (A) H_2 only
- (B) O_2 only
- (C) H_2O only
- (D) Both O_2 and H_2

Q107. CHEM

The molecular orbitals in benzene are:

- (A) Localized
- (B) Delocalized
- (C) Hybridized
- (D) Polarized

Q108. CHEM

Consider the reaction $2\text{A} + \text{B}_2 \rightarrow 2\text{AB}$. Which of the following mixtures would make A the limiting reagent?

- (A) 300 atoms of A and 400 molecules of B_2
- (B) 100 atoms of A and 50 molecules of B_2
- (C) 2 mol of A and 1 mol of B_2
- (D) 5 mol of A and 2.5 mol of B_2

Q109. CHEM

Given: Heat of sublimation of Na = 108 kJ/mol, Ionization energy of Na = 496 kJ/mol, Bond dissociation energy of Cl_2 = 121 kJ/mol, Electron affinity of Cl = -349 kJ/mol, and Enthalpy of formation of NaCl = -411 kJ/mol. Calculate the lattice energy of NaCl:

- (A) 678 kJ/mol
- (B) -727 kJ/mol
- (C) -819 kJ/mol
- (D) -832 kJ/mol

Q110. CHEM

Acetaldehyde reacts with ethanol in the presence of an acid catalyst to initially produce:

- (A) Acetal
- (B) Hemiacetal
- (C) Diol
- (D) Diethoxyethane

Q111. CHEM

If the absolute pressure and absolute temperature of an ideal gas are both doubled, the new volume will be:

- (A) Doubled
- (B) Halved
- (C) Tripled
- (D) Same

Q112. CHEM

The ground-state electronic configuration of the Fe^{3+} ion ($Z = 26$) is:

- (A) $[\text{Ar}] 4s^2 3d^3$
- (B) $[\text{Ar}] 4s^1 3d^4$
- (C) $[\text{Ar}] 4s^0 3d^5$
- (D) $[\text{Ar}] 4s^0 3d^6$

Q113. CHEM

On increasing the temperature, the rate of a reaction increases mainly because:

- (A) The activation energy of the reaction increases
- (B) The concentration of the reacting molecules increases
- (C) The collision frequency increases
- (D) The energy of molecules decreases

Q114. CHEM

The conversion of an alkyl halide into an alkane by treatment with metallic sodium in dry ether is called the:

- (A) Wurtz reaction
- (B) Frankland reaction
- (C) Grignard reaction
- (D) Kolbe reaction

Q115. CHEM

The organic compound that reacts with phenylhydrazine to form a crystalline phenylhydrazone derivative is:

- (A) Butanal
- (B) 1,3-Butadiene
- (C) Ethyl acetate
- (D) Ethanol

Q116. CHEM

Balance the redox equation using the oxidation number method: $\text{Cu} + \text{H}_2\text{SO}_4 \rightarrow \text{CuSO}_4 + \text{SO}_2 + \text{H}_2\text{O}$

- (A) $\text{Cu} + \text{H}_2\text{SO}_4 \rightarrow \text{CuSO}_4 + \text{SO}_2 + \text{H}_2\text{O}$
- (B) $\text{Cu} + \text{H}_2\text{SO}_4 \rightarrow \text{CuSO}_4 + \text{SO}_2 + \text{H}_2$
- (C) $\text{Cu} + 2\text{H}_2\text{SO}_4 \rightarrow \text{CuSO}_4 + \text{SO}_2 + 2\text{H}_2\text{O}$
- (D) $2\text{Cu} + 2\text{H}_2\text{SO}_4 \rightarrow 2\text{CuSO}_4 + \text{SO}_2 + 2\text{H}_2\text{O}$

Q117. CHEM

Which of the following best explains the reaction between Beryllium (Be) and Oxygen (O_2)?

- (A) Be burns vigorously with oxygen forming a layer of BeO , which accelerates the oxidation of remaining metal
- (B) Be reacts with oxygen forming a layer of BeO , which protects the metal from further oxidation
- (C) Be reacts slowly with oxygen to form a volatile oxide BeO , which evaporates quickly
- (D) Be is the only alkaline earth metal that doesn't react with oxygen

Q118. CHEM

The relative energy of an atomic orbital in a multi-electron atom is determined by:

- (A) Hund's rule
- (B) Pauli exclusion principle
- (C) The $(n + l)$ rule
- (D) Boyle's law

Q119. CHEM

The solubility product (K_{sp}) of a binary salt $\text{AB} \rightleftharpoons \text{A}^+ + \text{B}^-$ is 9×10^{-6} . Its molar solubility is:

- (A) $3 \times 10^{-6} \text{ mol/dm}^3$
- (B) $9 \times 10^{-3} \text{ mol/dm}^3$
- (C) $3 \times 10^{-3} \text{ mol/dm}^3$
- (D) $9 \times 10^{-6} \text{ mol/dm}^3$

Q120. CHEM

For an exothermic chemical reaction, the potential energy of the reactants is:

- (A) Less than that of the products
- (B) More than that of the products
- (C) Equal to that of the products
- (D) Zero

Q121. CHEM

When pure water cools from a liquid at 4°C to solid ice at 0°C , what is the percentage change in its volume?

- (A) 9% increase
- (B) 9% decrease
- (C) 19% increase
- (D) 19% decrease

Q122. CHEM

In which of the following chemical species does the central atom utilize sp^2 hybridization?

- (A) PH_3
- (B) NH_3
- (C) CH_3
- (D) SbH_3

Q123. CHEM

In an electrolytic cell when electrical current passes through an electrolyte solution, the anode is the:

- (A) Positive electrode where oxidation occurs
- (B) Positive electrode where reduction occurs
- (C) Negative electrode where oxidation occurs
- (D) Negative electrode where reduction occurs

Q124. CHEM

An increase in the internal energy of a chemical system can lead to all of the following EXCEPT:

- (A) An increase in temperature due to a rise in kinetic energy of particles
- (B) A phase change such as melting or evaporation
- (C) A chemical reaction if the energy supplied is sufficient to break bonds
- (D) An increase in temperature due to a drop in kinetic energy of particles

Q125. CHEM

In an ethene molecule (C_2H_4), each carbon atom has three hybridized sp^2 orbitals which are:

- (A) Coplanar
- (B) Tetrahedral
- (C) Linear
- (D) Pyramidal

Q126. CHEM

Identify the CORRECT ground-state electronic configuration for the chromium atom ($Z = 24$):

- (A) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$
- (B) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^4$
- (C) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$
- (D) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$

PHY SECTION: PHYSICS

Questions 127 to 162 (36 MCQs)

Q127. PHY

According to Lenz's Law, the direction of an induced current in a conductor is such that it:

- (A) Opposes the change in magnetic flux producing it
- (B) Enhances the change in magnetic flux producing it
- (C) Is perpendicular to the magnetic field
- (D) Is parallel to the magnetic field

Q128. PHY

In a pure capacitive AC circuit, the alternating current:

- (A) Lags behind voltage by 90°
- (B) Leads the voltage by 90°
- (C) Is in phase with the voltage
- (D) Leads the voltage by 45°

Q129. PHY

In a center-tapped full-wave rectifier using two diodes, the diodes D1 and D2 operate:

- (A) Simultaneously during both half-cycles
- (B) In alternate switching mode
- (C) Only when both ends of the transformer are positive
- (D) Only in reverse bias condition

Q130. PHY

The energy (E) of a quantum of electromagnetic radiation is given by:

- (A) $E = mc^2$
- (B) $E = hf$
- (C) $E = \frac{1}{2}mv^2$
- (D) $E = qV$

Q131. PHY

The area under the horizontal line on a velocity-time graph for an object moving with uniform velocity represents a:

- (A) Rectangle
- (B) Triangle
- (C) Trapezium
- (D) Parallelogram

Q132. PHY

A car starts from rest and moves with a uniform acceleration of 3 m/s^2 . What will be its velocity after 5 seconds?

- (A) 8 m/s
- (B) 12 m/s
- (C) 15 m/s
- (D) 18 m/s

Q133. PHY

A passenger is standing in a stationary bus. When the bus suddenly accelerates forward, the passenger falls backward. Which phenomenon best explains this observation?

- (A) Friction
- (B) Gravity
- (C) Inertia
- (D) Deceleration

Q134. PHY

A ball is projected at an angle of 45° with an initial speed of 20 m/s. How does R_W (range without air resistance) compare to R_A (range with air resistance)?

- (A) R_A will be greater than R_W because air resistance reduces horizontal speed
- (B) R_A will be lesser than R_W because air resistance reduces horizontal speed
- (C) R_W will be equal to R_A because gravity is unchanged
- (D) R_W will be lesser than R_A because air resistance is random

Q135. PHY

A 0.02 kg bullet moving at 300 m/s embeds itself in a 2 kg wooden block initially at rest on a smooth, frictionless surface. What is the velocity of the block-bullet system immediately after impact?

- (A) 2 m/s
- (B) 3 m/s
- (C) 4 m/s
- (D) 5 m/s

Q136. PHY

Which of the following statements about ideal projectile motion is CORRECT?

- (A) The horizontal velocity of a projectile changes constantly due to gravity
- (B) The vertical velocity of a projectile remains constant throughout the flight
- (C) At the highest point, the vertical velocity of the projectile is zero, but the horizontal velocity remains unchanged
- (D) The acceleration of the projectile is zero at the peak of its trajectory

Q137. PHY

The rate of doing work at any instant of time is called:

- (A) Work done
- (B) Instantaneous power
- (C) Average power
- (D) Mechanical energy

Q138. PHY

A 5 kg body falls from a height of 30 m toward the ground. If all its potential energy converts into heat on impact, what is the heat energy produced? (Take $g = 9.8 \text{ m/s}^2$)

- (A) 1270 J
- (B) 1370 J
- (C) 1470 J
- (D) 1570 J

Q139. PHY

Two students, A and B, each carry a 20 kg load to the top of a 10 m high staircase. Student A takes 10 seconds, while student B takes 20 seconds. Which statement is CORRECT?

- (A) Student A does more work than student B
- (B) Student B uses more power than student A
- (C) Both students do the same amount of work, but student A uses more power
- (D) Student A and B use the same power since they lifted the same weight

Q140. PHY

A wheel of radius 0.4 m has an angular acceleration of 6 rad/s^2 . Its tangential linear acceleration is:

- (A) 1.2 m/s^2
- (B) 1.2 m/s
- (C) 2.4 m/s
- (D) 2.4 m/s^2

Q141. PHY

If an object is moving counterclockwise along a circular path in a horizontal plane on a page, the direction of its angular velocity vector is:

- (A) Tangential to any point on the circle
- (B) Towards the center of the circle
- (C) Perpendicular to the plane and pointing out of the page
- (D) Perpendicular to the plane and pointing into the page

Q142. PHY

If a particle moves along a circular path of radius r through an angular displacement θ (in radians), the arc length s is given by:

- (A) $s = r / \theta$
- (B) $s = r \theta$
- (C) $s = r^2 \theta$
- (D) $s = \theta / r^2$

Q143. PHY

A ball of weight F_G is falling vertically downward through air. If the upward drag force acting on it at some instant is F_D , what is the net force F_{net} on the ball?

- (A) $FG + FD$
- (B) $FG - FD$
- (C) $FD - FG$
- (D) FD / FG

Q144. PHY

Most natural fluid flows are turbulent rather than laminar primarily because of:

- (A) Zero viscosity
- (B) Very low velocities
- (C) High velocities
- (D) No resistance

Q145. PHY

According to the equation of continuity, when the cross-sectional area of a pipe decreases, the fluid velocity:

- (A) Increases
- (B) Decreases
- (C) Remains the same
- (D) Becomes zero

Q146. PHY

Water flows steadily through a horizontal pipe that gradually narrows. At the wider end, the velocity is 1 m/s . At the narrower end, the velocity is 3 m/s . Which statement is CORRECT regarding fluid pressure in the narrow end compared to the wider end?

- (A) Pressure is lower at the narrow end because velocity is higher
- (B) Pressure is higher at the narrow end because velocity is higher
- (C) Pressure is the same at both ends since flow is continuous
- (D) Pressure is independent of velocity of water

Q147. PHY

What is the necessary mechanical condition for wave propagation through a material medium?

- (A) The medium must be elastic
- (B) The medium must be inelastic
- (C) The particles of the medium must be independent of each other
- (D) The particles of the medium must not be dependent on each other

Q148. PHY

A progressive wave is one which:

- (A) Does not vibrate the medium
- (B) Carries energy across the medium
- (C) Propagates only through air
- (D) Requires a denser medium for propagation

Q149. PHY

The speed of sound in air increases with:

- (A) Higher temperature, higher humidity
- (B) Lower temperature, lower humidity
- (C) Higher pressure at constant temperature
- (D) Higher density at constant elasticity

Q150. PHY

A wave has a velocity of 300 m/s and a frequency of 100 Hz . If the medium changes such that velocity doubles while frequency remains constant, the new wavelength will be:

- (A) Halved
- (B) Doubled
- (C) Same
- (D) Zero

Q151. PHY

When a particle executing simple harmonic motion moves from its mean position to an extreme position, its kinetic energy:

- (A) Increases continuously
- (B) Decreases continuously and becomes zero at the extreme position
- (C) Remains constant throughout the motion
- (D) Becomes maximum at the extreme position

Q152. PHY

By the Second Law of Thermodynamics, heat will spontaneously flow from a system of:

- (A) Lower to higher internal energy only
- (B) High pressure to low pressure
- (C) Low temperature to high temperature
- (D) High temperature to low temperature

Q153. PHY

The SI unit of molar specific heat capacity is:

- (A) $\text{J mol}^{-1} \text{K}^{-1}$
- (B) J mol K
- (C) J mol K^{-1}
- (D) $\text{J mol}^{-1} \text{K}$

Q154. PHY

For an ideal gas with molar heat capacity at constant volume

$C_v = \frac{3}{2}R$, the molar heat capacity at constant pressure C_p is:

- (A) R
- (B) $3/2 R$
- (C) $5/2 R$
- (D) $7/2 R$

Q155. PHY

The electric field intensity at a point in space is defined as the:

- (A) Potential per unit charge
- (B) Work done per unit time
- (C) Charge per unit area
- (D) Force per unit positive test charge

Q156. PHY

Coulomb's Law for electrostatic forces directly agrees with which of Newton's laws of motion?

- (A) Newton's 1st law
- (B) Newton's 2nd law
- (C) Newton's 3rd law
- (D) Gauss's Law

Q157. PHY

The work done in moving a unit positive charge from one point to another while keeping the charge in electrostatic equilibrium is called:

- (A) Kinetic energy
- (B) Potential energy
- (C) Elastic potential energy
- (D) Potential difference

Q158. PHY

If the potential difference V across an ohmic conductor is doubled while keeping resistance R constant, the electrical power dissipated becomes:

- (A) Doubled
- (B) Halved
- (C) Four times
- (D) Remains unchanged

Q159. PHY

When the area vector $\vec{A}$ is parallel to the magnetic field $\vec{B}$, the magnetic flux Φ_B through the surface is:

- (A) 0
- (B) BA
- (C) $BA \cos 90^\circ$
- (D) B/A

Q160. PHY

Which of the following statements best describes the nature of radioactive nuclear decay?

- (A) It occurs both spontaneously and randomly
- (B) It occurs only when external energy is supplied
- (C) It occurs at regular, predictable time intervals for each individual atom
- (D) It can be controlled by altering external temperature and pressure

Q161. PHY

A boat moves 4 km east and then 3 km north. Another boat moves 3 km north first and then 4 km east. Which statement is CORRECT about their final displacements?

- (A) Both boats have the same displacement vector
- (B) The second boat's displacement is greater because it traveled north first
- (C) The first boat's displacement is greater because it traveled east first
- (D) Both boats end at different positions but cover the same distance

Q162. PHY

In the emission spectrum of atomic hydrogen, the Brackett series lies in the:

- (A) Ultraviolet region
- (B) Visible region
- (C) Infrared region
- (D) X-ray region

ENG SECTION: ENGLISH

Questions 163 to 171 (9 MCQs)

Q163. ENG

All of the players forgot _____ jerseys.

- (A) his
- (B) her
- (C) there
- (D) their

Q164. ENG

The old man was feeble, barely able to walk. The word "feeble" means:

- (A) Healthy
- (B) Weak
- (C) Strong
- (D) Fat

Q165. ENG

"Revenge is a kind of wild justice." This sentence illustrates the use of which figurative device?

- (A) Personification
- (B) Pun
- (C) Metaphor
- (D) Hyperbole

Q166. ENG

Each of the boys _____ ambitious to lead the team.

- (A) have
- (B) has
- (C) is
- (D) are

Q167. ENG

"She completed the task with great difficulty." Identify the CORRECT passive voice transformation:

- (A) The task was completed with great difficulty by her
- (B) The task has been completed with great difficulty by her
- (C) The task was being completed with great difficulty by her
- (D) The task was been completed with great difficulty by her

Q168. ENG

In the sentence "Jogging every morning improves my mood," what grammatical role does the gerund phrase play?

- (A) Object of a verb
- (B) Direct object
- (C) Predicate noun
- (D) Subject

Q169. ENG

The meeting has been scheduled _____ 3 p.m. sharp.

- (A) on
- (B) at
- (C) in
- (D) to

Q170. ENG

She studied hard; _____, she passed the exam with distinction. Choose the CORRECT transitional device:

- (A) however
- (B) for instance
- (C) consequently
- (D) in contrast

Q171. ENG

Which literary device involves using words or phrases that convey the opposite of their literal meaning?

- (A) Irony
- (B) Parody
- (C) Satire
- (D) Sarcasm

LOGIC SECTION: LOGICAL REASONING

Questions 172 to 180 (9 MCQs)

Q172. LOGIC

Consider the geometric sequence: 64, 32, 16, 8, ... What is the 10th term of this sequence?

- (A) 2
- (B) 4
- (C) 1/4
- (D) 1/8

Q173. LOGIC

If 5 boxes of soap weigh 75 kg in total, and each box when empty weighs 3 kg, what is the total net weight of the soap alone?

- (A) 15 kg
- (B) 30 kg
- (C) 45 kg
- (D) 60 kg

Q174. LOGIC

Which number completes the series: 200, 180, 162, 146, 132, _____?

- (A) 118
- (B) 120
- (C) 122
- (D) 126

Q175. LOGIC

How is Ali related to Mustafa if Ali says, "Mustafa's mother is the only child of my grandmother"?

- (A) Brother
- (B) Cousin
- (C) Uncle
- (D) Father

Q176. LOGIC

Ahmed ranks 10th in a class of 46 students. There are exactly 7 students ranked below Bilal. How many students are ranked between Ahmed and Bilal?

- (A) 27
- (B) 28
- (C) 30
- (D) 32

Q177. LOGIC

A father is 5 years older than twice his son's age. If the son is 12 years old, what is the father's age?

- (A) 28 years
- (B) 29 years
- (C) 30 years
- (D) 32 years

Q178. LOGIC

A mobile company is deciding whether to collect personal user data to improve advertisements. Which of the following represents a moral argument against collecting this data?

- (A) Users may lose trust in the company, which could hurt corporate profits
- (B) It is wrong to collect data without users' clear and informed consent
- (C) Competitors already collect more data, so we need to stay competitive
- (D) More data means more accurate advertising, which boosts sales

Q179. LOGIC

A medication dose starts at 100 mg and halves each day. What will be the dose on day 4?

- (A) 12.5 mg
- (B) 25 mg
- (C) 30 mg
- (D) 50 mg

Q180. LOGIC

A library has 4 books on Shelf A and 8 books on Shelf B. Some books are removed from Shelf B such that both shelves have exactly the same number of books. How many books were removed from Shelf B?

- (A) 2 books
- (B) 3 books
- (C) 4 books
- (D) 6 books

OFFICIAL VERIFIED ANSWER KEY

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Online Portal >

Q#	KEY	SUB	Q#	KEY	SUB	Q#	KEY	SUB	Q#	KEY	SUB	Q#	KEY	SUB
1	B	BIO	37	D	BIO	73	B	BIO	109	B	CHEM	145	A	PHY
2	B	BIO	38	A	BIO	74	B	BIO	110	B	CHEM	146	A	PHY
3	C	BIO	39	D	BIO	75	C	BIO	111	D	CHEM	147	A	PHY
4	B	BIO	40	B	BIO	76	B	BIO	112	C	CHEM	148	B	PHY
5	C	BIO	41	B	BIO	77	B	BIO	113	C	CHEM	149	A	PHY
6	B	BIO	42	B	BIO	78	C	BIO	114	A	CHEM	150	B	PHY
7	A	BIO	43	A	BIO	79	B	BIO	115	A	CHEM	151	B	PHY
8	C	BIO	44	D	BIO	80	B	BIO	116	C	CHEM	152	D	PHY
9	C	BIO	45	D	BIO	81	D	BIO	117	B	CHEM	153	A	PHY
10	B	BIO	46	C	BIO	82	B	CHEM	118	C	CHEM	154	C	PHY
11	C	BIO	47	D	BIO	83	A	CHEM	119	C	CHEM	155	D	PHY
12	C	BIO	48	A	BIO	84	C	CHEM	120	B	CHEM	156	C	PHY
13	A	BIO	49	B	BIO	85	A	CHEM	121	A	CHEM	157	D	PHY
14	B	BIO	50	C	BIO	86	D	CHEM	122	C	CHEM	158	C	PHY
15	B	BIO	51	D	BIO	87	D	CHEM	123	A	CHEM	159	B	PHY
16	C	BIO	52	B	BIO	88	C	CHEM	124	D	CHEM	160	A	PHY
17	C	BIO	53	D	BIO	89	C	CHEM	125	A	CHEM	161	A	PHY
18	B	BIO	54	A	BIO	90	A	CHEM	126	C	CHEM	162	C	PHY
19	D	BIO	55	D	BIO	91	B	CHEM	127	A	PHY	163	D	ENG
20	B	BIO	56	D	BIO	92	C	CHEM	128	B	PHY	164	B	ENG
21	C	BIO	57	C	BIO	93	A	CHEM	129	B	PHY	165	C	ENG
22	B	BIO	58	C	BIO	94	B	CHEM	130	B	PHY	166	C	ENG
23	C	BIO	59	B	BIO	95	C	CHEM	131	A	PHY	167	A	ENG
24	B	BIO	60	C	BIO	96	C	CHEM	132	C	PHY	168	D	ENG
25	A	BIO	61	B	BIO	97	B	CHEM	133	C	PHY	169	B	ENG
26	C	BIO	62	D	BIO	98	B	CHEM	134	B	PHY	170	C	ENG
27	D	BIO	63	A	BIO	99	C	CHEM	135	B	PHY	171	A	ENG
28	D	BIO	64	B	BIO	100	D	CHEM	136	C	PHY	172	D	LOGIC
29	B	BIO	65	B	BIO	101	D	CHEM	137	B	PHY	173	D	LOGIC
30	B	BIO	66	C	BIO	102	D	CHEM	138	C	PHY	174	B	LOGIC
31	C	BIO	67	C	BIO	103	B	CHEM	139	C	PHY	175	A	LOGIC
32	B	BIO	68	C	BIO	104	A	CHEM	140	D	PHY	176	B	LOGIC
33	A	BIO	69	C	BIO	105	C	CHEM	141	C	PHY	177	B	LOGIC
34	B	BIO	70	C	BIO	106	B	CHEM	142	B	PHY	178	B	LOGIC
35	C	BIO	71	C	BIO	107	B	CHEM	143	B	PHY	179	A	LOGIC
36	C	BIO	72	B	BIO	108	A	CHEM	144	C	PHY	180	C	LOGIC

SUBJECT-WISE PERFORMANCE BREAKDOWN

SUBJECT	MAX	YOUR SCORE	ACCURACY
Biology	81		----- %
Chemistry	45		----- %
Physics	36		----- %
English	9		----- %
Logical Reasoning	9		----- %
TOTAL	180	-----	----- %

PMDC PROVINCIAL MERIT FORMULA

Official Weightage Law:

- MDCAT Component (50%): (Your Score / 180) × 50
- FSc / HSSC Component (40%): (FSc Marks / 1100) × 40
- Matric / SSC Component (10%): (Matric Marks / 1100) × 10

Estimated Provincial Merit Aggregate: ----- %

PROPOLIS COGNITIVE ERROR AUTOPSIES

Step-by-step conceptual derivations, formula working, and distractor autopsies for every question.

Question #1 Key: (B)

BIOLOGY
06. Digestion/Nutrition

Intrinsic factor secreted by parietal cells is essential for:

CORE CONCEPT & DERIVATION

Parietal (oxyntic) cells of the gastric mucosa synthesize and secrete hydrochloric acid and intrinsic factor. Intrinsic factor is a glycoprotein required for the physiological uptake of cobalamin in the terminal ileum.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Dietary vitamin B12 binds haptocorrin in the stomach, which is subsequently degraded by pancreatic proteases in the duodenum.
- Free vitamin B12 then binds to gastric intrinsic factor to form a stable complex resistant to enteric digestion.
- This complex travels to the ileum, where specific cubam receptor complexes bind intrinsic factor and trigger receptor-mediated endocytosis into enterocytes.

Why other options are incorrect:

- **Option A:** Pepsinogen is converted into active pepsin by gastric hydrochloric acid (lowering luminal pH below 3.0), not by intrinsic factor.
- **Option C:** Emulsification of dietary lipids is mediated by amphipathic bile salts synthesized by hepatocytes and stored in the gallbladder.
- **Option D:** Neutralization of acidic gastric chyme entering the duodenum is accomplished by aqueous sodium bicarbonate secreted by the exocrine pancreas and Brunner glands.

Question #2 Key: (B)

BIOLOGY
13. Chemical Coordination

The delta cells in the islets of Langerhans secrete:

CORE CONCEPT & DERIVATION

The endocrine pancreas consists of the islets of Langerhans, which contain distinct endocrine cell populations producing regulatory peptide hormones. Delta cells specifically produce somatostatin to modulate endocrine and digestive secretions.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Delta (δ) cells constitute approximately 5% to 10% of islet tissue and synthesize somatostatin (SS-14).
- Somatostatin exerts paracrine inhibitory control over adjacent alpha and beta cells, suppressing both glucagon and insulin release.

Why other options are incorrect:

- **Option A:** Insulin is synthesized and secreted by beta (β) cells, which comprise 65% to 80% of islet cells.
- **Option C:** Glucagon is synthesized and secreted by alpha (α) cells to elevate blood glucose levels via glycogenolysis.
- **Option D:** Pancreatic polypeptide is produced by F cells (PP cells) located primarily in the head of the pancreas.

Question #3 Key: (C)

BIOLOGY
06. Digestion/Nutrition

Identify the main function of the duodenum:

CORE CONCEPT & DERIVATION

The duodenum represents the initial, shortest segment of the small intestine. It serves as the primary site where enzymatic and chemical breakdown of macromolecules occurs.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The duodenum receives acidic chyme from the stomach through the pyloric sphincter.
- At the hepatopancreatic ampulla (ampulla of Vater), it receives alkaline pancreatic juice loaded with digestive enzymes (amylase, lipase, trypsinogen) and bile salts.
- These mixed secretions complete the major portion of chemical digestion of carbohydrates, proteins, and lipids.

Why other options are incorrect:

- **Option A:** Bile storage and concentration is carried out by the gallbladder.
- **Option B:** Net water absorption takes place predominantly in the jejunum, ileum, and large intestine (colon).
- **Option D:** Waste temporary storage and compaction occur in the rectum and sigmoid colon prior to defecation.

Question #4 Key: (B)

BIOLOGY
06. Digestion/Nutrition

Which stage of the swallowing process prevents food or liquid from being aspirated into the lung...

CORE CONCEPT & DERIVATION

Deglutition (swallowing) is divided into oral, pharyngeal, and esophageal stages. The pharyngeal stage is an involuntary reflex during which protective mechanisms seal the respiratory tract.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- During the pharyngeal stage, tactile receptors near the faucial pillars trigger involuntary brainstem reflexes.
- The soft palate and uvula elevate to close the posterior nares, while the larynx is pulled upward and forward.
- The epiglottis folds downward over the laryngeal inlet and vocal cords adduct tightly, preventing food or liquids from entering the trachea.

Why other options are incorrect:

- **Option A:** The oral stage is completely voluntary and prepares the bolus, rolling it posteriorly without sealing the laryngeal aditus.
- **Option C:** The esophageal stage involves moving the bolus down the muscular esophagus toward the stomach.
- **Option D:** Peristalsis describes involuntary, coordinated smooth muscle contraction along hollow viscera, not an airway protective stage.

Question #5 Key: (C)BIOLOGY
10. Homeostasis

Which type of nephron is responsible for the development of osmotic gradients in the renal medulla...

CORE CONCEPT & DERIVATION

Juxtamedullary nephrons originate deep in the renal cortex near the corticomedullary border and possess exceptionally long loops of Henle that penetrate the inner renal medulla.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Juxtamedullary nephrons account for approximately 15% of all nephrons in the human kidney.
- Their long loops of Henle run parallel to the specialized vasa recta capillary networks deep into the renal papilla.
- They operate as countercurrent multipliers, generating the hypertonic vertical osmotic gradient (from 300 mOsm/L at the cortex to 1200 mOsm/L at the inner medulla) essential for concentrated urine formation.

Why other options are incorrect:

- **Option A:** Glomerular refers to the filtration corpuscle found within all nephrons, not a classification type.
- **Option B:** Cortical nephrons comprise 85% of nephrons, have short loops of Henle restricted primarily to the outer cortex, and perform standard excretory and regulatory functions rather than gradient generation.
- **Option D:** Medullary is an imprecise term; no nephrons are entirely situated within the renal medulla because all renal corpuscles reside in the cortex.

Question #7 Key: (A)BIOLOGY
10. Homeostasis

The sodium-potassium pumps in the distal convoluted tubule are activated by:

CORE CONCEPT & DERIVATION

Aldosterone is a steroid mineralocorticoid produced by the zona glomerulosa of the adrenal cortex. It acts directly on principal cells in the late distal convoluted tubule and cortical collecting ducts to conserve sodium.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Aldosterone diffuses across the basolateral membrane and binds to intracellular mineralocorticoid receptors.
- The hormone-receptor complex acts as a transcription factor, upregulating the expression and activity of basolateral Na^+/K^+ -ATPase pumps.
- It also promotes the opening and synthesis of apical epithelial sodium channels (ENaC), driving sodium reabsorption into blood and potassium excretion into tubular urine.

Why other options are incorrect:

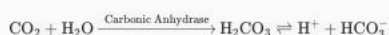
- **Option B:** Antidiuretic hormone (vasopressin) stimulates the insertion of aquaporin-2 water channels into the apical membrane of collecting duct cells.
- **Option C:** Atrial natriuretic peptide (ANP) inhibits sodium reabsorption and blocks aldosterone release to lower blood volume.
- **Option D:** Renin is an enzyme secreted by juxtaglomerular cells that converts circulating angiotensinogen into angiotensin I; it does not directly stimulate the tubule pumps.

Question #6 Key: (B)BIOLOGY
10. Homeostasis

Which of the following best describes how the distal convoluted tubule contributes to regulatio...

CORE CONCEPT & DERIVATION

Renal acid-base homeostasis depends on tubular secretion of protons and reclamation or generation of bicarbonate. Intercalated cells within the distal convoluted tubule and collecting duct regulate systemic pH.

Formula / Rule / Reaction:**Solution:**

- Type A intercalated cells of the late distal tubule actively pump H^+ ions into the tubular lumen via primary active H^+ -ATPase and H^+/K^+ -ATPase transporters.
- Simultaneously, newly synthesized HCO_3^- is transported across the basolateral membrane into the peritubular capillary blood via $\text{Cl}^-/\text{HCO}_3^-$ antiporters.
- This active secretion of excess protons raises the pH of systemic blood back to the physiological range (7.35 to 7.45).

Why other options are incorrect:

- **Option A:** Selective reabsorption of glucose occurs in the proximal convoluted tubule via secondary active Na^+ -glucose cotransporters (SGLT2/SGLT1) and does not regulate pH.
- **Option C:** Sodium is actively reabsorbed from filtrate into the peritubular capillaries, not secreted into the filtrate.
- **Option D:** The distal tubule secretes potassium under the influence of aldosterone rather than reabsorbing it to correct acid-base balance.

Question #8 Key: (C)BIOLOGY
10. Homeostasis

If a person drinks an excessive amount of water, how does the kidney respond to maintain osmore...

CORE CONCEPT & DERIVATION

Osmoregulation balances water and solute concentrations. Hypothalamic osmoreceptors monitor blood plasma osmolarity and modulate the release of antidiuretic hormone (ADH) from the neurohypophysis.

Formula / Rule / Reaction:

Water intake $\uparrow \Rightarrow$ Plasma Osmolarity $\downarrow \Rightarrow$ ADH Release $\downarrow \Rightarrow$ Urine Volume $\uparrow$

Solution:

- Excessive water intake dilutes the blood, lowering extracellular fluid osmolarity below 285 mOsm/kg.
- Hypothalamic osmoreceptors swell and decrease their firing rate, suppressing ADH secretion from the posterior pituitary.
- Without ADH, collecting duct epithelial cells endocytose aquaporin-2 water channels, rendering the luminal membrane impermeable to water.
- Consequently, large volumes of hypotonic urine are excreted (diuresis), restoring normal blood osmolarity.

Why other options are incorrect:

- Option A:** Increasing ADH release and water reabsorption is the physiological response to dehydration or hyperosmotic states.
- Option B:** Aldosterone is stimulated by hypovolemia or hyperkalemia, not water overload.
- Option D:** Retaining more water would worsen overhydration and trigger dangerous systemic hyponatremia.

Question #9 Key: (C)BIOLOGY
10. Homeostasis

The primary function of glomerular capillaries is:

CORE CONCEPT & DERIVATION

The glomerulus is a specialized high-pressure capillary bed situated between afferent and efferent arterioles. It functions as an ultrafiltration unit across a three-layered filtration barrier.

Formula / Rule / Reaction:

$$\text{Net Filtration Pressure (NFP)} = P_{GC} - (P_{BS} + \Pi_{GC})$$

Solution:

- High hydrostatic pressure inside the glomerular capillaries (approximately 55 mm Hg) forces water and small dissolved solutes across the fenestrated endothelium, basement membrane, and podocyte slit diaphragms into Bowman's space.
- This non-selective bulk flow generates approximately 125 mL/min (180 L/day) of protein-free glomerular filtrate.

Why other options are incorrect:

- Option A:** Solute and water reabsorption is carried out downstream by peritubular capillaries and vasa recta surrounding the tubules.
- Option B:** Tubular secretion occurs primarily across peritubular capillary beds into the proximal and distal convoluted tubules.
- Option D:** Peritubular capillaries deliver oxygenated blood and nutrients to renal parenchymal cells.

Question #10 Key: (B)BIOLOGY
10. Homeostasis

In a heat stroke the hypothalamus will detect an increase in core body temperature, which of th...

CORE CONCEPT & DERIVATION

Thermoregulation is coordinated by the preoptic area of the anterior hypothalamus. When core temperature exceeds the set point, autonomic efferent mechanisms are triggered to maximize physiological heat dissipation.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Central thermoreceptors signal the hypothalamic heat-loss center.
- Sympathetic adrenergic tone to cutaneous arterioles is inhibited, causing cutaneous vasodilation to shunt warm blood toward the skin surface for radiation and convection.
- Sympathetic cholinergic fibers stimulate eccrine sweat glands, allowing evaporative cooling to remove latent heat from the body.

Why other options are incorrect:

- Option A:** Peripheral vasoconstriction and shivering thermogenesis are activated during cold exposure (hypothermia) to retain and generate heat.
- Option C:** Increasing metabolic rate elevates internal heat production, exacerbating hyperthermia.
- Option D:** Thyroxine (T4) release stimulates cellular basal metabolic rate and is promoted during prolonged cold adaptation.

Question #11 Key: (C)BIOLOGY
10. Homeostasis

Which nitrogenous waste has the lowest solubility in water?

CORE CONCEPT & DERIVATION

Terrestrial adaptation influences the chemical structure of excreted nitrogenous wastes. Animals excrete ammonia, urea, or uric acid depending on physiological water availability.

Formula / Rule / Reaction:

Relative solubilities: Ammonia > Urea >> Uric Acid.

Solution:

- Uric acid ($C_5H_4N_4O_3$) is a purine derivative with very low water solubility (approximately 0.06 g/L at 20 degrees Celsius).
- Because it precipitates as a semi-solid paste or crystals, uricotelic organisms (birds, reptiles, insects) can excrete it with minimal water loss (1 mL of water per gram of nitrogen).

Why other options are incorrect:

- Option A:** Urea is highly soluble in water (approximately 1000 g/L at room temperature) and requires moderate water (about 50 mL per gram of nitrogen) for safe excretion.
- Option B:** Ammonia is extremely soluble in water (exceeding 500 g/L) and highly toxic, requiring roughly 500 mL of water per gram of nitrogen excreted.
- Option D:** Nitrite is an intermediate mineral ion in the nitrogen cycle, not a primary end-product of animal nitrogenous excretion.

Question #12 Key: (C)BIOLOGY
10. Homeostasis*By nature, human excretory system is:***CORE CONCEPT & DERIVATION**

Animals are categorized according to their predominant nitrogenous waste product into ammoniotelic, ureotelic, or uricotelic organisms.

Formula / Rule / Reaction:*Factual recall / Qualitative concept.***Solution:**

- Humans deaminate excess amino acids in the liver, producing toxic ammonia.
- Hepatic enzymes convert this ammonia into urea through the ornithine-urea cycle.
- Urea represents roughly 80% to 90% of total urinary nitrogen in humans, classifying the human excretory system as ureotelic.

Why other options are incorrect:

- **Option A:** Ammoniotelic organisms (e.g., aquatic invertebrates, bony fishes, tadpoles) excrete ammonia directly into copious water.
- **Option B:** Uricotelic organisms (e.g., birds, reptiles, terrestrial insects) predominantly excrete uric acid to conserve water.
- **Option D:** Aminotelic organisms (e.g., some echinoderms and mollusks) excrete uncatabolized amino acids directly.

Question #13 Key: (A)BIOLOGY
10. Homeostasis*Hyperparathyroidism may lead to the formation of:***CORE CONCEPT & DERIVATION**

Primary hyperparathyroidism results from autonomous hypersecretion of parathyroid hormone (PTH) by a parathyroid adenoma or hyperplasia. PTH regulates calcium and phosphate homeostasis.

Formula / Rule / Reaction:
$$\text{PTH} \uparrow \Rightarrow \text{Bone Resorption} \uparrow + \text{Serum Ca}^{2+} \uparrow \Rightarrow \text{Hypercalciuria} \Rightarrow \text{Nephrolithiasis}$$
Solution:

- Excess PTH stimulates osteoclast activity, accelerates bone resorption, and increases renal synthesis of 1,25-dihydroxyvitamin D.
- The filtered load of calcium exceeds the tubular reabsorptive capacity, producing hypercalciuria and hyperphosphaturia.
- High concentrations of calcium and phosphate in the renal tubules cause supersaturation, leading to precipitation of calcium phosphate or calcium oxalate nephrolithiasis.

Why other options are incorrect:

- **Option B:** Uric acid stones form when urine is persistently acidic (pH below 5.5) or during purine metabolic disorders such as gout.
- **Option C:** Cystine stones develop due to an inherited genetic defect in the renal tubular transporter for dibasic amino acids (cystinuria).
- **Option D:** Struvite (magnesium ammonium phosphate) stones develop during chronic urinary tract infections caused by urease-producing bacteria such as *Proteus*.

Question #14 Key: (B)BIOLOGY
17. Biotechnology*In somatic cell hybridization, which two cells are fused to produce monoclonal antibodies?***CORE CONCEPT & DERIVATION**

Monoclonal antibody production relies on hybridoma technology developed by Georges Kohler and Cesar Milstein. An antibody-producing cell is fused with an immortalized cell to produce a hybrid cell line.

Formula / Rule / Reaction:
$$\text{B-Lymphocyte (Spleen Cell)} + \text{Myeloma Cell} \xrightarrow{\text{PEG}} \text{Hybridoma Cell}$$
Solution:

- An animal (typically a mouse) is immunized with a target antigen to stimulate specific B-lymphocytes in the spleen.
- B-lymphocytes harvested from the spleen provide genetic instructions for specific antibody production.
- These are fused with immortal cancerous myeloma cells using polyethylene glycol (PEG) to yield hybridomas capable of indefinite monoclonal antibody synthesis.
- *Past paper board note:* KMU test keys frequently use 'B-lymphocytes and spleen cells' to denote the splenic B-cell lineage isolated during the procedure.

Why other options are incorrect:

- **Option A:** T-cells provide cell-mediated immunity and do not produce secreted humoral antibodies; nerve cells do not divide.
- **Option C:** Neither T-cells nor hepatocytes secrete antibodies.
- **Option D:** Macrophages are non-specific phagocytes and do not produce clonally restricted immunoglobulins.

Question #15 Key: (B)BIOLOGY
17. Biotechnology*In molecular diagnostics, the primary function of DNA/RNA probes is to:***CORE CONCEPT & DERIVATION**

A nucleic acid probe is a single-stranded sequence of DNA or RNA labeled with a radioisotope or fluorescent tag. It identifies complementary target sequences in biological specimens.

Formula / Rule / Reaction:*Complementary base pairing: A pairs with T (or U) and G pairs with C.***Solution:**

- Target DNA or RNA is denatured into single strands and immobilized on a membrane or analyzed in situ.
- Labeled probes are added and hybridize specifically with complementary target nucleotide sequences.
- Autoradiography or fluorescence detection visualizes the hybrid, confirming the presence or absence of a pathogen, gene mutation, or transcript.

Why other options are incorrect:

- **Option A:** Replacing defective genes in patient cells is the therapeutic goal of gene therapy, which uses viral or non-viral vectors.
- **Option C:** Cutting double-stranded DNA at specific palindromic recognition sequences is carried out by restriction endonucleases.
- **Option D:** Stimulating immune responses against infectious organisms is the function of vaccines and adjuvants.

Question #16 Key: (C)BIOLOGY
17. Biotechnology

A set of uniform proteins generated by genetically identical immune cells, which are:

CORE CONCEPT & DERIVATION

Monoclonal antibodies are identical immunoglobulins synthesized by a single clone of hybridoma cells. Because they derive from one ancestral B-lymphocyte, every antibody molecule possesses identical paratope specificity and affinity.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- When a single hybridoma cell divides mitotically, it produces a clone of genetically identical cells.
- These cloned cells synthesize and secrete uniform antibody molecules targeting the exact same antigenic epitope.
- They are termed monoclonal antibodies (mAbs).

Why other options are incorrect:

- **Option A:** Therapeutic proteins is a broad commercial class that includes recombinant hormones, cytokines, and clotting factors.
- **Option B:** Immunoglobulins includes all physiological antibodies, which in serum form a polyclonal mixture produced by diverse B-cell lineages.
- **Option D:** Recombinant proteins are produced by inserting foreign genes into expression hosts such as bacteria or yeast, not necessarily immune cells.

Question #17 Key: (C)BIOLOGY
17. Biotechnology

Which biotechnological product is used to replace an abnormal gene in a patient's cells?

CORE CONCEPT & DERIVATION

Gene therapy involves introducing exogenous genetic material into somatic cells to correct genetic defects. Delivery requires specialized molecular transport systems called vectors.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Vectors can be viral (retrovirus, adenovirus, adeno-associated virus, lentivirus) or non-viral (liposomes, nanoparticles).
- The therapeutic functional gene is packaged inside the vector, which infects or transfects target host cells and delivers the cargo to the nucleus to replace or supplement the mutant gene.

Why other options are incorrect:

- **Option A:** Antibiotics are low-molecular-weight chemical substances that inhibit bacterial metabolic processes or cell wall synthesis.
- **Option B:** Vaccines introduce attenuated pathogens or antigens to elicit active acquired immunity.
- **Option D:** Interferons are signaling cytokines released by virus-infected host cells to inhibit viral replication in neighboring cells.

Question #18 Key: (B)BIOLOGY
02. Biomolecules

In Watson and Crick's DNA model, which of the following pairs with Cytosine?

CORE CONCEPT & DERIVATION

The B-DNA double helix model developed by James Watson and Francis Crick incorporates Chargaff's rules of base pairing, maintaining a constant 2.0 nm helix diameter.

Formula / Rule / Reaction:**Solution:**

- Watson-Crick base pairing requires a pyrimidine to pair with a purine.
- Cytosine (a pyrimidine) forms three specific hydrogen bonds with Guanine (a purine): one between an amino group and a carbonyl, one between ring nitrogens, and one between a carbonyl and an amino group.

Why other options are incorrect:

- **Option A:** Adenine is a purine that pairs with Thymine in DNA via two hydrogen bonds.
- **Option C:** Thymine is a pyrimidine that pairs with Adenine; two pyrimidines together would narrow the helix diameter.
- **Option D:** Uracil replaces thymine in ribonucleic acid (RNA) and does not occur in standard DNA.

Question #19 Key: (D)BIOLOGY
04. Bioenergetics

Fats are considered as a very efficient source of energy because they:

CORE CONCEPT & DERIVATION

Triacylglycerols (fats) represent the most concentrated form of metabolic energy storage in animals, providing 9 kcal/g compared to 4 kcal/g from carbohydrates and proteins.

Formula / Rule / Reaction:**Solution:**

- Fatty acid hydrocarbons are composed predominantly of reduced $-\text{CH}_2-\text{CH}_2-$ units with high carbon-hydrogen bond density and minimal oxygen content.
- Mitochondrial β -oxidation sequentially cleaves fatty acyl chains into numerous two-carbon acetyl-CoA molecules.
- Each acetyl-CoA enters the citric acid cycle, driving electron transport and oxidative phosphorylation to yield large amounts of ATP.

Why other options are incorrect:

- **Option A:** Fats cannot yield ATP without cellular respiration; fatty acid breakdown strictly requires oxygen as the terminal electron acceptor in mitochondria.
- **Option B:** Fatty acids cannot enter glycolysis; only the minor glycerol backbone can be phosphorylated and converted into dihydroxyacetone phosphate.
- **Option C:** Fats are highly reduced compounds; carbohydrates are comparatively much more oxidized.

Question #20 Key: (B)BIOLOGY
12. Nervous Coordination

The junction between two consecutive neurons where information is transmitted from one neuron to...

CORE CONCEPT & DERIVATION

Intercellular communication between excitable nerve cells occurs across specialized contact zones termed synapses.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- A synapse comprises the presynaptic terminal, the synaptic cleft (approximately 20 nm wide), and the postsynaptic membrane.
- Action potentials reaching the presynaptic bulb trigger exocytosis of neurotransmitters, which diffuse across the cleft to bind receptors on the postsynaptic neuron.

Why other options are incorrect:

- **Option A:** Nodes of Ranvier are regular unmyelinated gaps along an axon where voltage-gated Na^+ channels are concentrated for saltatory conduction.
- **Option C:** The axon terminal (bouton) is the anatomical swollen end of the presynaptic axon, not the junction between two cells.
- **Option D:** Dendrite cleft is an erroneous anatomical term.

Question #21 Key: (C)BIOLOGY
01. Cell

All of the following are the functions of Golgi bodies EXCEPT:

CORE CONCEPT & DERIVATION

The Golgi apparatus is the central sorting, modifying, and packaging organelle of the endomembrane system. Cellular respiration is carried out by mitochondria and the cytosol.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Cellular respiration comprises glycolysis (cytoplasm), the link reaction, the Krebs cycle (mitochondrial matrix), and oxidative phosphorylation (inner mitochondrial cristae).
- The Golgi complex has no respiratory enzymes and does not generate metabolic ATP.

Why other options are incorrect:

- **Option A:** The Golgi modifies newly synthesized polypeptides via glycosylation, phosphorylation, and sulfation.
- **Option B:** Golgi-derived transport vesicles fuse with the cell surface, replenishing lipids and proteins of the plasma membrane.
- **Option D:** Primary lysosomes bud off directly from the trans-Golgi network containing packaged acid hydrolases.

Question #22 Key: (B)BIOLOGY
12. Nervous Coordination

Which ion is tenfold higher in concentration outside the membrane of neuron during resting pote...

CORE CONCEPT & DERIVATION

The resting membrane potential (-70 mV) is sustained by the electrogenic Na^+/K^+ -ATPase pump and differential membrane permeabilities.

Formula / Rule / Reaction:

Resting ion distributions: $[\text{Na}^+]_{\text{out}} \approx 145 \text{ mM}$, $[\text{Na}^+]_{\text{in}} \approx 12 - 15 \text{ mM}$.

Solution:

- The extracellular concentration of sodium ions (Na^+) is roughly 145 mM, while intracellular concentration is roughly 12 to 15 mM.
- This represents an approximate tenfold concentration gradient across the resting membrane.

Why other options are incorrect:

- **Option A:** Potassium ions (K^+) are approximately 30 times more concentrated inside the cell (140 to 150 mM) than outside (4 to 5 mM).
- **Option C:** Calcium ions have an extracellular-to-intracellular gradient of approximately 10,000 to 1 (1 mM extracellular vs 0.0001 mM intracellular).
- **Option D:** Hydrogen ion concentration is kept in the nanomolar range (pH 7.2 to 7.4) and does not define the major resting monovalent gradient.

Question #23 Key: (C)BIOLOGY
05. Acellular Life

All of the following are the modes of transmission of AIDS, EXCEPT:

CORE CONCEPT & DERIVATION

Acquired Immunodeficiency Syndrome (AIDS) is caused by the Human Immunodeficiency Virus (HIV). Transmission requires exchange of specific virion-containing bodily fluids across mucosal or vascular barriers.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- HIV is an enveloped, fragile virus that rapidly loses viability when exposed outside host physiological fluids.
- It is not transmitted by casual non-sexual contact, such as shaking hands, hugging, sharing utensils, or touching intact skin.

Why other options are incorrect:

- **Option A:** Transfusion of infected whole blood, plasma, or clotting factors delivers high viral loads directly into circulation.
- **Option B:** Sharing contaminated intravenous hypodermic needles transfers blood micro-droplets containing live virus.
- **Option D:** Unprotected vaginal, anal, or oral sexual intercourse exposes vulnerable mucosal membranes to infectious semen, vaginal secretions, or blood.

Question #24 Key: (B)BIOLOGY
01. Cell

Which organelle of the cell is involved in the detoxification of toxins and poisonous compounds...

CORE CONCEPT & DERIVATION

The smooth endoplasmic reticulum (SER) is a non-ribosome-bearing tubular organelle specialized for lipid synthesis, calcium storage, and xenobiotic metabolism.

Formula / Rule / Reaction:**Solution:**

- In hepatocytes, the SER contains membrane-bound enzymes of the cytochrome P450 monooxygenase system.
- These enzymes add polar hydroxyl groups to hydrophobic drugs, alcohol, and metabolic poisons, rendering them water-soluble for renal excretion.

Why other options are incorrect:

- **Option A:** Lysosomes degrade cellular debris and endocytosed macromolecules using acid hydrolases.
- **Option C:** Ribosomes translate messenger RNA into polypeptide chains.
- **Option D:** Mitochondria generate ATP through the tricarboxylic acid cycle and oxidative phosphorylation.

Question #25 Key: (A)BIOLOGY
03. Enzymes

The active site is important in enzyme action because:

CORE CONCEPT & DERIVATION

Enzymes are stereospecific biological catalysts. Their catalytic function resides within a three-dimensional cleft or crevice termed the active site.

Formula / Rule / Reaction:**Solution:**

- The active site is composed of contact residues that recognize and bind the complementary substrate, and catalytic residues that act on chemical bonds.
- Substrate binding forms the enzyme-substrate (ES) complex, aligning reactants in the optimal orientation to lower activation energy.

Why other options are incorrect:

- **Option B:** The ambient chemical buffer system maintains environmental pH, not the enzyme active site.
- **Option C:** Enzymes do not supply energy; they accelerate reaction rates by lowering the activation energy barrier.
- **Option D:** Although an induced fit adjustment occurs upon binding, altering enzyme structure is not the primary purpose of the active site.

Question #26 Key: (C)BIOLOGY
16. Evolution

The idea that acquired characters are inherited is part of:

CORE CONCEPT & DERIVATION

Early evolutionary thought included Jean-Baptiste Lamarck's transformist theory published in Philosophie Zoologique (1809).

Formula / Rule / Reaction:

Lamarck's Postulates: Use and disuse + Inheritance of acquired characteristics.

Solution:

- Lamarck proposed that physical changes acquired by an organism during its lifetime in response to environmental needs are directly transmitted to its offspring.
- This hypothesis is known as the inheritance of acquired characters (Lamarckism).

Why other options are incorrect:

- **Option A:** Darwinism relies on natural selection acting on existing, heritable variations across populations.
- **Option B:** Neo-Darwinism synthesizes Mendelian genetics with natural selection, demonstrating that acquired somatic modifications are not inherited.
- **Option D:** Biogenesis states that living organisms arise exclusively from preexisting living matter (omne vivum ex vivo).

Question #27 Key: (D)BIOLOGY
05. Acellular Life

Which disease is caused by syncytial virus?

CORE CONCEPT & DERIVATION

Respiratory syncytial virus (RSV) is an enveloped, negative-sense, single-stranded RNA virus of the family Pneumoviridae.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- RSV possesses specialized fusion (F) surface glycoproteins that cause adjacent host cell membranes to merge, forming multinucleated syncytia.
- It directly causes respiratory syncytial virus infection, a primary cause of bronchiolitis and pneumonia in infants.

Why other options are incorrect:

- **Option A:** Leaf curl disease of cotton is caused by whitefly-transmitted Begomoviruses (Cotton leaf curl virus) belonging to the Geminiviridae family.
- **Option B:** Polio is caused by poliovirus, an enterovirus of the Picornaviridae family.
- **Option C:** Hepatitis A is caused by hepatitis A virus (HAV), an enterically transmitted hepatovirus of the Picornaviridae family.

Question #28 Key: (D)BIOLOGY
01. Cell*The glycoproteins are commonly found in:***CORE CONCEPT & DERIVATION**

Glycoproteins are conjugated proteins covalently bound to branched oligosaccharide chains. They predominate on the outer leaflet of biological surface membranes.

Formula / Rule / Reaction:*Factual recall / Qualitative concept.***Solution:**

- Proteins synthesized by rough endoplasmic reticulum ribosomes are glycosylated in the lumen and Golgi apparatus.
- Secretory vesicles transport these molecules to the plasma membrane, where carbohydrate chains project into the extracellular matrix.
- This forms the cellular glycocalyx essential for cell recognition, immune identification, and receptor signaling.

Why other options are incorrect:

- Option A:** The mitochondrial inner membrane contains high levels of cardiolipin and transport proteins, not cell-surface glycoproteins.
- Option B:** Chloroplast thylakoid membranes are enriched with galactolipids and photosynthetic complexes rather than glycoproteins.
- Option C:** Ribosomes are ribonucleoprotein complexes consisting solely of ribosomal RNA (rRNA) and structural proteins without carbohydrate branching.

Question #29 Key: (B)BIOLOGY
01. Cell*Which structure enables the exchange of material between nucleus and cytoplasm?***CORE CONCEPT & DERIVATION**

The nuclear envelope is a double-membrane barrier perforated by multiprotein structures called nuclear pore complexes (NPCs).

Formula / Rule / Reaction:*Factual recall / Qualitative concept.***Solution:**

- Nuclear pores span both inner and outer nuclear membranes.
- They allow passive aqueous diffusion of small ions and metabolites, and mediate active, receptor-dependent transport of macromolecules (import of histones and polymerases; export of mRNA, tRNA, and ribosomal subunits).

Why other options are incorrect:

- Option A:** The plasma membrane surrounds the entire cell and controls transport between intracellular and extracellular compartments.
- Option C:** Lysosomes are digestive vesicles containing acid hydrolases for intracellular catabolism.
- Option D:** Mitochondria are cytoplasmic organelles dedicated to aerobic respiration and ATP synthesis.

Question #30 Key: (B)BIOLOGY
02. Biomolecules*The high specific heat capacity of water is due to:***CORE CONCEPT & DERIVATION**

Specific heat capacity is the amount of heat energy required to raise the temperature of 1 gram of a substance by 1 degree Celsius. Water possesses a very high specific heat capacity of 4.184 J/(g K).

Formula / Rule / Reaction:

$$Q = mc\Delta T$$

Solution:

- Water molecules are strongly dipolar and form dynamic intermolecular hydrogen bonds.
- Much of the absorbed thermal energy is consumed in breaking these intermolecular hydrogen bonds rather than immediately accelerating molecular translational kinetic energy.
- As a result, water can absorb or release large amounts of heat with minimal changes in temperature, acting as an effective thermal buffer.

Why other options are incorrect:

- Option A:** Pure liquid water does not contain ionic bonds; ionic lattices occur in mineral salts.
- Option C:** Intramolecular covalent bonds link hydrogen to oxygen within a single molecule and are not broken during normal heating of liquid water.
- Option D:** Hydrophilic describes the affinity of polar solutes for water; it is not a recognized thermodynamic bond type.

Question #31 Key: (C)BIOLOGY
01. Cell*The contracted region of a chromosome that attaches to spindle fiber is called:***CORE CONCEPT & DERIVATION**

Eukaryotic chromosomes contain specialized structural domains that coordinate chromosome segregation during nuclear division.

Formula / Rule / Reaction:*Factual recall / Qualitative concept.***Solution:**

- The centromere (primary constriction) is a distinct heterochromatic region of the chromosome.
- During prophase, kinetochore protein complexes assemble onto centromeric DNA to capture kinetochore microtubules of the mitotic spindle apparatus.

Why other options are incorrect:

- Option A:** Telomeres are repetitive nucleotide caps located at the ends of linear chromosomes that protect them from degradation and fusion.
- Option B:** Chromatin is the generalized nucleoprotein complex of genomic DNA and histone proteins.
- Option D:** Nucleosomes are fundamental chromatin subunits consisting of DNA wound around a histone octamer core.

Question #32 Key: (B)BIOLOGY
12. Nervous Coordination

Touching a sharp object stimulates pain receptors. This information is carried to the central n...

CORE CONCEPT & DERIVATION

The reflex arc is the neural pathway mediating reflex actions. Afferent signals are conveyed toward the central nervous system (CNS) by specialized sensory pathways.

Formula / Rule / Reaction:**Solution:**

- Nociceptors in the dermis transduce mechanical injury into action potentials.
- These action potentials propagate along the pseudounipolar axons of sensory (afferent) neurons into the dorsal horn of the spinal cord.

Why other options are incorrect:

- **Option A:** Motor (efferent) neurons transmit impulses away from the CNS to effector targets (muscles or glands).
- **Option C:** Associative neurons (interneurons) reside entirely within the gray matter of the spinal cord or brain to integrate sensory input.
- **Option D:** Effector neurons is an alternate name for motor neurons that deliver output signals to reacting tissues.

Question #33 Key: (A)BIOLOGY
15. Inheritance / Variation & Genetics

The number of chromosomes in a haploid cell are:

CORE CONCEPT & DERIVATION

Ploidy refers to the number of complete sets of chromosomes within a biological cell. Somatic cells are diploid (2n), whereas gametes are haploid (n).

Formula / Rule / Reaction:

$$n = \frac{2n}{2}$$

Solution:

- Diploid body cells contain paired homologous chromosomes (2n = 46 in humans).
- Meiotic reduction division segregates homologous pairs, producing haploid gametes containing one set (n = 23 in humans), which is exactly half the somatic number.

Why other options are incorrect:

- **Option B:** Doubling the diploid chromosome complement produces tetraploidy (4n = 92).
- **Option C:** One quarter of the normal complement would yield an incomplete fractional genome incompatible with cellular life.
- **Option D:** An equal chromosome count is produced during equational mitotic division of somatic cells.

Question #34 Key: (B)BIOLOGY
02. Biomolecules

Which of the following is a branched polysaccharide found in animals:

CORE CONCEPT & DERIVATION

Polysaccharides serve structural or metabolic storage roles. Glycogen functions as the primary carbohydrate storage macromolecule in animal liver and skeletal muscle.

Formula / Rule / Reaction:**Solution:**

- Glycogen is a branched homopolysaccharide composed entirely of D-glucose units.
- It contains linear chains linked by $\alpha(1 \rightarrow 4)$ glycosidic bonds and frequent branch points formed by $\alpha(1 \rightarrow 6)$ bonds every 8 to 12 residues, allowing rapid enzymatic mobilization of glucose.

Why other options are incorrect:

- **Option A:** Cellulose is an unbranched structural polysaccharide made of $\beta(1 \rightarrow 4)$ -linked glucose units found in plant cell walls.
- **Option C:** Amylose is an unbranched, helical plant starch polysaccharide consisting solely of $\alpha(1 \rightarrow 4)$ glycosidic bonds.
- **Option D:** Chitin is an unbranched structural polysaccharide composed of N-acetylglucosamine units found in fungal cell walls and arthropod exoskeletons.

Question #35 Key: (C)BIOLOGY
03. Enzymes

A substance that binds to an enzyme, but NOT at the active site and reduces the enzyme activity...

CORE CONCEPT & DERIVATION

Enzyme inhibitors are chemical agents that diminish catalytic rates. They are classified by whether they compete directly for the active site or act allosterically.

Formula / Rule / Reaction:

Non-competitive inhibition: $V_{\max}$ decreases, K_m remains unchanged.

Solution:

- A non-competitive inhibitor binds to an allosteric regulatory site distinct from the catalytic active site.
- This binding induces a conformational change in the enzyme that reduces catalytic turnover ($V_{\max}$) without preventing substrate binding.

Why other options are incorrect:

- **Option A:** Competitive inhibitors bind directly to the active site, competing with the substrate and increasing apparent K_m .
- **Option B:** The substrate is the specific reactant that binds to the active site to be converted into products.
- **Option D:** A cofactor is a non-protein component (e.g., metal ion or coenzyme) required for enzyme activity, not an inhibitor.

Question #36 Key: (C)BIOLOGY
05. Acellular Life

On the basis of morphological classification, influenza virus is an example of:

CORE CONCEPT & DERIVATION

Viruses are classified morphologically by capsid symmetry (helical, icosahedral, complex) and whether a host-derived lipid envelope encloses the nucleocapsid.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The influenza virus (an orthomyxovirus) possesses a segmented, helical ribonucleoprotein core.
- This core is surrounded by an outer lipoprotein bilayer membrane (envelope) acquired from the host plasma membrane during budding, studded with hemagglutinin and neuraminidase glycoproteins.

Why other options are incorrect:

- **Option A:** While its internal ribonucleoproteins are helical, classifying influenza virus strictly as a naked helical capsid ignores its defining outer envelope.
- **Option B:** Polyhedral (icosahedral) naked viruses include adenoviruses and parvoviruses, which exhibit geometric symmetry without an envelope.
- **Option D:** Non-enveloped viruses (e.g., poliovirus, hepatitis A) lack a lipid bilayer envelope and are resistant to lipid solvents.

Question #37 Key: (D)BIOLOGY
02. Biomolecules

Which of the following is NOT a globular protein?

CORE CONCEPT & DERIVATION

Proteins are classified by overall conformation into globular and fibrous proteins. Globular proteins are spherical and water-soluble, whereas fibrous proteins are elongated, insoluble structural molecules.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Collagen is an insoluble, fibrous structural protein composed of a triple helix of polypeptide chains.
- It provides tensile strength to tendons, ligaments, skin, and bones.

Why other options are incorrect:

- **Option A:** Enzymes are water-soluble globular proteins with compact tertiary structures that form active catalytic pockets.
- **Option B:** Albumin is a soluble globular serum protein that maintains blood oncotic pressure and transports hydrophobic molecules.
- **Option C:** Hemoglobin is a soluble globular tetramer that transports oxygen within red blood cells.

Question #38 Key: (A)BIOLOGY
12. Nervous Coordination

The state, when a neuron is NOT conducting an impulse during resting membrane potential is called...

CORE CONCEPT & DERIVATION

The resting state of an unexcited excitable cell exhibits an electrical charge separation across its membrane, maintaining an inside-negative electrical potential.

Formula / Rule / Reaction:

$$V_m \approx -70 \text{ mV (Resting Potential)}$$

Solution:

- In a non-conducting neuron, the Na^+/K^+ -ATPase pump and potassium leak channels establish a net negative electrical charge inside relative to the outside.
- Because an electrical polarity exists across the lipid bilayer, this resting physiological state is termed polarized.

Why other options are incorrect:

- **Option B:** Depolarized describes an active state where inward Na^+ influx drives the membrane potential toward zero and into positive values.
- **Option C:** Repolarized describes the recovery phase during which outward K^+ efflux restores the resting electrical gradient following an action potential.
- **Option D:** Hyperpolarized describes a transient state where membrane potential becomes more negative than the standard resting level.

Question #39 Key: (D)BIOLOGY
12. Nervous Coordination

Which of the following waves travel along a neuron during nerve impulse conduction?

CORE CONCEPT & DERIVATION

A nerve impulse (action potential) is a self-propagating disturbance in membrane potential that travels along the axolemma.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- An action potential involves transient changes in electrical potential driven by the movement of chemical ions (Na^+ and K^+) through voltage-gated ion channels.
- Because it integrates both electrical charge displacement and chemical concentration flux, it propagates as an electrochemical wave.

Why other options are incorrect:

- **Option A:** Thermal waves are oscillations in temperature and do not mediate nervous transmission.
- **Option B:** Magnetic waves do not propagate biological action potentials along axons.
- **Option C:** Electromagnetic waves (such as light or radio waves) consist of oscillating coupled electric and magnetic fields traveling through space at the speed of light.

Question #40 Key: (B)BIOLOGY
12. Nervous Coordination

The reticular formation in the brain runs through which specific regions?

CORE CONCEPT & DERIVATION

The reticular formation is a diffuse, interconnected network of brainstem nuclei and nerve fibers that modulates consciousness, sleep-wake cycles, and cardiovascular and motor reflexes.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The reticular formation extends longitudinally throughout the core of the brainstem.
- Anatomically, it spans the hindbrain (myelencephalon / medulla oblongata and metencephalon / pons) and continues rostrally through the midbrain (mesencephalon).

Why other options are incorrect:

- Option A:** The reticular formation does not originate in the forebrain, although it projects ascending activating signals to the thalamus and cortex.
- Option C:** The cerebellum is a distinct dorsal motor structure and does not contain the reticular formation.
- Option D:** The telencephalon constitutes the cerebral hemispheres and basal ganglia, which lie above the brainstem core.

Question #41 Key: (B)BIOLOGY
03. Enzymes

Enzymes increase the rate of reaction by:

CORE CONCEPT & DERIVATION

Enzymes accelerate chemical reactions without altering overall thermodynamic equilibrium (ΔG). They achieve catalysis by stabilizing transition states.

Formula / Rule / Reaction:

$$k = Ae^{-\frac{E_a}{RT}}$$

Note that lowering E_a exponentially increases the rate constant k .

Solution:

- Every chemical reaction requires reactants to overcome an energy barrier termed the activation energy (E_a).
- Enzyme active sites bind substrates, orienting functional groups and stabilizing high-energy transition state complexes.
- This lowers the activation energy barrier, allowing a higher fraction of substrate molecules to react per unit time.

Why other options are incorrect:

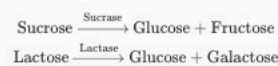
- Option A:** Increasing activation energy increases the barrier height, slowing reaction velocity.
- Option C:** Altering pH changes the ionization states of amino acid side chains and can denature the enzyme.
- Option D:** Decreasing environmental pH increases acidity, which does not act as a generalized mechanism for accelerating enzymatic catalysis.

Question #42 Key: (B)BIOLOGY
02. Biomolecules

A diabetic patient is advised to avoid both sucrose and lactose, because they both:

CORE CONCEPT & DERIVATION

Sucrose and lactose are dietary disaccharides that are cleaved by intestinal brush-border disaccharidases into absorbable monosaccharides.

Formula / Rule / Reaction:**Solution:**

- Both disaccharides yield free D-glucose upon enzymatic hydrolysis in the small intestine.
- Absorbed glucose enters portal circulation, causing postprandial hyperglycemia that diabetic patients cannot clear efficiently due to absolute or relative insulin deficiency.

Why other options are incorrect:

- Option A:** Sucrose and lactose are soluble transport disaccharides, not structural polymers such as cellulose or keratin.
- Option C:** Both disaccharides are digested in humans who produce sucrase and lactase.
- Option D:** Both sugars provide approximately 4 kcal/g and are caloric carbohydrates.

Question #43 Key: (A)BIOLOGY
12. Nervous Coordination

Match the CORRECT structure of the brain with its function:

CORE CONCEPT & DERIVATION

The brainstem contains vital autonomic centers that sustain life-supporting visceral processes.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The medulla oblongata contains the dorsal and ventral respiratory groups that set the autonomic rhythm of breathing and regulate ventilation in response to blood $p\text{CO}_2$ and pH.

Why other options are incorrect:

- Option B:** Memory consolidation is coordinated by the hippocampus and temporal lobes, while the pons relays impulses between cerebrum and cerebellum.
- Option C:** The cerebellum coordinates voluntary muscular activity and equilibrium, not dreaming.
- Option D:** Equilibrium and balance are coordinated primarily by the vestibular system and cerebellum, while the midbrain integrates visual and auditory reflexes.

Question #44 Key: (D)BIOLOGY
04. Bioenergetics

Living cells Do NOT directly acquire energy released from the breakdown of food molecules because...

CORE CONCEPT & DERIVATION

Biological combustion of nutrients is coupled to high-energy phosphate intermediates rather than occurring in a single explosive step.

Formula / Rule / Reaction:**Solution:**

- Direct, single-step breakdown of glucose would release 2870 kJ/mol predominantly as thermal energy.
- This sudden release of heat would denature cellular proteins, melt lipid membranes, and waste available chemical energy.
- Cells instead use multi-step metabolic pathways (glycolysis, Krebs cycle, oxidative phosphorylation) to capture this free energy in discrete units of ATP.

Why other options are incorrect:

- **Option A:** Glucose is routinely metabolized inside cells through glycolysis in the cytosol.
- **Option B:** The free energy released by complete oxidation of glucose is substantial, not too small.
- **Option C:** Glucose stores high chemical potential energy within its covalent carbon-hydrogen and carbon-carbon bonds.

Question #45 Key: (D)BIOLOGY
02. Biomolecules

Which properties of water enable it to circulate in living bodies and act as transport medium?

CORE CONCEPT & DERIVATION

Fluid circulation in vascular networks (such as plant xylem and animal cardiovascular systems) requires fluid continuity and adhesion to vessel surfaces.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Cohesion (hydrogen bonding between water molecules) provides high tensile strength, holding continuous columns of water together under negative pressure.
- Adhesion (attraction between water dipoles and polar hydrophilic vessel wall surfaces) supports capillary action and prevents column collapse during mass flow.

Why other options are incorrect:

- **Option A:** Low self-ionization ($K_w = 10^{-14}$) determines acid-base neutrality, not vascular fluid transport.
- **Option B:** Ionization does not establish mechanical continuity in vascular flow.
- **Option C:** Ionization is unrelated to bulk circulatory movement.

Question #46 Key: (C)BIOLOGY
02. Biomolecules

How are the phospholipid molecules arranged in the plasma membrane?

CORE CONCEPT & DERIVATION

Phospholipids are amphipathic molecules possessing a polar, hydrophilic phosphate head and two nonpolar, hydrophobic fatty acyl tails. In an aqueous biological environment, thermodynamic stability dictates their bilayer orientation.

Formula / Rule / Reaction:

Thermodynamic self-assembly: Hydrophilic heads orient toward water; hydrophobic tails sequester in the nonpolar core.

Solution:

- The extracellular fluid and intracellular cytosol are aqueous solutions.
- Phospholipids spontaneously arrange into a bimolecular leaflet where the polar phosphate heads orient outward to contact water on both cytosolic and extracellular surfaces.
- The nonpolar fatty acid hydrocarbon chains project inward, facing each other to create an internal hydrophobic barrier.

Why other options are incorrect:

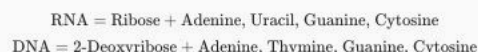
- **Option A:** Hydrophobic fatty acid tails cannot face outward into aqueous intra- and extracellular fluids because unfavorable contact with water disrupts the membrane.
- **Option B:** Polar hydrophilic heads cannot face each other within the dry, nonpolar hydrocarbon interior of the bilayer.
- **Option D:** Phospholipids assemble into an ordered thermodynamic bilayer rather than a random distribution.

Question #47 Key: (D)BIOLOGY
02. Biomolecules

The structure of RNA is distinguished from DNA by the:

CORE CONCEPT & DERIVATION

Ribonucleic acid (RNA) and deoxyribonucleic acid (DNA) are informational polynucleotides that differ in their pentose sugar component and nitrogenous base composition.

Formula / Rule / Reaction:**Solution:**

- RNA incorporates the pyrimidine uracil (which lacks a methyl group at C5) in place of thymine (5-methyluracil).
- During transcription and translation, uracil forms two complementary hydrogen bonds with adenine.

Why other options are incorrect:

- **Option A:** Cellular RNA molecules typically exist as single polynucleotide strands, whereas genomic DNA forms a double-stranded antiparallel helix.
- **Option B:** Deoxyribose sugar is characteristic of DNA; RNA contains D-ribose, which possesses a hydroxyl group at the 2-prime carbon.
- **Option C:** Both standard DNA and standard RNA utilize four distinct nucleotide monomers, not five.

Question #48 Key: (A)BIOLOGY
02. Biomolecules

The constant diameter of DNA is maintained by pairing:

CORE CONCEPT & DERIVATION

The B-DNA double helix maintains a constant width of 2.0 nm (20 Angstroms) throughout its length, as described by James Watson and Francis Crick.

Formula / Rule / Reaction:

$$\text{Diameter} = \text{Purine (2 rings, } \approx 1.2 \text{ nm)} + \text{Pyrimidine (1 ring, } \approx 0.8 \text{ nm)} = 2.0 \text{ nm}$$

Solution:

- Purines (adenine and guanine) possess a bicyclic structure, whereas pyrimidines (thymine and cytosine) have a smaller monocyclic structure.
- Pairing a two-ring purine with a single-ring pyrimidine ensures that the distance between the two sugar-phosphate backbones remains constant along the entire helix.

Why other options are incorrect:

- **Option B:** Pyrimidine-pyrimidine pairing involves two single rings, which would narrow the helix diameter to roughly 1.6 nm and prevent hydrogen bond formation.
- **Option C:** Purine-purine pairing involves two bulky double rings, which would widen the helix diameter to roughly 2.4 nm and create steric distortion.
- **Option D:** Phosphodiester linkages between deoxyribose sugars and phosphate groups form the outer structural backbone and do not span the central transverse axis of the double helix.

Question #49 Key: (B)BIOLOGY
02. Biomolecules

Identify the CORRECT option that matches the sugar with its carbon number and functional group:

CORE CONCEPT & DERIVATION

Monosaccharides are classified according to the number of carbon atoms they contain (triose, tetrose, pentose, hexose) and the chemical nature of their carbonyl group (aldose with an aldehyde group, or ketose with a ketone group).

Formula / Rule / Reaction:**Solution:**

- Ribose contains five carbon atoms (pentose) and has an aldehyde functional group ($-\text{CHO}$) at carbon-1, classifying it as an aldopentose.

Why other options are incorrect:

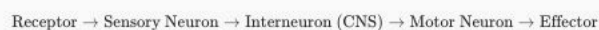
- **Option A:** Glyceraldehyde is a triose, but it possesses an aldehyde group at C1 (aldotriose); its ketose isomer is dihydroxyacetone.
- **Option C:** Ribulose is a five-carbon sugar (pentose), but it contains a ketone group at C2 (ketopentose).
- **Option D:** Galactose is a six-carbon sugar (hexose), but it contains an aldehyde group at C1 (aldohexose).

Question #50 Key: (C)BIOLOGY
12. Nervous Coordination

The CORRECT sequence of events in a reflex arc is:

CORE CONCEPT & DERIVATION

A reflex arc is the basic anatomical and physiological pathway that mediates an involuntary, rapid reflex response to a stimulus.

Formula / Rule / Reaction:**Solution:**

- A peripheral receptor detects a stimulus and generates action potentials.
- Sensory (afferent) neurons transmit the impulse through the dorsal root into the central nervous system.
- Associative neurons (interneurons) in the spinal gray matter process and integrate the incoming information.
- Motor (efferent) neurons carry the outgoing command via the ventral root to the effector muscle or gland to produce a response.

Why other options are incorrect:

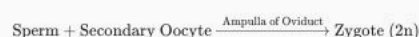
- **Option A:** Places the associative neuron before the sensory neuron, which contradicts the anatomical flow of afferent signals.
- **Option B:** Reverses the sequence by placing motor output before sensory conduction.
- **Option D:** Places the motor neuron before the integrating associative neuron.

Question #51 Key: (D)BIOLOGY
14. Reproduction

Fertilization normally occurs in the:

CORE CONCEPT & DERIVATION

Fertilization is the fusion of a haploid spermatozoon with a haploid secondary oocyte to form a diploid zygote. In the human female reproductive tract, this event occurs within the oviduct.

Formula / Rule / Reaction:**Solution:**

- Following ovulation, the secondary oocyte is swept into the fallopian tube (oviduct) by the fimbriae.
- Spermatozoa travel through the cervix and uterine cavity into the fallopian tube.
- Fertilization typically occurs in the ampulla, the widest and longest section of the fallopian tube.

Why other options are incorrect:

- **Option A:** The uterus is the site of blastocyst implantation and fetal development, not initial fertilization.
- **Option B:** The ovaries are the gonads responsible for oogenesis and hormone production (estrogen, progesterone); fertilization does not occur within ovarian follicles.
- **Option C:** The vagina receives semen during coitus and acts as the birth canal; its acidic pH is hostile to prolonged sperm survival.

Question #52 Key: (B)BIOLOGY
14. Reproduction*Which cells of the fallopian tube moisten and nourish the ovum?***CORE CONCEPT & DERIVATION**

The mucosal lining of the fallopian tube is composed of simple columnar epithelium containing two distinct functional cell types: ciliated cells and non-ciliated secretory cells (peg cells).

Formula / Rule / Reaction:*Factual recall / Qualitative concept.***Solution:**

- Non-ciliated epithelial cells (peg cells) possess apical microvilli and active secretory machinery.
- They produce a nutrient-rich fluid containing glycoproteins, glycogen, pyruvate, and lipids.
- This tubal secretion moistens the epithelium, nourishes the ovum and pre-implantation embryo, and promotes sperm capacitation.

Why other options are incorrect:

- **Option A:** Ciliated epithelial cells beat rhythmically toward the uterus to sweep the oocyte and fluid along the tube; they do not synthesize the nourishing secretion.
- **Option C:** Primordial germ cells give rise to gametes in the gonads and are not components of the oviductal epithelium.
- **Option D:** Endometrial cells line the uterine cavity, not the fallopian tubes.

Question #53 Key: (D)BIOLOGY
14. Reproduction*Which of the following is NOT an accessory gland of the human male reproductive system?***CORE CONCEPT & DERIVATION**

The male reproductive system consists of primary sex organs (gonads) and secondary accessory reproductive glands that contribute fluids to form seminal plasma.

Formula / Rule / Reaction:

Semen = Spermatozoa (from Testes) + Seminal Plasma (from Accessory Glands)

Solution:

- The testes are the primary reproductive organs (male gonads) responsible for spermatogenesis and testosterone synthesis.
- The male accessory glands are the paired seminal vesicles, the single prostate gland, and the paired bulbourethral (Cowper) glands.

Why other options are incorrect:

- **Option A:** The bulbourethral glands are accessory glands that secrete an alkaline pre-ejaculatory mucus to neutralize urethral acidity.
- **Option B:** The seminal vesicles are accessory glands that produce approximately 60% of semen volume, rich in fructose, prostaglandins, and coagulating proteins.
- **Option C:** The prostate gland is an accessory gland that secretes a milky, slightly acidic fluid containing citrate, proteolytic enzymes, and zinc.

Question #54 Key: (A)BIOLOGY
14. Reproduction*Syphilis is caused by what kind of bacteria?***CORE CONCEPT & DERIVATION**

Bacteria are classified morphologically by cell shape. Syphilis is a sexually transmitted infection caused by the bacterium *Treponema pallidum*.

Formula / Rule / Reaction:

Morphological category: Helical / spiral spirochete with endoflagella (axial filaments).

Solution:

- *Treponema pallidum* is a slender, tightly coiled, corkscrew-shaped bacterium classified as a spirochaete.
- It moves with characteristic flexing and rotational motility driven by periplasmic flagella located between its peptidoglycan layer and outer membrane.

Why other options are incorrect:

- **Option B:** Cocci are spherical bacteria, such as *Streptococcus pneumoniae* or *Neisseria gonorrhoeae*.
- **Option C:** Bacilli are straight, rod-shaped bacteria, such as *Escherichia coli* and *Bacillus anthracis*.
- **Option D:** Vibrios are comma-shaped curved rods, such as *Vibrio cholerae*.

Question #55 Key: (D)BIOLOGY
11. Support & Movement*What is FALSE about cartilages?***CORE CONCEPT & DERIVATION**

Cartilage is a specialized avascular connective tissue consisting of chondrocytes embedded within an extracellular matrix rich in glycosaminoglycans and collagen fibers.

Formula / Rule / Reaction:*Factual recall / Qualitative concept.***Solution:**

- Cartilage is completely avascular. It contains no blood vessels, lymphatic vessels, or nerves within its matrix.
- Chondrocytes rely entirely on the diffusion of oxygen and nutrients through the hydrated gel matrix from vessels in the outer perichondrium or synovial fluid.
- Therefore, stating that cartilage has an extensive blood supply is false.

Why other options are incorrect:

- **Option A:** Mature cartilage cells residing within small matrix cavities called lacunae are indeed called chondrocytes.
- **Option B:** The fibrillar extracellular matrix of hyaline and elastic cartilage is predominantly composed of Type II collagen fibers.
- **Option C:** Because cartilage lacks a direct vascular supply, damaged tissue undergoes repair very slowly and often incompletely.

Question #56 Key: (D)BIOLOGY
02. Biomolecules

Bones provide a rigid framework with an inorganic matrix of:

CORE CONCEPT & DERIVATION

Bone tissue is a composite material composed of an organic protein matrix reinforced with mineralized inorganic salts.

Formula / Rule / Reaction:

$$\text{Bone Matrix} \approx 35\% \text{ Organic (Osteoid)} + \approx 65\% \text{ Inorganic Mineral}$$

Solution:

- The inorganic phase accounts for approximately 65% of bone dry weight.
- It consists primarily of crystalline calcium phosphate organized as hydroxyapatite crystals $[\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2]$.
- These mineral crystals give bone its characteristic hardness, compressive strength, and rigidity.

Why other options are incorrect:

- Option A:** 35% represents the organic component of bone matrix (osteoid), which consists mainly of Type I collagen fibers and ground substance.
- Option B:** 45% is significantly below the physiological mineral content of mature compact and trabecular bone.
- Option C:** 55% underestimates the mineral density required to resist compressive loads.

Question #57 Key: (C)BIOLOGY
11. Support & Movement

An important feature of bone remodeling is bone breakdown. Which cell carries out this function...

CORE CONCEPT & DERIVATION

Bone remodeling is a dynamic process involving a balance between bone resorption and new bone deposition.

Formula / Rule / Reaction:**Solution:**

- Osteoclasts are large, multinucleated giant cells derived from the monocyte-macrophage hematopoietic lineage.
- They attach to the mineralized bone surface, form a sealed ruffled border, and secrete hydrochloric acid to dissolve hydroxyapatite along with cathepsin K proteases to degrade collagen fibers.
- This enzymatic process breaks down bone during remodeling.

Why other options are incorrect:

- Option A:** Chondrocytes are cartilage cells that maintain the cartilaginous extracellular matrix.
- Option B:** Osteocytes are mature bone cells trapped within lacunae that act as mechanosensors to coordinate remodeling signals.
- Option D:** Osteoblasts are bone-forming cells derived from osteoprogenitor mesenchyme that synthesize and secrete new osteoid matrix.

Question #58 Key: (C)BIOLOGY
11. Support & Movement

Myofibrils consist of small contractile units called:

CORE CONCEPT & DERIVATION

Skeletal muscle fibers are packed with cylindrical organelles termed myofibrils, which display a repeating banding pattern of contractile units.

Formula / Rule / Reaction:

$$\text{Sarcomere} = \text{Segment between two successive Z-lines}$$

Solution:

- The sarcomere is the basic structural and functional repeating contractile unit of a muscle fiber.
- It extends from one Z-line to the next and contains organized thick (myosin) and thin (actin) myofilaments that slide past one another during muscle contraction.

Why other options are incorrect:

- Option A:** Sarcoplasm is the cytoplasm of a muscle fiber, containing glycogen, myoglobin, and mitochondria.
- Option B:** The sarcolemma is the specialized plasma membrane enclosing each muscle fiber.
- Option D:** The sarcoplasmic reticulum is a modified smooth endoplasmic reticulum that stores and releases calcium ions.

Question #59 Key: (B)BIOLOGY
11. Support & Movement

Which muscle type is under conscious control and is multinucleated?

CORE CONCEPT & DERIVATION

Vertebrate muscle tissues are categorized into skeletal, cardiac, and smooth muscle based on histological appearance, innervation, and nuclear arrangement.

Formula / Rule / Reaction:

Skeletal muscle: Striated, multinucleated syncytium, voluntary somatic motor control.

Solution:

- Skeletal muscle fibers form by the fusion of embryonic myoblasts, resulting in long, cylindrical, multinucleated cells with peripherally located nuclei.
- They are innervated by somatic motor neurons, placing their contraction under conscious, voluntary control.

Why other options are incorrect:

- Option A:** Smooth muscle cells are spindle-shaped, non-striated, contain a single central nucleus, and operate involuntarily under autonomic nervous control.
- Option C:** Cardiac muscle fibers are striated, branched, possess one or two central nuclei, and contract involuntarily under intrinsic pacemaker and autonomic control.
- Option D:** Ciliary muscle of the eye is composed of smooth muscle tissue controlled involuntarily by the parasympathetic nervous system.

Question #60 Key: (C)BIOLOGY
11. Support & Movement*Which part of the sarcomere contain both actin and myosin filament?***CORE CONCEPT & DERIVATION**

The sarcomere displays alternating dark and light bands under polarized light due to the geometric arrangement and overlap of myofilaments.

Formula / Rule / Reaction:

A-band = Full length of thick filaments (Myosin) + Regions of overlapping thin filaments (Actin)

Solution:

- The A-band (anisotropic band) corresponds to the entire length of the thick myosin filaments.
- In its peripheral zones of overlap, thin actin filaments interdigitate between the thick filaments, meaning the A-band contains both actin and myosin filaments.

Why other options are incorrect:

- **Option A:** The I-band (isotropic band) contains only thin actin filaments anchored to the Z-line, with no overlapping myosin.
- **Option B:** The Z-line is a structural protein disc (alpha-actinin) that anchors thin actin filaments at each end of the sarcomere.
- **Option D:** The H-zone is the central, paler region of the A-band that contains only thick myosin filaments and no overlapping actin at rest.

Question #61 Key: (B)BIOLOGY
11. Support & Movement*The primary role of calcium ions in muscle contraction is to:***CORE CONCEPT & DERIVATION**

Excitation-contraction coupling in skeletal muscle requires calcium ions to remove steric inhibition of actin-myosin interaction.

Formula / Rule / Reaction:
$$\text{Ca}^{2+} + \text{Troponin C} \Rightarrow \text{Tropomyosin shift} \Rightarrow \text{Myosin binding sites exposed}$$
Solution:

- Depolarization of the sarcolemma spreads down T-tubules, triggering the release of Ca^{2+} from the terminal cisternae of the sarcoplasmic reticulum into the sarcoplasm.
- Ca^{2+} binds specifically to the troponin C subunit on the thin filament.
- This binding induces a conformational change in the troponin complex, shifting tropomyosin deeper into the actin groove and exposing the myosin-binding sites on actin to initiate cross-bridge cycling.

Why other options are incorrect:

- **Option A:** Metabolic energy is supplied by ATP hydrolysis, not by calcium ions.
- **Option C:** Nerve impulses along motor axons are propagated by the movement of sodium and potassium ions through voltage-gated channels.
- **Option D:** ATP breakdown is catalyzed by the intrinsic ATPase activity located on the globular head of the myosin heavy chain.

Question #62 Key: (D)BIOLOGY
11. Support & Movement*Which of the following is an example of a fibrous joint?***CORE CONCEPT & DERIVATION**

Joints (articulations) are classified structurally into fibrous, cartilaginous, and synovial joints depending on the connective tissue uniting the articulating bones and the presence of a joint cavity.

Formula / Rule / Reaction:

Fibrous joints (synarthroses): Bones held tightly by dense fibrous connective tissue with no joint cavity.

Solution:

- Cranial sutures uniting the flat bones of the skull are fibrous joints.
- Adjacent bone margins interlock and are bound together by dense connective tissue fibers (Sharpey fibers), forming immovable synarthroses that protect the underlying brain.

Why other options are incorrect:

- **Option A:** The glenohumeral (shoulder) joint is a freely movable (diarthrotic) ball-and-socket synovial joint.
- **Option B:** The elbow joint is a freely movable hinge synovial joint surrounded by a capsule containing synovial fluid.
- **Option C:** Intervertebral discs are cartilaginous joints (symphyses) containing fibrocartilage pads between adjacent vertebral bodies.

Question #63 Key: (A)BIOLOGY
15. Inheritance / Variation & Genetics*Which of Mendel's laws can best explain why a child may inherit brown eyes even if one parent h...***CORE CONCEPT & DERIVATION**

Gregor Mendel's Law of Dominance states that in a heterozygote carrying two different alleles for a specific trait, one allele masks or suppresses the phenotypic expression of the alternate allele.

Formula / Rule / Reaction:
$$\text{Genotype: } Bb \Rightarrow \text{Phenotype: Brown eyes (B is dominant over b)}$$
Solution:

- The allele for brown eye color (B) is dominant, whereas the allele for blue eye color (b) is recessive.
- When a child inherits the dominant allele from one parent and the recessive allele from the other, the resulting heterozygous genotype (Bb) expresses the brown eye phenotype because the dominant allele masks the recessive allele.

Why other options are incorrect:

- **Option B:** The Law of Segregation states that the two alleles for a heritable character separate during gamete formation and end up in different gametes; it does not explain the masking of one allele by another.
- **Option C:** The Law of Independent Assortment applies to the independent inheritance of two or more gene pairs located on different chromosome pairs.
- **Option D:** Recombination refers to the production of new allele combinations via crossing over, not the dominance relationship between paired alleles.

Question #64 Key: (B)BIOLOGY
15. Inheritance / Variation & Genetics

What is the significance of the 9:3:3:1 ratio in a dihybrid cross?

CORE CONCEPT & DERIVATION

A dihybrid cross involves mating individuals that are both heterozygous for two non-linked, independently assorting gene loci.

Formula / Rule / Reaction:

$$(3 \text{ Dominant} : 1 \text{ Recessive}) \times (3 \text{ Dominant} : 1 \text{ Recessive}) = 9 : 3 : 3 : 1$$

Solution:

- In a classic cross between $RrYy \times RrYy$, the four phenotypic classes appear in a 9:3:3:1 ratio (9 round yellow : 3 round green : 3 wrinkled yellow : 1 wrinkled green).
- This outcome arises because the segregation of seed shape alleles is statistically independent of the segregation of seed color alleles during meiosis, demonstrating Mendel's Law of Independent Assortment.

Why other options are incorrect:

- Option A:** Linked genes on the same chromosome do not assort independently and deviate from the 9:3:3:1 ratio, showing an excess of parental phenotypes.
- Option C:** Codominance produces distinct intermediate or dual phenotypes, altering expected Mendelian ratios.
- Option D:** The 9:3:3:1 ratio represents normal Mendelian inheritance and is not an indicator of genetic mutations.

Question #65 Key: (B)BIOLOGY
15. Inheritance / Variation & Genetics

In crossing over, an exchange of maternal and paternal chromatid parts occurs while homologous ...

CORE CONCEPT & DERIVATION

Genetic recombination via crossing over occurs during the first meiotic division, when homologous chromosomes pair to form bivalents (tetrads).

Formula / Rule / Reaction:

Synapsis (Zygotene) → Crossing Over (Pachytene) → Chiasmata visible (Diplotene)

Solution:

- During Prophase I of meiosis, homologous chromosomes pair lengthwise in synapsis to form bivalents.
- In the pachytene substage of Prophase I, non-sister chromatids break and rejoin at chiasmata, exchanging reciprocal segments between maternal and paternal homologs.

Why other options are incorrect:

- Option A:** During Metaphase I, paired homologous chromosomes align along the equatorial metaphase plate; genetic exchange has already concluded.
- Option C:** Anaphase II involves the separation and poleward migration of sister chromatids in haploid cells.
- Option D:** Telophase I involves the reorganization of nuclear envelopes around segregated homologous dyads.

Question #66 Key: (C)BIOLOGY
15. Inheritance / Variation & Genetics

Linked genes DO NOT follow Mendel's Law of Independent Assortment because:

CORE CONCEPT & DERIVATION

Mendel's Law of Independent Assortment applies to genes located on separate, non-homologous chromosomes. Genes located on the same physical chromosome form a linkage group.

Formula / Rule / Reaction:

Genetic linkage: Genes residing on the same chromosome tend to be transmitted together during meiosis.

Solution:

- Linked genes are physically located along the same linear DNA molecule on a chromosome.
- Unless separated by a crossover event, these syntenic genes segregate together into the same gamete during meiosis, causing phenotypic ratios to deviate from independent assortment.

Why other options are incorrect:

- Option A:** Genes located on different non-homologous chromosomes assort completely independently.
- Option B:** Linked genes do not always undergo crossing over; the probability of crossing over depends directly on the physical distance between the loci.
- Option D:** Although closely linked genes stay together, the fundamental biological explanation is their shared physical presence on the same chromosome.

Question #67 Key: (C)BIOLOGY
15. Inheritance / Variation & Genetics

A carrier female for an X-linked recessive disorder:

CORE CONCEPT & DERIVATION

In human sex-linked inheritance, females possess two X chromosomes (XX) while males possess one X and one Y chromosome (XY).

Formula / Rule / Reaction:

$\text{Carrier Mother: } X^A X^a \implies \text{Gives either } X^A \text{ or } X^a \text{ to offspring with equal 50\% probability}$

Solution:

- A carrier female has the heterozygous genotype $X^A X^a$, carrying one normal dominant allele and one mutant recessive allele.
- She has a 50% probability of passing the affected X^a chromosome to any son.
- Because a son inherits a Y chromosome from his father and has no second X to counteract the mutant allele, receiving the X^a chromosome causes him to express the recessive disorder.

Why other options are incorrect:

- Option A:** Because the wild-type dominant allele on her second X chromosome provides functional product, she is typically asymptomatic.
- Option B:** She has a 50% chance in each pregnancy of transmitting the mutant X chromosome to her offspring.
- Option D:** She passes her X chromosomes to both sons and daughters with equal probability.

Question #68 Key: (C)BIOLOGY
15. Inheritance / Variation & Genetics

Which of the following is an X-linked recessive disorder in humans?

CORE CONCEPT & DERIVATION

X-linked recessive disorders are caused by mutations in genes located on the X chromosome and affect males much more frequently than females.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Hemophilia A (factor VIII deficiency) and Hemophilia B (factor IX deficiency) are caused by recessive mutations located near the telomere of the long arm of the X chromosome (Xq28).
- Because males have only one X chromosome (hemizygous), inheriting a single defective allele causes the clinical bleeding disorder.

Why other options are incorrect:

- **Option A:** Cystic fibrosis is an autosomal recessive disorder caused by mutations in the CFTR gene located on chromosome 7.
- **Option B:** Thalassemia is an autosomal recessive hemoglobinopathy involving defects on chromosome 16 (alpha-thalassemia) or chromosome 11 (beta-thalassemia).
- **Option D:** Sickle cell anemia is an autosomal recessive hemoglobin disorder caused by a point mutation in the beta-globin gene on chromosome 11.

Question #69 Key: (C)BIOLOGY
15. Inheritance / Variation & Genetics

Which of the following CORRECTLY describes the expected outcome of children from a carrier moth...

CORE CONCEPT & DERIVATION

Inheritance of an X-linked recessive gene can be predicted by constructing a Punnett square for the cross between a heterozygous mother and a hemizygous normal father.

Formula / Rule / Reaction:**Solution:**

- Male offspring receive the Y chromosome from the father and either X^H or X^h from the mother: 50% are normal ($X^H Y$) and 50% have hemophilia ($X^h Y$).
- Female offspring receive X^H from the father and either X^H or X^h from the mother: 50% are homozygous normal ($X^H X^H$) and 50% are heterozygous asymptomatic carriers ($X^H X^h$).

Why other options are incorrect:

- **Option A:** Only 50% of sons inherit the affected maternal X^h chromosome; the remaining 50% inherit the normal X^H chromosome.
- **Option B:** Only 50% of daughters inherit the maternal X^h chromosome to become carriers; the other 50% are homozygous normal.
- **Option D:** Ignores the 50% risk of hemophilia among male children and the 50% carrier risk among female children.

Question #70 Key: (C)BIOLOGY
09. Respiration / Gaseous Exchange

The heart is surrounded by a tough, inelastic double membranous covering called:

CORE CONCEPT & DERIVATION

The heart is enclosed within the middle mediastinum by a fibrous sac that protects the organ, anchors it in the thorax, and prevents acute overfilling.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The pericardium consists of an outer tough fibrous pericardium and an inner serous pericardium (comprising parietal and visceral layers).
- Between the two serous layers is the pericardial cavity, which contains serous fluid to minimize frictional wear during cardiac contractions.

Why other options are incorrect:

- **Option A:** The pleura is the double-layered serous membrane surrounding each lung within the thoracic cavity.
- **Option B:** The peritoneum is the extensive serous membrane lining the abdominopelvic cavity and covering abdominal viscera.
- **Option D:** The meninges (dura mater, arachnoid mater, pia mater) are protective connective tissue coverings enclosing the brain and spinal cord.

Question #71 Key: (C)BIOLOGY
09. Respiration / Gaseous Exchange

The primary effect of smoking on the respiratory system:

CORE CONCEPT & DERIVATION

Inhaled cigarette smoke contains oxidants, particulate toxins, and carcinogens that disrupt the cellular and structural integrity of the lung parenchyma.

Formula / Rule / Reaction:

Protease-antiprotease imbalance: Elastase $\uparrow$ + α_1 -antitrypsin inactivation $\Rightarrow$ Alveolar septal destruction (Emphysema).

Solution:

- Cigarette smoke stimulates alveolar macrophages and neutrophils to release elastase while simultaneously oxidizing and inactivating protective alpha-1 antitrypsin.
- Unregulated proteolysis destroys the delicate interalveolar septa, permanently reducing the total alveolar surface area available for gas exchange (pulmonary emphysema).

Why other options are incorrect:

- **Option A:** Nicotine causes peripheral vasoconstriction, elevates systemic blood pressure, and paralyzes ciliary clearance without improving pulmonary mechanics.
- **Option B:** Cigarette smoke contains potent polycyclic aromatic hydrocarbons and nitrosamines that markedly increase the risk of bronchogenic carcinoma.
- **Option D:** Carbon monoxide in tobacco smoke binds hemoglobin with high affinity to form carboxyhemoglobin, reducing oxygen-carrying capacity.

Question #72 Key: (B)BIOLOGY
09. Respiration / Gaseous Exchange

What happens when the external intercostal muscles contract during inhalation in humans?

CORE CONCEPT & DERIVATION

Pulmonary ventilation operates by Boyle's law. Inhalation requires increasing the volume of the thoracic cavity to generate sub-atmospheric intrapleural pressure.

Formula / Rule / Reaction:

Thoracic Volume $\uparrow \implies$ Intrapulmonary Pressure $\downarrow$ ($P_1 V_1 = P_2 V_2$) $\implies$ Air rushes into lungs

Solution:

- Contraction of the external intercostal muscles elevates the ribs and rotates them outward (bucket-handle movement), while pushing the sternum forward (pump-handle movement).
- This expansion increases the anterior-posterior and lateral dimensions of the thoracic cage.

Why other options are incorrect:

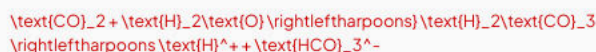
- **Option A:** The ribcage compresses during forced exhalation through the contraction of internal intercostal and abdominal muscles.
- **Option C:** The sternum moves anteriorly and superiorly (outward and upward) during inhalation, not inward.
- **Option D:** The muscular diaphragm contracts and flattens downward during active inhalation; relaxation occurs during passive exhalation.

Question #73 Key: (B)BIOLOGY
09. Respiration / Gaseous Exchange

During gaseous exchange in human respiration, enzyme carbonic anhydrase is directly involved in...

CORE CONCEPT & DERIVATION

Carbon dioxide is transported from tissues to the lungs primarily (roughly 70%) as dissolved bicarbonate ions (HCO_3^-) in the blood plasma.

Formula / Rule / Reaction:**Solution:**

- Erythrocytes contain high concentrations of the zinc metalloenzyme carbonic anhydrase.
- This enzyme accelerates the reversible hydration of carbon dioxide with water to produce carbonic acid (H_2CO_3) by several orders of magnitude.
- Carbonic acid then rapidly dissociates into protons and bicarbonate ions.

Why other options are incorrect:

- **Option A:** The release of oxygen from oxyhemoglobin is governed by the Bohr effect, temperature, 2,3-BPG, and partial pressure of oxygen, not direct enzymatic cleavage by carbonic anhydrase.
- **Option C:** Oxyhemoglobin dissociation is a non-enzymatic allosteric process driven by oxygen concentration gradients.
- **Option D:** Oxygen binding to muscle myoglobin depends on local pO_2 and the protein's hyperbolic binding affinity, independent of carbonic anhydrase.

Question #74 Key: (B)BIOLOGY
09. Respiration / Gaseous Exchange

Which of the following best describes Inspiratory Reserve Volume (IRV)?

CORE CONCEPT & DERIVATION

Spirometric lung volumes measure dynamic and static capacities of the human respiratory system during ventilation.

Formula / Rule / Reaction:

Inspiratory Capacity (IC) = Tidal Volume (TV) + Inspiratory Reserve Volume (IRV)

Solution:

- Inspiratory Reserve Volume (IRV) is the maximal additional volume of gas that can be forcibly inhaled above the resting tidal volume.
- In healthy adult males, normal IRV is approximately 3000 mL (and roughly 2000 mL in adult females).

Why other options are incorrect:

- **Option A:** The volume of air inspired or expired during quiet, restful breathing is the Tidal Volume (TV, roughly 500 mL).
- **Option C:** The volume of air remaining in the lungs at the end of a normal tidal exhalation is the Functional Residual Capacity (FRC).
- **Option D:** The maximum additional volume of air that can be forcibly exhaled after a normal tidal exhalation is the Expiratory Reserve Volume (ERV, roughly 1100 mL).

Question #75 Key: (C)BIOLOGY
08. Immunity

Identify the primary component of the T cell's defense.

CORE CONCEPT & DERIVATION

The immune system is divided into innate (non-specific) and adaptive (specific) immunity. T-lymphocytes form the core of cell-mediated adaptive immunity.

Formula / Rule / Reaction:

Adaptive immunity features: High antigen specificity, clonal selection, and immunological memory.

Solution:

- T-cells express unique clonotypic T-cell receptors (TCRs) generated by somatic V(D)J gene rearrangement.
- They recognize specific foreign peptide antigens presented on major histocompatibility complex (MHC) molecules.
- Following activation, a subset of antigen-primed T-cells differentiates into long-lived memory T-cells that confer protective, rapid immunity upon re-exposure.

Why other options are incorrect:

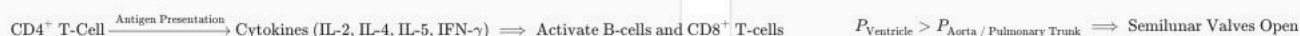
- **Option A:** The complement cascade and type I interferons are soluble protein components of the non-specific innate immune system.
- **Option B:** The keratinized epidermis of intact skin provides a non-specific physical barrier belonging to the first line of defense.
- **Option D:** Acute inflammation mediated by mast cells, histamine, and neutrophils is a localized innate immune response.

Question #76 Key: (B)BIOLOGY
08. Immunity

The primary role of helper T-cells in immune response is:

CORE CONCEPT & DERIVATION

Helper T-lymphocytes (CD4+ T-cells) act as central coordinators of both humoral and cell-mediated adaptive immunity.

Formula / Rule / Reaction:**Solution:**

- Helper T-cells recognize exogenous peptide antigens presented by MHC Class II molecules on antigen-presenting cells (dendritic cells, macrophages, B-cells).
- Upon activation, they secrete specific cytokines (such as interleukins) that drive B-cell proliferation and antibody class switching, while also stimulating the clonal expansion of cytotoxic T-cells and activating macrophages.

Why other options are incorrect:

- **Option A:** Secreting pore-forming perforins and granzymes to lyse abnormal target cells is the function of cytotoxic CD8+ T-cells and Natural Killer (NK) cells.
- **Option C:** Downregulating and suppressing excessive immune responses is the specialized role of regulatory T-cells (Tregs, CD4+CD25+FoxP3+).
- **Option D:** Engulfing and digesting pathogens is carried out by professional phagocytic cells such as macrophages and neutrophils.

Question #77 Key: (B)BIOLOGY
07. Circulation / Transport

What is the primary function of lymphatic vessels?

CORE CONCEPT & DERIVATION

Microvascular filtration generates a net fluid movement out of arterial capillaries into the interstitial space according to Starling forces.

Formula / Rule / Reaction:

$$\text{Net Capillary Filtration (} \approx 20 \text{ L/day)} - \text{Venular Reabsorption (} \approx 17 \text{ L/day)} = \text{Lymph Flow (} \approx 3 \text{ L/day)}$$

Solution:

- Roughly 2 to 4 liters of fluid filtered from blood capillaries each day remains in the interstitial space.
- Blind-ended lymphatic capillaries absorb this excess interstitial fluid, along with extravasated plasma proteins and cellular debris, returning it as lymph to the venous circulation via the thoracic duct and right lymphatic duct.
- This continuous drainage prevents tissue edema and maintains circulating plasma volume.

Why other options are incorrect:

- **Option A:** Oxygenated blood is transported under high pressure by systemic arteries and arterioles.
- **Option C:** Antibodies are synthesized and secreted by differentiated plasma B-cells within lymphoid tissues, not by the vessel conduits themselves.
- **Option D:** Metabolic wastes are cleared by renal, hepatic, and respiratory excretion; lymphatic channels serve as transit routes, not storage reservoirs.

Question #78 Key: (C)BIOLOGY
07. Circulation / Transport

Which phase of the cardiac cycle is characterized by the opening of semilunar valves?

CORE CONCEPT & DERIVATION

Cardiac valves open and close passively in response to pressure gradients across the valve orifices during distinct phases of the cardiac cycle.

Formula / Rule / Reaction:

$$P_{\text{Ventricle}} > P_{\text{Aorta / Pulmonary Trunk}} \Rightarrow \text{Semilunar Valves Open}$$

Solution:

- During ventricular systole, myocardial contraction rapidly raises pressure within the closed ventricles (isovolumetric contraction).
- Once left and right ventricular pressures exceed the diastolic pressures in the aorta (80 mm Hg) and pulmonary artery (10 mm Hg), the aortic and pulmonary semilunar valves are pushed open.
- Blood is then rapidly ejected into the arterial trunks.

Why other options are incorrect:

- **Option A:** Atrial systole delivers an active atrial booster volume into the relaxed ventricles through open atrioventricular valves while semilunar valves remain closed.
- **Option B:** During atrial diastole, atria relax and refill with blood while ventricular dynamics proceed independently.
- **Option D:** During ventricular diastole, ventricular pressure falls below arterial pressure, causing backflow that snaps the semilunar valves shut.

Question #79 Key: (B)BIOLOGY
07. Circulation / Transport

Which part of the heart's conducting system delays the impulse from atria to the ventricles?

CORE CONCEPT & DERIVATION

The specialized electrical conduction system of the heart coordinates the sequential contraction of cardiac chambers to maximize stroke volume.

Formula / Rule / Reaction:

$$\text{AV Nodal Delay} \approx 0.09 \text{ to } 0.12 \text{ seconds}$$

Solution:

- Action potentials initiated by the sinoatrial (SA) node travel across the atria and converge on the atrioventricular (AV) node.
- The AV node features small-diameter nodal fibers with fewer gap junctions, which slows conduction velocity to roughly 0.05 m/s.
- This anatomical delay (approximately 0.1 seconds) ensures the atria complete their mechanical contraction and empty their blood into the ventricles before ventricular systole begins.

Why other options are incorrect:

- **Option A:** The SA node is the primary physiological pacemaker that initiates electrical impulses at the highest intrinsic firing frequency.
- **Option C:** Purkinje fibers are specialized for very rapid impulse propagation (roughly 2 to 4 m/s) to ensure synchronous depolarization of the ventricular myocardium.
- **Option D:** The atrioventricular valves are mechanical fibrous tissue flaps, not electrical conduction structures.

Question #80 Key: (B)BIOLOGY
07. Circulation / Transport

The heartbeat sound "LUB" is produced on closure of:

CORE CONCEPT & DERIVATION

Heart sounds heard during auscultation are caused by blood turbulence and vibrations of cardiac walls associated with the sudden closure of heart valves.

Formula / Rule / Reaction:

First Heart Sound (S1, 'LUB') = Closure of Mitral and Tricuspid (AV) Valves

Solution:

- At the onset of ventricular systole, ventricular pressure rises sharply above atrial pressure.
- This pressure differential forces the tricuspid and bicuspid (mitral) atrioventricular valves shut.
- The sudden closure and tensing of the valve cusps and chordae tendineae produces the low-pitched, longer-duration first heart sound (S1 or 'LUB').

Why other options are incorrect:

- Option A:** Closure of the aortic valve contributes to the higher-pitched, sharper second heart sound (S2 or 'DUB') at the onset of ventricular diastole.
- Option C:** Closure of the pulmonary valve contributes to the second heart sound (S2), specifically its pulmonary component (P2).
- Option D:** Semilunar valves (aortic and pulmonary) together generate the second heart sound ('DUB'), not the first heart sound.

Question #81 Key: (D)BIOLOGY
05. Acellular Life

Which disease is caused by syncytial virus?

CORE CONCEPT & DERIVATION

Syncytia are multinucleated cytoplasmic masses formed by the fusion of adjacent single uninucleated cells. Several enveloped animal viruses induce syncytium formation during pathogenesis.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Human respiratory syncytial virus (RSV) expresses surface fusion (F) glycoproteins that promote the fusion of neighboring infected respiratory epithelial cells into giant multinucleated syncytia.
- It is a leading cause of acute lower respiratory infections (bronchiolitis and viral pneumonia) in infants.

Why other options are incorrect:

- Option A:** Cotton leaf curl disease is caused by circular single-stranded DNA begomoviruses (Geminiviridae) transmitted by whiteflies.
- Option B:** Polio is caused by poliovirus, an enterovirus of the Picornaviridae family with a naked icosahedral capsid.
- Option C:** Hepatitis A is caused by hepatitis A virus (HAV), a naked, single-stranded positive-sense RNA picornavirus.

Question #82 Key: (B)CHEMISTRY
03. Chemical Bonding

In a molecule of phenol, the carbon atom which is attached to OH group is:

CORE CONCEPT & DERIVATION

Aromatic rings consist of conjugated carbon frameworks where each ring carbon forms three coplanar sigma bonds and contributes one p-orbital to a delocalized pi cloud.

Formula / Rule / Reaction:

Steric Number = 3 σ -bonds + 0 lone pairs = 3 $\Rightarrow$ sp^2 Hybridization

Solution:

- The carbon atom bonded to the hydroxyl group (C1 of phenol) forms three coplanar σ -bonds: two with adjacent ring carbons and one with the oxygen atom of the -OH group.
- It reserves an unhybridized $2p_z$ orbital perpendicular to the plane to participate in the delocalized π -electron system of the benzene ring.
- Therefore, this carbon atom is sp^2 hybridized.

Why other options are incorrect:

- Option A:** sp hybridization produces a linear molecular geometry (180-degree bond angles) with two σ -bonds and two π -bonds, as in alkynes.
- Option C:** sp^3 hybridization produces a tetrahedral geometry (109.5-degree bond angles) with four σ -bonds, as seen in aliphatic alcohols like cyclohexanol or ethanol.
- Option D:** Carbon atoms forming stable covalent bonds in aromatic ring systems undergo hybridization rather than remaining unhybridized.

Question #83 Key: (A)CHEMISTRY
04. Gases

The value of R in $\text{atm} \cdot \text{dm}^3 \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$ is:

CORE CONCEPT & DERIVATION

The universal gas constant (R) is the proportionality constant in the ideal gas equation, and its numerical value depends on the units used for pressure and volume.

Formula / Rule / Reaction:

$$R = \frac{PV}{nT} = \frac{(1 \text{ atm})(22.414 \text{ dm}^3)}{(1 \text{ mol})(273.15 \text{ K})} = 0.082057 \approx 0.0821 \text{ atm} \cdot \text{dm}^3 \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$$

Solution:

- At standard temperature and pressure (STP), 1 mole of an ideal gas occupies 22.414 dm^3 at 1 atm and 273.15 K.
- Substituting these values into the ideal gas equation yields $R = 0.0821 \text{ atm} \cdot \text{dm}^3 \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$.

Why other options are incorrect:

- Option B:** 0.821 is an incorrect value shifted by a factor of ten due to a decimal error.
- Option C:** 62.4 (or 62,364) corresponds to the value of R when pressure is expressed in millimeters of mercury ($\text{mmHg} \cdot \text{dm}^3 \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$).
- Option D:** 8.314 is the SI value of R expressed in units of $\text{J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$ (or $\text{N} \cdot \text{m} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$ and $\text{kPa} \cdot \text{dm}^3 \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$).

Question #84 Key: (C)

CHEMISTRY
03. Chemical Bonding

Which one of the following is a planar molecule?

CORE CONCEPT & DERIVATION

Molecular geometry is determined by Valence Shell Electron Pair Repulsion (VSEPR) theory, which minimizes electrostatic repulsion among bonding pairs and non-bonding lone pairs.

Formula / Rule / Reaction:



Solution:

- In boron trifluoride (BF_3), the central boron atom forms three single covalent bonds with fluorine atoms and has no unshared lone pairs.
- Repulsion is minimized when the three B-F bonds lie in the same geometric plane at 120° -degree angles, producing a completely planar trigonal structure.

Why other options are incorrect:

- Option A:** Ammonia (NH_3) has three bond pairs and one lone pair on nitrogen (steric number 4), producing a three-dimensional trigonal pyramidal geometry.
- Option B:** Water (H_2O) has two bond pairs and two lone pairs on oxygen, producing a bent or V-shaped geometry.
- Option D:** Methane (CH_4) has four equivalent bonding pairs (steric number 4), forming a three-dimensional tetrahedral geometry.

Question #85 Key: (A)

CHEMISTRY
08. Reaction Kinetics

The rate of a chemical reaction changes with:

CORE CONCEPT & DERIVATION

According to collision theory and the law of mass action, the instantaneous rate of a chemical reaction depends directly on the frequency of effective collisions among reacting particles.

Formula / Rule / Reaction:

$$\text{Rate} = k[\text{A}]^m[\text{B}]^n$$

Solution:

- Increasing the concentration of reactant molecules increases the number of particles per unit volume.
- This higher particle density increases the collision frequency between reactant molecules with energy exceeding the activation energy, accelerating the reaction rate.

Why other options are incorrect:

- Option B:** In an irreversible forward reaction, product molecules do not participate in rate-determining collisions that drive the forward rate.
- Option C:** Forward reaction velocity is determined by reactant concentrations rather than product accumulation.
- Option D:** The specific rate constant (k) is an intrinsic proportionality constant that remains fixed at a given temperature and does not vary with changing concentrations.

Question #86 Key: (D)

CHEMISTRY
02. Atomic Structure

According to Planck's quantum theory, if the frequency of photon is doubled, the value of 'h' w...

CORE CONCEPT & DERIVATION

Planck's quantum theory states that radiant energy is emitted or absorbed in discrete packets called quanta, whose energy is directly proportional to radiation frequency.

Formula / Rule / Reaction:

$$E = hf \quad \text{where } h = 6.626 \times 10^{-34} \text{ J} \cdot \text{s}$$

Solution:

- Planck's constant (h) is a fundamental universal constant of nature.
- When the frequency (f) of a photon is doubled, the energy carried by the photon (E) doubles proportionally, while the numerical value of h remains unchanged.

Why other options are incorrect:

- Option A:** Fundamental physical constants (such as h , c , and G) do not vary with wave frequency or energy.
- Option B:** Tripling would violate the invariant definition of a physical constant.
- Option C:** Quadrupling incorrectly assumes that Planck's constant is a variable dependent on frequency.

Question #87 Key: (D)

CHEMISTRY
08. Reaction KineticsThe specific rate constant (k) of a reaction is related to the concentration of reactants:

CORE CONCEPT & DERIVATION

The specific rate constant (k) is a proportionality constant in the experimental differential rate law of a chemical reaction.

Formula / Rule / Reaction:

$$k = Ae^{-\frac{E_a}{RT}}$$

Solution:

- The value of the rate constant (k) depends on temperature, the activation energy of the reaction, and the presence of a catalyst, as described by the Arrhenius equation.
- It is entirely independent of the starting concentrations of the reacting species.
- Past paper board note:* Some unverified answer keys marked 'exponentially' by confusing the reaction rate dependence on reactant concentration with the rate constant itself; however, chemical kinetics dictates that k is independent of concentration.

Why other options are incorrect:

- Option A:** While the overall reaction rate may increase directly with reactant concentration, the constant k remains unchanged.
- Option B:** The rate constant does not vary inversely with concentration.
- Option C:** 'Exponentially' describes how temperature affects k through the Arrhenius equation, but k does not depend on reactant concentration.

Question #88 Key: (C)

CHEMISTRY
04. Gases

Which of the following is NOT a postulate of kinetic molecular theory of gases?

CORE CONCEPT & DERIVATION

The Kinetic Molecular Theory (KMT) provides a microscopic model explaining the macroscopic properties and pressure-volume behaviors of ideal gases.

Formula / Rule / Reaction:

$$P = \frac{F}{A} = \frac{1}{3} \frac{mN\overline{v^2}}{V}$$

Solution:

- A core postulate of KMT states that gas pressure results directly from the continuous momentum-transferring collisions of gas molecules against the interior walls of their container.
- Therefore, stating that gas molecules do not exert pressure when colliding with container walls contradicts the theory, making it the incorrect statement.

Why other options are incorrect:

- **Option A:** KMT explicitly postulates that collisions between gas molecules and with container walls are perfectly elastic, meaning total translational kinetic energy is conserved.
- **Option B:** KMT postulates that gas molecules are in constant, chaotic, straight-line random motion.
- **Option D:** KMT postulates that individual gas molecules are separated by distances much greater than their molecular diameters, meaning the actual volume of the molecules is negligible.

Question #89 Key: (C)

CHEMISTRY
02. Atomic Structure

Spectral series for hydrogen spectrum are:

CORE CONCEPT & DERIVATION

The atomic emission spectrum of hydrogen consists of discrete sets of spectral lines produced by electron de-excitations to specific lower principal quantum levels (n_1).

Formula / Rule / Reaction:

$$\frac{1}{\lambda} = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

Solution:

- The five standard, well-characterized spectral series recognized in intermediate chemistry curricula are:
 - 1. Lyman series ($n_1 = 1$, ultraviolet region)
 - 2. Balmer series ($n_1 = 2$, visible region)
 - 3. Paschen series ($n_1 = 3$, infrared region)
 - 4. Brackett series ($n_1 = 4$, infrared region)
 - 5. Pfund series ($n_1 = 5$, far-infrared region)
- *Past paper board note:* Some provincial question banks keyed '3' based on older textbook summaries that emphasized only the primary UV, visible, and infrared categories; however, five series are recognized across textbook curricula.

Why other options are incorrect:

- **Option A:** 2 accounts only for the Lyman and Balmer series.
- **Option B:** 3 counts only the Lyman, Balmer, and Paschen series, omitting the higher infrared Brackett and Pfund series.
- **Option D:** 7 includes rare, highly excited laboratory series (such as Humphreys and Hansen-Strong) beyond standard syllabus classification.

Question #90 Key: (A)CHEMISTRY
03. Chemical Bonding

The most electronegative element in periodic table is:

CORE CONCEPT & DERIVATION

Electronegativity is the relative tendency of an atom in a covalent bond to attract shared electron density toward itself.

Formula / Rule / Reaction:

Pauling scale values: $F(3.98) > O(3.44) > N(3.04) > Cl(3.16)$.

Solution:

- Fluorine (F) has an atomic number of 9 and an electron configuration of $1s^2 2s^2 2p^5$.
- Because of its small atomic radius and high effective nuclear charge, fluorine exerts the strongest electrostatic pull on bonding electron pairs.
- It is assigned the maximum value of 4.0 on the Pauling electronegativity scale.

Why other options are incorrect:

- Option B:** Chlorine has a larger atomic radius than fluorine due to an additional electron shell, which shields the nucleus and lowers its electronegativity to roughly 3.16.
- Option C:** Nitrogen has an electronegativity of roughly 3.04, which is lower than both fluorine and oxygen.
- Option D:** Oxygen is the second most electronegative element (3.44), but it remains less electronegative than fluorine.

Question #91 Key: (B)CHEMISTRY
19. Macromolecules / Biochemistry

An experiment shows that heating a protein disrupts its alpha-helix structure. Which level of p...

CORE CONCEPT & DERIVATION

Protein architecture is organized into four hierarchical levels. The secondary structure refers to localized, repetitive spatial arrangements of the polypeptide backbone stabilized by hydrogen bonds.

Formula / Rule / Reaction:

Alpha-helix stabilization: Hydrogen bonds between $C=O_{(n)}$ and $N-H_{(n+4)}$

Solution:

- The alpha-helix and beta-pleated sheet represent the two principal forms of protein secondary structure.
- Heating increases molecular kinetic energy, which physically breaks the relatively weak hydrogen bonds holding the helical coils together.
- Consequently, the ordered secondary structure unfolds into a disordered random coil conformation.

Why other options are incorrect:

- Option A:** Primary structure consists of covalent peptide bonds linking the linear amino acid sequence, which are thermally stable and require strong acid, base, or specific proteases for cleavage.
- Option C:** Tertiary structure involves overall three-dimensional folding stabilized by disulfide bridges, hydrophobic interactions, and ionic salt bridges; while affected during complete denaturation, the alpha-helix itself is the defining motif of secondary structure.
- Option D:** Quaternary structure describes the spatial assembly of multiple independent polypeptide subunits in multimeric proteins.

Question #92 Key: (C)CHEMISTRY
03. Chemical Bonding

Which of the following hydrogen halides has the highest bond energy?

CORE CONCEPT & DERIVATION

Bond dissociation energy in hydrogen halides depends inversely on bond length and directly on the electronegativity difference and orbital overlap between the bonded atoms.

Formula / Rule / Reaction:

Bond Energy: $HF(565 \text{ kJ/mol}) > HCl(431 \text{ kJ/mol}) > HBr(366 \text{ kJ/mol}) > HI(298 \text{ kJ/mol})$

Solution:

- Fluorine is the smallest and most electronegative halogen, resulting in the shortest covalent bond length (92 pm) and strongest orbital overlap with hydrogen's 1s orbital.
- The substantial electronegativity difference gives the H-F bond strong ionic character, yielding the highest bond dissociation energy among all hydrogen halides (565 kJ/mol).

Why other options are incorrect:

- Option A:** HCl has a longer bond length (127 pm) and lower bond energy (431 kJ/mol) than HF.
- Option B:** HI contains the largest halogen atom, yielding the longest, weakest bond (298 kJ/mol).
- Option D:** HBr has an intermediate bond energy (366 kJ/mol), significantly lower than HF.

Question #93 Key: (A)CHEMISTRY
07. Equilibrium

In which case does a chemical reaction proceed nearly to completion?

CORE CONCEPT & DERIVATION

The equilibrium constant (K_c) quantifies the ratio of equilibrium product concentrations to reactant concentrations, each raised to the power of their stoichiometric coefficients.

Formula / Rule / Reaction:

$$K_c = \frac{[\text{Products}]^{\text{coefficients}}}{[\text{Reactants}]^{\text{coefficients}}}$$

Solution:

- A very large numerical value of K_c (typically $K_c > 10^3$) indicates that the numerator (products) is vastly greater than the denominator (reactants) at equilibrium.
- This demonstrates that almost all initial reactants have been converted into products, meaning the reaction proceeds virtually to completion.

Why other options are incorrect:

- Option B:** A very small positive K_c ($K_c < 10^{-3}$) indicates that reactants dominate at equilibrium, meaning the forward reaction barely occurs.
- Option C:** When $K_c \approx 1$, comparable concentrations of both reactants and products exist at equilibrium.
- Option D:** Equilibrium constants represent ratios of concentrations and absolute rate constants; they cannot be negative.

Question #94 Key: (B)CHEMISTRY
14. Hydrocarbons

The addition of water to propene in the presence of sulfuric acid produces:

CORE CONCEPT & DERIVATION

Electrophilic addition of unsymmetrical polar reagents to unsymmetrical alkenes follows Markovnikov's rule, proceeding via the more stable carbocation intermediate.

Formula / Rule / Reaction:**Solution:**

- Electrophilic attack of a proton (H^+) across the propene double bond forms a secondary carbocation ($\text{CH}_3 - \text{CH}^+ - \text{CH}_3$), which is more stable than the alternative primary carbocation.
- Nucleophilic attack of water on the secondary carbocation followed by deprotonation yields propan-2-ol (isopropyl alcohol) as the major product.

Why other options are incorrect:

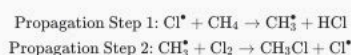
- Option A:** Propan-1-ol (propanol) is an anti-Markovnikov product and forms only via hydroboration-oxidation, not acid-catalyzed hydration.
- Option C:** Butanol contains four carbon atoms, whereas propene is a three-carbon substrate.
- Option D:** Ethanol contains two carbon atoms, which cannot be formed without carbon-carbon bond cleavage.

Question #95 Key: (C)CHEMISTRY
14. Hydrocarbons

Consider the chlorination of methane to methyl chloride. The attack of the chlorine free radical...

CORE CONCEPT & DERIVATION

Free-radical halogenation of alkanes is a photochemical chain reaction comprising three distinct mechanistic stages: initiation, propagation, and termination.

Formula / Rule / Reaction:**Solution:**

- Initiation involves the homolytic fission of molecular chlorine by ultraviolet light into two chlorine radicals ($\text{Cl}_2 \xrightarrow{h\nu} 2\text{Cl}^\bullet$).
- In the first propagation step, a reactive chlorine radical attacks a methane molecule, abstracting a hydrogen atom to form hydrogen chloride and a methyl free radical ($\text{CH}_3^\bullet$).
- Because this step consumes and regenerates free radicals to sustain the chain process, it is classified as propagation.

Why other options are incorrect:

- Option A:** Before initiation, only non-reactive ground-state molecular reactants exist.
- Option B:** Initiation involves homolysis of halogen-halogen bonds to generate the initial radicals; methane does not react in this step.
- Option D:** Termination involves the coupling of two free radicals to form stable covalent bonds, quenching the chain reaction.

Question #96 Key: (C)CHEMISTRY
19. Macromolecules / Biochemistry

A patient with pancreatic insufficiency shows reduced activity of an enzyme that hydrolyzes the...

CORE CONCEPT & DERIVATION

Proteolytic digestive enzymes are categorized as endopeptidases (which cleave internal peptide bonds) or exopeptidases (which cleave terminal peptide bonds).

Formula / Rule / Reaction:**Solution:**

- Carboxypeptidases (A and B) are zinc metallo-exopeptidases synthesized by pancreatic acinar cells and secreted as procarboxypeptidases into the duodenum.
- They remove amino acid residues sequentially from the free carboxyl (C-terminal) end of peptides.

Why other options are incorrect:

- Option A:** Elastase is an endopeptidase that cleaves internal peptide bonds adjacent to small aliphatic amino acids like alanine and glycine.
- Option B:** Pepsin is a gastric endopeptidase secreted by stomach chief cells that hydrolyzes internal peptide bonds adjacent to aromatic residues.
- Option D:** Collagenase is a specialized matrix metalloproteinase that degrades helical collagen fibers.

Question #97 Key: (B)CHEMISTRY
05. Liquids

The intermolecular force of attraction resulting from temporary instantaneous dipoles is:

CORE CONCEPT & DERIVATION

Van der Waals forces describe non-covalent attractive interactions between neutral molecules. Dispersion forces occur universally across all chemical species.

Formula / Rule / Reaction:

Mechanism: Symmetrical electron distribution $\rightarrow$ Momentary electron fluctuation $\rightarrow$ Instantaneous dipole $\rightarrow$ Induced dipole in neighbor.

Solution:

- London dispersion forces arise from the continuous, random motion of electrons within atomic and molecular orbitals.
- Temporary asymmetric electron distributions create an instantaneous dipole, which polarizes electron clouds of neighboring atoms to induce complementary dipoles.
- The resulting short-range electrostatic attraction is termed a dispersion force.

Why other options are incorrect:

- Option A:** Dipole-dipole interactions occur between molecules possessing permanent molecular dipoles, such as HCl or sulfur dioxide.
- Option C:** Debye forces represent induction interactions where a permanent dipole induces a temporary dipole in an adjacent nonpolar molecule.
- Option D:** Ion-dipole forces operate between formal ionic charges and polar solvent molecules, such as hydrated sodium ions in water.

Question #98 Key: (B)

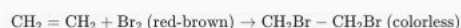
CHEMISTRY
14. Hydrocarbons

A student adds bromine water to ethene and observes decolourisation. What makes ethene more reactive...

CORE CONCEPT & DERIVATION

Alkenes are unsaturated hydrocarbons containing a carbon-carbon double bond consisting of one strong sigma bond and one weaker pi bond.

Formula / Rule / Reaction:



Solution:

- The pi (π) bond in ethene is formed by the lateral overlap of unhybridized 2p atomic orbitals.
- Because the π -electron cloud lies exposed above and below the internuclear plane, its electrons are loosely held and serve as an accessible nucleophilic source.
- Electrophiles like molecular bromine readily polarize and attack this exposed electron density, causing rapid addition and decolourisation at room temperature.

Why other options are incorrect:

- Option A:** Ethene (28 g/mol) has a lower molecular mass than ethane (30 g/mol); molecular weight does not drive electrophilic addition.
- Option C:** Ethane contains 7 sigma bonds, whereas ethene contains 5 sigma bonds and 1 pi bond.
- Option D:** Ethene undergoes electrophilic addition reactions, not free-radical substitution, under ambient conditions.

Question #99 Key: (C)

CHEMISTRY
14. Hydrocarbons

What best describes the overall reaction in electrophilic aromatic substitution in benzene?

CORE CONCEPT & DERIVATION

Benzene possesses a delocalized aromatic sextet of six pi electrons with an extraordinary resonance stabilization energy of roughly 150 kJ/mol (36 kcal/mol).

Formula / Rule / Reaction:



Solution:

- An incoming electrophile (E^+) attacks the electron-rich aromatic ring, forming a resonance-stabilized arenium ion intermediate (Wheland complex / sigma complex).
- In the second step, a base abstracts the ring proton (H^+) from the sp^3 -hybridized carbon.
- Loss of the proton restores the fully conjugated, highly stable aromatic sextet, yielding an overall substitution of H^+ by the electrophile.

Why other options are incorrect:

- Option A:** Addition across double bonds disrupts the aromatic conjugation, leading to permanent loss of resonance stabilization.
- Option B:** Benzene lacks halogen substituents in its parent form and resists direct nucleophilic substitution due to electron repulsion from the pi cloud.
- Option D:** Parent benzene contains only hydrogen atoms bonded to ring carbons, not methyl groups.

Question #100 Key: (D)

CHEMISTRY
04. Gases

Real gases DO NOT reach absolute zero in practice because:

CORE CONCEPT & DERIVATION

According to the Kinetic Molecular Theory of gases, ideal behavior assumes point-mass particles with zero intermolecular attractions. Real gases deviate significantly under low-temperature and high-pressure regimes.

Formula / Rule / Reaction:

$$\text{At low } T: E_k = \frac{3}{2}k_B T \rightarrow 0, \text{ making attractive potential energy } (U_{\text{attraction}}) \text{ dominant}$$

Solution:

- As a real gas is cooled toward absolute zero (0 Kelvin / -273.15 degrees Celsius), the average molecular kinetic energy decreases continuously.
- Before reaching absolute zero, attractive intermolecular forces (van der Waals attractions) become stronger than the diminishing kinetic energy.
- These cohesive forces pull the molecules together, causing condensation into a liquid and ultimately freezing into a solid well above absolute zero.

Why other options are incorrect:

- Option A:** Kinetic energy decreases toward zero as temperature drops; it does not increase.
- Option B:** Intermolecular forces become dominant, not negligible, as molecular velocities diminish.
- Option C:** Compression does not increase thermal kinetic energy if heat is systematically removed during cooling.

Question #101 Key: (D)

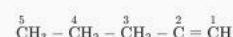
CHEMISTRY
13. Fundamental Principles of Organic Chemistry

The IUPAC name of the compound [Formula] is:

CORE CONCEPT & DERIVATION

IUPAC rules for alkyne nomenclature require identifying the longest continuous carbon chain containing the triple bond and numbering it to give the triple bond the lowest possible locant.

Formula / Rule / Reaction:



Solution:

- The longest continuous chain contains five carbon atoms, giving the root name 'pent'.
- The chain is numbered from right to left so that the triple bond starts at carbon-1.
- The IUPAC name is therefore pent-1-yne.

Why other options are incorrect:

- Option A:** Hex-1-yne has a six-carbon parent chain, whereas this compound contains only five carbons.
- Option B:** Pent-2-yne has the triple bond located between carbon-2 and carbon-3 ($\text{CH}_3 - \text{C} \equiv \text{C} - \text{CH}_2 - \text{CH}_3$).
- Option C:** Pent-4-yne violates the lowest locant rule by numbering the chain from the wrong end.

Question #102 Key: (D)

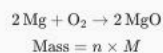
CHEMISTRY
01. Stoichiometry

If 10 moles of magnesium react with an excess of oxygen, calculate the theoretical yield of mag...

CORE CONCEPT & DERIVATION

Stoichiometric calculations relate molar amounts of limiting reactants to theoretical masses of product using balanced chemical equations.

Formula / Rule / Reaction:



Solution:

- From the balanced chemical equation, 2 moles of Mg produce 2 moles of MgO (a 1:1 molar ratio).
- Therefore, 10 moles of Mg react with excess oxygen to produce 10 moles of MgO.
- Molar mass of MgO = 24 g/mol (Mg) + 16 g/mol (O) = 40 g/mol.
- Theoretical yield = 10 mol × 40 g/mol = 400 g.

Why other options are incorrect:

- Option A:** 160 g corresponds to only 4 moles of MgO.
- Option B:** 240 g corresponds to the mass of the unreacted magnesium (10 mol × 24 g/mol), neglecting oxygen incorporation.
- Option C:** 320 g corresponds to 8 moles of MgO.

Question #103 Key: (B)

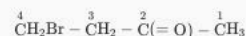
CHEMISTRY
13. Fundamental Principles of Organic Chemistry

The IUPAC name of the compound [Formula] is:

CORE CONCEPT & DERIVATION

Under IUPAC nomenclature, principal functional groups (such as ketones) take precedence over halogen substituents and dictate the numbering direction of the carbon parent chain.

Formula / Rule / Reaction:



Solution:

- The longest continuous carbon chain contains four carbons, defining the parent alkane as butane.
- The carbonyl functional group (–CO–) defines the compound as a ketone ('-one') and must receive the lowest locant; numbering from right to left places the carbonyl at C2.
- The bromine substituent is located at carbon-4.
- The complete IUPAC name is 4-bromobutan-2-one.
- Past paper board note:* Some unedited exam keys mislabelled this option as 1-bromobutan-2-one due to an inverted numbering typographical error; the correct IUPAC name is 4-bromobutan-2-one.

Why other options are incorrect:

- Option A:** A ketone carbonyl cannot exist at carbon-1 in a simple unbranched chain because that forms an acyl bromide or aldehyde.
- Option C:** Numbering from left to right gives the carbonyl an unnecessarily high locant of 3, violating priority rules.
- Option D:** Placing the ketone suffix at carbon-4 contradicts basic carbon chain numbering.

Question #104 Key: (A)

CHEMISTRY
01. Stoichiometry

Consider the reaction: [Formula]. If 4 moles of Na and 2 moles of [Formula] are reacted, how m...

CORE CONCEPT & DERIVATION

Stoichiometric proportions from balanced chemical equations dictate the exact stoichiometric consumption of reactants in the absence of a limiting reagent.

Formula / Rule / Reaction:

$$\frac{n_{\text{Na}}}{n_{\text{Cl}_2}} = \frac{2}{1}$$

Solution:

- According to the balanced equation, 2 moles of Na react completely with 1 mole of Cl_2 .
- To consume 4 moles of Na, the required amount of chlorine is:
- Moles of Cl_2 required = $4 \text{ mol Na} \times \frac{1 \text{ mol Cl}_2}{2 \text{ mol Na}} = 2 \text{ mol Cl}_2$
- Because exactly 2 moles of Cl_2 are provided, both reactants are consumed completely with neither in excess.
- Amount of unreacted $\text{Cl}_2 = 2 \text{ mol} - 2 \text{ mol} = 0 \text{ mol}$.

Why other options are incorrect:

- Option B:** 0.5 mol would remain only if 3 moles of Na were provided initially.
- Option C:** 1 mol would remain if only 2 moles of Na were reacted.
- Option D:** 1.5 mol would remain if only 1 mole of Na were supplied.

Question #105 Key: (C)

CHEMISTRY
07. Equilibrium

According to Le Chatelier's Principle, when the pressure of a gaseous equilibrium system is inc...

CORE CONCEPT & DERIVATION

Le Chatelier's Principle states that if an external stress (such as pressure, temperature, or concentration) is applied to a dynamic equilibrium, the system shifts to counteract that stress.

Formula / Rule / Reaction:

Pressure $\uparrow \Rightarrow$ System shifts toward fewer moles of gas (lower volume)

Solution:

- Gaseous pressure is directly proportional to the total number of moles of gas per unit volume ($P = \frac{nRT}{V}$).
- Increasing total pressure acts as a stress that compresses the system.
- The equilibrium shifts toward the side with fewer moles of gas, which occupies a smaller volume, relieving the applied pressure.

Why other options are incorrect:

- Option A:** The equilibrium position remains unchanged only when the sum of gaseous stoichiometric coefficients is identical on both sides ($\Delta n_g = 0$).
- Option B:** Shifting toward greater volume increases total moles, which would elevate pressure further and exacerbate the disturbance.
- Option D:** Shifting toward more moles of gas would increase total pressure, violating Le Chatelier's principle.

Question #106 Key: (B)

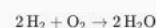
CHEMISTRY
01. Stoichiometry

If 4 g of [Formula] reacts with 2 moles of [Formula] to form water, which reagent is in excess?

CORE CONCEPT & DERIVATION

The limiting reagent is completely consumed first in a chemical reaction, while the excess reagent remains partially unreacted after the limiting reagent is exhausted.

Formula / Rule / Reaction:



Solution:

- Molar mass of $\text{H}_2 = 2.016 \text{ g/mol}$. Moles of $\text{H}_2 = \frac{4 \text{ g}}{2 \text{ g/mol}} = 2 \text{ mol}$.
- According to the balanced equation, 2 moles of H_2 require 1 mole of O_2 for complete reaction.
- The mixture contains 2 moles of O_2 , but only 1 mole is consumed by the available H_2 .
- After complete consumption of H_2 , 1 mole of O_2 remains unreacted, making O_2 the excess reagent.

Why other options are incorrect:

- Option A:** H_2 is completely consumed and acts as the limiting reagent.
- Option C:** Water is the reaction product, not a chemical reactant.
- Option D:** Only one reagent can be present in excess when stoichiometric ratios are unequal.

Question #107 Key: (B)

CHEMISTRY
03. Chemical Bonding

The molecular orbitals in benzene are:

CORE CONCEPT & DERIVATION

Benzene possesses a planar hexagonal ring of six sp^2 -hybridized carbon atoms. The unhybridized 2p orbitals overlap continuously around the entire ring.

Formula / Rule / Reaction:

Huckel's Rule: $4n + 2 = 6 \pi\text{-electrons} (n = 1) \Rightarrow$ Delocalized aromatic system

Solution:

- The six unhybridized 2p atomic orbitals on adjacent carbon atoms overlap sideways to form three bonding and three antibonding molecular orbitals.
- The six π -electrons are not confined to specific carbon-carbon bonds, but are shared equally across the entire ring as continuous toroidal electron clouds above and below the plane.
- This arrangement is termed delocalized.

Why other options are incorrect:

- Option A:** Localized orbitals confine electrons between two specific atomic nuclei, as in simple isolated alkenes.
- Option C:** Hybridization (sp^2) forms localized carbon-carbon and carbon-hydrogen sigma bonds, whereas the pi molecular orbitals themselves are unhybridized and delocalized.
- Option D:** Benzene is a nonpolar, highly symmetrical hydrocarbon with zero permanent molecular dipole.

Question #108 Key: (A)

CHEMISTRY
01. Stoichiometry

Consider the reaction [Formula]. Which of the following mixtures would make A the limiting reagent...

CORE CONCEPT & DERIVATION

The limiting reagent is determined by comparing the mole or particle ratio of available reactants with the stoichiometric coefficients of the balanced equation.

Formula / Rule / Reaction:

$$\text{Required Stoichiometric Ratio: } \frac{N_A}{N_{B_2}} = \frac{2}{1} = 2.0$$

Solution:

- For Option A: $\frac{N_A}{N_{B_2}} = \frac{300}{400} = 0.75$. Because 0.75 is less than the required ratio of 2.0, reactant A will be exhausted first, making A the limiting reagent.
- Reacting 300 atoms of A consumes only 150 molecules of B_2 , leaving 250 molecules of B_2 in excess.

Why other options are incorrect:

- Option B:** $\frac{100}{50} = 2.0$; reactants are present in exact stoichiometric balance, so neither is limiting.
- Option C:** $\frac{2 \text{ mol}}{1 \text{ mol}} = 2.0$; reactants are present in exact stoichiometric proportion.
- Option D:** $\frac{5 \text{ mol}}{2.5 \text{ mol}} = 2.0$; both reactants are consumed simultaneously without excess.

Question #109 Key: (B)

CHEMISTRY
09. Thermochemistry

Given: Heat of sublimation of [Formula], Ionization energy of [Formula], Bond dissociation en...

CORE CONCEPT & DERIVATION

The Born-Haber cycle applies Hess's law to relate the standard enthalpy of formation of an ionic solid to its component atomization, ionization, and lattice enthalpies.

Formula / Rule / Reaction:

$$\Delta H_f^\circ = \Delta H_{\text{sub}}(\text{Na}) + \text{IE}(\text{Na}) + \frac{1}{2} D(\text{Cl}_2) + \text{EA}(\text{Cl}) + U_{\text{lattice}}$$

Solution:

- Substitute the given thermodynamic values into the cycle:
- $-411 = 108 + 496 + \frac{1}{2}(121) + (-349) + U_{\text{lattice}}$
- $-411 = 108 + 496 + 60.5 - 349 + U_{\text{lattice}}$
- $-411 = 315.5 + U_{\text{lattice}}$
- $U_{\text{lattice}} = -411 - 315.5 = -726.5 \approx -727 \text{ kJ/mol}$

Why other options are incorrect:

- Option A:** 678 kJ/mol results from omitting the bond dissociation enthalpy and using incorrect signs.
- Option C:** -819 kJ/mol results from using the full bond dissociation energy of Cl_2 (121 kJ/mol) instead of half ($\frac{1}{2}D$) and arithmetic sign errors.
- Option D:** -832 kJ/mol is an incorrect value from adding positive enthalpy components without subtracting electron affinity.

Question #110 Key: (B)

CHEMISTRY
17. Aldehydes & Ketones

Acetaldehyde reacts with ethanol in the presence of an acid catalyst to initially produce:

CORE CONCEPT & DERIVATION

Aldehydes undergo reversible acid-catalyzed nucleophilic addition with alcohols. The initial product contains both a hydroxyl group and an alkoxy group on the same carbon atom.

Formula / Rule / Reaction:



Solution:

- Protonation of the carbonyl oxygen enhances the electrophilicity of the carbonyl carbon.
- Nucleophilic attack by the ethanol hydroxyl oxygen followed by proton loss forms a hemiacetal (1-ethoxyethanol).
- Under continued exposure to excess alcohol and acid, the hemiacetal reacts further to eliminate water and form an acetal (1,1-diethoxyethane).

Why other options are incorrect:

- Option A:** An acetal is the final dialkoxy product formed only after a second mole of alcohol reacts with the intermediate hemiacetal.
- Option C:** A diol contains two hydroxyl groups, formed by hydration of carbonyls with water rather than addition of an alcohol.
- Option D:** Diethoxyethane (diethyl acetal) is the final product formed upon completion of the second substitution step.

Question #111 Key: (D)

CHEMISTRY
04. Gases

If the absolute pressure and absolute temperature of an ideal gas are both doubled, the new vol...

CORE CONCEPT & DERIVATION

The combined ideal gas equation expresses the relationship between pressure, volume, and absolute temperature for a fixed mass of gas.

Formula / Rule / Reaction:

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \Rightarrow V_2 = V_1 \left(\frac{P_1}{P_2} \right) \left(\frac{T_2}{T_1} \right)$$

Solution:

- Let initial conditions be P_1 , V_1 , and T_1 .
- The new pressure is $P_2 = 2P_1$ and the new absolute temperature is $T_2 = 2T_1$.
- $V_2 = V_1 \left(\frac{P_1}{2P_1} \right) \left(\frac{2T_1}{T_1} \right) = V_1 \left(\frac{1}{2} \right) (2) = V_1$
- The doubling of pressure compresses the gas by half, while the doubling of absolute temperature expands it by a factor of two, leaving the final volume unchanged.

Why other options are incorrect:

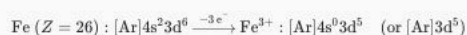
- Option A:** Volume doubles only if temperature doubles at constant pressure (Charles's Law).
- Option B:** Volume is halved only if pressure doubles at constant temperature (Boyle's Law).
- Option C:** Tripling would require a threefold change in the temperature-to-pressure ratio.

Question #112 Key: (C)CHEMISTRY
12. Transition Elements

The ground-state electronic configuration of the [Formula] ion ($Z = 26$) is:

CORE CONCEPT & DERIVATION

Transition metals lose electrons from their outermost 4s subshell before losing electrons from the inner 3d subshell during cation formation.

Formula / Rule / Reaction:**Solution:**

- Neutral iron has 26 electrons with ground-state configuration $[\text{Ar}]4s^23d^6$.
- Ionization to the ferric ion (Fe^{3+}) involves the loss of three electrons: both 4s electrons are removed first, followed by one 3d electron.
- This leaves a stable, half-filled d-subshell with configuration $[\text{Ar}]4s^03d^5$.
- Past paper board note: Some provincial paper keys errantly marked Option D through a setter typo that confused ferrous (Fe^{2+}) with ferric (Fe^{3+}). Chemical principles confirm that $[\text{Ar}]4s^03d^5$ is the correct configuration.

Why other options are incorrect:

- Option A:** Suggests that three 3d electrons are lost while 4s electrons are retained, which violates the Aufbau ionization rule.
- Option B:** Represents an excited or non-physical ionization state.
- Option D:** Represents the ferrous ion (Fe^{2+}), which has lost only two electrons.

Question #113 Key: (C)CHEMISTRY
08. Reaction Kinetics

On increasing the temperature, the rate of a reaction increases mainly because:

CORE CONCEPT & DERIVATION

According to collision theory and the Maxwell-Boltzmann distribution, reaction rate depends on the frequency of collisions between molecules that possess energy greater than or equal to the activation energy (E_a).

Formula / Rule / Reaction:

$$k = Ae^{-\frac{E_a}{RT}}$$

Solution:

- Raising the temperature increases the mean kinetic energy of the molecules, leading to more frequent molecular collisions.
- More importantly, it substantially increases the fraction of collisions with kinetic energy exceeding the activation energy threshold, increasing the effective collision frequency.

Why other options are incorrect:

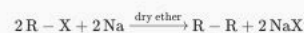
- Option A:** Activation energy is an intrinsic property of the reaction pathway and is not increased by raising temperature.
- Option B:** In a closed system, temperature change does not increase the molar quantity of reactant molecules.
- Option D:** Thermal heating increases the kinetic energy of reacting molecules; it does not decrease it.

Question #114 Key: (A)CHEMISTRY
15. Alkyl Halides

The conversion of an alkyl halide into an alkane by treatment with metallic sodium in dry ether...

CORE CONCEPT & DERIVATION

Alkyl halides undergo reductive carbon-carbon coupling when treated with electropositive alkali metals in anhydrous aprotic solvents.

Formula / Rule / Reaction:**Solution:**

- Charles Adolphe Wurtz discovered that two equivalents of an alkyl halide couple in the presence of sodium metal in dry diethyl ether to form a symmetrical higher alkane.
- Anhydrous ether is required because sodium metal reacts vigorously with moisture.

Why other options are incorrect:

- Option B:** The Frankland reaction couples alkyl halides using zinc metal (Zn) instead of sodium to yield dialkylzinc intermediates and alkanes.
- Option C:** The Grignard reaction involves treating alkyl halides with magnesium metal (Mg) to form organomagnesium halides (RMgX).
- Option D:** Kolbe's electrolytic synthesis produces symmetrical alkanes via the anodic decarboxylation of alkali metal carboxylate salts.

Question #115 Key: (A)CHEMISTRY
17. Aldehydes & Ketones

The organic compound that reacts with phenylhydrazine to form a crystalline phenylhydrazone der...

CORE CONCEPT & DERIVATION

Aldehydes and ketones contain a polar carbonyl group ($\text{C} = \text{O}$) that undergoes nucleophilic addition-elimination (condensation) with ammonia derivatives.

Formula / Rule / Reaction:**Solution:**

- Butanal is an aliphatic aldehyde possessing an electrophilic carbonyl carbon.
- The primary amino group of phenylhydrazine attacks the carbonyl carbon, followed by the elimination of a water molecule.
- This forms butanal phenylhydrazone, a stable crystalline solid used for characterizing aldehydes and ketones.

Why other options are incorrect:

- Option B:** 1,3-Butadiene is a conjugated diene and lacks a carbonyl group.
- Option C:** Ethyl acetate is an ester and forms hydroxamic acids or hydrazides under harsh conditions rather than standard crystalline hydrazones.
- Option D:** Ethanol is an alcohol and does not condense with hydrazine derivatives.

Question #116 Key: (C)

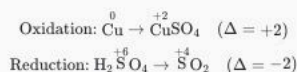
CHEMISTRY
10. Electrochemistry

Balance the redox equation using the oxidation number method: [Formula]

CORE CONCEPT & DERIVATION

In balancing redox equations by the oxidation number method, the total increase in oxidation number during oxidation must equal the total decrease in oxidation number during reduction.

Formula / Rule / Reaction:



Solution:

- The change in oxidation state of copper (+2) balances the change in sulfur (-2) in a 1:1 ratio.
- One additional molecule of sulfuric acid is required to act as an unreacted acid spectator to supply the sulfate anion for CuSO_4 .
- This requires 2 moles of H_2SO_4 on the reactant side.
- Balancing hydrogen and oxygen atoms requires 2 moles of H_2O on the product side: $\text{Cu} + 2\text{H}_2\text{SO}_4 \rightarrow \text{CuSO}_4 + \text{SO}_2 + 2\text{H}_2\text{O}$.

Why other options are incorrect:

- Option A:** Unbalanced; contains only 2 hydrogen and 4 oxygen atoms on the left, but 4 hydrogen and 7 oxygen atoms on the right.
- Option B:** Concentrated sulfuric acid is an oxidizing acid that is reduced to SO_2 and H_2O ; it does not produce H_2 gas with copper.
- Option D:** Fails mass conservation; 2 moles of copper on the left would require 4 moles of sulfuric acid.

Question #117 Key: (B)

CHEMISTRY
11. S & P Block Elements

Which of the following best explains the reaction between Beryllium (Be) and Oxygen ([Formula])...

CORE CONCEPT & DERIVATION

Beryllium exhibits anomalous chemical properties compared to other Group 2 alkaline earth metals due to its very small atomic size and high charge density.

Formula / Rule / Reaction:



Solution:

- When exposed to air or oxygen at normal temperatures, beryllium metal forms an adherent, insoluble, non-porous surface film of beryllium oxide (BeO).
- This compact oxide layer passivates the metal, preventing oxygen from reaching underlying atoms and halting further oxidation.

Why other options are incorrect:

- Option A:** Bulk beryllium does not burn vigorously at room temperature; its oxide layer inhibits, rather than accelerates, further reaction.
- Option C:** Beryllium oxide is a high-melting, refractory ionic-covalent solid (melting point 2507 degrees Celsius); it is not volatile.
- Option D:** Beryllium reacts with oxygen, especially when heated or powdered, so stating that it does not react at all is incorrect.

Question #118 Key: (C)

CHEMISTRY
02. Atomic Structure

The relative energy of an atomic orbital in a multi-electron atom is determined by:

CORE CONCEPT & DERIVATION

The Aufbau principle states that electrons fill atomic subshells in order of increasing orbital energy.

Formula / Rule / Reaction:

$$\text{Orbital Energy} \propto (n + l)$$

If $(n + l)$ values are identical, the orbital with the lower principal quantum number n is lower in energy.

Solution:

- The $(n + l)$ rule (Madelung rule) determines subshell energy by summing the principal quantum number (n) and the azimuthal quantum number (l).
- For example, the 4s orbital ($4 + 0 = 4$) fills before the 3d orbital ($3 + 2 = 5$) because its $(n + l)$ sum is smaller.

Why other options are incorrect:

- Option A:** Hund's rule of maximum multiplicity governs electron spin pairing in degenerate orbitals of equal energy.
- Option B:** The Pauli exclusion principle states that no two electrons in an atom can share the same four quantum numbers.
- Option D:** Boyle's law is a gas law relating pressure and volume at constant temperature.

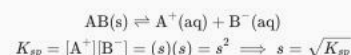
Question #119 Key: (C)

CHEMISTRY
07. EquilibriumThe solubility product (K_{sp}) of a binary salt [Formula] is [Formula]. Its molar solubility...

CORE CONCEPT & DERIVATION

The solubility product constant (K_{sp}) represents the equilibrium between an undissolved ionic solid and its dissolved ions in a saturated solution.

Formula / Rule / Reaction:



Solution:

- Let the molar solubility of salt AB be s mol/dm³.
- In a saturated solution, $[\text{A}^+] = s$ and $[\text{B}^-] = s$.

$$s^2 = 9 \times 10^{-6}$$

$$s = \sqrt{9 \times 10^{-6}} = 3 \times 10^{-3} \text{ mol/dm}^3$$

Why other options are incorrect:

- Option A:** Fails to take the square root of the exponent 10^{-6} .
- Option B:** Takes the square root of the exponent but fails to take the square root of the coefficient 9.
- Option D:** Equates molar solubility directly to K_{sp} without taking the square root.

Question #120 Key: (B)

CHEMISTRY
09. Thermochemistry

For an exothermic chemical reaction, the potential energy of the reactants is:

CORE CONCEPT & DERIVATION

The enthalpy change (ΔH) of a chemical reaction is the difference between the total enthalpy of products and reactants.

Formula / Rule / Reaction:

$$\Delta H = H_{\text{products}} - H_{\text{reactants}} < 0 \implies H_{\text{reactants}} > H_{\text{products}}$$

Solution:

- In an exothermic reaction, heat is released to the surroundings because the chemical bonds formed in the products are stronger and more stable than those broken in the reactants.
- Consequently, the products settle into a lower potential energy state, meaning the initial potential energy of the reactants is greater than that of the products.

Why other options are incorrect:

- Option A:** Reactants have less potential energy than products in endothermic reactions ($\Delta H > 0$), which absorb heat.
- Option C:** If reactant and product potential energies were equal, the enthalpy change would be zero ($\Delta H = 0$), producing no net thermal exchange.
- Option D:** Chemical substances contain chemical bond energy and electronic potential energy; their potential energy is not zero.

Question #121 Key: (A)

CHEMISTRY
05. Liquids

When pure water cools from a liquid at 4 °C to solid ice at 0 °C, what is the percentage change...

CORE CONCEPT & DERIVATION

Water exhibits anomalous thermal expansion between 4 °C and 0 °C due to open three-dimensional hydrogen bonding in its solid crystalline phase.

Formula / Rule / Reaction:

$$\rho_{\text{liquid}}(4^\circ\text{C}) \approx 1.000 \text{ g/cm}^3, \quad \rho_{\text{ice}}(0^\circ\text{C}) \approx 0.917 \text{ g/cm}^3$$

$$\Delta V(\%) = \left(\frac{V_{\text{ice}} - V_{\text{water}}}{V_{\text{water}}} \right) \times 100 \approx +9\%$$

Solution:

- At 4 °C, liquid water achieves its maximum density because molecular translational kinetic energy allows molecules to pack closely together.
- As water freezes at 0 °C, molecules arrange into a rigid, open hexagonal crystal lattice in which each water molecule forms four fixed tetrahedral hydrogen bonds.
- This open cage-like lattice creates empty internal cavities, lowering the density by approximately 9% and increasing the volume by approximately 9%.

Why other options are incorrect:

- Option B:** Most liquids contract upon freezing, but water expands; stating that volume decreases by 9% contradicts this anomalous expansion.
- Option C:** 19% overestimates the expansion of ice by more than double.
- Option D:** Contraction by 19% is physically incorrect.

Question #122 Key: (C)

CHEMISTRY
03. Chemical Bonding

In which of the following chemical species does the central atom utilize [Formula] hybridization...

CORE CONCEPT & DERIVATION

The hybridization state of a central atom is determined by its steric number, which sums its bonded atoms and non-bonding lone pairs.

Formula / Rule / Reaction:

$$\text{Steric Number} = 3 \implies \text{sp}^2 \text{ Hybridization (Trigonal Planar)}$$

Solution:

- The methyl free radical ($\cdot\text{CH}_3$) or methyl carbocation ($^+\text{CH}_3$) features a central carbon atom bonded to three hydrogen atoms with no paired lone pair.
- It adopts a planar geometry with 120-degree bond angles, using sp^2 hybrid orbitals.
- Past paper board note:* In the official KMU 2025 exam, Option C was designated as the intended board answer; the other three hydrides are Group 15 pyramidal species with steric number 4.

Why other options are incorrect:

- Option A:** PH_3 contains three bond pairs and one lone pair (Drago compound / predominantly unhybridized pure p-orbitals with sp^3 geometry characteristics), not sp^2 .
- Option B:** NH_3 has three bond pairs and one lone pair on nitrogen (steric number 4), utilizing sp^3 hybridization to form a trigonal pyramidal shape.
- Option D:** SbH_3 possesses three bond pairs and one lone pair with near 90-degree bond angles; it does not exhibit sp^2 planar hybridization.

Question #123 Key: (A)

CHEMISTRY
10. Electrochemistry

In an electrolytic cell when electrical current passes through an electrolyte solution, the ano...

CORE CONCEPT & DERIVATION

An electrolytic cell uses an external electrical power supply to drive a non-spontaneous redox reaction.

Formula / Rule / Reaction:

Anode: Oxidation (Loss of Electrons, Anode = Positive terminal)
Cathode: Reduction (Gain of Electrons, Cathode = Negative terminal)

Solution:

- In an electrolytic cell, the anode is wired to the positive terminal of the external direct-current power source, giving it a positive charge.
- Negatively charged anions migrate toward the anode and surrender electrons, meaning oxidation occurs at the anode.

Why other options are incorrect:

- Option B:** Reduction never takes place at the anode; reduction occurs exclusively at the cathode.
- Option C:** The anode is negative in galvanic (voltaic) cells, but it is positive in an electrolytic cell.
- Option D:** The negative electrode where reduction occurs is the cathode of an electrolytic cell.

Question #124 Key: (D)

CHEMISTRY
09. Thermochemistry

An increase in the internal energy of a chemical system can lead to all of the following EXCEPT...

CORE CONCEPT & DERIVATION

Internal energy (U) represents the sum of all microscopic kinetic and potential energies within a thermodynamic system.

Formula / Rule / Reaction:

$$T \propto \overline{E_k} \implies \text{Temperature rises only when particle translational kinetic energy increases}$$

Solution:

- Temperature is a direct measure of the average translational kinetic energy of constituent particles.
- An increase in temperature can occur only when average kinetic energy rises.
- A rise in temperature accompanying a drop in kinetic energy is physically impossible and contradicts thermodynamics, making Option D the exception.

Why other options are incorrect:

- **Option A:** Absorbing internal energy as kinetic energy directly elevates system temperature.
- **Option B:** Absorbing internal energy as potential energy overcomes intermolecular attractions, driving phase transitions at constant temperature.
- **Option C:** Absorbed thermal energy can supply the activation energy needed to break chemical bonds and initiate reactions.

Question #125 Key: (A)

CHEMISTRY
03. Chemical Bonding

In an ethene molecule ([Formula]), each carbon atom has three hybridized [Formula] orbitals w...

CORE CONCEPT & DERIVATION

Mixing one 2s orbital and two 2p orbitals generates three equivalent sp² hybrid orbitals oriented to minimize electron repulsion.

Formula / Rule / Reaction:

$$sp^2 \text{ Hybridization} \implies \text{Trigonal Planar Geometry, } 120^\circ \text{ Bond Angles}$$

Solution:

- In ethene, the three sp² hybrid orbitals on each carbon atom lie within the same geometric plane, directed toward the corners of an equilateral triangle at 120-degree angles.
- This arrangement ensures all sigma bonds in ethene are coplanar.

Why other options are incorrect:

- **Option B:** Tetrahedral geometry arises from sp³ hybridization with 109.5-degree angles, as in ethane or methane.
- **Option C:** Linear geometry arises from sp hybridization with 180-degree bond angles, as in ethyne.
- **Option D:** Pyramidal geometry occurs when sp³ orbitals contain one non-bonding lone pair, as in ammonia.

Question #126 Key: (C)

CHEMISTRY
12. Transition Elements

Identify the CORRECT ground-state electronic configuration for the chromium atom (Z = 24):

CORE CONCEPT & DERIVATION

Anomalous electron configurations occur when subshell promotion yields half-filled or fully filled d-orbitals that confer enhanced quantum-mechanical stability.

Formula / Rule / Reaction:

$$\text{Cr (Z = 24)} : [\text{Ar}] 4s^1 3d^5 \quad (\text{Half-filled } 4s^1 \text{ and } 3d^5 \text{ subshells})$$

Solution:

- The standard Aufbau principle would predict [Ar]4s²3d⁴.
- However, promoting one 4s electron to the 3d subshell produces half-filled 4s and 3d subshells (4s¹3d⁵).
- This configuration provides extra stability due to symmetrical spatial charge distribution and maximized electron exchange energy among the five parallel-spin 3d electrons.

Why other options are incorrect:

- **Option A:** Accounts for only 22 electrons and omits the 4s subshell entirely.
- **Option B:** The unpromoted Aufbau configuration, which is less stable than the actual half-filled configuration.
- **Option D:** Accounts for 26 electrons, which is the configuration for iron (Fe).

Question #127 Key: (A)

PHYSICS
11. Electromagnetic Induction

According to Lenz's Law, the direction of an induced current in a conductor is such that it:

CORE CONCEPT & DERIVATION

Lenz's law provides the physical basis for the negative sign in Faraday's law of electromagnetic induction and represents an expression of the law of conservation of energy.

Formula / Rule / Reaction:

$$\mathcal{E} = -N \frac{\Delta \Phi_B}{\Delta t}$$

Solution:

- When the magnetic flux linked with a closed conducting loop changes, an electromotive force (EMF) and current are induced.
- The induced current generates its own magnetic field oriented to oppose the change in external magnetic flux that created it.
- If external flux increases, the induced field points in the opposite direction; if external flux decreases, the induced field points in the same direction to oppose the decrease.

Why other options are incorrect:

- **Option B:** If the induced current enhanced the flux change, it would create an unstable runaway magnetic field and generate energy from nothing, violating conservation of energy.
- **Option C:** The induced current circulates around the area bounding the changing flux and is not universally perpendicular to the field.
- **Option D:** The induced current is not constrained to be parallel to the magnetic field lines.

Question #128 Key: (B)PHYSICS
12. Alternating Current

In a pure capacitive AC circuit, the alternating current:

CORE CONCEPT & DERIVATION

In an alternating current circuit containing pure capacitance, the continuous charging and discharging cycles establish a quarter-cycle phase displacement between current and voltage.

Formula / Rule / Reaction:

$$i(t) = C \frac{dv(t)}{dt} \Rightarrow \text{If } v(t) = V_0 \sin(\omega t), \text{ then } i(t) = I_0 \sin\left(\omega t + \frac{\pi}{2}\right)$$

Solution:

- Current flows at its maximum rate when the capacitor is completely uncharged and voltage across it is zero.
- As charge accumulates, the opposing voltage rises, reducing current to zero once the voltage reaches its peak.
- Therefore, the current reaches its peaks and zero-crossings 90 degrees ($\frac{\pi}{2}$ radians) ahead of the voltage.

Why other options are incorrect:

- **Option A:** Current lags voltage by 90 degrees in a purely inductive AC circuit.
- **Option C:** Current and voltage are in phase only in a purely resistive AC circuit ($\phi = 0^\circ$).
- **Option D:** A 45-degree phase lead occurs in a series RC circuit where capacitive reactance equals resistance ($X_C = R$).

Question #129 Key: (B)PHYSICS
13. Electronics

In a center-tapped full-wave rectifier using two diodes, the diodes D1 and D2 operate:

CORE CONCEPT & DERIVATION

Full-wave rectification converts both positive and negative half-cycles of an alternating input voltage into unidirectional direct current.

Formula / Rule / Reaction:

Positive half-cycle: D1 forward-biased (ON), D2 reverse-biased (OFF)

Negative half-cycle: D1 reverse-biased (OFF), D2 forward-biased (ON)

Solution:

- A center-tapped secondary winding produces two anti-phase voltages relative to the center tap.
- During the positive half-cycle, the anode of diode D1 is positive, placing it in forward bias (conducting), while diode D2 is reverse-biased (non-conducting).
- During the negative half-cycle, the polarities invert, placing D2 in forward bias and D1 in reverse bias.
- Thus, the two diodes conduct alternately during successive half-cycles.

Why other options are incorrect:

- **Option A:** The two diodes cannot conduct simultaneously because the center tap forces opposite ends of the secondary winding to have opposite polarities.
- **Option C:** Opposite terminals of a transformer winding cannot be positive at the same time.
- **Option D:** Diodes conduct significant current only when forward-biased, not in reverse bias.

Question #130 Key: (B)PHYSICS
14. Dawn of Modern Physics

The energy (E) of a quantum of electromagnetic radiation is given by:

CORE CONCEPT & DERIVATION

Max Planck proposed that electromagnetic radiation is emitted and absorbed in discrete packets called quanta (photons).

Formula / Rule / Reaction:

$$E = hf = \frac{hc}{\lambda}$$

Solution:

- Planck's equation states that the energy (E) of a single quantum is directly proportional to its radiation frequency (f).
- The proportionality constant is Planck's constant (h), equal to $6.626 \times 10^{-34} \text{ J} \cdot \text{s}$.

Why other options are incorrect:

- **Option A:** $E = mc^2$ is Einstein's mass-energy equivalence equation relating resting mass to equivalent rest energy.
- **Option C:** $E_k = \frac{1}{2}mv^2$ is the classical equation for the translational kinetic energy of a non-relativistic body with mass.
- **Option D:** $W = qV$ gives the work done or electrostatic potential energy gained when a charge q moves through potential difference V.

Question #131 Key: (A)PHYSICS
02. Force & Motion

The area under the horizontal line on a velocity-time graph for an object moving with uniform v...

CORE CONCEPT & DERIVATION

On a velocity-time (v-t) graph, the definite integral (area under the curve) between two time points equals the total linear displacement.

Formula / Rule / Reaction:

$$\text{Displacement } (s) = \int_{t_1}^{t_2} v(t) dt = v \times \Delta t = \text{Height} \times \text{Base} = \text{Area of Rectangle}$$

Solution:

- When an object moves with uniform (constant) velocity, its velocity does not change over time, producing a horizontal line parallel to the time axis.
- The geometric area bounded by this line, the time axis, and the vertical time limits forms a rectangle.
- *Past paper board note:* The original paper text referenced a 'displacement-time graph', but paper-setters evaluated the standard kinematics concept of uniform velocity producing a rectangular area under a velocity-time graph.

Why other options are incorrect:

- **Option B:** A triangular area occurs on a v-t graph for uniformly accelerated motion starting from rest ($\text{Area} = \frac{1}{2}vt$).
- **Option C:** A trapezoidal area occurs on a v-t graph when an object undergoes uniform acceleration starting with a non-zero initial velocity.
- **Option D:** The orthogonal time boundaries form right angles with the time axis, producing a rectangle rather than a slanted parallelogram.

Question #132 Key: (C)

PHYSICS
02. Force & Motion

A car starts from rest and moves with a uniform acceleration of [Formula]. What will be its velocity...

CORE CONCEPT & DERIVATION

For rectilinear motion with uniform acceleration, velocity varies linearly with elapsed time according to the first equation of motion.

Formula / Rule / Reaction:

$$v_f = v_i + at$$

Solution:

- Initial velocity: $v_i = 0 \text{ m/s}$ (starts from rest).
- Uniform acceleration: $a = 3 \text{ m/s}^2$.
- Time: $t = 5 \text{ s}$.
- $v_f = 0 + (3 \text{ m/s}^2)(5 \text{ s}) = 15 \text{ m/s}$

Why other options are incorrect:

- Option A:** 8 m/s results from adding acceleration to time (3 + 5) instead of multiplying them.
- Option B:** 12 m/s corresponds to motion after only 4 seconds of acceleration.
- Option D:** 18 m/s corresponds to motion after 6 seconds of acceleration.

Question #133 Key: (C)

PHYSICS
02. Force & Motion

A passenger is standing in a stationary bus. When the bus suddenly accelerates forward, the passenger...

CORE CONCEPT & DERIVATION

Newton's First Law of Motion states that an object remains at rest or in uniform motion unless acted upon by a net external force. Inertia is an object's resistance to changes in its state of motion.

Formula / Rule / Reaction:

$$F_{\text{net}} = 0 \implies \Delta v = 0 \quad (\text{Principle of Inertia})$$

Solution:

- Initially, both the bus and the passenger are at rest.
- When the bus accelerates forward, friction accelerates the passenger's feet forward with the bus floor.
- However, due to inertia, the passenger's upper body tends to maintain its original stationary state.
- As the lower body moves forward beneath the stationary torso, the passenger falls backward relative to the bus.

Why other options are incorrect:

- Option A:** Friction between feet and floor acts forward to move the lower body; it is not what causes the upper body to fall backward.
- Option B:** Gravity acts vertically downward toward the Earth's center and does not create the horizontal backward motion.
- Option D:** Deceleration occurs when a vehicle slows down, which would cause passengers to lurch forward, not backward.

Question #134 Key: (B)

PHYSICS
02. Force & Motion

A ball is projected at an angle of 45° with an initial speed of 20 m/s. How does [Formula] (range)...

CORE CONCEPT & DERIVATION

In ideal projectile motion, horizontal velocity remains constant because gravity acts only vertically. In real fluids, aerodynamic drag provides a continuous retarding force opposing motion.

Formula / Rule / Reaction:

$$R_W = \frac{v_0^2 \sin(2\theta)}{g}, \quad \vec{F}_{\text{drag}} = -\frac{1}{2} C_d \rho A v \vec{v}$$

Solution:

- Without air resistance, horizontal acceleration is zero ($a_x = 0$), allowing the projectile to cover maximum theoretical range R_W .
- With air resistance, the drag force opposes motion, introducing negative horizontal acceleration ($a_x < 0$) that continuously reduces horizontal velocity.
- Air resistance also reduces the maximum vertical height and total time of flight, ensuring the actual range R_A is always smaller than the ideal range R_W .

Why other options are incorrect:

- Option A:** R_A cannot exceed R_W because retarding drag forces always reduce the projectile's forward velocity and range.
- Option C:** Although gravity remains unchanged, aerodynamic drag dissipates kinetic energy, preventing the two ranges from being equal.
- Option D:** Claiming ideal vacuum range R_W is less than actual range R_A contradicts energy conservation.

Question #135 Key: (B)

PHYSICS
02. Force & Motion

A 0.02 kg bullet moving at 300 m/s embeds itself in a 2 kg wooden block initially at rest on a...

CORE CONCEPT & DERIVATION

In a completely inelastic collision where two bodies stick together after impact, total linear momentum is conserved in the absence of net external forces.

Formula / Rule / Reaction:

$$m_1 v_1 + m_2 v_2 = (m_1 + m_2) v_f$$

Solution:

- Mass of bullet: $m_1 = 0.02 \text{ kg}$; initial velocity: $v_1 = 300 \text{ m/s}$.
- Mass of block: $m_2 = 2.0 \text{ kg}$; initial velocity: $v_2 = 0 \text{ m/s}$.
- Total initial momentum: $p_i = (0.02)(300) + (2.0)(0) = 6.0 \text{ kg} \cdot \text{m/s}$.
- Combined mass after impact: $M = 0.02 + 2.0 = 2.02 \text{ kg}$.
- $v_f = \frac{p_i}{M} = \frac{6.0 \text{ kg} \cdot \text{m/s}}{2.02 \text{ kg}} \approx 2.97 \text{ m/s} \approx 3 \text{ m/s}$

Why other options are incorrect:

- Option A:** 2 m/s would require a combined mass of 3.0 kg.
- Option C:** 4 m/s violates conservation of linear momentum.
- Option D:** 5 m/s corresponds to an initial momentum of 10.1 kg·m/s, which exceeds the bullet's momentum.

Question #136 Key: (C)PHYSICS
02. Force & Motion

Which of the following statements about ideal projectile motion is CORRECT?

CORE CONCEPT & DERIVATION

Projectile motion represents two-dimensional motion under constant gravitational acceleration. In the absence of aerodynamic drag, horizontal and vertical components of motion are entirely independent.

Formula / Rule / Reaction:

$$v_x(t) = v_0 \cos \theta = \text{constant}, \quad v_y(t) = v_0 \sin \theta - gt$$

Solution:

- Because gravity acts exclusively in the downward vertical direction, horizontal acceleration is zero ($a_x = 0$), keeping horizontal velocity (v_x) constant throughout the entire trajectory.
- In the vertical direction, gravity decelerates the projectile until its vertical velocity momentarily becomes zero ($v_y = 0$) at the apex (maximum height).
- At this highest point, the projectile continues moving forward with its full horizontal velocity ($v_x = v_0 \cos \theta$).

Why other options are incorrect:

- **Option A:** Gravity acts strictly vertically downward and exerts zero component along the horizontal axis in ideal projectile motion.
- **Option B:** Vertical velocity changes continuously at a constant rate of -9.8 m/s^2 under gravitational acceleration.
- **Option D:** Gravitational acceleration remains constant at $g = 9.8 \text{ m/s}^2$ downward at all points along the path, including the trajectory peak.

Question #137 Key: (B)PHYSICS
03. Work & Energy

The rate of doing work at any instant of time is called:

CORE CONCEPT & DERIVATION

Power measures the time rate at which energy is transferred or mechanical work is performed.

Formula / Rule / Reaction:

$$P_{\text{inst}} = \lim_{\Delta t \rightarrow 0} \frac{\Delta W}{\Delta t} = \frac{dW}{dt} = \vec{F} \cdot \vec{v}$$

Solution:

- Instantaneous power is defined as the limiting value of average power as the time interval approaches zero.
- It evaluates the precise rate of doing work at a single, specific instant in time.

Why other options are incorrect:

- **Option A:** Work done is the total scalar product of force and displacement over a given distance, measured in joules.
- **Option C:** Average power is the ratio of total work done to the total elapsed time interval ($P_{\text{avg}} = \frac{\Delta W}{\Delta t}$).
- **Option D:** Mechanical energy is the sum of kinetic and potential energies possessed by a physical body.

Question #138 Key: (C)PHYSICS
03. Work & Energy

A 5 kg body falls from a height of 30 m toward the ground. If all its potential energy converts...

CORE CONCEPT & DERIVATION

The law of conservation of mechanical energy dictates that gravitational potential energy lost during free fall equals kinetic energy gained, which dissipates into thermal energy upon an inelastic impact.

Formula / Rule / Reaction:

$$\Delta Q = E_p = mgh$$

Solution:

- Mass: $m = 5 \text{ kg}$.
- Acceleration due to gravity: $g = 9.8 \text{ m/s}^2$.
- Vertical height: $h = 30 \text{ m}$.
- $E_p = (5 \text{ kg})(9.8 \text{ m/s}^2)(30 \text{ m}) = 1470 \text{ J}$
- Because all mechanical potential energy converts completely into thermal energy on collision, the heat produced is exactly 1470 J.

Why other options are incorrect:

- **Option A:** 1270 J results from an arithmetic error.
- **Option B:** 1370 J underestimates the potential energy calculation.
- **Option D:** 1570 J overestimates the gravitational energy.

Question #139 Key: (C)

PHYSICS
03. Work & Energy

Two students, A and B, each carry a 20 kg load to the top of a 10 m high staircase. Student A t...

CORE CONCEPT & DERIVATION

Work done against gravity depends entirely on mass, gravitational acceleration, and vertical height, independent of the time taken. Power measures the time rate of performing work.

Formula / Rule / Reaction:

$$W = mgh, \quad P = \frac{W}{t}$$

Solution:

- Both students lift identical masses ($m = 20 \text{ kg}$) through the same vertical displacement ($h = 10 \text{ m}$).
- $W_A = W_B = (20 \text{ kg})(9.8 \text{ m/s}^2)(10 \text{ m}) = 1960 \text{ J}$
- Power expended by Student A: $P_A = \frac{1960 \text{ J}}{10 \text{ s}} = 196 \text{ W}$.
- Power expended by Student B: $P_B = \frac{1960 \text{ J}}{20 \text{ s}} = 98 \text{ W}$.
- Both perform identical work, but Student A develops twice as much power because Student A completes the task in half the time.

Why other options are incorrect:

- Option A:** Work done is path- and time-independent in a conservative gravitational field; both students perform identical work.
- Option B:** Student B takes longer time, producing lower power output (98 W vs 196 W).
- Option D:** Identical load does not imply identical power when the elapsed time differs.

Question #140 Key: (D)

PHYSICS
04. Rotational & Circular Motion

A wheel of radius 0.4 m has an angular acceleration of [Formula]. Its tangential linear accele...

CORE CONCEPT & DERIVATION

Tangential linear acceleration relates directly to rotational angular acceleration through the radius of rotation.

Formula / Rule / Reaction:

$$a_t = r\alpha$$

Solution:

- Radius: $r = 0.4 \text{ m}$.
- Angular acceleration: $\alpha = 6 \text{ rad/s}^2$.
- $a_t = (0.4 \text{ m})(6 \text{ rad/s}^2) = 2.4 \text{ m/s}^2$

Why other options are incorrect:

- Option A:** 1.2 m/s^2 corresponds to a radius of 0.2 m.
- Option B:** m/s is a unit of velocity, not acceleration.
- Option C:** 2.4 m/s carries incorrect velocity dimensions instead of acceleration (m/s^2).

Question #141 Key: (C)

PHYSICS
04. Rotational & Circular Motion

If an object is moving counterclockwise along a circular path in a horizontal plane on a page, ...

CORE CONCEPT & DERIVATION

Angular velocity ($\vec{\omega}$) is an axial vector whose spatial orientation is defined by the right-hand grip rule.

Formula / Rule / Reaction:

$$\vec{v} = \vec{\omega} \times \vec{r}$$

Solution:

- Curl the fingers of the right hand in the direction of circular rotation (counterclockwise along the page).
- The extended right thumb points perpendicularly outward, normal to the plane of the page.
- Therefore, the angular velocity vector points perpendicularly out of the page.

Why other options are incorrect:

- Option A:** Tangential vectors describe instantaneous linear velocity ($\vec{v}$), not angular velocity.
- Option B:** Centripetal acceleration and net centripetal force point radially inward toward the center.
- Option D:** Pointing perpendicularly into the page corresponds to clockwise rotation by the right-hand rule.

Question #142 Key: (B)

PHYSICS
04. Rotational & Circular Motion

If a particle moves along a circular path of radius [Formula] through an angular displacement [...]

CORE CONCEPT & DERIVATION

The radian measure of an angle is defined geometrically as the ratio of subtended circular arc length to the radius of the circle.

Formula / Rule / Reaction:

$$\theta = \frac{s}{r} \implies s = r\theta$$

Solution:

- By fundamental definition of circular radian measure, angular displacement in radians equals arc length divided by radius.
- Rearranging for arc length gives $s = r\theta$.

Why other options are incorrect:

- Option A:** $s = r/\theta$ yields dimensions of length per radian squared, which is dimensionally invalid.
- Option C:** $s = r^2\theta$ carries dimensions of area rather than linear length.
- Option D:** $s = \theta/r^2$ carries inverse area units, which is dimensionally incorrect.

Question #143 Key: (B)PHYSICS
02. Force & Motion

A ball of weight [Formula] is falling vertically downward through air. If the upward drag force...

CORE CONCEPT & DERIVATION

Newton's Second Law requires summing collinear forces vectorially taking coordinate direction into account.

Formula / Rule / Reaction:

$$F_{\text{net}} = \sum F_y = F_G - F_D = ma$$

Solution:

- The gravitational force (weight F_G) acts vertically downward.
- Aerodynamic fluid resistance (drag F_D) opposes motion, acting vertically upward.
- Taking the downward direction of motion as positive, the resultant net downward force is $F_G - F_D$.

Why other options are incorrect:

- Option A:** Adding drag to weight assumes drag acts downward in the same direction as gravity, which violates fluid resistance principles.
- Option C:** $F_D - F_G$ evaluates net upward force, which applies only if upward drag exceeds weight (deceleration during parachute deployment).
- Option D:** Dividing the forces yields a dimensionless ratio rather than a resultant force in newtons.

Question #144 Key: (C)PHYSICS
06. Fluid Dynamics

Most natural fluid flows are turbulent rather than laminar primarily because of:

CORE CONCEPT & DERIVATION

Fluid flow regime (laminar versus turbulent) is governed by the dimensionless Reynolds number (Re), which quantifies the ratio of inertial forces to viscous forces.

Formula / Rule / Reaction:

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

When $Re > 4000$, flow transitions into turbulence.

Solution:

- At elevated flow velocities (v), inertial forces completely overwhelm stabilizing internal viscous shear stresses.
- This produces chaotic streamlines, eddies, and internal fluid vortices, driving the transition from smooth laminar flow to turbulent flow.

Why other options are incorrect:

- Option A:** Real fluids always possess non-zero viscosity; an ideal fluid with zero viscosity is an inviscid theoretical abstraction.
- Option B:** Very low velocities produce low Reynolds numbers ($Re < 2000$), ensuring smooth, predictable laminar streamline flow.
- Option D:** Fluids always experience shear resistance during flow.

Question #145 Key: (A)PHYSICS
06. Fluid Dynamics

According to the equation of continuity, when the cross-sectional area of a pipe decreases, the...

CORE CONCEPT & DERIVATION

The equation of continuity expresses the principle of conservation of mass for steady, incompressible fluid flow.

Formula / Rule / Reaction:

$$A_1 v_1 = A_2 v_2 = \text{Constant (Volume Flow Rate } Q)$$

Solution:

- For an incompressible fluid of constant density, the mass entering a pipe segment must equal the mass exiting in the same time interval.
- Because cross-sectional area and fluid velocity are inversely related ($v \propto \frac{1}{A}$), reducing the pipe area forces the fluid to accelerate, increasing its flow velocity.

Why other options are incorrect:

- Option B:** Velocity decreases when pipe cross-sectional area increases (widens).
- Option C:** Velocity remains constant only if cross-sectional area does not vary.
- Option D:** Velocity would become zero only if the conduit were completely blocked.

Question #146 Key: (A)PHYSICS
06. Fluid Dynamics

Water flows steadily through a horizontal pipe that gradually narrows. At the wider end, the ve...

CORE CONCEPT & DERIVATION

Bernoulli's principle states that for steady, incompressible, non-viscous streamline flow along a horizontal streamline, total mechanical energy remains constant.

Formula / Rule / Reaction:

$$P + \frac{1}{2}\rho v^2 = \text{Constant} \implies P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$$

Solution:

- As the pipe constricts, fluid velocity increases from 1 m/s to 3 m/s, increasing kinetic energy density ($\frac{1}{2}\rho v^2$).
- To maintain conservation of mechanical energy along a horizontal plane, static fluid pressure must drop in the high-velocity region.
- Therefore, static pressure is lower at the narrower end.

Why other options are incorrect:

- Option B:** Higher velocity corresponds to reduced static pressure; claiming pressure increases violates Bernoulli's conservation principle.
- Option C:** Continuity of flow requires constant mass transport, but pressure varies with changing kinetic energy density.
- Option D:** Pressure and velocity are interdependent through Bernoulli's equation.

Question #147 Key: (A)

PHYSICS
05. Waves

What is the necessary mechanical condition for wave propagation through a material medium?

CORE CONCEPT & DERIVATION

Mechanical waves require a physical material medium that possesses both inertia (mass) and elasticity to transmit vibrational energy.

Formula / Rule / Reaction:

$$v = \sqrt{\frac{E}{\rho}} \quad (E = \text{Elastic Modulus}, \rho = \text{Inertial Density})$$

Solution:

- When a particle in a medium is displaced from equilibrium, elasticity provides a restoring force that pulls it back toward its resting position.
- Intermolecular elastic forces couple neighboring particles, allowing the disturbance to propagate sequentially through the material.

Why other options are incorrect:

- Option B:** In an inelastic medium, displaced particles deform permanently without generating restoring forces, preventing wave transmission.
- Option C:** If particles were independent, no coupling forces would exist to transmit disturbances to neighboring particles.
- Option D:** Particle independence prevents cohesive mechanical wave propagation.

Question #148 Key: (B)

PHYSICS
05. Waves

A progressive wave is one which:

CORE CONCEPT & DERIVATION

Progressive (traveling) waves are disturbances that move continuously through a medium, transporting energy and momentum away from the source without net bulk transport of matter.

Formula / Rule / Reaction:

$$y(x, t) = A \sin(kx - \omega t)$$

Solution:

- In a progressive wave, particles of the medium oscillate periodically about their mean equilibrium positions.
- The wave profile advances continuously through space, transferring energy from one region of the medium to another.

Why other options are incorrect:

- Option A:** Mechanical progressive waves require localized particle oscillations in the medium.
- Option C:** Progressive waves travel through solids, liquids, and gases, as well as vacuum in the case of electromagnetic waves.
- Option D:** Waves propagate through low-density media (e.g., sound in air) and do not strictly require high density.

Question #149 Key: (A)

PHYSICS
05. Waves

The speed of sound in air increases with:

CORE CONCEPT & DERIVATION

The speed of sound in a gaseous medium depends on absolute temperature and molecular mass as described by the Laplace-Newton equation.

Formula / Rule / Reaction:

$$v = \sqrt{\frac{\gamma RT}{M}}$$

Speed increases by 0.61 m/s per °C rise in air temperature

Solution:

- Higher temperature increases the thermal velocity of gas molecules, accelerating acoustic energy transmission.
- Humid air contains water vapor ($M = 18 \text{ g/mol}$), which is lighter than dry air (mean $M \approx 29 \text{ g/mol}$), reducing overall air density and increasing sound speed.
- Thus, higher temperature and higher humidity both increase the speed of sound.

Why other options are incorrect:

- Option B:** Lower temperature and lower humidity decrease acoustic propagation speed.
- Option C:** At constant temperature, pressure changes cause proportional density changes ($P/\rho = \text{constant}$), leaving sound speed unaffected.
- Option D:** Sound speed is inversely proportional to the square root of density ($v \propto 1/\sqrt{\rho}$); higher density at constant elasticity reduces speed.

Question #150 Key: (B)

PHYSICS
05. Waves

A wave has a velocity of 300 m/s and a frequency of 100 Hz. If the medium changes such that vel...

CORE CONCEPT & DERIVATION

The fundamental wave equation relates wave speed (v), frequency (f), and wavelength (λ). Frequency is determined by the wave source and remains invariant across media boundaries.

Formula / Rule / Reaction:

$$v = f\lambda \implies \lambda = \frac{v}{f}$$

Solution:

- Initial wavelength: $\lambda_1 = \frac{v_1}{f} = \frac{300 \text{ m/s}}{100 \text{ Hz}} = 3 \text{ m}$.
- When the wave enters a new medium, its speed doubles to $v_2 = 2v_1 = 600 \text{ m/s}$, while frequency remains constant at 100 Hz.
- New wavelength: $\lambda_2 = \frac{v_2}{f} = \frac{600 \text{ m/s}}{100 \text{ Hz}} = 6 \text{ m}$.
- Because $\lambda_2 = 2\lambda_1$, the wavelength doubles.

Why other options are incorrect:

- Option A:** Wavelength would halve only if wave speed were halved at constant frequency.
- Option C:** Wavelength cannot remain unchanged when wave velocity changes at fixed frequency.
- Option D:** A nonzero traveling wave cannot have zero wavelength.

Question #151 Key: (B)PHYSICS
05. Waves

When a particle executing simple harmonic motion moves from its mean position to an extreme pos...

CORE CONCEPT & DERIVATION

In simple harmonic motion (SHM), mechanical energy continuously alternates between kinetic energy and elastic potential energy.

Formula / Rule / Reaction:

$$E_k = \frac{1}{2} m \omega^2 (x_0^2 - x^2)$$

Solution:

- At the mean position ($x = 0$), particle velocity and kinetic energy reach their maximum values: $E_k = \frac{1}{2} m \omega^2 x_0^2$.
- As the particle moves toward an extreme position ($x \rightarrow x_0$), restoring forces decelerate the particle, continuously converting kinetic energy into potential energy.
- At the extreme position ($x = x_0$), velocity drops to zero, and kinetic energy becomes zero.

Why other options are incorrect:

- Option A:** Kinetic energy decreases, rather than increases, as displacement increases away from the mean position.
- Option C:** Total mechanical energy remains constant, but kinetic energy varies with position.
- Option D:** Potential energy, not kinetic energy, reaches its maximum at the extreme position.

Question #152 Key: (D)PHYSICS
07. Thermodynamics

By the Second Law of Thermodynamics, heat will spontaneously flow from a system of:

CORE CONCEPT & DERIVATION

The Clausius statement of the Second Law of Thermodynamics establishes that thermal energy transfers spontaneously only in the direction of decreasing temperature.

Formula / Rule / Reaction:

$$\Delta S = \int \frac{dQ}{T} > 0 \implies Q \text{ flows spontaneously from } T_{\text{hot}} \rightarrow T_{\text{cold}}$$

Solution:

- Temperature reflects the average translational kinetic energy per molecule and determines thermal potential.
- Thermal contact between two bodies causes random molecular collisions to transfer net heat energy spontaneously from the higher-temperature body to the lower-temperature body until thermal equilibrium is established.

Why other options are incorrect:

- Option A:** Total internal energy is an extensive property dependent on mass; heat can flow spontaneously from a low-internal-energy hot object to a high-internal-energy cold reservoir.
- Option B:** Pressure gradients govern bulk fluid mechanical displacement, not spontaneous microscopic heat transfer.
- Option C:** Heat transfer from cold to hot requires an input of external mechanical work, as in a refrigeration cycle.

Question #153 Key: (A)PHYSICS
07. Thermodynamics

The SI unit of molar specific heat capacity is:

CORE CONCEPT & DERIVATION

Molar specific heat capacity is the quantity of heat energy required to raise the temperature of 1 mole of a substance by 1 Kelvin.

Formula / Rule / Reaction:

$$C_m = \frac{\Delta Q}{n \Delta T} \implies \text{Units} = \frac{\text{J}}{\text{mol} \cdot \text{K}} = \text{J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$$

Solution:

- Heat energy (ΔQ) is measured in joules (J).
- Amount of substance (n) is measured in moles (mol).
- Temperature change (ΔT) is measured in kelvins (K).
- Combining these dimensions yields $\text{J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$.

Why other options are incorrect:

- Option B:** Omits negative exponents for both mole and kelvin in the denominator.
- Option C:** Omits the negative exponent for the mole dimension.
- Option D:** Fails to place the kelvin unit in the denominator.

Question #154 Key: (C)PHYSICS
07. Thermodynamics

For an ideal gas with molar heat capacity at constant volume [Formula], the molar heat capacit...

CORE CONCEPT & DERIVATION

Mayer's thermodynamic relation relates the molar heat capacity at constant pressure to that at constant volume for an ideal gas.

Formula / Rule / Reaction:

$$C_p - C_v = R \implies C_p = C_v + R$$

Solution:

- Given: $C_v = \frac{3}{2} R$ (characteristic of a monoatomic ideal gas).

$$C_p = \frac{3}{2} R + R = \frac{3}{2} R + \frac{2}{2} R = \frac{5}{2} R$$

Why other options are incorrect:

- Option A:** R is the universal gas constant, representing the difference $C_p - C_v$.
- Option B:** $3/2 R$ is the value of C_v , which accounts only for internal kinetic energy change without isobaric expansion work.
- Option D:** $7/2 R$ corresponds to C_p for a rigid diatomic ideal gas where $C_v = \frac{5}{2} R$.

Question #155 Key: (D)PHYSICS
08. Electrostatics

The electric field intensity at a point in space is defined as the:

CORE CONCEPT & DERIVATION

Electric field intensity ($\vec{E}$) is a vector field describing electrostatic force experienced by charged particles in space.

Formula / Rule / Reaction:

$$\vec{E} = \lim_{q_0 \rightarrow 0} \frac{\vec{F}}{q_0}$$

Solution:

- The electric field intensity at a point equals the electrostatic force exerted on an infinitesimal positive test charge placed at that location, divided by the magnitude of the test charge.
- Its SI unit is newtons per coulomb (N/C) or volts per meter (V/m).

Why other options are incorrect:

- Option A:** Potential energy per unit charge defines electric potential ($V = W/q$), measured in volts.
- Option B:** Work done per unit time defines power, measured in watts.
- Option C:** Charge per unit area defines surface charge density ($\sigma = Q/A$), measured in coulombs per square meter.

Question #156 Key: (C)PHYSICS
08. Electrostatics

Coulomb's Law for electrostatic forces directly agrees with which of Newton's laws of motion?

CORE CONCEPT & DERIVATION

Coulomb's law describes the mutual electrostatic force between two stationary point charges.

Formula / Rule / Reaction:

$$\vec{F}_{12} = -\vec{F}_{21} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} \hat{r}$$

Solution:

- The electrostatic force exerted by charge q_1 on charge q_2 is equal in magnitude and opposite in direction to the force exerted by q_2 on q_1 .
- Because these interaction forces act along the line joining the charge centers and form an action-reaction pair, Coulomb's law agrees with Newton's Third Law of Motion.

Why other options are incorrect:

- Option A:** Newton's First Law describes the law of inertia in the absence of net external force.
- Option B:** Newton's Second Law relates net external force to rate of change of momentum ($\vec{F} = m\vec{a}$).
- Option D:** Gauss's Law is an equivalent formulation of electrostatics relating electric flux to enclosed charge, not one of Newton's laws of motion.

Question #157 Key: (D)PHYSICS
08. Electrostatics

The work done in moving a unit positive charge from one point to another while keeping the char...

CORE CONCEPT & DERIVATION

Electrostatic potential difference between two points is defined through the work required to move a unit charge through a conservative electric field.

Formula / Rule / Reaction:

$$\Delta V = V_B - V_A = \frac{W_{A \rightarrow B}}{q_0}$$

Solution:

- When an external agent moves a test charge without acceleration (in electrostatic equilibrium), the work done per unit positive charge against the electric field equals the electric potential difference between those two points.
- It is measured in volts ($1 \text{ V} = 1 \text{ J/C}$).

Why other options are incorrect:

- Option A:** Kinetic energy is the energy of motion; keeping the charge in equilibrium ensures its kinetic energy does not change ($\Delta E_k = 0$).
- Option B:** Electric potential energy represents total work done on an arbitrary charge q , rather than per unit test charge.
- Option C:** Elastic potential energy is mechanical energy stored by deforming an elastic solid.

Question #158 Key: (C)PHYSICS
12. Alternating Current

If the potential difference [Formula] across an ohmic conductor is doubled while keeping resist...

CORE CONCEPT & DERIVATION

Joule's law of electric heating relates power dissipation to applied potential difference and electrical resistance.

Formula / Rule / Reaction:

$$P = \frac{V^2}{R}$$

Solution:

- Initial power: $P_1 = \frac{V^2}{R}$.
- When potential difference is doubled ($V_2 = 2V$) at constant resistance:

$$P_2 = \frac{(2V)^2}{R} = \frac{4V^2}{R} = 4P_1$$

- Because electrical power dissipation scales with the square of voltage, doubling voltage quadruples power dissipation.

Why other options are incorrect:

- Option A:** Power would double only if current were held constant, but doubling voltage across fixed resistance also doubles current, resulting in a fourfold power increase.
- Option B:** Halving power would require reducing voltage to $V/\sqrt{2}$.
- Option D:** Power dissipation depends directly on applied voltage; it cannot remain unchanged.

Question #159 Key: (B)PHYSICS
10. Electromagnetism

When the area vector [Formula] is parallel to the magnetic field [Formula], the magnetic flux ...

CORE CONCEPT & DERIVATION

Magnetic flux measures the total number of magnetic field lines passing through a given surface area.

Formula / Rule / Reaction:

$$\Phi_B = \vec{B} \cdot \vec{A} = BA \cos \theta$$

Solution:

- The area vector $\vec{A}$ is defined perpendicular to the surface plane.
- When $\vec{A}$ is parallel to the magnetic field vector $\vec{B}$, the angle between them is $\theta = 0^\circ$.
- $\Phi_B = BA \cos(0^\circ) = BA(1) = BA$
- This orientation produces maximum magnetic flux through the surface.

Why other options are incorrect:

- Option A:** Flux is zero when the area vector is perpendicular to the field ($\theta = 90^\circ$), meaning field lines run parallel to the surface without passing through it.
- Option C:** $BA \cos 90^\circ = 0$, representing minimum (zero) flux.
- Option D:** B/A carries incorrect physical dimensions for flux.

Question #160 Key: (A)PHYSICS
16. Nuclear Physics

Which of the following statements best describes the nature of radioactive nuclear decay?

CORE CONCEPT & DERIVATION

Radioactivity is an intrinsic nuclear process governed by quantum tunneling and nuclear instability.

Formula / Rule / Reaction:

$$-\frac{dN}{dt} = \lambda N \implies N(t) = N_0 e^{-\lambda t}$$

Solution:

- Nuclear decay is spontaneous because unstable parent nuclei disintegrate without requiring external energy input.
- It is random because it is fundamentally impossible to predict the exact moment a specific individual nucleus will decay; only the statistical decay probability per unit time (λ) can be known.

Why other options are incorrect:

- Option B:** Natural radioactivity does not require external activation energy; induced artificial reactions are distinct from spontaneous decay.
- Option C:** Individual nuclear disintegration events follow Poisson statistics and do not occur at fixed, regular intervals.
- Option D:** Nuclear forces operate within femtometer scales, unaffected by chemical conditions, laboratory temperature, or ambient pressure.

Question #161 Key: (A)PHYSICS
01. Vectors & Equilibrium

A boat moves 4 km east and then 3 km north. Another boat moves 3 km north first and then 4 km e...

CORE CONCEPT & DERIVATION

Displacement is a vector pointing from the initial position to the final position. Vector addition satisfies the commutative property.

Formula / Rule / Reaction:

$$\vec{s}_1 = 4\hat{i} + 3\hat{j}, \quad \vec{s}_2 = 3\hat{j} + 4\hat{i} = 4\hat{i} + 3\hat{j} \implies \vec{s}_1 = \vec{s}_2$$

Solution:

- Boat 1 undergoes displacements of $4\hat{i}$ km followed by $3\hat{j}$ km, arriving at coordinates (4, 3).
- Boat 2 undergoes displacements of $3\hat{j}$ km followed by $4\hat{i}$ km, arriving at the exact same coordinates (4, 3).
- Both boats share identical net displacement vectors of magnitude $|\vec{s}| = \sqrt{4^2 + 3^2} = 5$ km directed at $\theta = \tan^{-1}(3/4) \approx 36.9^\circ$ north of east.

Why other options are incorrect:

- Option B:** The order of vector addition does not alter the resultant vector ($\vec{A} + \vec{B} = \vec{B} + \vec{A}$).
- Option C:** The first boat's displacement magnitude is exactly 5 km, identical to the second.
- Option D:** Both boats terminate at the identical coordinate position (4, 3).

Question #162 Key: (C)PHYSICS
15. Atomic Spectra

In the emission spectrum of atomic hydrogen, the Brackett series lies in the:

CORE CONCEPT & DERIVATION

Bohr's model explains hydrogen spectral emission series based on lower principal quantum energy levels (n_1).

Formula / Rule / Reaction:

$$\frac{1}{\lambda} = R_H \left(\frac{1}{4^2} - \frac{1}{n_2^2} \right) \quad \text{where } n_2 = 5, 6, 7, \dots \implies \text{Brackett Series (Infrared)}$$

Solution:

- The Brackett series corresponds to electronic transitions from higher energy levels ($n_2 \geq 5$) down to the fourth orbit ($n_1 = 4$).
- These transitions emit radiation with wavelengths ranging from 1.458 to 4.051 micrometers, which falls in the infrared region.

Why other options are incorrect:

- Option A:** The Lyman series (transitions to $n_1 = 1$) lies in the ultraviolet region.
- Option B:** The Balmer series (transitions to $n_1 = 2$) produces spectral lines in the visible region.
- Option D:** X-rays arise from inner-shell transitions in heavy multi-electron elements or high-energy deceleration, not hydrogen outer transitions.

Question #163 Key: (D)ENGLISH
03. Parts of Speech, Prepositions & Modifiers

All of the players forgot _____ jerseys.

CORE CONCEPT & DERIVATION

A pronoun must agree in number, person, and gender with its antecedent noun. Possessive determiners indicate ownership.

Formula / Rule / Reaction:

Plural Antecedent ('players') $\Rightarrow$ Third-Person Plural Possessive Determiner ('their')

Solution:

- The subject antecedent 'players' is a plural noun.
- The sentence requires a third-person plural possessive pronoun to modify the plural noun 'jerseys'.
- 'Their' is the grammatically correct plural possessive determiner.

Why other options are incorrect:

- **Option A:** 'His' is a singular masculine possessive pronoun and clashes with the plural antecedent 'players'.
- **Option B:** 'Her' is a singular feminine possessive pronoun and fails number agreement.
- **Option C:** 'There' is an adverb of place, not a possessive pronoun.

Question #164 Key: (B)ENGLISH
01. Vocabulary, Synonyms, Antonyms & Spelling

The old man was feeble, barely able to walk. The word "feeble" means:

CORE CONCEPT & DERIVATION

Context clues within a sentence clarify vocabulary meaning through adjacent descriptive modifiers.

Formula / Rule / Reaction:

'Feeble' $\iff$ Lacking physical strength or vigor; physically weak, frail, or debilitated

Solution:

- The clause 'barely able to walk' indicates impaired physical mobility resulting from physical frailty or debility.
- 'Weak' directly matches the definition of 'feeble'.

Why other options are incorrect:

- **Option A:** 'Healthy' is an antonym denoting vigorous physical well-being.
- **Option C:** 'Strong' is a direct antonym representing robust physical strength.
- **Option D:** 'Fat' refers to body mass and adipose tissue, unrelated to physical weakness.

Question #165 Key: (C)ENGLISH
02. Idioms, Phrasal Verbs & Literary Figures

"Revenge is a kind of wild justice." This sentence illustrates the use of which figurative device...

CORE CONCEPT & DERIVATION

A metaphor is a figure of speech that makes an implicit, direct comparison between two fundamentally distinct things without using connective words such as 'like' or 'as'.

Formula / Rule / Reaction:

Metaphor: Concept A is Concept B (direct figurative equation)

Solution:

- Francis Bacon's statement directly equates the abstract concept 'revenge' to 'wild justice'.
- Because it creates a direct figurative equation without using 'like' or 'as', it represents a metaphor.

Why other options are incorrect:

- **Option A:** Personification attributes human emotions, agency, or physical actions to non-human entities or abstractions.
- **Option B:** A pun is humorous wordplay exploiting multiple meanings of a word or words that sound similar.
- **Option D:** Hyperbole involves deliberate rhetorical exaggeration for dramatic emphasis.

Question #166 Key: (C)ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

Each of the boys _____ ambitious to lead the team.

CORE CONCEPT & DERIVATION

Subject-verb agreement requires indefinite distributive pronouns such as 'each', 'either', and 'neither' to take singular verbs regardless of intervening prepositional phrases.

Formula / Rule / Reaction:

Each (Singular Subject) + [of the boys (Prepositional Modifier)] + is (Singular Linking Verb)

Solution:

- The grammatical subject of the sentence is the singular indefinite pronoun 'Each'.
- The intervening prepositional phrase 'of the boys' does not alter the grammatical number of the subject.
- The predicate requires a singular linking verb connecting the subject to the predicate adjective 'ambitious', making 'is' correct.

Why other options are incorrect:

- **Option A:** 'Have' is a plural auxiliary/transitive verb and does not function as a linking verb with an adjective complement here.
- **Option B:** 'Has' is a singular verb of possession, which cannot link a subject to the predicate adjective 'ambitious'.
- **Option D:** 'Are' is a plural verb that erroneously agrees with the object of the preposition ('boys') rather than the true subject ('Each').

Question #167 Key: (A)ENGLISH
05. Active-Passive Voice, Reported Speech & Syntax

"She completed the task with great difficulty." Identify the CORRECT passive voice transformation...

CORE CONCEPT & DERIVATION

In transforming active voice sentences in the simple past tense into passive voice, the direct object becomes the subject, followed by 'was/were' and the past participle of the main verb.

Formula / Rule / Reaction:

Active: $S + V_2 + O \Rightarrow$ Passive: $O + \text{was/were} + V_3 + \text{by } S$

Solution:

- Active sentence: 'She' (Subject) + 'completed' (Past simple verb) + 'the task' (Direct object).
- The singular object 'The task' becomes the passive subject.
- The appropriate past auxiliary for a singular subject is 'was', followed by the past participle 'completed'.
- The resulting sentence is: 'The task was completed with great difficulty by her.'

Why other options are incorrect:

- Option B:** Uses present perfect 'has been completed', altering the simple past tense of the original active sentence.
- Option C:** Uses past continuous 'was being completed', which applies only to continuous ongoing actions.
- Option D:** 'Was been' is an ungrammatical verb sequence in English.

Question #168 Key: (D)ENGLISH
05. Active-Passive Voice, Reported Speech & Syntax

In the sentence "Jogging every morning improves my mood," what grammatical role does the gerund...

CORE CONCEPT & DERIVATION

A gerund is a non-finite verb form ending in '-ing' that functions syntactically as a noun. A gerund phrase includes the gerund and its modifiers or objects.

Formula / Rule / Reaction:

[Jogging every morning]Gerund Phrase as Subject + [improves]Transitive Verb + [my mood]Direct Object

Solution:

- The gerund phrase 'Jogging every morning' occupies the initial nominal position preceding the finite predicate verb 'improves'.
- It performs the action of improving, functioning as the grammatical subject of the sentence.

Why other options are incorrect:

- Option A:** The phrase does not follow a transitive verb as an object.
- Option B:** 'My mood' is the direct object receiving the action of 'improves'.
- Option C:** A predicate noun follows a linking verb (e.g., 'is', 'became') to rename the subject; here, 'improves' is an active transitive verb.

Question #169 Key: (B)ENGLISH
03. Parts of Speech, Prepositions & Modifiers

The meeting has been scheduled _____ 3 p.m. sharp.

CORE CONCEPT & DERIVATION

Prepositions of time are selected according to the specificity of the temporal reference.

Formula / Rule / Reaction:

'At' is used for precise clock times and specific points in time

Solution:

- Standard English idiom uses the preposition 'at' before designated clock times (e.g., at 3 p.m., at noon, at midnight).
- Therefore, 'at 3 p.m. sharp' is grammatically correct.

Why other options are incorrect:

- Option A:** 'On' is used for specific calendar days and dates (e.g., on Monday, on July 12).
- Option C:** 'In' is used for non-specific periods such as months, years, centuries, and seasons (e.g., in July, in 2025).
- Option D:** 'To' indicates spatial direction or destination rather than a scheduled clock time.

Question #170 Key: (C)ENGLISH
03. Parts of Speech, Prepositions & Modifiers

She studied hard; _____, she passed the exam with distinction. Choose the CORRECT transitional...

CORE CONCEPT & DERIVATION

Transitional conjunctive adverbs establish logical relationships (cause-and-effect, contrast, illustration) between two independent clauses separated by a semicolon.

Formula / Rule / Reaction:

Cause (Studied hard) $\Rightarrow$ Effect/Result (Passed with distinction) $\Rightarrow$ 'Consequently'

Solution:

- The second clause ('she passed the exam with distinction') represents the natural result of the action in the first clause ('She studied hard').
- 'Consequently' expresses this cause-and-effect relationship correctly.

Why other options are incorrect:

- Option A:** 'However' signals contrast or concession between opposing ideas.
- Option B:** 'For instance' introduces a specific illustrative example rather than a logical consequence.
- Option D:** 'In contrast' indicates juxtaposition of differences.

Question #171 **Key: (A)**ENGLISH
02. Idioms, Phrasal Verbs & Literary Figures

Which literary device involves using words or phrases that convey the opposite of their literal...

CORE CONCEPT & DERIVATION

Figures of speech alter the relationship between literal and intended meaning for rhetorical or artistic effect.

Formula / Rule / Reaction:

Verbal Irony: Intended figurative meaning $\equiv$ Direct opposite of literal expression

Solution:

- Verbal irony occurs when a speaker says one thing while meaning the opposite.
- More broadly, irony describes incongruity between literal expression and intended reality.

Why other options are incorrect:

- **Option B:** A parody is an exaggerated, humorous imitation of a specific genre, style, or author.
- **Option C:** Satire uses humor, irony, or ridicule to expose and criticize human vice or societal shortcomings.
- **Option D:** Sarcasm is a specific, caustic form of verbal irony intended to mock, but irony is the broader literary device based on expressing the opposite of literal meaning.

Question #172 **Key: (D)**LOGICAL REASONING
07. Number Series & Numerical Progressions

Consider the geometric sequence: 64, 32, 16, 8, ... What is the 10th term of this sequence?

CORE CONCEPT & DERIVATION

A geometric progression is a sequence in which each successive term is obtained by multiplying the preceding term by a constant common ratio (r).

Formula / Rule / Reaction:

$$a_n = a_1 r^{n-1}$$

Solution:

- First term: $a_1 = 64$.
- Common ratio: $r = \frac{32}{64} = \frac{1}{2}$.
- The 10th term ($n = 10$) is:

$$a_{10} = 64 \times \left(\frac{1}{2}\right)^{10-1} = 64 \times \left(\frac{1}{2}\right)^9 = 64 \times \frac{1}{512} = \frac{64}{512} = \frac{1}{8}$$

- **Past paper board note:** In uncurated spreadsheet dumps, fractional options '1/4' and '1/8' frequently appeared corrupted as Excel date serial integers ('46026' and '46030'); they are restored here to their intended mathematical fractions.

Why other options are incorrect:

- **Option A:** 2 is the 6th term of the sequence ($64 \times (1/2)^5 = 2$).
- **Option B:** 4 is the 5th term of the sequence ($64 \times (1/2)^4 = 4$).
- **Option C:** 1/4 is the 9th term of the sequence ($64 \times (1/2)^8 = 1/4$).

Question #173 **Key: (D)**LOGICAL REASONING
10. Percentages, Ratios & Unit Calculations

If 5 boxes of soap weigh 75 kg in total, and each box when empty weighs 3 kg, what is the total...

CORE CONCEPT & DERIVATION

Gross weight is the sum of net content weight and container tare weight.

Formula / Rule / Reaction:

$$\text{Net Weight of Soaps} = \text{Total Gross Weight} - \text{Total Weight of Empty Boxes}$$

Solution:

- Total gross weight of 5 filled boxes = 75 kg.
- Weight of 1 empty box = 3 kg.
- Total tare weight of 5 empty boxes = $5 \times 3 \text{ kg} = 15 \text{ kg}$.
- Net weight of soap = $75 \text{ kg} - 15 \text{ kg} = 60 \text{ kg}$

Why other options are incorrect:

- **Option A:** 15 kg is the tare weight of the five empty boxes alone.
- **Option B:** 30 kg results from subtracting 15 kg twice.
- **Option C:** 45 kg corresponds to subtracting 10 empty boxes.

Question #174 **Key: (B)**LOGICAL REASONING
07. Number Series & Numerical Progressions

Which number completes the series: 200, 180, 162, 146, 132, _____?

CORE CONCEPT & DERIVATION

Number series patterns are analyzed by examining the differences between successive terms.

Formula / Rule / Reaction:

$$\Delta_n = \Delta_{n-1} - 2 \quad (\text{Differences decrease by 2 each step})$$

Solution:

- $200 - 180 = 20$
- $180 - 162 = 18$
- $162 - 146 = 16$
- $146 - 132 = 14$
- The successive differences decrease by 2 at each step: 20, 18, 16, 14.
- The next difference must be $14 - 2 = 12$.
- $132 - 12 = 120$

Why other options are incorrect:

- **Option A:** 118 results from subtracting 14 again instead of decreasing the difference to 12.
- **Option C:** 122 results from subtracting 10 instead of 12.
- **Option D:** 126 results from subtracting only 6.

Question #175 **Key: (A)**LOGICAL REASONING
13. Blood Relations & Kinship

How is Ali related to Mustafa if Ali says, "Mustafa's mother is the only child of my grandmother..."

CORE CONCEPT & DERIVATION

Kinship deduction resolves generational links and sibling relationships through unambiguous genealogical descriptors.

Formula / Rule / Reaction:

'Only child of my maternal grandmother' $\equiv$ Ali's mother

Solution:

- Ali's grandmother has an 'only child', which means that child is Ali's mother.
- Ali states that this person is also 'Mustafa's mother'.
- Because Mustafa and Ali share the same mother, Ali is Mustafa's brother.

Why other options are incorrect:

- **Option B:** They cannot be cousins because Ali's grandmother has only one child, precluding any maternal aunts or uncles.
- **Option C:** 'Uncle' represents an older generation, which is incompatible with sharing the same mother.
- **Option D:** The statement identifies Mustafa's mother, not his father.

Question #176 **Key: (B)**LOGICAL REASONING
12. Linear Ranking, Ordering & Inequalities

Ahmed ranks 10th in a class of 46 students. There are exactly 7 students ranked below Bilal. How...

CORE CONCEPT & DERIVATION

Linear ranking calculations determine intermediate positions by finding absolute numerical ranks from a shared reference point.

Formula / Rule / Reaction:

Rank from top = Total students – Students below
Students strictly between ranks R_1 and $R_2 = R_2 - R_1 - 1$

Solution:

- Ahmed's rank from the top = 10th.
- Bilal has 7 students below him in a class of 46, so Bilal's rank from the top is:
- $$\text{Bilal's rank} = 46 - 7 = 39\text{th}$$
- The number of students ranked strictly between the 10th rank and the 39th rank is:
- $$\text{Intermediate students} = 39 - 10 - 1 = 28$$

Why other options are incorrect:

- **Option A:** 27 underestimates the range by subtracting an extra position.
- **Option C:** 30 results from including both boundaries rather than excluding them.
- **Option D:** 32 fails to compute Bilal's rank from the bottom correctly.

Question #177 **Key: (B)**LOGICAL REASONING
09. Word Problems on Ages

A father is 5 years older than twice his son's age. If the son is 12 years old, what is the father's age?

CORE CONCEPT & DERIVATION

Linear algebraic word problems translate descriptive quantitative relationships into solvable equations.

Formula / Rule / Reaction:

$$F = 2S + 5$$

Solution:

- Son's age: $S = 12$.
- Twice the son's age = $2 \times 12 = 24$.
- The father is 5 years older than this product:

$$F = 24 + 5 = 29 \text{ years}$$

Why other options are incorrect:

- **Option A:** 28 years corresponds to adding 4 years instead of 5.
- **Option C:** 30 years corresponds to adding 6 years.
- **Option D:** 32 years corresponds to adding 8 years.

Question #178 **Key: (B)**LOGICAL REASONING
04. Argument Evaluation & Ethics

A mobile company is deciding whether to collect personal user data to improve advertisements. Which principle is most relevant?

CORE CONCEPT & DERIVATION

A moral argument is grounded in ethical principles of duty, human rights, and autonomy, evaluating rightness or wrongness independent of commercial self-interest or profit outcomes.

Formula / Rule / Reaction:

Ethical Principle: Autonomy and Informed Consent (Deontological Ethics).

Solution:

- Option B addresses the moral imperative of respecting individual autonomy and informed consent, framing unauthorized data collection as inherently unethical.
- This makes it a moral argument against the practice.

Why other options are incorrect:

- **Option A:** Presents a prudential business argument based on financial self-interest and corporate profit rather than ethics.
- **Option C:** An argument in favor of collection based on market competition.
- **Option D:** A pragmatic commercial argument in favor of collection based on sales performance.

Question #179 **Key: (A)**LOGICAL REASONING
10. Percentages, Ratios & Unit Calculations

A medication dose starts at 100 mg and halves each day. What will be the dose on day 4?

CORE CONCEPT & DERIVATION

Exponential decay follows geometric progression where quantity decreases by a constant halving factor over discrete daily intervals.

Formula / Rule / Reaction:

$$D_n = D_1 \times \left(\frac{1}{2}\right)^{n-1}$$

Solution:

- Day 1: 100 mg
- Day 2: $100/2 = 50$ mg
- Day 3: $50/2 = 25$ mg
- Day 4: $25/2 = 12.5$ mg
- The dose on Day 4 is 12.5 mg.

Why other options are incorrect:

- **Option B:** 25 mg is the dose administered on Day 3.
- **Option C:** 30 mg does not fit geometric halving.
- **Option D:** 50 mg is the dose administered on Day 2.

Question #180 **Key: (C)**LOGICAL REASONING
10. Percentages, Ratios & Unit Calculations

A library has 4 books on Shelf A and 8 books on Shelf B. Some books are removed from Shelf B su...

CORE CONCEPT & DERIVATION

Equating quantities across two sets after removing elements from one set requires direct algebraic substitution.

Formula / Rule / Reaction:

$$\text{Final Books on Shelf B} = \text{Initial Books on Shelf B} - x = \text{Books on Shelf A}$$

Solution:

- Shelf A contains 4 books.
- Shelf B initially contains 8 books.
- Let x be the number of books removed from Shelf B:
- $$8 - x = 4 \implies x = 8 - 4 = 4$$
- Therefore, exactly 4 books were removed from Shelf B.

Why other options are incorrect:

- **Option A:** Removing 2 books leaves 6 on Shelf B, which does not equal Shelf A's 4.
- **Option B:** Removing 3 books leaves 5 on Shelf B.
- **Option D:** Removing 6 books leaves 2 on Shelf B.