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SZABMU ISLAMABAD

SZABMU Islamabad MDCAT 2023 Official Paper

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

🏷️ Official Admitting Board: Shaheed Zulfiqar Ali Bhutto Medical University Islamabad 🎯 Archive Code: BEAMBE-FLP-SZABMU-2023

🕒 Duration: 200 Minutes (3h 20m)

200

TOTAL QUESTIONS

200m

OFFICIAL DURATION

+1 / 0.00

ZERO NEGATIVE MARKING

200

MAXIMUM MARKS

📄 EXAMINATION BLUEPRINT & SUBJECT WEIGHTAGE

Biology**68 MCQs**

34.0% weight

Chemistry**54 MCQs**

27.0% weight

Physics**54 MCQs**

27.0% weight

English**18 MCQs**

9.0% weight

Logical Reasoning**6 MCQs**

3.0% weight

BIO SECTION: BIOLOGY

Questions 1 to 68 (68 MCQs)

Q1. BIO

A non-protein, inorganic, and detachable cofactor required by an enzyme for its activity is called an:

- (A) Activator
- (B) Prosthetic group
- (C) Coenzyme
- (D) Apoenzyme

Q2. BIO

The Lock and Key Model for enzyme action, proposed by Emil Fischer in 1894, suggests that:

- (A) Enzymes are unbiased for the substrate
- (B) Enzymes can modify their active sites during binding
- (C) Enzymes are restricted to one reaction type
- (D) An enzyme can catalyze a wide variety of reactions

Q3. BIO

Enzymes accelerate chemical reactions by lowering the _____ of the substrate molecules:

- (A) Kinetic energy
- (B) Activation energy
- (C) Heat energy
- (D) Potential energy

Q4. BIO

The allele frequency of a newly arisen mutant gene in a natural population is most likely to increase over successive generations if:

- (A) The gene confers a selective advantage to the organism
- (B) The gene is dominant over the wild-type allele
- (C) The gene is located on a sex chromosome
- (D) The overall population size increases

Q5. BIO

Which of the following statements is NOT consistent with Charles Darwin's theory of natural selection?

- (A) Survival in the struggle for existence is entirely random
- (B) Fitter individuals leave more offspring in their environment
- (C) Unequal survival and reproduction lead to gradual population changes
- (D) Favorable variations accumulate over generations, producing new species

Q6. BIO

A mathematical equation used to calculate the frequencies of alleles and genotypes in a non-evolving gene pool at equilibrium was derived by:

- (A) Carolus Linnaeus
- (B) Jean-Baptiste Lamarck
- (C) Charles Darwin
- (D) Godfrey Hardy and Wilhelm Weinberg

Q7. BIO

When humans purposefully apply selective pressure to breed plants or animals with desired characteristics, the process is termed:

- (A) Natural selection
- (B) Artificial selection
- (C) Genetic drift
- (D) Speciation

Q8. BIO

Which of the following is NOT a direct biological characteristic or action of interferons?

- (A) They belong to the cytokine class of regulatory glycoproteins
- (B) They activate natural killer (NK) cells
- (C) They enhance immune cell activation against pathogens
- (D) They directly secrete interleukins

Q9. BIO

Which of the following proteolytic enzymes is NOT secreted as an inactive zymogen precursor?

- (A) Chymotrypsin
- (B) Pepsin
- (C) Trypsin
- (D) Erepsin

Q10. BIO

In the human cardiovascular system, the left atrium receives oxygen-rich blood directly from:

- (A) The superior vena cava
- (B) The ascending aorta
- (C) The inferior vena cava
- (D) The four pulmonary veins

Q11. BIO

Choose the correct anatomical pathway for the microvascular flow of blood through a capillary bed:

- (A) Arterioles → metarterioles → thoroughfare channels → true capillaries
- (B) Capillaries → thoroughfare channels → metarterioles → arterioles
- (C) Thoroughfare channels → metarterioles → capillaries → arterioles
- (D) Metarterioles → arterioles → thoroughfare channels → capillaries

Q12. BIO

Regarding the internal anatomy of the human heart, chordae tendineae are located exclusively within the:

- (A) Atria
- (B) Pulmonary valve sinuses
- (C) Ventricles
- (D) Aortic valve sinuses

Q13. BIO

In intestinal mucosal enterocytes, chylomicrons are synthesized by the assembly of:

- (A) Proteins and carbohydrates
- (B) Fats and proteins
- (C) Fats and carbohydrates
- (D) Vitamins and fats only

Q14. BIO

The pathway of symplastic water transport in plant roots involves movement from cell to cell via:

- (A) Apoplastic cell walls
- (B) Plasmodesmata
- (C) Tonoplasts and central vacuoles
- (D) Xylem tracheary elements

Q15. BIO

In a typical bacterial batch culture growth curve, cells divide at their maximal, constant geometric rate during the:

- (A) Lag phase
- (B) Log phase
- (C) Stationary phase
- (D) Decline phase

Q16. BIO

The unique macromolecule that forms the rigid structural framework of the eubacterial cell wall is:

- (A) Polysaccharide cellulose
- (B) Chitin
- (C) Peptidoglycan
- (D) Cholesterol

Q17. BIO

In bacteria, specialized hollow proteinaceous surface appendages known as pili function primarily in:

- (A) Increasing pathogenic cell motility
- (B) Degrading the host plasma membrane
- (C) Degrading host extracellular enzymes
- (D) Facilitating the exchange of genetic material

Q18. BIO

Which of the following lipid components is normally ABSENT from the plasma membrane of typical prokaryotes?

- (A) Glycolipids
- (B) Cholesterol
- (C) Glycoproteins
- (D) Phospholipids

Q19. BIO

Which of the following cellular processes is NOT performed by lysosomes?

- (A) Intracellular heterophagic digestion
- (B) Autophagy of worn-out organelles
- (C) Autolysis of damaged cells
- (D) Processing and packaging of cell secretions

Q20. BIO

The peripheral zone of the cytoplasm in many eukaryotic cells (ectoplasm) exhibits a physical consistency resembling a:

- (A) Sol
- (B) Gel
- (C) True solution
- (D) Coarse suspension

Q21. BIO

The single semipermeable biological membrane that separates the plant central vacuole from the cytoplasm is known as the:

- (A) Crista
- (B) Tonoplast
- (C) Cisterna
- (D) Mesosome

Q22. BIO

Which biochemical component of the fluid mosaic model primarily determines and modulates membrane fluidity?

- (A) Extrinsic glycoproteins
- (B) Integral carrier proteins
- (C) Lipids
- (D) Surface carbohydrates

Q23. BIO

The microscopic functional junction between the terminal axonal branch of a neuron and the dendrites or cell body of another neuron is called a:

- (A) Synapse
- (B) Nissl body
- (C) Neuroglial junction
- (D) Myelin sheath gap

Q24. BIO

Which of the following physiological mechanisms operates through a positive feedback control loop?

- (A) Uterine labor contractions during childbirth
- (B) Thermoregulation of core body temperature
- (C) Regulation of blood glucose via insulin production
- (D) Regulation of basal metabolic rate via thyroxine release

Q25. BIO

Which neuroendocrine hormone is synthesized by the hypothalamus and released from the posterior pituitary to stimulate labor contractions and milk ejection?

- (A) Estrogen
- (B) Progesterone
- (C) Calcitonin
- (D) Oxytocin

Q26. BIO

During the non-conducting resting potential state of an axon, the neural membrane exhibits selective permeability to the efflux of:

- (A) K^+
- (B) Na^+
- (C) Ca^{2+}
- (D) Cl^-

Q27. BIO

Gamma-aminobutyric acid (GABA) is an important chemical messenger in the mammalian brain that acts as an:

- (A) Allosteric metabolic enzyme
- (B) Inhibitory neurotransmitter
- (C) Excitatory neurotransmitter
- (D) Endocrine steroid hormone

Q28. BIO

What is the normal physiological fate of neurotransmitter molecules immediately following the stimulation of postsynaptic receptors?

- (A) They remain bound irreversibly to the postsynaptic membrane
- (B) They persist continuously within the synaptic cleft
- (C) They are degraded by specific enzymes or recaptured by reuptake
- (D) They are internalized directly into the postsynaptic nucleus

Q29. BIO

Advanced physiological homeostasis maintained through complex negative feedback mechanisms is a distinctive characteristic of:

- (A) Class Pisces
- (B) Class Amphibia
- (C) Class Reptilia
- (D) Class Mammalia

Q30. BIO

Which of the following biological statements is TRUE regarding organisms of the genus *Amoeba*?

- (A) They possess specialized locomotory flagella
- (B) They are complex multicellular protozoans
- (C) No species of amoebae causes disease in humans
- (D) They move by forming temporary cytoplasmic projections called pseudopodia

Q31. BIO

Which of the following vertebrate organisms is classified as an anamniote?

- (A) Snake
- (B) Parrot
- (C) Frog
- (D) Crocodile

Q32. BIO

Organisms that are multicellular, display heterotrophic ingestive nutrition, and develop from blastulae with cells that completely lack cell walls are placed in Kingdom:

- (A) Protista
- (B) Fungi
- (C) Plantae
- (D) Animalia

Q33. BIO

Which of the following enzymes serves as an important regulatory, rate-limiting control point in the glycolytic pathway?

- (A) Urease
- (B) Hexokinase
- (C) Maltase
- (D) Sucrase

Q34. BIO

Many hydrolytic and proteolytic enzymes are synthesized and secreted as inactive precursors (zymogens) primarily to protect the host:

- (A) Mitochondrial membranes
- (B) Nuclear DNA strands
- (C) Cellular membranes and surrounding tissues from autolysis
- (D) Cytoplasmic storage vacuoles

Q35. BIO

Mesosomes observed in electron micrographs of bacteria are internal structural invaginations of the bacterial:

- (A) Peptidoglycan cell wall
- (B) Cell membrane
- (C) Covalently closed plasmid
- (D) Protective capsule

Q36. BIO

Which of the following living organisms completely lacks a cell wall around its vegetative cells?

- (A) Cyanobacteria
- (B) Sea fan (*Gorgonia*)
- (C) *Saccharomyces cerevisiae*
- (D) Blue-green algae

Q37. BIO

Follicle-stimulating hormone (FSH) is synthesized and secreted into the systemic circulation by the:

- (A) Ovaries
- (B) Anterior pituitary gland
- (C) Adrenal cortex
- (D) Testes

Q38. BIO

Which of the following physiological events is NOT an established function of testosterone in human males?

- (A) Negative feedback inhibition of luteinizing hormone (LH)
- (B) Stimulation and maintenance of sperm production
- (C) Development of male secondary sexual characteristics
- (D) Direct limitation or suppression of spermatogenesis

Q39. BIO

In human males, the protein hormone inhibin is synthesized and secreted by:

- (A) Interstitial Leydig cells
- (B) Hensen's node organizing cells
- (C) Sertoli cells
- (D) Secondary spermatocytes

Q40. BIO

Which of the following reproductive and endocrine functions is NOT directly performed by the ovaries?

- (A) Progesterone production
- (B) Estrogen production
- (C) Ovulation of the secondary oocyte
- (D) Human chorionic gonadotropin (hCG) production

Q41. BIO

Following ovulation during the menstrual cycle, the remnants of the ruptured Graafian follicle reorganize into the corpus luteum, which primarily secretes:

- (A) Progesterone
- (B) Follicle-stimulating hormone
- (C) Luteinizing hormone
- (D) Testosterone

Q42. BIO

A clinical condition in which a synovial joint becomes swollen, painful, stiff, and restricted in movement is diagnosed as:

- (A) Spondylosis
- (B) Arthritis
- (C) Sciatica
- (D) Rickets

Q43. BIO

Which of the following cellular and morphological features is characteristic of visceral smooth muscle tissue?

- (A) Multinucleate cylindrical syncytial cells
- (B) Repeating contractile sarcomeric striations
- (C) Uninucleate, spindle-shaped non-striated cells
- (D) Branched fibers linked by intercalated discs

Q44. BIO

Mature bone cells that reside trapped within small fluid-filled cavities called lacunae in the mineralized matrix are:

- (A) Chondrocytes
- (B) Osteoblasts
- (C) Osteoclasts
- (D) Osteocytes

Q45. BIO

The specialized outer plasma membrane surrounding an individual skeletal muscle fiber is termed the:

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

Q46. BIO

The reciprocal exchange of non-sister chromatid segments between paired homologous chromosomes during pachytene of meiosis I is called:

- (A) Crossing over
- (B) Autosomal linkage
- (C) Chromosomal non-disjunction
- (D) Centromeric fission

Q47. BIO

A permanent, heritable change occurring within the nucleotide sequence of a specific gene that produces an altered allele is termed a:

- (A) Chromosomal aberration
- (B) Gene mutation
- (C) Ploidy shift
- (D) Homologous recombination

Q48. BIO

Which of the following human genetic systems is controlled by multiple alleles located at a single autosomal locus?

- (A) The ABO blood group system
- (B) Cystic fibrosis
- (C) Down syndrome
- (D) Hemophilia A

Q49. BIO

In classical genetics, the term 'phenotype' refers to:

- (A) The total genetic composition and allelic combinations of an individual
- (B) The specific partner allele located on a homologous chromosome
- (C) The observable physical, physiological, or biochemical manifestation of a trait
- (D) The precise physical position of a gene on a chromosome

Q50. BIO

If a female carrier for X-linked recessive hemophilia ($X^H X^h$) marries a hemophilic male ($X^h Y$), what proportion of their offspring is expected to be affected?

- (A) All children will be affected
- (B) All daughters will be affected and all sons will be normal
- (C) Half of the daughters and all sons will be affected
- (D) Half of the sons and half of the daughters will be affected

Q51. BIO

The particular array and complete visual display of homologous chromosomes possessed by an individual, arranged by size and centromere location, is called a:

- (A) Genotype
- (B) Phenotype
- (C) Karyotype
- (D) Allelic profile

Q52. BIO

Which of the following statements is NOT a characteristic feature of enveloped animal viruses?

- (A) They survive for a relatively short time outside the host environment
- (B) They are highly tolerant to neutralizing antibodies
- (C) Their outer envelope is sensitive to sunlight, heat, and lipophilic detergents
- (D) Their outer lipid envelope is derived directly from host cell membranes

Q53. BIO

Choose the infectious agent that requires only a single host cellular gene to encode the protein that constitutes the infectious particle:

- (A) Viroid
- (B) Prion
- (C) Complex enveloped virus
- (D) Naked virion

Q54. BIO

Which of the following human pathogens is transmitted primarily through contaminated blood transfusions and unsterilized hypodermic syringes?

- (A) Human Immunodeficiency Virus (HIV)
- (B) Influenza A virus
- (C) Morbillivirus (Measles virus)
- (D) *Vibrio cholerae*

Q55. BIO

Which of the following clinical viral infections is caused by a subviral, circular single-stranded RNA agent resembling a viroid?

- (A) Hepatitis A
- (B) Hepatitis D (Delta agent)
- (C) Mad cow disease
- (D) Mysterious brain infection (Kuru)

Q56. BIO

The final physiological acceptor of both electrons and protons during the light-dependent non-cyclic reactions of photosynthesis is:

- (A) Plastoquinone (PQ)
- (B) Plastocyanin (PC)
- (C) Ferredoxin (Fd)
- (D) $NADP^+$

Q57. BIO

The only copper-containing mobile protein carrier involved in the electron transport chain of the photosynthetic light reactions is:

- (A) Plastoquinone
- (B) Cytochrome b_6f
- (C) Ferredoxin
- (D) Plastocyanin

Q58. BIO

The primary end product of anaerobic glycolysis in human skeletal muscle tissue during strenuous, oxygen-depleting exercise is:

- (A) Ethanol and carbon dioxide
- (B) Lactate
- (C) Pyruvate
- (D) Acetyl-CoA

Q59. BIO

The primary three-carbon carbohydrate product directly exported from the stroma during the Calvin cycle is:

- (A) 3-phosphoglycerate
- (B) 1,3-bisphosphoglycerate
- (C) Glyceraldehyde 3-phosphate (G3P)
- (D) Glucose

Q60. BIO

The second most abundant chemical bioelement by total body mass in the human body is:

- (A) Oxygen
- (B) Carbon
- (C) Hydrogen
- (D) Nitrogen

Q61. BIO

The primary structural framework that forms the universal, stable matrix of all biological unit membranes is composed of:

- (A) Phospholipids
- (B) Glycoproteins
- (C) Lipoproteins
- (D) Nucleoproteins

Q62. BIO

When three hydrophobic fatty acid molecules undergo esterification with a single molecule of glycerol, the resulting lipid is a:

- (A) Monoglyceride
- (B) Diglyceride
- (C) Triglyceride (Triacylglycerol)
- (D) Phospholipid

Q63. BIO

The specific five-carbon aldopentose sugar that forms the structural backbone of ribonucleic acid (RNA) is:

- (A) D-Ribulose
- (B) D-Ribose
- (C) 2-Deoxyribulose
- (D) 2-Deoxyribose

Q64. BIO

Which of the following biochemical processes is responsible for the enzymatic cleavage of proteins into individual free amino acids?

- (A) Condensation polymerization
- (B) Hydrolysis
- (C) Glycolysis
- (D) Biological nitrogen fixation

Q65. BIO

Select the major fibrous structural protein that provides tensile strength, resilience, and support to animal connective tissues including bone, tendons, and cartilage:

- (A) Histone
- (B) Keratin
- (C) Elastin
- (D) Collagen

Q66. BIO

Fibrous structural proteins do NOT participate directly in which of the following physiological functions?

- (A) Blood coagulation and clot stabilization
- (B) Formation of protective cutaneous appendages like nails and hair
- (C) Skeletal muscle filament sliding and contraction
- (D) Reversible oxygen transport in the systemic circulation

Q67. BIO

The outer membranes of mitochondria and chloroplasts resemble each other fundamentally because both:

- (A) Are freely permeable to large folded proteins and nucleic acids
- (B) Are freely permeable to small molecules and ions through porin channels
- (C) Are completely impermeable to all hydrophilic solutes
- (D) Contain proton-pumping ATP synthase complexes

Q68. BIO

In eukaryotic mitochondria, the catalytic F_1F_0 -ATP synthase complex is anchored directly within the:

- (A) Outer mitochondrial membrane
- (B) Intermembrane space
- (C) Inner mitochondrial membrane
- (D) Mitochondrial matrix

CHEM SECTION: CHEMISTRY

Questions 69 to 122 (54 MCQs)

Q69. CHEM

An alkali metal reacts vigorously with cold water, melting into a silvery molten sphere that skates across the water surface with effervescence and burns with a persistent golden-yellow flame. What is the identity of this metal?

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

Q70. CHEM

Among the alkali metals of Group IA, which element reacts most slowly and least vigorously with liquid water at room temperature?

- (A) Sodium (Na)
- (B) Potassium (K)
- (C) Rubidium (Rb)
- (D) Lithium (Li)

Q71. CHEM

Which of the following elements has the smallest electron shielding (screening) effect on its outermost valence electrons?

- (A) Magnesium (Mg)
- (B) Calcium (Ca)
- (C) Rubidium (Rb)
- (D) Strontium (Sr)

Q72. CHEM

Across the first transition series (3d series), the total number of unpaired d-electrons increases progressively from Group IIIB up to Group:

- (A) IIIB and IVB
- (B) IB and IIB
- (C) IVB and IIIB
- (D) VB and VIB

Q73. CHEM

The binding energy and melting points of transition elements weaken progressively toward the end of the series, reaching a minimum at Group:

- (A) IIIB
- (B) IVB
- (C) IIB
- (D) VB

Q74. CHEM

Metamers are structural isomers that differ from each other specifically due to the:

- (A) Identity of the functional group present in the compound
- (B) Position of the principal functional group along the carbon chain
- (C) Rapid intramolecular migration of a proton
- (D) Unequal distribution of carbon atoms (alkyl groups) on either side of a polyvalent functional group

Q75. CHEM

Structural isomerism caused by the dynamic intramolecular shifting of a proton from one atom to another within the same molecule is known as:

- (A) Metamerism
- (B) Tautomerism
- (C) Position isomerism
- (D) Functional group isomerism

Q76. CHEM

A neutral aliphatic organic compound having the molecular formula C_2H_6O can exist as two distinct structural isomers that display:

- (A) Functional group isomerism
- (B) Position isomerism
- (C) Chain isomerism
- (D) Metamerism

Q77. CHEM

In the laboratory, benzene is prepared by decarboxylation of sodium benzoate upon heating in the presence of:

- (A) Dilute aqueous NaOH
- (B) Alcoholic KOH
- (C) Soda lime ($NaOH + CaO$)
- (D) Metallic sodium in anhydrous ether

Q78. CHEM

Which of the following hydrocarbons does NOT typically undergo substitution reactions under normal experimental conditions, reacting instead via electrophilic addition?

- (A) $CH_3 - CH_3$
- (B) $CH_2 = CH_2$
- (C) $CH \equiv CH$
- (D) C_6H_6

Q79. CHEM

According to IUPAC rules, when both a double bond and a triple bond are present in the same hydrocarbon molecule, the suffix appended to the parent root is:

- (A) -enyne
- (B) -ene
- (C) -yne
- (D) -ane

Q80. CHEM

Which of the following hydrocarbons is chemically the LEAST reactive toward typical addition and oxidation reagents?

- (A) Ethane
- (B) Ethene
- (C) Benzene
- (D) Ethyne

Q81. CHEM

What is the general decreasing order of chemical reactivity for aliphatic hydrocarbons toward electrophilic addition reagents?

- (A) Alkanes > Alkynes > Alkenes
- (B) Alkenes > Alkanes > Alkynes
- (C) Alkynes > Alkenes > Alkanes
- (D) Alkenes > Alkynes > Alkanes

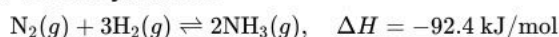
Q82. CHEM

In the Aldol condensation and the Cannizzaro reaction, the specific chemical role of the hydroxide ion (OH^-) is respectively as a:

- (A) Nucleophile and electrophile
- (B) Base and nucleophile
- (C) Electrophile and nucleophile
- (D) Nucleophile and base

Q83. CHEM

Which of the following modifications will NOT shift the equilibrium to favor an increased yield of ammonia in the Haber-Bosch synthesis?



- (A) Decreasing the operational reaction temperature
- (B) Increasing the total pressure in the reactor
- (C) Continuously removing liquid NH_3 from the equilibrium vessel
- (D) Continuously adding gaseous NH_3 into the reactor

Q84. CHEM

Which of the following statements is NOT a valid feature or deduction of Le Chatelier's principle?

- (A) It allows prediction of the direction of equilibrium shift when reactant concentration changes
- (B) It allows direct prediction of changes in absolute reaction rates for a system at equilibrium
- (C) It allows prediction of the direction of equilibrium shift when total pressure changes
- (D) It allows prediction of the direction of equilibrium shift when system temperature changes

Q85. CHEM

For a reversible gas-phase reaction in which the total number of moles of gaseous reactants equals the total number of moles of gaseous products ($\Delta n_g = 0$):

- (A) The value of K_p is always strictly greater than K_c
- (B) The value of K_c is always strictly greater than K_p
- (C) The values of K_p and K_c differ and depend on system pressure
- (D) The values of K_p and K_c are numerically identical ($K_p = K_c$)

Q86. CHEM

In a chemical rate law equation, the specific rate constant (k) is numerically equal to the rate of the reaction when the concentration of each reacting species is:

- (A) 1 M
- (B) 2 M
- (C) 3 M
- (D) 4 M

Q87. CHEM

As a typical chemical reaction proceeds forward under constant volume and temperature, the rate of the reaction:

- (A) Increases progressively
- (B) Decreases progressively
- (C) Remains completely unchanged
- (D) Remains constant initially and then increases

Q88. CHEM

For all thermodynamically exothermic chemical reactions, the sign assigned to the standard enthalpy change of reaction (ΔH°) is always:

- (A) Zero
- (B) Positive
- (C) Negative
- (D) Variable depending on the temperature

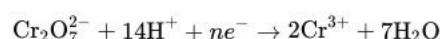
Q89. CHEM

Which of the following fundamental structural insights is directly provided by the experimental lattice energy of a crystalline solid?

- (A) It quantifies the electrostatic stability, bond strength, and structure of an ionic compound
- (B) It explains the covalent overlap and directional bonding in molecular compounds
- (C) It describes the metallic properties and sea of electrons in alloys
- (D) It characterizes the geometry and dipole moments of covalent molecules

Q90. CHEM

In the balanced redox half-reaction occurring in acidic solution:



How many electrons are gained by each chromium atom?

- (A) 12 electrons
- (B) 3 electrons
- (C) 6 electrons
- (D) 1 electron

Q91. CHEM

In peroxides such as sodium peroxide (Na_2O_2) and hydrogen peroxide (H_2O_2), the oxidation number assigned to each oxygen atom is:

- (A) -1
- (B) +2
- (C) -2
- (D) +1

Q92. CHEM

Which of the following electron addition processes is endothermic and therefore associated with a positive electron affinity ($\Delta H > 0$)?

- (A) Addition of an electron to a neutral chlorine atom: $\text{Cl}(g) + e^- \rightarrow \text{Cl}^-(g)$
- (B) Addition of an electron to an excited chlorine atom
- (C) Addition of an electron to a neutral oxygen atom: $\text{O}(g) + e^- \rightarrow \text{O}^-(g)$
- (D) Addition of an electron to a uninegative oxide ion: $\text{O}^-(g) + e^- \rightarrow \text{O}^{2-}(g)$

Q93. CHEM

Which of the following chemical species contains a central atom with sp^2 hybridization and a trigonal planar geometry?

- (A) NH_3
- (B) BF_3
- (C) H_2O
- (D) BeCl_2

Q94. CHEM

Among the third-period elements sodium (Na), magnesium (Mg), phosphorus (P), and sulfur (S), which neutral atom has the smallest atomic radius?

- (A) Magnesium (Mg)
- (B) Sulfur (S)
- (C) Phosphorus (P)
- (D) Sodium (Na)

Q95. CHEM

The melting point of elemental sulfur (S_8) is significantly higher than that of elemental white phosphorus (P_4) primarily because:

- (A) Sulfur molecules have stronger London dispersion forces due to a larger molecular size and electron cloud
- (B) Sulfur molecules contain polar covalent bonds while phosphorus does not
- (C) Phosphorus molecules experience stronger van der Waals forces than sulfur
- (D) Sulfur forms a continuous three-dimensional giant covalent network lattice

Q96. CHEM

Alkyl halide nucleophilic substitution reactions in which C – X bond cleavage and C – Nu bond formation occur simultaneously in a single concerted step follow the:

- (A) $\text{S}_{\text{N}}1$ mechanism
- (B) $\text{S}_{\text{N}}2$ mechanism
- (C) E1 mechanism
- (D) E2 mechanism

Q97. CHEM

A nucleophilic substitution reaction of an optically active alkyl halide that results in approximately 50% inversion and 50% retention of spatial configuration (racemization) is characteristic of the:

- (A) E2 mechanism
- (B) E1 mechanism
- (C) $\text{S}_{\text{N}}2$ mechanism
- (D) $\text{S}_{\text{N}}1$ mechanism

Q98. CHEM

When alcohols react via cleavage of the O – H bond (acting as Bronsted acids in the presence of active metals), the correct decreasing order of reactivity is:

- (A) Primary alcohol > Secondary alcohol > Tertiary alcohol
- (B) Methyl alcohol > Primary alcohol > Secondary alcohol > Tertiary alcohol
- (C) Tertiary alcohol > Secondary alcohol > Primary alcohol
- (D) Secondary alcohol > Tertiary alcohol > Primary alcohol

Q99. CHEM

The controlled oxidation of primary and secondary alcohols yields which pair of functional groups, respectively?

- (A) Aldehyde and ketone
- (B) Aldehyde and alkane
- (C) Ketone and alkane
- (D) Carboxylic acid and ether

Q100. CHEM

What is the correct decreasing order of relative acidic strength among carboxylic acids, phenols, water, and aliphatic alcohols?

- (A) $-\text{COOH} > \text{H}_2\text{O} > \text{C}_6\text{H}_5\text{OH} > \text{R} - \text{OH}$
- (B) $-\text{COOH} > \text{C}_6\text{H}_5\text{OH} > \text{H}_2\text{O} > \text{R} - \text{OH}$
- (C) $-\text{COOH} > \text{R} - \text{OH} > \text{C}_6\text{H}_5\text{OH} > \text{H}_2\text{O}$
- (D) $-\text{COOH} > \text{H}_2\text{O} > \text{R} - \text{OH} > \text{C}_6\text{H}_5\text{OH}$

Q101. CHEM

Aliphatic and aromatic aldehydes can be oxidized by mild and strong oxidizing agents, but they cannot be oxidized by:

- (A) Acidified $\text{K}_2\text{Cr}_2\text{O}_7$
- (B) Concentrated HNO_3
- (C) Alkaline KMnO_4
- (D) Hydrochloric acid (HCl)

Q102. CHEM

Aldehydes do NOT give a positive identification result in which of the following qualitative diagnostic tests?

- (A) 2,4-Dinitrophenylhydrazine (2,4-DNPH) test
- (B) Tollens' silver mirror test
- (C) Sodium nitroprusside test
- (D) Fehling's solution test

Q103. CHEM

In aqueous solution, the equilibrium percentage of the gem-diol hydrate form is highest for:

- (A) Propanal
- (B) Acetone (Propanone)
- (C) Formaldehyde (Methanal)
- (D) Acetaldehyde (Ethanal)

Q104. CHEM

When a carboxylic acid is heated with an excess of an alcohol in the presence of concentrated H_2SO_4 , the functional group conversion that occurs is from a:

- (A) Carboxyl group to a carbonyl group
- (B) Carboxyl group to an ester group
- (C) Carbonyl group to a carboxyl group
- (D) Carboxyl group to a hydroxyl group

Q105. CHEM

The reaction of acetic acid with thionyl chloride (SOCl_2) results in the chemical transformation of the carboxyl group into an:

- (A) Acetamide
- (B) Acid halide (Acyl chloride)
- (C) Alcohol
- (D) Ester

Q106. CHEM

The chemical reactivity and susceptibility of the carboxyl group ($-\text{COOH}$) toward nucleophilic acyl substitution is primarily due to the presence of the:

- (A) Hydroxyl group
- (B) Terminal hydrogen atom
- (C) Strongly polarized carbonyl group
- (D) Attached alkyl group

Q107. CHEM

Which two characteristic organic functional groups are present in all proteinogenic α -amino acids?

- (A) Carboxylic acid and amino groups
- (B) Amino and aldehyde groups
- (C) Ether and carboxylic acid groups
- (D) Aldehyde and carboxylic acid groups

Q108. CHEM

The total number of water molecules present in a 10.0 g piece of pure ice is approximately:

- (A) 3.34×10^{23}
- (B) 0.331×10^{23}
- (C) 33.1×10^{23}
- (D) 6.02×10^{23}

Q109. CHEM

The practical efficiency of a synthetic chemical reaction is quantitatively expressed in the laboratory as the:

- (A) Theoretical yield
- (B) Actual yield
- (C) Percent yield (% yield)
- (D) Maximum stoichiometric yield

Q110. CHEM

By international convention, one mole of any pure chemical substance contains exactly:

- (A) 6.02×10^{23} elementary entities
- (B) 6.02×10^{24} elementary entities
- (C) 6.02×10^{22} elementary entities
- (D) 3.01×10^{23} elementary entities

Q111. CHEM

According to the Aufbau principle and the $(n + l)$ energy rule, which of the following atomic subshells is filled with electrons immediately before the $4p$ subshell?

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

Q112. CHEM

If the azimuthal quantum number for a given electron subshell is $l = 1$, the permitted values for the magnetic quantum number (m) range from:

- (A) -1 to $+1$
- (B) -1 to $+2$
- (C) -1 to $+3$
- (D) -1 to $+4$

Q113. CHEM

An applied pressure of 10.0 Pascals (Pa) is equivalent to approximately:

- (A) 9.87×10^{-5} atm (0.000098 atm)
- (B) 1.98 atm
- (C) 10.019 kPa
- (D) 4.014 psi

Q114. CHEM

The dumbbell-shaped atomic orbitals (p orbitals) can be oriented along how many mutually perpendicular spatial axes?

- (A) 7
- (B) 5
- (C) 1
- (D) 3

Q115. CHEM

For any given principal energy level n , the maximum permitted value of the azimuthal quantum number (l) is defined by the mathematical relationship:

- (A) $n = l - 1$
- (B) $l = n - 2$
- (C) $l = n - 1$
- (D) $n = l - 2$

Q116. CHEM

In the kinetic molecular theory of ideal gases, the intermolecular forces of attraction and repulsion between gas molecules are assumed to be:

- (A) Very strong
- (B) Very weak but measurable
- (C) Zero
- (D) Moderately strong

Q117. CHEM

Real gases show their maximum deviation from ideal gas behavior under which of the following physical conditions?

- (A) Low temperature and low pressure
- (B) High temperature and high pressure
- (C) Low temperature and high pressure
- (D) High temperature and low pressure

Q118. CHEM

Which of the following liquids exhibits the lowest equilibrium vapor pressure at room temperature (20°C)?

- (A) Diethyl ether
- (B) Chloroform
- (C) Carbon tetrachloride
- (D) Water

Q119. CHEM

The intermolecular forces of attraction holding hydrogen molecules together in the crystalline lattice of solid molecular hydrogen (H_2) are:

- (A) Hydrogen bonds
- (B) Covalent bonds
- (C) Coordinate covalent bonds
- (D) Van der Waals (London dispersion) forces

Q120. CHEM

Which of the following substances forms a soft molecular crystalline solid with weak intermolecular forces that readily undergoes sublimation?

- (A) Ice (H_2O)
- (B) Iodine (I_2)
- (C) Cane sugar (Sucrose)
- (D) Graphite

Q121. CHEM

Which of the following solid elements possesses the strongest metallic bonding and highest melting point among the choices?

- (A) Potassium (K)
- (B) Phosphorus (P)
- (C) Calcium (Ca)
- (D) Sulfur (S)

Q122. CHEM

A rigid container with a porous wall contains an equimolar gaseous mixture of H_2 , He, N_2 , and O_2 . Which of these gases will take the MAXIMUM time to effuse out of the container?

- (A) H_2
- (B) He
- (C) N_2
- (D) O_2

PHY SECTION: PHYSICS

Questions 123 to 176 (54 MCQs)

Q123. PHY

The relative permittivity (dielectric constant, ϵ_r) of dry air at standard atmospheric pressure (1 atm) is approximately:

- (A) 1.0
- (B) 1.0006
- (C) 22.25
- (D) 2.284

Q124. PHY

In which combination of capacitors is the equivalent capacitance strictly less than the smallest individual capacitance present in the network?

- (A) Series combination
- (B) Parallel combination
- (C) Closed bridge network
- (D) Open circuit combination

Q125. PHY

According to Coulomb's law, the magnitude of the electrostatic force between two stationary point charges is directly proportional to the:

- (A) Distance separating the two point charges
- (B) Square of the distance separating the charges
- (C) Cube of the distance separating the charges
- (D) Product of the magnitudes of the two charges

Q126. PHY

When an insulating dielectric slab is inserted between the conducting plates of an isolated, charged parallel plate capacitor, its capacitance will:

- (A) Decrease
- (B) Increase
- (C) Become half
- (D) Remain unchanged

Q127. PHY

A total electric charge of 90.0 Coulombs (C) passes through the cross-section of a conducting wire in 30.0 seconds. The electric current flowing in the wire is:

- (A) 3.0 A
- (B) 0.3 A
- (C) 3.0 mA
- (D) 0.3 mA

Q128. PHY

'The magnitude of the electric current flowing through a metallic conductor is directly proportional to the potential difference across its ends, provided the physical state and temperature of the conductor remain constant.' This is the statement of:

- (A) Joule's law
- (B) Gauss's law
- (C) Ohm's law
- (D) Ampere's law

Q129. PHY

When the length of a copper wire is doubled by uniform stretching, its electrical resistivity (ρ) will:

- (A) Become double
- (B) Become half
- (C) Remain unchanged
- (D) Become four times greater

Q130. PHY

The electrical resistance of a pure intrinsic semiconductor (such as silicon or germanium) with a rise in temperature:

- (A) Increases linearly
- (B) Decreases exponentially
- (C) Remains completely unchanged
- (D) Becomes infinite

Q131. PHY

A heating coil has an electrical resistance of $10.0\ \Omega$ and is designed to operate on a 20.0 V DC supply. What total electrical energy is supplied to the heater in 10.0 seconds?

- (A) 100 J
- (B) 200 J
- (C) 300 J
- (D) 400 J

Q132. PHY

The derived SI unit of electrical resistivity (specific resistance) is:

- (A) Ω
- (B) $\Omega \cdot m$
- (C) Ω/m
- (D) m/Ω

Q133. PHY

The derived SI unit of magnetic flux (Φ_B) is the:

- (A) Weber (Wb)
- (B) Tesla (T)
- (C) Gauss (G)
- (D) Henry (H)

Q134. PHY

Magnetic flux through a surface is physically defined as the scalar (dot) product of:

- (A) Magnetic field and scalar area
- (B) Magnetic field vector and vector area
- (C) Magnetic field per unit scalar area
- (D) Magnetic field per unit vector area

Q135. PHY

The physical dimension and SI unit of magnetic field strength ($\vec{B}$) is identical to that of:

- (A) Magnetic flux density
- (B) Magnetic flux
- (C) Magnetic force
- (D) Magnetic dipole moment

Q136. PHY

At what banking angle should a curved road of radius 36.0 m be engineered so that an automobile traveling at 12.0 m/s can negotiate the turn without relying on friction? (Take $g = 9.8 \text{ m/s}^2$)

- (A) 10°
- (B) 15°
- (C) 20°
- (D) 22°

Q137. PHY

A wave generator produces 500 periodic wave pulses in a total time interval of 50.0 seconds. Its operational frequency is:

- (A) 10 s^{-1} (10 Hz)
- (B) 0.1 s^{-1}
- (C) 500 s^{-1}
- (D) 50 s^{-1}

Q138. PHY

Determine the amplitude of the transverse wave shown in the graph below:



- (A) 1 m
- (B) 2 m
- (C) 0.5 m
- (D) 0.25 m

Q139. PHY

Which of the following represents the correct ascending order of electromagnetic photon radiation arranged according to increasing photon energy?

- (A) Microwaves < Ultraviolet rays < Gamma rays
- (B) Gamma rays < Ultraviolet rays < Microwaves
- (C) Gamma rays < Microwaves < Ultraviolet rays
- (D) Ultraviolet rays < Gamma rays < Microwaves

Q140. PHY

The speed of sound in dry air at 0°C is 332 m/s. What is its speed at a temperature of 10.0°C ?

- (A) 332.0 m/s
- (B) 338.1 m/s
- (C) 332.61 m/s
- (D) 334.1 m/s

Q141. PHY

The number of complete revolutions or cycles executed per second by a rotating body is defined as its:

- (A) Linear (rotational) frequency
- (B) Angular frequency
- (C) Time period
- (D) Angular acceleration

Q142. PHY

Which of the following physical factors does NOT affect the speed of sound in air when temperature remains constant?

- (A) Density of the gas
- (B) Moisture content (humidity)
- (C) Air temperature
- (D) Static pressure of the gas

Q143. PHY

For small angular displacements, the time period of oscillation of a simple pendulum is independent of its:

- (A) Pendulum length
- (B) Amplitude of vibration
- (C) Local acceleration due to gravity g
- (D) Oscillation frequency

Q144. PHY

Mayer's relation connecting the principal molar heat capacity at constant pressure (C_p) and at constant volume (C_v) for one mole of an ideal gas is:

- (A) $C_p - C_v = R$
- (B) $C_p + C_v = R$
- (C) $C_v - C_p = R$
- (D) $R - C_v = C_p$

Q145. PHY

The mathematical equation describing the First Law of Thermodynamics for a closed system performing expansion work (W) is:

- (A) $Q = \Delta U + W$
- (B) $\Delta U = Q + W$
- (C) $W = Q + \Delta U$
- (D) $Q = W$

Q146. PHY

A thermodynamic process during which the pressure of the working substance remains strictly constant throughout is designated as an:

- (A) Isochoric process
- (B) Adiabatic process
- (C) Isobaric process
- (D) Isothermal process

Q147. PHY

A $1.0 \mu\text{F}$ capacitor in a television deflection circuit is charged to a potential difference of 4000 V. The total electrical potential energy stored within the electric field of the capacitor is:

- (A) 16.0 J
- (B) 4.0×10^{-3} J
- (C) 2.0×10^{-3} J
- (D) 8.0 J

Q148. PHY

A charged subatomic particle carrying an electric charge of $2e$ falls through an accelerating electrical potential difference of 3.0 V. The kinetic energy acquired by the particle is:

- (A) 6.0 eV
- (B) 7.0 eV
- (C) 1.5 eV
- (D) 5.0 eV

Q149. PHY

Due to the electric polarization of an insulating dielectric material placed within an external electric field, the net electric field intensity inside the dielectric:

- (A) Increases significantly
- (B) Decreases
- (C) Remains completely unchanged
- (D) Becomes exactly zero

Q150. PHY

The electromagnetic induction phenomenon in which a time-varying electric current in one electrical coil induces an electromotive force (EMF) in a nearby coupled coil is called:

- (A) Self-induction
- (B) Mutual induction
- (C) Eddy current dissipation
- (D) Choke filtering

Q151. PHY

'The induced electric current always flows in such a direction that its magnetic action opposes the change in magnetic flux that produces it.' This is the statement of:

- (A) Ampere's law
- (B) Faraday's law of electromagnetic induction
- (C) Lenz's law
- (D) Joule's law

Q152. PHY

An electrical transformer operates based on electromagnetic induction and therefore depends on the use of:

- (A) Steady direct current (DC)
- (B) Alternating current (AC)
- (C) Direct current of constant magnitude
- (D) Static electrostatic voltage

Q153. PHY

The commercial domestic alternating current (AC) electricity supply in Pakistan operates at a standardized frequency of:

- (A) 100 Hz
- (B) 50 Hz
- (C) 60 Hz
- (D) 25 Hz

Q154. PHY

An electrical power transformer functions on the fundamental physical principle of:

- (A) Self-induction
- (B) Full-wave rectification
- (C) Mutual induction
- (D) The Hall effect

Q155. PHY

The conversion of alternating current (AC) into direct current (DC) is called rectification. Which semiconductor device is primarily used as a rectifier?

- (A) Semiconductor p-n junction diode
- (B) Bipolar junction transistor
- (C) Step-down transformer
- (D) Inductor choke

Q156. PHY

The de Broglie wavelength associated with an electron accelerated through standard laboratory potential differences (approximately 50 V to 100 V) is of the order of:

- (A) Visible light
- (B) X-rays
- (C) Radio waves
- (D) Infrared radiation

Q157. PHY

Red light illumination is used in photographic darkrooms primarily because red light photons possess:

- (A) High frequency and short wavelength
- (B) Low frequency and short wavelength
- (C) Low frequency and long wavelength
- (D) High frequency and long wavelength

Q158. PHY

Which of the following visible light photons carries the highest quantum of energy?

- (A) Blue
- (B) Violet
- (C) Red
- (D) Green

Q159. PHY

In characteristic X-ray emission spectra, which electron transition produces a photon with the lowest energy and therefore the LONGEST wavelength?

- (A) K_{α}
- (B) K_{β}
- (C) K_{γ}
- (D) M_{α}

Q160. PHY

Which of the following pairs of hydrogen spectral series lies entirely within the infrared (IR) region of the electromagnetic spectrum?

- (A) Lyman and Balmer series
- (B) Balmer and Paschen series
- (C) Paschen and Brackett series
- (D) Lyman and Pfund series

Q161. PHY

The standard historical unit of radioactivity, the Curie (Ci), is defined as equivalent to exactly:

- (A) 7.3×10^{10} disintegrations/s
- (B) 3.7×10^{10} disintegrations/s
- (C) 3.7×10^7 disintegrations/s
- (D) 1.0×10^6 disintegrations/s

Q162. PHY

The spontaneous rate of radioactive disintegration ($-dN/dt$) of a sample is directly proportional to the total number of undecayed nuclei and depends on the nuclear instability of the specific:

- (A) Surrounding physical medium
- (B) Ambient atmospheric pressure
- (C) Radioisotope
- (D) Ambient temperature of the source

Q163. PHY

Clinical signs of radiation exposure such as skin erythema, epilation (hair loss), leukopenia (drop in white blood cell count), and carcinogenesis in an exposed individual are classified as:

- (A) Genetic effects of radiation
- (B) Zener breakdown effects
- (C) Somatic effects of radiation
- (D) Photomagnetic biological effects

Q164. PHY

An automobile travels along the negative y-axis and is speeding up. The direction of its acceleration vector is along the:

- (A) Positive x-axis
- (B) Negative x-axis
- (C) Positive y-axis
- (D) Negative y-axis

Q165. PHY

Linear momentum is defined as the product of mass and velocity ($\vec{p} = m\vec{v}$). Because mass is a positive scalar quantity, the momentum and velocity vectors are always:

- (A) Parallel
- (B) Perpendicular
- (C) Anti-parallel
- (D) Independent in direction

Q166. PHY

For a projectile launched on level ground with a fixed initial speed, which pair of launch angles produces the same horizontal range?

- (A) 30° and 70°
- (B) 40° and 50°
- (C) 35° and 40°
- (D) 45° and 40°

Q167. PHY

The slope of a velocity-time graph for a particle moving along a straight line represents its:

- (A) Speed
- (B) Total displacement
- (C) Acceleration
- (D) Total distance traveled

Q168. PHY

According to Newton's second law of motion, the time rate of change of linear momentum of a body is equal to the:

- (A) Net applied force
- (B) Mechanical impulse
- (C) Power developed
- (D) Inertia of the body

Q169. PHY

At what angle of projection does the horizontal range of a projectile on level ground become equal to half of its maximum possible range?

- (A) 15°
- (B) 20°
- (C) 30°
- (D) 40°

Q170. PHY

According to the work–energy theorem for translational motion, the net work done on a particle by all acting forces equals the:

- (A) Change in potential energy
- (B) Sum of kinetic and potential energies
- (C) Change in kinetic energy
- (D) Total mechanical power

Q171. PHY

A body of mass m at rest is accelerated along a smooth, frictionless horizontal surface by a constant net horizontal force F through a displacement S . The work done ($F \times S$) is converted into:

- (A) Thermal internal energy
- (B) Kinetic energy
- (C) Gravitational potential energy
- (D) Elastic potential energy

Q172. PHY

One megawatt–hour ($1 \text{ MW} \cdot \text{h}$) of electrical energy is equivalent to:

- (A) $3.6 \times 10^6 \text{ J}$
- (B) $3.6 \times 10^9 \text{ J}$
- (C) $3.6 \times 10^{12} \text{ J}$
- (D) $3.6 \times 10^3 \text{ J}$

Q173. PHY

A motorboat moves through water at a steady speed of 4.0 m/s . If the net forward propulsive force exerted by the boat's engine is 4000 N , what is the power output of the engine?

- (A) 1000 W
- (B) 160 W
- (C) 16 W
- (D) 16000 W (16 kW)

Q174. PHY

In rotational angular kinematics, one complete revolution (rotation) corresponds to an angular displacement of:

- (A) π radians
- (B) 2π radians
- (C) $\frac{\pi}{2}$ radians
- (D) $\frac{\pi}{4}$ radians

Q175. PHY

A stone of mass 1.0 kg is whirled in a horizontal circle of radius 1.0 m at a constant speed of 1.0 m/s . The time period of its circular motion is:

- (A) 4π seconds
- (B) 2π seconds
- (C) π seconds
- (D) $\frac{\pi}{2}$ seconds

Q176. PHY

The mathematical relationship between tangential linear acceleration (a) and angular acceleration (α) for a particle rotating at radius r is:

- (A) $a = r\alpha$
- (B) $a = \frac{r}{\alpha}$
- (C) $a = r^2\alpha$
- (D) $a = r\alpha^2$

ENG SECTION: ENGLISH

Questions 177 to 194 (18 MCQs)

Q177. ENGThe vocabulary word **RELUCTANT** most nearly means:

- (A) Hesitant
- (B) Current
- (C) Remarkable
- (D) Rude

Q178. ENGThe closest **SYNONYM** of the word **APPAREL** is:

- (A) Dubious
- (B) Disguise
- (C) Dress
- (D) Apron

Q179. ENGThe direct **ANTONYM** of the word **ENDEAVOUR** is:

- (A) Inaction
- (B) Inexact
- (C) Effort
- (D) Striving

Q180. ENGWhat is the direct **ANTONYM** of the word **ZEALOUS**?

- (A) Unenthusiastic
- (B) Religious
- (C) Contagious
- (D) Fanatic

Q181. ENG

Fill in the blank with the appropriate article:

'It is _____ honor for me to address you this evening.'

- (A) a
- (B) an
- (C) the
- (D) no article required

Q182. ENG

Fill in the blank with the appropriate preposition:

'He was sitting next _____ her throughout the lecture.'

- (A) with
- (B) by
- (C) to
- (D) at

Q183. ENG

Fill in the blank with the appropriate preposition:

'Each handmade article in the auction was sold _____ over a pound.'

- (A) out
- (B) at
- (C) off
- (D) in

Q184. ENGThe word **ANCESTOR** is defined as:

- (A) A collection of celestial constellations
- (B) A specialized branch of astrology
- (C) Forefathers from whom one is descended
- (D) A class of sensory biological receptors

Q185. ENGThe vocabulary word **BASHFUL** most nearly describes a person who is:

- (A) Brimful of confidence
- (B) Highly skillful
- (C) Embarrassed, shy, and socially reserved
- (D) Extremely wonderful

Q186. ENG

Choose the sentence that exhibits correct punctuation between independent clauses:

- (A) Dr. Umer has reached, Dr. Jamal has not.
- (B) Dr. Umer has reached; Dr. Jamal has not.
- (C) Dr. Umer has reached/Dr. Jamal has not.
- (D) Dr. Umer has reached: Dr. Jamal has not.

Q187. ENG

Choose the grammatically correct comparative sentence:

- (A) The population of China is much more than Pakistan.
- (B) The population of China are much more than Pakistan.
- (C) The population of China is more than Pakistan.
- (D) The population of China is much more than Pakistan's.

Q188. ENG

Choose the grammatically correct sentence with proper modifier placement:

- (A) The machine printed the stuff which was new fast.
- (B) The machine which was new printed the stuff fast.
- (C) The machine which was new printed fast the stuff.
- (D) The machine which was new printed the stuff fastly.

Q189. ENG

Choose the sentence that correctly employs the subjunctive mood for an unreal, hypothetical wish:

- (A) I wish I have been a millionaire.
- (B) I wish I am being a millionaire.
- (C) I wish I were a millionaire.
- (D) I wish I was a millionaire.

Q190. ENG

Fill in the blank with the appropriate verb tense:

'The historical town _____ its appearance completely since 1980.'

- (A) is changing
- (B) changed
- (C) has changed
- (D) changes

Q191. ENG

Fill in the blank with the appropriate future perfect continuous construction:

'By next March, we _____ here for four years.'

- (A) would had been living
- (B) would have lived
- (C) shall have been living
- (D) shall live

Q192. ENG

Fill in the blank with the appropriate verb form:

'The students, accompanied by their teacher, _____ entering the museum.'

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

Q193. ENG

Fill in the blank with the grammatically correct verb form:

'None of us _____ beyond a mile.'

- (A) gone
- (B) were gone
- (C) has gone
- (D) were go

Q194. ENG

Fill in the blank with the appropriate future perfect tense construction:

'I _____ before 10:00 p.m. tonight.'

- (A) shall have slept
- (B) shall have slept
- (C) will have sleep
- (D) shall have been slept

LOGIC SECTION: LOGICAL REASONING

Questions 195 to 200 (6 MCQs)

Q195. LOGIC

Observe the shifting marker in the sequence below:

Term 1: [Δ | _ | _ | _ | _]

Term 2: [_ | _ | Δ | _ | _]

Term 3: [_ | _ | _ | _ | Δ]

What is the logical rule governing the next term in the sequence?

- (A) The symbol shifts backward by one position
- (B) The symbol remains fixed at the terminal position
- (C) The symbol advances forward by two discrete positions in each step
- (D) The symbol alternates randomly across positions

Q196. LOGIC

A person looks at their printed shirt in a vertical plane mirror and reads: $\leq \text{WOIHA} \geq$. What text is printed on the shirt when viewed directly by an observer standing in front of them?

- (A) $\geq \text{WOIHA} \leq$
- (B) $\leq \text{AHIOW} \geq$
- (C) $\leq \text{WOIHA} \geq$
- (D) $\geq \text{AHIOW} \leq$

Q197. LOGIC

Read the passage below and evaluate the statements, basing your conclusion ONLY on the provided text:

'Pakistan is rich in wildlife and culture. It is home to many sorts of wildlife, from the Ibex to the Indus River Dolphin; and people from most countries in the world have made their home here.'

Statements:

- I. Pakistan is a wealthy country economically.
- II. People from all nationalities of the world live in Pakistan.
- III. Pakistan is home to at least one dolphin species.

Which of the conclusions logically follows?

- (A) Only statement III is correct
- (B) Only statements I and II are correct
- (C) Only statements I and III are correct
- (D) Only statements II and III are correct

Q198. LOGIC

Consider the following logical premises:

1. A ball is a sphere.
2. All spheres are round.
3. Some round things are mesmerizing.

Which of the following conclusions logically follows?

- (A) Some mesmerizing things are spheres
- (B) All balls are mesmerizing
- (C) All round things are spheres
- (D) All mesmerizing things are balls

Q199. LOGIC

Analyze the two factual statements below and determine the logical cause-and-effect relationship between them:

Statement I: There is a sharp decline in the domestic agricultural production of oilseeds this year.

Statement II: The Government has decided to significantly increase the import quantum of edible oil.

- (A) Statement I is the direct cause and Statement II is its logical effect
- (B) Statement II is the cause and Statement I is its effect
- (C) Both statements are independent causes
- (D) Both statements are effects of independent causes

Q200. LOGIC

Read the statement and evaluate which of the suggested courses of action logically follows and is worth pursuing:

Statement: Employees in an office are arriving to work more than 5 minutes late every single day.

Courses of Action:

- I. Impose an immediate strict penalty of deducting half a day's salary every single time an employee is late by even a few minutes.
- II. Introduce a 15-minute buffer allowance, and dock one day's pay only if an employee exceeds this buffer more than twice in a calendar month.

- (A) Only Course of Action I logically follows
- (B) Only Course of Action II logically follows
- (C) Both Courses of Action I and II logically follow
- (D) Neither Course of Action I nor II logically follows

OFFICIAL VERIFIED ANSWER KEY

SZABMU Islamabad MDCAT 2023 Official Paper • Rapid Self-Grading Grid

[Online Portal >](#)

Q#	KEY	SUB	Q#	KEY	SUB	Q#	KEY	SUB	Q#	KEY	SUB	Q#	KEY	SUB
1	A	BIO	41	A	BIO	81	D	CHEM	121	C	CHEM	161	B	PHY
2	C	BIO	42	B	BIO	82	B	CHEM	122	D	CHEM	162	C	PHY
3	B	BIO	43	C	BIO	83	D	CHEM	123	B	PHY	163	C	PHY
4	A	BIO	44	D	BIO	84	B	CHEM	124	A	PHY	164	D	PHY
5	A	BIO	45	A	BIO	85	D	CHEM	125	D	PHY	165	A	PHY
6	D	BIO	46	A	BIO	86	A	CHEM	126	B	PHY	166	B	PHY
7	B	BIO	47	B	BIO	87	B	CHEM	127	A	PHY	167	C	PHY
8	D	BIO	48	A	BIO	88	C	CHEM	128	C	PHY	168	A	PHY
9	D	BIO	49	C	BIO	89	A	CHEM	129	C	PHY	169	A	PHY
10	D	BIO	50	D	BIO	90	B	CHEM	130	B	PHY	170	C	PHY
11	A	BIO	51	C	BIO	91	A	CHEM	131	D	PHY	171	B	PHY
12	C	BIO	52	B	BIO	92	D	CHEM	132	B	PHY	172	B	PHY
13	B	BIO	53	B	BIO	93	B	CHEM	133	A	PHY	173	D	PHY
14	B	BIO	54	A	BIO	94	B	CHEM	134	B	PHY	174	B	PHY
15	B	BIO	55	B	BIO	95	A	CHEM	135	A	PHY	175	B	PHY
16	C	BIO	56	D	BIO	96	B	CHEM	136	D	PHY	176	A	PHY
17	D	BIO	57	D	BIO	97	D	CHEM	137	A	PHY	177	A	ENG
18	B	BIO	58	B	BIO	98	B	CHEM	138	A	PHY	178	C	ENG
19	D	BIO	59	C	BIO	99	A	CHEM	139	A	PHY	179	A	ENG
20	B	BIO	60	B	BIO	100	B	CHEM	140	B	PHY	180	A	ENG
21	B	BIO	61	A	BIO	101	D	CHEM	141	A	PHY	181	B	ENG
22	C	BIO	62	C	BIO	102	C	CHEM	142	D	PHY	182	C	ENG
23	A	BIO	63	B	BIO	103	C	CHEM	143	B	PHY	183	B	ENG
24	A	BIO	64	B	BIO	104	B	CHEM	144	A	PHY	184	C	ENG
25	D	BIO	65	D	BIO	105	B	CHEM	145	A	PHY	185	C	ENG
26	A	BIO	66	D	BIO	106	C	CHEM	146	C	PHY	186	B	ENG
27	B	BIO	67	B	BIO	107	A	CHEM	147	D	PHY	187	D	ENG
28	C	BIO	68	C	BIO	108	A	CHEM	148	A	PHY	188	B	ENG
29	D	BIO	69	B	CHEM	109	C	CHEM	149	B	PHY	189	C	ENG
30	D	BIO	70	D	CHEM	110	A	CHEM	150	B	PHY	190	C	ENG
31	C	BIO	71	A	CHEM	111	C	CHEM	151	C	PHY	191	C	ENG
32	D	BIO	72	D	CHEM	112	A	CHEM	152	B	PHY	192	C	ENG
33	B	BIO	73	C	CHEM	113	A	CHEM	153	B	PHY	193	C	ENG
34	C	BIO	74	D	CHEM	114	D	CHEM	154	C	PHY	194	B	ENG
35	B	BIO	75	B	CHEM	115	C	CHEM	155	A	PHY	195	C	LOGIC
36	B	BIO	76	A	CHEM	116	C	CHEM	156	B	PHY	196	B	LOGIC
37	B	BIO	77	C	CHEM	117	C	CHEM	157	C	PHY	197	A	LOGIC
38	D	BIO	78	B	CHEM	118	D	CHEM	158	B	PHY	198	A	LOGIC
39	C	BIO	79	A	CHEM	119	D	CHEM	159	D	PHY	199	A	LOGIC
40	D	BIO	80	A	CHEM	120	B	CHEM	160	C	PHY	200	B	LOGIC

SUBJECT-WISE PERFORMANCE BREAKDOWN

SUBJECT	MAX	YOUR SCORE	ACCURACY
Biology	68		----- %
Chemistry	54		----- %
Physics	54		----- %
English	18		----- %
Logical Reasoning	6		----- %
TOTAL	200		----- %

PMDC PROVINCIAL MERIT FORMULA

Official Weightage Law:

- MDCAT Component (50%): (Your Score / 200) × 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: (A)

BIOLOGY
03. Enzymes

A non-protein, inorganic, and detachable cofactor required by an enzyme for its activity is called...

CORE CONCEPT & DERIVATION

Enzyme cofactors are non-protein chemical components required for biological catalysis; inorganic ions that detach easily are specifically defined as activators.

Formula / Rule / Reaction:

Conjugate Enzyme (Holoenzyme) = Apoenzyme (Protein) + Cofactor (Non-protein)

Solution:

- Cofactors are classified into three distinct categories based on their chemical nature and bonding affinity.
- Inorganic ions (such as Mg^{2+} , Fe^{2+} , or Zn^{2+}) that are loosely bound and detachable from the enzyme protein are termed activators.
- Organic detachable molecules are coenzymes, whereas permanently attached organic groups are prosthetic groups. Therefore, Option A is correct.

Why other options are incorrect:

- Option B:** A prosthetic group is an organic cofactor that is covalently or permanently bound to the apoenzyme.
- Option C:** A coenzyme is an organic non-protein cofactor derived mainly from vitamins, not an inorganic ion.
- Option D:** An apoenzyme is the purely protein portion of an enzyme that remains inactive without its cofactor.

Question #2 Key: (C)

BIOLOGY
03. Enzymes

The Lock and Key Model for enzyme action, proposed by Emil Fischer in 1894, suggests that:

CORE CONCEPT & DERIVATION

Emil Fischer proposed that the enzyme active site possesses a rigid, pre-shaped geometric conformation complementary only to its specific substrate.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Fischer compared the enzyme active site to a lock and the substrate to a key.
- Because the active site is viewed as an unyielding, pre-formed template that undergoes no structural alteration, an enzyme can accommodate only one specific substrate configuration.
- This rigidity restricts the enzyme to a single reaction pathway, making Option C the correct choice.

Why other options are incorrect:

- Option A:** Enzymes exhibit high specificity and are never unbiased toward arbitrary substrates.
- Option B:** Active site conformational flexibility is the central postulate of Koshland's Induced Fit Model, not Fischer's Lock and Key Model.
- Option D:** Fischer's model rejects broad catalytic flexibility because an inflexible active site cannot bind diverse chemical substrates.

Question #3 Key: (B)BIOLOGY
03. Enzymes

Enzymes accelerate chemical reactions by lowering the _____ of the substrate molecules:

CORE CONCEPT & DERIVATION

Enzymes increase reaction velocity exclusively by reducing the minimum energy barrier needed to reach the transition state.

Formula / Rule / Reaction:

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

Solution:

- Activation energy (E_a) is the minimum kinetic energy reacting molecules must possess to overcome the transition state barrier.
- Enzymes stabilize the transition state through specific interactions at the active site, lowering E_a .
- They do not change the net free energy change (ΔG) or the intrinsic kinetic energy of the reactants. Hence, Option B is correct.

Why other options are incorrect:

- **Option A:** Kinetic energy depends strictly on system temperature and is not decreased by enzymes.
- **Option C:** Enzymes do not lower thermal energy; they function under isothermal biological conditions.
- **Option D:** The initial and final potential energy levels of reactants and products remain unaffected by catalyst presence.

Question #4 Key: (A)BIOLOGY
15. Inheritance / Variation & Genetics

The allele frequency of a newly arisen mutant gene in a natural population is most likely to in...

CORE CONCEPT & DERIVATION

Natural selection acts directly on phenotypic fitness, promoting alleles that improve survival and reproductive success.

Formula / Rule / Reaction:

$$\Delta q = \frac{sq^2(1-q)}{1-sq^2}$$

Solution:

- An allele's frequency rises systematically across generations when it confers a positive selection coefficient ($s > 0$).
- Dominance alone does not cause an allele to increase in frequency; natural selection requires differential reproductive success.
- Sex linkage and population expansion do not inherently favor allele retention or propagation without selective advantage. Option A is correct.

Why other options are incorrect:

- **Option B:** Dominance affects phenotypic expression in heterozygotes but does not alter reproductive fitness by itself.
- **Option C:** Sex linkage influences inheritance ratios across sexes but does not dictate positive directional selection.
- **Option D:** A larger population buffers against genetic drift but does not drive a specific mutant allele to higher frequency without selective advantage.

Question #5 Key: (A)BIOLOGY
16. Evolution

Which of the following statements is NOT consistent with Charles Darwin's theory of natural sel...

CORE CONCEPT & DERIVATION

Darwinian natural selection is fundamentally non-random; survival and reproductive output depend on hereditary variations conferring environmental fitness.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Darwin's theory is built on overproduction, struggle for existence, variation, and differential survival.
- Survival in the struggle for existence is non-random because individuals with advantageous adaptations are preferentially preserved.
- Stating that survival is entirely random describes genetic drift, which contradicts the core principle of natural selection. Option A is the false statement.

Why other options are incorrect:

- **Option B:** Fitter individuals possessing adaptive traits leave more offspring, which is an accurate tenet of Darwinism.
- **Option C:** Differential reproductive success causing gradual modification of populations over time correctly describes Darwinian descent with modification.
- **Option D:** Gradual accumulation of favorable traits across generations leading to speciation is Darwin's central evolutionary mechanism.

Question #6 Key: (D)BIOLOGY
16. Evolution

A mathematical equation used to calculate the frequencies of alleles and genotypes in a non-evo...

CORE CONCEPT & DERIVATION

The Hardy-Weinberg law states that allele and genotype frequencies in a large, randomly mating diploid population remain constant in the absence of evolutionary forces.

Formula / Rule / Reaction:

$$p + q = 1, \quad p^2 + 2pq + q^2 = 1$$

Solution:

- In 1908, English mathematician G. H. Hardy and German physician W. Weinberg independently developed the binomial formulation for population genetics.
- The equation tracks homozygous dominant (p^2), heterozygous ($2pq$), and homozygous recessive (q^2) genotypic frequencies based on allelic frequencies p and q .
- Therefore, Option D is the correct historical and scientific choice.

Why other options are incorrect:

- **Option A:** Linnaeus established the binomial system of taxonomic nomenclature, not population genetics equations.
- **Option B:** Lamarck proposed the inheritance of acquired characteristics, not quantitative population models.
- **Option C:** Darwin formulated natural selection qualitatively without mathematical models of allele frequencies.

Question #7 Key: (B)BIOLOGY
16. Evolution

When humans purposefully apply selective pressure to breed plants or animals with desired chara...

CORE CONCEPT & DERIVATION

Artificial selection involves intentional human intervention in reproductive pairings to enrich specific economic or aesthetic traits in domesticated species.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Unlike natural selection where environmental conditions determine survival, artificial selection relies on human choice.
- Plant crops (e.g., modern wheat, brassicas) and animal breeds (e.g., dogs, cattle) are products of repeated artificial selection.
- Hence, Option B is correct.

Why other options are incorrect:

- **Option A:** Natural selection operates via abiotic and biotic environmental pressures without conscious human intent.
- **Option C:** Genetic drift refers to stochastic, random fluctuations in allele frequencies in finite populations.
- **Option D:** Speciation is the evolutionary splitting of ancestral lineages into distinct, reproductively isolated species.

Question #8 Key: (D)BIOLOGY
08. Immunity

Which of the following is NOT a direct biological characteristic or action of interferons?

CORE CONCEPT & DERIVATION

Interferons are antiviral signaling cytokines produced by infected host cells; they regulate immune cells but do not secrete other cytokines such as interleukins.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Interferons (α , β , γ) are low-molecular-weight regulatory glycoproteins released in response to viral invasion.
- They bind to cell surface receptors on neighboring cells, induce protein kinase R (PKR) and 2'-5'-oligoadenylate synthetase, and activate NK cells and cytotoxic T lymphocytes.
- Interferons are signaling molecules; they cannot synthesize or secrete interleukins (which are secreted by leukocytes such as helper T cells and macrophages).
- Thus, Option D is NOT a direct action of interferons. (Note: Some preliminary keys erroneously highlighted classification categories, but direct cytokine secretion is biologically invalid for a cytokine molecule).

Why other options are incorrect:

- **Option A:** Interferons are cytokines, making this a true statement.
- **Option B:** Type I and Type II interferons stimulate cytotoxic activity of natural killer cells, making this a true action.
- **Option C:** Interferons upregulate MHC class I and II expression to activate antigen-presenting and immune cells, making this a true action.

Question #9 Key: (D)BIOLOGY
06. Digestion/Nutrition

Which of the following proteolytic enzymes is NOT secreted as an inactive zymogen precursor?

CORE CONCEPT & DERIVATION

Potent endopeptidases are secreted as inactive zymogens to prevent autolysis, whereas intestinal brush-border exopeptidases (erepsin) are released in their active forms.

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

- Pepsin is secreted by chief cells as pepsinogen (activated by HCl).
- Trypsin and chymotrypsin are secreted by the pancreas as trypsinogen and chymotrypsinogen (activated by enterokinase and trypsin).
- Erepsin is a traditional term for the mixture of intestinal peptidases (such as dipeptidases and aminopeptidases) secreted in active form in succus entericus. Hence, Option D is correct.

Why other options are incorrect:

- **Option A:** Chymotrypsin is secreted as the inactive proenzyme chymotrypsinogen.
- **Option B:** Pepsin is secreted as inactive pepsinogen into gastric juice.
- **Option C:** Trypsin is secreted as inactive trypsinogen from pancreatic acinar cells.

Question #10 Key: (D)BIOLOGY
07. Circulation / Transport

In the human cardiovascular system, the left atrium receives oxygen-rich blood directly from:

CORE CONCEPT & DERIVATION

Pulmonary circulation terminates at the left atrium, which receives oxygenated blood from the pulmonary capillary beds via four pulmonary veins.

Formula / Rule / Reaction:

Right Ventricle → Pulmonary Trunk → Lungs → 4 Pulmonary Veins → Left Atrium

Solution:

- Two pulmonary veins emerge from each lung (left superior, left inferior, right superior, right inferior).
- All four vessels enter the posterior wall of the left atrium through separate valveless ostia.
- Therefore, Option D is the correct anatomical answer.

Why other options are incorrect:

- **Option A:** The superior vena cava returns deoxygenated systemic venous blood to the right atrium.
- **Option B:** The aorta originates from the left ventricle to distribute systemic arterial blood.
- **Option C:** The inferior vena cava drains deoxygenated blood from the lower body into the right atrium.

Question #11 Key: (A)BIOLOGY
07. Circulation / Transport

Choose the correct anatomical pathway for the microvascular flow of blood through a capillary bed...

CORE CONCEPT & DERIVATION

Microcirculation proceeds from terminal arterioles into metarterioles, which feed central thoroughfare channels and branching true capillary networks.

Formula / Rule / Reaction:

Terminal Arteriole → Metarteriole → Thoroughfare Channel / Capillaries → Postcapillary Venule

Solution:

- Terminal muscular arterioles branch into intermediate metarterioles containing discontinuous smooth muscle cuffs.
- Metarterioles lead into central thoroughfare channels, from which true capillaries branch out controlled by precapillary sphincters.
- Option A matches this microvascular order.

Why other options are incorrect:

- **Option B:** This reverses the physiological direction of blood flow.
- **Option C:** Thoroughfare channels receive blood from metarterioles, not prior to them.
- **Option D:** Arterioles deliver blood into metarterioles, not the reverse.

Question #12 Key: (C)BIOLOGY
07. Circulation / Transport

Regarding the internal anatomy of the human heart, chordae tendineae are located exclusively wi...

CORE CONCEPT & DERIVATION

Chordae tendineae are collagenous fibrous cords anchored within the ventricular cavities that prevent atrioventricular valve eversion during systole.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Chordae tendineae connect the free margins of the tricuspid and mitral valve cusps to papillary muscles located on the ventricular walls.
- When the ventricles contract during systole, papillary muscles contract simultaneously, pulling the cords taut to prevent cusps from prolapsing into the atria.
- Because both papillary muscles and chordae tendineae reside inside the ventricular lumens, Option C is correct.

Why other options are incorrect:

- **Option A:** Atria lack papillary muscles and chordae tendineae; their inner walls feature pectinate muscles.
- **Option B:** Semilunar valves (pulmonary valve) possess pocket-like cusps that close by back-pressure without chordae tendineae.
- **Option D:** The aortic valve is a semilunar valve devoid of chordae tendineae attachments.

Question #13 Key: (B)BIOLOGY
01. Cell

In intestinal mucosal enterocytes, chylomicrons are synthesized by the assembly of:

CORE CONCEPT & DERIVATION

Chylomicrons are large lipoprotein complexes synthesized in enterocytes to package re-esterified triglycerides with specific apolipoproteins for lymphatic export.

Formula / Rule / Reaction:

Dietary Lipids (Triglycerides + Cholesterol) + Apoproteins (e.g., Apo B-48) → Chylomicrons

Solution:

- Absorbed monoglycerides and free fatty acids are resynthesized into triglycerides in the smooth endoplasmic reticulum of enterocytes.
- These hydrophobic lipid cores are packaged with phospholipids, free cholesterol, and apolipoproteins (predominantly Apo B-48) in the Golgi apparatus.
- Thus, chylomicrons are defined as lipoprotein particles composed of fats and proteins. Option B is correct.

Why other options are incorrect:

- **Option A:** Chylomicrons do not contain significant structural carbohydrates; they are primarily lipid transport vehicles.
- **Option C:** Lipoproteins require protein coats (apolipoproteins) for structural stability and receptor-mediated uptake.
- **Option D:** Fat-soluble vitamins dissolve within chylomicrons, but structural apolipoproteins are mandatory for particle assembly.

Question #14 Key: (B)BIOLOGY
07. Circulation / Transport

The pathway of symplastic water transport in plant roots involves movement from cell to cell vi...

CORE CONCEPT & DERIVATION

The symplast represents the continuous network of living plant protoplasm interconnected across cell boundaries by plasmodesmata.

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

- Water and dissolved solutes enter root hair cytoplasm by crossing the plasma membrane once.
- Movement then proceeds through cytoplasmic strands running through cell wall apertures known as plasmodesmata without crossing intervening plasma membranes repeatedly.
- This designates the symplast pathway, making Option B the correct choice.

Why other options are incorrect:

- **Option A:** Water movement through non-living cell walls and intercellular spaces constitutes the apoplast pathway.
- **Option C:** Movement through vacuolar membranes represents the vacuolar (transcellular) pathway.
- **Option D:** Tracheary elements mediate bulk flow along vascular bundles, not cell-to-cell root radial transport.

Question #15 Key: (B)BIOLOGY
14. Reproduction

In a typical bacterial batch culture growth curve, cells divide at their maximal, constant geom...

CORE CONCEPT & DERIVATION

During the logarithmic (exponential) phase, bacterial cells adapt to their medium, achieve metabolic balance, and divide by binary fission at a maximal rate.

Formula / Rule / Reaction:

$$N_t = N_0 \cdot 2^n, \quad n = \frac{t}{g}$$

Solution:

- The log phase displays a linear increase when plotted as log(cell count) versus time.
- Nutrient availability is optimal, waste accumulation is sub-toxic, and generation time is minimized.
- Therefore, exponential division occurs exclusively in the log phase, validating Option B.

Why other options are incorrect:

- **Option A:** The lag phase involves physiological adaptation and enzyme synthesis with no net population increase.
- **Option C:** In the stationary phase, cell division rate equals cell death rate due to nutrient depletion and toxic waste accumulation.
- **Option D:** In the decline (death) phase, the rate of cell mortality exceeds any residual cell division.

Question #16 Key: (C)BIOLOGY
01. Cell

The unique macromolecule that forms the rigid structural framework of the eubacterial cell wall...

CORE CONCEPT & DERIVATION

Peptidoglycan (murein) is a complex polymer unique to domain Bacteria that provides osmotic structural stability to the cell wall.

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

- The bacterial cell wall consists of alternating aminosugar glycan chains (NAG and NAM).
- These chains are covalently cross-linked via tetrapeptide side chains attached to NAM residues.
- This structure is exclusive to eubacteria and absent in eukaryotes and archaea. Hence, Option C is correct.

Why other options are incorrect:

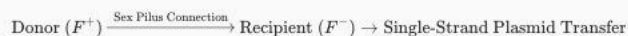
- **Option A:** Cellulose forms plant and algal cell walls, consisting of unbranched $\beta(1 \rightarrow 4)$ -glucan chains.
- **Option B:** Chitin constitutes fungal cell walls and arthropod exoskeletons, made of *N*-acetylglucosamine homopolymers.
- **Option D:** Cholesterol is a eukaryotic membrane steroid and is absent from bacterial walls and prokaryotic membranes.

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

In bacteria, specialized hollow proteinaceous surface appendages known as pili function primarily...

CORE CONCEPT & DERIVATION

Sex pili (F-pili) mediate bacterial conjugation by establishing physical bridges between donor and recipient cells for plasmid DNA transfer.

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

- Pili are composed of the tubular oligomeric protein pilin.
- Sex pili encoded by fertility plasmids attach to specific outer membrane receptors of recipient bacteria.
- Depolymerization brings the cells into close contact to enable conjugative genetic exchange, making Option D correct.

Why other options are incorrect:

- **Option A:** Bacterial swimming motility is driven by flagellar rotation; normal pili (fimbriae) mediate adhesion.
- **Option B:** Membrane degradation is executed by secreted bacterial toxins and lipases, not pili.
- **Option C:** Pili do not possess intrinsic protease activity to degrade host enzymes.

Question #18 Key: (B)BIOLOGY
01. Cell

Which of the following lipid components is normally ABSENT from the plasma membrane of typical...

CORE CONCEPT & DERIVATION

Unlike eukaryotic cell membranes, prokaryotic plasma membranes lack sterols such as cholesterol, utilizing hopanoids instead for stability.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Bacterial cell membranes are lipid bilayers primarily composed of glycerol phospholipids and associated functional proteins.
- With the exception of wall-less *Mycoplasma* species that scavenge sterols from host tissue, bacteria do not synthesize cholesterol.
- Instead, they synthesize pentacyclic hopanoids to modulate membrane rigidity and permeability. Thus, Option B is correct.

Why other options are incorrect:

- **Option A:** Glycolipids are abundant components of prokaryotic outer and cytoplasmic membranes.
- **Option C:** Membrane proteins in bacteria can be glycosylated, forming functional glycoproteins.
- **Option D:** Phospholipids (such as phosphatidylethanolamine and phosphatidylglycerol) form the primary bilayer matrix of all prokaryotic membranes.

Question #19 Key: (D)BIOLOGY
01. Cell

Which of the following cellular processes is NOT performed by lysosomes?

CORE CONCEPT & DERIVATION

Lysosomes specialize in acid-hydrolase-mediated catabolic degradation; the chemical processing and packaging of secretory proteins is the function of the Golgi apparatus.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Lysosomes maintain an acidic internal lumen (pH 4.5 to 5.0) packed with hydrolytic enzymes.
- Their functions include digesting phagocytosed foreign material (heterophagy), recycling intracellular organelles (autophagy), and programmed cell destruction (autolysis).
- Post-translational modification, sorting, and packaging of secretory cargo are functions of the rough ER and Golgi cisternae. Option D is correct.

Why other options are incorrect:

- **Option A:** Digestion of phagocytosed food vacuoles or pathogens is a primary lysosomal function.
- **Option B:** Fusion with autophagosomes to recycle damaged mitochondria or peroxisomes is a classical lysosomal pathway.
- **Option C:** Programmed rupture of lysosomal membranes causing cellular self-destruction (autolysis) occurs during developmental remodeling and tissue injury.

Question #20 Key: (B)BIOLOGY
01. Cell

The peripheral zone of the cytoplasm in many eukaryotic cells (ectoplasm) exhibits a physical c...

CORE CONCEPT & DERIVATION

Cytoplasm exhibits colloidal sol-gel reversibility; the outer peripheral ectoplasm contains cross-linked actin microfilaments that keep it in a viscous gel state.

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

- The cytoplasm is organized into an inner, fluid endoplasm (sol state) and an outer, rigid cortical ectoplasm (gel state).
- The gel state of the peripheral cytoplasm provides structural mechanical support and drives pseudopodial amoeboid crawling through sol-gel transformations.
- Therefore, Option B accurately identifies the physical consistency of the peripheral cytoplasm.

Why other options are incorrect:

- Option A:** The fluid sol state characterizes the inner core of the cell (endoplasm), where organelle streaming occurs.
- Option C:** The cytoplasm is a complex colloidal system containing heterogeneous macromolecular aggregates, not a homogenous true solution.
- Option D:** Biological cytoplasm is a colloidal system with particles between 1 nm and 100 nm, not an unstable coarse suspension.

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

The single semipermeable biological membrane that separates the plant central vacuole from the ...

CORE CONCEPT & DERIVATION

The tonoplast is the specialized lipid bilayer enclosing the plant cell central vacuole, regulating turgor and selective ion transport.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The large central vacuole is bounded by a single selectively permeable unit membrane named the tonoplast (vacuolar membrane).
- It contains active V-type H^+ -ATPases and secondary active antiporters that accumulate solutes within the cell sap, maintaining cellular turgor.
- Option B is the precise biological term.

Why other options are incorrect:

- Option A:** Cristae are inner membrane folds of mitochondria containing respiratory complexes.
- Option C:** Cisternae are flattened, membrane-bound saccules of the endoplasmic reticulum and Golgi complex.
- Option D:** Mesosomes are artifactual infoldings of prokaryotic plasma membranes.

Question #22 Key: (C)BIOLOGY
01. Cell

Which biochemical component of the fluid mosaic model primarily determines and modulates membra...

CORE CONCEPT & DERIVATION

Membrane fluidity is governed by the chemical composition of the lipid bilayer, specifically the ratio of unsaturated to saturated fatty acids and the abundance of cholesterol.

Formula / Rule / Reaction:

$$\text{Fluidity} \propto \frac{\text{Unsaturated Fatty Acyl Chains} + \text{Optimal Sterols}}{\text{Saturated Acyl Chains} + \text{Low Temperature}}$$

Solution:

- Phospholipid acyl chains provide the dynamic hydrocarbon matrix that allows lateral diffusion of membrane constituents.
- Cis-double bonds in unsaturated fatty acids introduce kinks that inhibit close hydrocarbon packing, preventing freezing at lower temperatures.
- Cholesterol intercalates between phospholipids to prevent tight packaging at low temperatures and reduce excessive motion at high temperatures.
- Because both phospholipids and cholesterol belong to the lipid category, Option C is correct.

Why other options are incorrect:

- Option A:** Glycoproteins act as receptors and cell recognition ligands, without controlling structural bilayer fluidity.
- Option B:** Carrier proteins mediate transmembrane solute transport, moving within the lipid bilayer rather than dictating its fluidity.
- Option D:** Surface carbohydrates form the protective exterior glycocalyx without modulating the interior viscosity of the lipid core.

Question #23 Key: (A)BIOLOGY
12. Nervous Coordination

The microscopic functional junction between the terminal axonal branch of a neuron and the dend...

CORE CONCEPT & DERIVATION

A synapse is the specialized intercellular junction across which action potentials are transmitted unidirectionally via chemical neurotransmitters or electrical gap junctions.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- A chemical synapse consists of a presynaptic terminal, a narrow synaptic cleft (20 to 30 nm), and a postsynaptic membrane containing specific receptors.
- Neurotransmitters released from presynaptic vesicles diffuse across the cleft to alter the postsynaptic membrane potential.
- Option A is the accurate term for this communicative contact point.

Why other options are incorrect:

- **Option B:** Nissl bodies (chromophilic substances) are granular aggregates of rough endoplasmic reticulum and free ribosomes in the perikaryon.
- **Option C:** Neuroglia provide non-conducting physical, nutritive, and insulation support to neurons rather than forming communicative synaptic links.
- **Option D:** Gaps in the myelin sheath are known as Nodes of Ranvier, which enable saltatory nerve impulse conduction along a single axon.

Question #24 Key: (A)BIOLOGY
13. Chemical Coordination

Which of the following physiological mechanisms operates through a positive feedback control lo...

CORE CONCEPT & DERIVATION

Positive feedback amplifies the initial physiological perturbation, driving a directional response to a defined physiological endpoint rather than maintaining homeostatic equilibrium.

Formula / Rule / Reaction:

Cervical Stretch → Hypothalamic Oxytocin → Stronger Contractions → Increased Stre...

Solution:

- The Ferguson reflex during parturition is a classic positive feedback mechanism.
- Fetal engagement stretches the uterine cervix, firing mechanoreceptors that send sensory impulses to the hypothalamus.
- The posterior pituitary releases oxytocin, which stimulates stronger myometrial contractions, driving the fetus further into the cervix.
- This self-amplifying cycle continues until birth is complete. Option A is correct.

Why other options are incorrect:

- **Option B:** Thermoregulation uses negative feedback via the hypothalamus to counteract deviations from the 37 °C set point.
- **Option C:** Insulin release reduces elevated blood glucose back to normal levels, exemplifying negative feedback.
- **Option D:** Thyroxine secretion is governed by the hypothalamic-pituitary-thyroid axis via negative feedback inhibition of TRH and TSH.

Question #25 Key: (D)BIOLOGY
13. Chemical Coordination

Which neuroendocrine hormone is synthesized by the hypothalamus and released from the posterior...

CORE CONCEPT & DERIVATION

Oxytocin is a nonapeptide hormone produced in the paraventricular and supraoptic nuclei of the hypothalamus and stored in the neurohypophysis to stimulate smooth muscle contraction.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- During parturition, oxytocin binds to G_q -protein coupled receptors on myometrial smooth muscle cells, activating the phospholipase C pathway to induce forceful contractions.
- In lactating mothers, infant suckling triggers the milk-ejection reflex, stimulating oxytocin release to contract mammary myoepithelial cells.
- Option D is correct.

Why other options are incorrect:

- **Option A:** Estrogen is a steroid hormone synthesized primarily by ovarian granulosa cells and placenta.
- **Option B:** Progesterone is a steroid hormone secreted by the corpus luteum and placenta that inhibits myometrial contractility.
- **Option C:** Calcitonin is a peptide hormone secreted by thyroid parafollicular (C) cells to lower blood calcium levels.

Question #26 Key: (A)BIOLOGY
12. Nervous Coordination

During the non-conducting resting potential state of an axon, the neural membrane exhibits sele...

CORE CONCEPT & DERIVATION

The negative resting membrane potential is generated primarily by the passive diffusion of K^+ down its concentration gradient through open non-gated potassium leak channels.

Formula / Rule / Reaction:

$$E_K = \frac{RT}{zF} \ln \left(\frac{[K^+]_{out}}{[K^+]_{in}} \right) \approx -90 \text{ mV}$$

Solution:

- At rest, the neuronal membrane possesses far more open K^+ leak channels than Na^+ leak channels (permeability ratio approximately 25:1 to 50:1).
- Because intracellular K^+ concentration is high (established by Na^+/K^+ -ATPase pumps), K^+ continuously diffuses outward.
- This selective outward movement leaves behind nondiffusible organic anions, generating the negative resting potential (-70 mV). Option A is correct.

Why other options are incorrect:

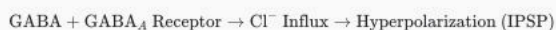
- **Option B:** Sodium voltage-gated channels are closed at rest; membrane permeability to Na^+ influx is minimal.
- **Option C:** Calcium channels remain closed at resting potential, maintaining a low cytosolic Ca^{2+} concentration.
- **Option D:** Chloride ions do not drive resting potential generation; the resting membrane permeability to K^+ dominates.

Question #27 Key: (B)BIOLOGY
12. Nervous Coordination

Gamma-aminobutyric acid (GABA) is an important chemical messenger in the mammalian brain that a...

CORE CONCEPT & DERIVATION

GABA is the principal inhibitory neurotransmitter of the vertebrate central nervous system, mediating postsynaptic membrane hyperpolarization.

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

- GABA is synthesized from glutamate via the enzyme glutamate decarboxylase.
- Binding of GABA to ionotropic GABA_A receptors opens ligand-gated chloride channels, causing Cl^- influx into the postsynaptic neuron.
- This shifts the membrane potential further from the excitation threshold, inhibiting action potential generation. Option B is correct.

Why other options are incorrect:

- **Option A:** GABA is a low-molecular-weight amino acid derivative, not an enzyme.
- **Option C:** Glutamate and acetylcholine are classic excitatory neurotransmitters; GABA is typically inhibitory.
- **Option D:** GABA acts locally across synaptic junctions and is not a circulating endocrine steroid hormone.

Question #28 Key: (C)BIOLOGY
12. Nervous Coordination

What is the normal physiological fate of neurotransmitter molecules immediately following the s...

CORE CONCEPT & DERIVATION

Rapid clearance of neurotransmitters from the synaptic cleft via enzymatic cleavage or presynaptic reuptake is essential to terminate signaling and enable new impulse transmission.

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

- Continuous presence of neurotransmitters in the synaptic cleft would cause receptor desensitization and uncontrollable tetanic firing.
- Neurotransmitters are promptly cleared via enzymatic hydrolysis (e.g., acetylcholine broken down by acetylcholinesterase) or high-affinity reuptake transporters into the presynaptic terminal (e.g., serotonin, dopamine, norepinephrine).
- Option C correctly identifies this mechanism.

Why other options are incorrect:

- **Option A:** Neurotransmitter-receptor binding is non-covalent, reversible, and brief.
- **Option B:** Prolonged persistence in the cleft causes receptor desensitization and pathological neurotoxicity.
- **Option D:** Neurotransmitters bind to cell-surface receptors and are not targeted to the postsynaptic nucleus.

Question #29 Key: (D)BIOLOGY
10. Homeostasis

Advanced physiological homeostasis maintained through complex negative feedback mechanisms is a...

CORE CONCEPT & DERIVATION

Endothermy and homeothermy require homeostatic regulatory networks, which achieve their highest physiological complexity in Class Mammalia.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Fishes, amphibians, and reptiles are ectotherms whose internal body temperatures track their thermal surroundings.
- Mammals maintain constant internal conditions (body temperature, blood osmolarity, blood glucose, arterial pH) through the autonomic nervous system and neuroendocrine axes.
- Option D is the intended evolutionary group.

Why other options are incorrect:

- **Option A:** Class Pisces contains poikilothermic, ectothermic aquatic vertebrates with variable core body temperatures.
- **Option B:** Class Amphibia consists of ectothermic animals lacking advanced autonomic thermoregulatory loops.
- **Option C:** Class Reptilia features ectothermic physiology dependent on behavioral thermoregulation rather than internal autonomic feedback.

Question #30 Key: (D)BIOLOGY
01. Cell

Which of the following biological statements is TRUE regarding organisms of the genus *Amoeba*?

CORE CONCEPT & DERIVATION

Amoebae are unicellular sarcodine protozoans that move and capture prey by extending actin-driven cytoplasmic projections called pseudopodia.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Amoebae lack fixed pellicles or rigid cell walls; their shape changes continuously.
- They form blunt, lobose pseudopodia through dynamic sol-gel actin microfilament transformations in the cytoplasm.
- Option D is biologically accurate.

Why other options are incorrect:

- **Option A:** Amoebae do not possess flagella for locomotion (flagella characterize flagellates such as *Euglena* and *Trypanosoma*).
- **Option B:** Amoebae belong to Kingdom Protista and are strictly unicellular.
- **Option C:** Several amoebae are human pathogens, including *Entamoeba histolytica* (amoebic dysentery) and *Naegleria fowleri* (primary amoebic meningoencephalitis).

Question #31 Key: (C)BIOLOGY
10. Homeostasis

Which of the following vertebrate organisms is classified as an amniote?

CORE CONCEPT & DERIVATION

Anamniotes are aquatic or semi-aquatic vertebrates whose embryos lack extraembryonic membranes (specifically the amnion, chorion, and allantois) during development.

Formula / Rule / Reaction:

$$\text{Vertebrata} = \begin{cases} \text{Anamniota:} & \text{Fishes, Amphibians} \\ \text{Amniota:} & \text{Reptiles, Birds, Mammals} \end{cases}$$

Solution:

- Amphibians (such as frogs) lay gelatinous, shell-less eggs in moist or aquatic environments.
- Their embryos develop without an amnion, relying on water for respiratory gas exchange, waste clearance, and hydration.
- Reptiles, birds, and mammals possess amniotic eggs featuring protective fluid-filled amnions. Option C is correct.

Why other options are incorrect:

- **Option A:** Snakes are reptiles belonging to the Amniota group.
- **Option B:** Parrots are birds (Aves) that produce cleidoic amniotic eggs.
- **Option D:** Crocodiles are non-avian reptiles and represent true amniotes.

Question #32 Key: (D)BIOLOGY
01. Cell

Organisms that are multicellular, display heterotrophic ingestive nutrition, and develop from b...

CORE CONCEPT & DERIVATION

Kingdom Animalia includes multicellular, eukaryotic, heterotrophic organisms that ingest food and lack cell walls throughout all life stages.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Plantae possess cellulose cell walls and perform autotrophic photosynthesis.
- Fungi possess chitinous cell walls and feed via absorptive osmotic heterotrophy.
- Animalia lack rigid cell walls, depend on ingestive heterotrophy, and typically form an embryonic blastula during development. Option D is correct.

Why other options are incorrect:

- **Option A:** Kingdom Protista (Protoctista) consists primarily of unicellular or colonial eukaryotes.
- **Option B:** Fungi possess cell walls composed of chitin and β -glucans and feed via extracellular absorption.
- **Option C:** Kingdom Plantae consists of autotrophic organisms possessing cellulose-pectin cell walls.

Question #33 Key: (B)BIOLOGY
03. Enzymes

Which of the following enzymes serves as an important regulatory, rate-limiting control point i...

CORE CONCEPT & DERIVATION

Glycolysis is regulated by enzymes catalyzing irreversible exergonic reactions, predominantly hexokinase, phosphofructokinase-1, and pyruvate kinase.

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

- Hexokinase catalyzes the initial priming phosphorylation of glucose, trapping it intracellularly as glucose-6-phosphate.
- It is allosterically inhibited by its reaction product, glucose-6-phosphate, providing negative feedback regulation over glycolytic flux.
- Option B is the correct regulatory enzyme.

Why other options are incorrect:

- **Option A:** Urease hydrolyzes urea into carbon dioxide and ammonia and is absent from human metabolic pathways.
- **Option C:** Maltase is a digestive brush-border disaccharidase that hydrolyzes maltose into two glucose molecules.
- **Option D:** Sucrase is an intestinal digestive enzyme that hydrolyzes dietary sucrose into glucose and fructose.

Question #34 Key: (C)BIOLOGY
01. Cell

Many hydrolytic and proteolytic enzymes are synthesized and secreted as inactive precursors (zymogens).

CORE CONCEPT & DERIVATION

Secretion of proteases as inactive proenzymes prevents premature destruction of the synthesizing cell's structural proteins and membranes.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Enzymes like trypsin, chymotrypsin, and elastase hydrolyze peptide bonds non-specifically within protein structures.
- If produced in active forms within the rough endoplasmic reticulum or secretory vesicles, they would digest intracellular structural proteins, transport pumps, and cell membranes, causing autolysis and pancreatitis.
- Secreting them as inactive zymogens prevents cellular self-digestion. Option C is correct.

Why other options are incorrect:

- Option A:** While mitochondrial protection occurs indirectly, zymogen synthesis protects the cell membrane and secretory pathway overall.
- Option B:** Nuclear DNA is targeted by nucleases, not by proteolytic digestive enzymes.
- Option D:** Vacuolar integrity is not the primary evolutionary pressure for zymogen production in animal exocrine glands.

Question #35 Key: (B)BIOLOGY
01. Cell

Mesosomes observed in electron micrographs of bacteria are internal structural invaginations of...

CORE CONCEPT & DERIVATION

Mesosomes are convoluted membranous invaginations formed by the inward folding of the prokaryotic plasma membrane.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Mesosomes were historically described as convoluted pocket-like infoldings of the bacterial plasma membrane, especially prominent in Gram-positive bacteria.
- They were hypothesized to assist in DNA segregation, cell wall synthesis, and respiratory electron transport by increasing surface area.
- Modern cryo-fixation shows they are chemical fixation artifacts, but textbook curricula classify them as plasma membrane invaginations. Option B is correct.

Why other options are incorrect:

- Option A:** The cell wall is a rigid external peptidoglycan envelope that does not fold internally to form mesosomal structures.
- Option C:** Plasmids are extrachromosomal circular DNA molecules in the cytoplasm.
- Option D:** The capsule is an external gelatinous polysaccharide layer outside the cell wall.

Question #36 Key: (B)BIOLOGY
01. Cell

Which of the following living organisms completely lacks a cell wall around its vegetative cell...

CORE CONCEPT & DERIVATION

All members of Kingdom Animalia lack cell walls; cnidarians like *Gorgonia* are surrounded only by animal plasma membranes.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- A sea fan (*Gorgonia*) is a marine colonial animal belonging to Phylum Cnidaria.
- As an animal, its cells lack cell walls and are enclosed solely by a flexible plasma membrane.
- Cyanobacteria (blue-green algae) possess peptidoglycan cell walls, and *Saccharomyces* (yeast) possesses a fungal cell wall made of glucans, mannans, and chitin.
- Thus, Option B is the only organism lacking a cell wall.

Why other options are incorrect:

- Option A:** Cyanobacteria are Gram-negative prokaryotes with peptidoglycan walls.
- Option C:** *Saccharomyces* is a unicellular fungus with a rigid chitinous-glucan wall.
- Option D:** Blue-green algae is a common name for cyanobacteria, which possess thick peptidoglycan cell walls.

Question #37 Key: (B)BIOLOGY
13. Chemical Coordination

Follicle-stimulating hormone (FSH) is synthesized and secreted into the systemic circulation by...

CORE CONCEPT & DERIVATION

FSH is a dimeric peptide gonadotropin secreted by gonadotropic cells of the adenohypophysis under the pulsatile regulation of GnRH.

Formula / Rule / Reaction:

$\text{Hypothalamic GnRH} \rightarrow \text{Hypophyseal Portal System} \rightarrow \text{Anterior Pituitary} \rightarrow \text{FSH \& LH Secretion}$

Solution:

- Gonadotrophs in the anterior lobe of the pituitary gland produce two gonadotropins: follicle-stimulating hormone (FSH) and luteinizing hormone (LH).
- FSH targets ovarian granulosa cells in females to stimulate follicular growth and Sertoli cells in males to support spermatogenesis.
- Option B is correct.

Why other options are incorrect:

- Option A:** Ovaries are target organs that secrete estrogen, progesterone, and inhibin, not FSH.
- Option C:** The adrenal cortex secretes steroid hormones (mineralocorticoids, glucocorticoids, and androgens).
- Option D:** Testes respond to FSH and produce testosterone and inhibin.

Question #38 Key: (D)BIOLOGY
14. Reproduction

Which of the following physiological events is NOT an established function of testosterone in h...

CORE CONCEPT & DERIVATION

Testosterone is the principal androgen required to drive and maintain spermatogenesis; it does not suppress or limit sperm production under physiological conditions.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Testosterone is secreted by interstitial Leydig cells in response to LH.
- It diffuses into seminiferous tubules where it binds to androgen receptors on Sertoli cells, driving spermatogenesis.
- Selective inhibition of FSH to modulate the rate of spermatogenesis is performed by inhibin, not by testosterone suppressing sperm production.
- Therefore, Option D is NOT a function of testosterone.

Why other options are incorrect:

- **Option A:** Testosterone exerts negative feedback on the hypothalamus and anterior pituitary to inhibit GnRH and LH release.
- **Option B:** High intratesticular testosterone levels are required for spermatogenesis to proceed past meiosis.
- **Option C:** Testosterone promotes secondary sexual characteristics including vocal cord thickening, facial hair, and skeletal muscle growth.

Question #39 Key: (C)BIOLOGY
14. Reproduction

In human males, the protein hormone inhibin is synthesized and secreted by:

CORE CONCEPT & DERIVATION

Sertoli cells (sustentacular cells) produce inhibin to exert negative feedback control over pituitary FSH secretion without altering LH secretion.

Formula / Rule / Reaction:

Sertoli Cells $\xrightarrow{\text{Inhibin B}}$ Anterior Pituitary Gonadotrophs $\xrightarrow{\text{Inhibition}}$ FSH Secretion ↓

Solution:

- Sertoli cells support, nourish, and regulate developing spermatogenic cells in the seminiferous tubules.
- When the rate of spermatogenesis is sufficient, Sertoli cells release the glycoprotein hormone inhibin B.
- Inhibin acts on the anterior pituitary to downregulate FSH release, adjusting the stimulus for sperm production. Option C is correct.

Why other options are incorrect:

- **Option A:** Leydig cells synthesize and secrete steroid androgens (primarily testosterone).
- **Option B:** Hensen's node is an embryonic organizer in vertebrate gastrulation, not an adult endocrine tissue.
- **Option D:** Secondary spermatocytes are haploid germ cells undergoing meiosis II, with no endocrine secretory function.

Question #40 Key: (D)BIOLOGY
14. Reproduction

Which of the following reproductive and endocrine functions is NOT directly performed by the ov...

CORE CONCEPT & DERIVATION

Ovaries produce steroid sex hormones and release gametes; hCG is produced by the syncytiotrophoblast of the developing blastocyst and placenta.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The ovaries produce estrogens (via developing follicles) and progesterone (via the corpus luteum).
- They release the secondary oocyte during ovulation.
- Human chorionic gonadotropin (hCG) is synthesized by syncytiotrophoblast cells of the embryonic chorion and placenta to maintain the corpus luteum during early gestation. It is not an ovarian product. Option D is correct.

Why other options are incorrect:

- **Option A:** Progesterone is secreted directly by the ovarian corpus luteum during the post-ovulatory phase.
- **Option B:** Estrogens are synthesized by follicular granulosa and theca cells of the ovary.
- **Option C:** Ovulation is the direct release of the mature secondary oocyte from the Graafian follicle of the ovary.

Question #41 Key: (A)BIOLOGY
14. Reproduction

Following ovulation during the menstrual cycle, the remnants of the ruptured Graafian follicle

CORE CONCEPT & DERIVATION

Under the influence of the LH surge, luteinized theca and granulosa cells form the corpus luteum, the major source of progesterone during the secretory phase.

Formula / Rule / Reaction:

Ruptured Follicle $\xrightarrow{\text{LH Surge}}$ Corpus Luteum $\xrightarrow{\text{Luteal Phase}}$ High Progesterone + Moderate Estrogen

Solution:

- Following extrusion of the secondary oocyte, granulosa cells enlarge and accumulate lipid droplets, transforming into granulosa lutein cells.
- The corpus luteum secretes progesterone to convert the endometrium into a secretory receptive bed for blastocyst implantation.
- Option A is the correct hormone.

Why other options are incorrect:

- Option B:** Follicle-stimulating hormone is an adenohypophyseal glycoprotein, not a luteal secretion.
- Option C:** Luteinizing hormone is secreted by the anterior pituitary; it stimulates luteinization but is not secreted by the ovary.
- Option D:** Testosterone is primarily synthesized by male testicular Leydig cells.

Question #42 Key: (B)BIOLOGY
11. Support & Movement

A clinical condition in which a synovial joint becomes swollen, painful, stiff, and restricted ...

CORE CONCEPT & DERIVATION

Arthritis is an inflammatory disorder of the joints characterized by pain, synovial swelling, articular cartilage degradation, and reduced range of motion.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The term arthritis derives from Greek *arthron* (joint) and *-itis* (inflammation).
- Its main forms (osteoarthritis, rheumatoid arthritis, gouty arthritis) share common cardinal signs: pain, swelling, tenderness, and joint stiffness.
- Option B matches the provided clinical description.

Why other options are incorrect:

- Option A:** Spondylosis is a non-inflammatory degenerative osteoarthritis localized to the intervertebral discs and vertebral bodies of the spine.
- Option C:** Sciatica is neuropathic radiating leg pain caused by compression of the sciatic nerve, not a joint inflammation.
- Option D:** Rickets is a metabolic bone disease in children caused by vitamin D and calcium deficiency, leading to defective mineralization of growth plates.

Question #43 Key: (C)BIOLOGY
11. Support & Movement

Which of the following cellular and morphological features is characteristic of visceral smooth...

CORE CONCEPT & DERIVATION

Smooth muscle consists of involuntary, non-striated, mononucleate, spindle-shaped cells that control the walls of hollow visceral organs.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Smooth muscle fibers are fusiform (tapered at both ends) and contain a single centrally located oval nucleus.
- Unlike skeletal and cardiac muscle, their myofilaments (actin and myosin) are not organized into regular repeating sarcomeres, so they lack transverse striations.
- Option C describes these cellular features.

Why other options are incorrect:

- Option A:** Multinucleate cylindrical syncytia are characteristic of voluntary skeletal muscle fibers.
- Option B:** Sarcomeric striations are present in skeletal and cardiac muscle tissues, not smooth muscle.
- Option D:** Branched fibers joined by intercalated discs containing gap junctions and desmosomes define cardiac muscle.

Question #44 Key: (D)BIOLOGY
11. Support & Movement

Mature bone cells that reside trapped within small fluid-filled cavities called lacunae in the ...

CORE CONCEPT & DERIVATION

Osteocytes are differentiated bone cells derived from osteoblasts that become encased within calcified lacunae to maintain bone matrix homeostasis.

Formula / Rule / Reaction:

Osteoprogenitor Cell $\rightarrow$ Osteoblast (Bone Forming) $\xrightarrow{\text{Entrapment in Matrix}}$ Osteocyte (Main)

Solution:

- When active bone-forming osteoblasts become surrounded by their secreted osteoid matrix, they differentiate into mature osteocytes.
- Each osteocyte occupies an isolated space called a lacuna and extends dendritic processes through canaliculi to form gap-junction networks with neighboring cells.
- They act as mechanosensors and maintain mineral homeostasis. Option D is correct.

Why other options are incorrect:

- Option A:** Chondrocytes are mature cartilage cells residing within the lacunae of cartilaginous extracellular matrix.
- Option B:** Osteoblasts are active, bone-depositing cells that line bone surfaces and are not yet entrapped within calcified lacunae.
- Option C:** Osteoclasts are large, multinucleated phagocytic cells derived from monocyte-macrophage lineages that resorb bone matrix.

Question #45 Key: (A)BIOLOGY
11. Support & Movement

The specialized outer plasma membrane surrounding an individual skeletal muscle fiber is termed...

CORE CONCEPT & DERIVATION

The sarcolemma is the specialized cell surface membrane of a muscle cell, consisting of a lipid bilayer fused with a thin outer polysaccharide and collagenous basement membrane.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The plasma membrane of a muscle fiber is historically designated as the sarcolemma (from Greek *sarx*, flesh, and *lemma*, sheath).
- It conducts action potentials initiated at neuromuscular junctions and forms transverse tubules (T-tubules) that penetrate the interior of the muscle fiber.
- Option A is correct.

Why other options are incorrect:

- **Option B:** Sarcoplasm is the cytoplasmic matrix of a muscle fiber, containing glycogen stores, myoglobin, and organelles.
- **Option C:** The sarcoplasmic reticulum is a modified smooth endoplasmic reticulum network that stores and releases Ca^{2+} .
- **Option D:** Perimysium is a dense irregular connective tissue sheath grouping multiple muscle fibers into a fascicle.

Question #46 Key: (A)BIOLOGY
15. Inheritance / Variation & Genetics

The reciprocal exchange of non-sister chromatid segments between paired homologous chromosomes ...

CORE CONCEPT & DERIVATION

Crossing over is the reciprocal breakage and rejoining of non-sister chromatids of homologous chromosomes that generates novel genetic recombinations.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- During the pachytene stage of prophase I, homologous chromosomes form synaptonemal bivalents.
- Endonucleases induce double-stranded DNA breaks, leading to segment swapping between non-sister chromatids.
- The physical sites of exchange become visible as chiasmata during diplotene.
- Option A is the standard genetic term.

Why other options are incorrect:

- **Option B:** Autosomal linkage refers to the tendency of genes situated on the same autosome to be inherited together without recombination.
- **Option C:** Non-disjunction is the failure of homologous chromosomes or sister chromatids to separate properly during nuclear division.
- **Option D:** Centromeric fission describes abnormal transverse splitting of centromeres, producing isochromosomes.

Question #47 Key: (B)BIOLOGY
15. Inheritance / Variation & Genetics

A permanent, heritable change occurring within the nucleotide sequence of a specific gene that ...

CORE CONCEPT & DERIVATION

A gene (point) mutation involves base-pair substitutions, insertions, or deletions within a gene that alter the encoded polypeptide sequence.

Formula / Rule / Reaction:

Wild-type DNA Sequence $\xrightarrow{\text{Mutation}}$ Mutant Allele Sequence $\rightarrow$ Altered Polypeptide

Solution:

- Mutations altering individual base pairs or small segments restricted to a single genetic locus are termed gene mutations (point mutations).
- These generate alternative alleles of the gene, altering phenotype.
- Changes affecting broad chromosomal architecture or chromosome numbers are chromosomal aberrations. Option B is correct.

Why other options are incorrect:

- **Option A:** Chromosomal aberrations involve large-scale structural disruptions (translocations, inversions, large deletions) affecting millions of base pairs.
- **Option C:** Ploidy shifts involve whole-genome duplications or losses (aneuploidy or polyploidy), not alterations within single genes.
- **Option D:** Homologous recombination rearranges existing alleles rather than synthesizing new nucleotide variations.

Question #49 Key: (C)BIOLOGY
15. Inheritance / Variation & Genetics

In classical genetics, the term 'phenotype' refers to:

CORE CONCEPT & DERIVATION

Phenotype is the expressed structural, physiological, and behavioral profile of an organism produced by the interaction between its genotype and environment.

Formula / Rule / Reaction:

Phenotype = Genotype + Environment + (Genotype $\times$ Environment)

Solution:

- Genotype is the complete underlying hereditary constitution of alleles.
- Phenotype represents the observable properties of an organism (e.g., eye color, blood group, enzyme activity).
- Option C is the definition of phenotype.

Why other options are incorrect:

- **Option A:** The complete underlying allelic makeup is the genotype.
- **Option B:** An alternative allelic partner located at the identical locus on a homologous chromosome is simply an allele.
- **Option D:** The fixed physical location of a gene along a chromosome is its locus.

Question #48 Key: (A)BIOLOGY
15. Inheritance / Variation & Genetics

Which of the following human genetic systems is controlled by multiple alleles located at a sin...

CORE CONCEPT & DERIVATION

Multiple allelism occurs when a gene locus in a population possesses more than two allelic variants; the ABO locus on chromosome 9 has three primary alleles: I^A , I^B , and i .

Formula / Rule / Reaction:

$$\text{Number of Genotypes} = \frac{n(n+1)}{2} = \frac{3(4)}{2} = 6 \quad (\text{for } n = 3 \text{ alleles})$$

Solution:

- The ABO blood groups are determined by the *ABO* glycosyltransferase gene on the long arm of autosome 9 (9q34.2).
- Three major alleles exist: I^A and I^B (which show codominance) and i (recessive).
- Because three alleles occupy the same autosomal locus in human populations, Option A is the classic multiple-allele example.

Why other options are incorrect:

- **Option B:** Cystic fibrosis is an autosomal recessive disorder caused by mutations in the single *CFTR* gene, behaving as a monogenic trait.
- **Option C:** Down syndrome is a chromosomal aneuploidy (trisomy 21), not a multiple allelic trait.
- **Option D:** Hemophilia A is an X-linked recessive bleeding disorder resulting from mutations in the coagulation Factor VIII gene.

Question #50 Key: (D)BIOLOGY
15. Inheritance / Variation & Genetics

If a female carrier for X-linked recessive hemophilia ([Formula]) marries a hemophilic male (...)

CORE CONCEPT & DERIVATION

Hemophilia A is inherited as an X-linked recessive trait; inheritance patterns depend on whether mutant X chromosomes are transmitted to male or female offspring.

Formula / Rule / Reaction:

$$\text{Cross: } X^H X^h \times X^h Y \Rightarrow \begin{cases} \text{Daughters: } \frac{1}{2} X^H X^h \text{ (Carrier), } \frac{1}{2} X^h X^h \text{ (Affected)} \\ \text{Sons: } \frac{1}{2} X^H Y \text{ (Normal), } \frac{1}{2} X^h Y \text{ (Affected)} \end{cases}$$

Solution:

- Female gametes: 50% X^H , 50% X^h . Male gametes: 50% X^h , 50% Y .

- Female offspring:

$$\begin{aligned} X^H \times X^h &= X^H X^h \text{ (Carrier daughter, unaffected)} \\ X^h \times X^h &= X^h X^h \text{ (Affected daughter)} \end{aligned}$$

This equals 1 out of 2 daughters affected (50%).

- Male offspring:

$$\begin{aligned} X^H \times Y &= X^H Y \text{ (Normal son)} \\ X^h \times Y &= X^h Y \text{ (Affected son)} \end{aligned}$$

This equals 1 out of 2 sons affected (50%).

- Thus, half of the sons and half of the daughters will be affected. Option D is correct.

Why other options are incorrect:

- Option A:** Only 50% of the total offspring are affected; carrier daughters and normal sons are unaffected.
- Option B:** Only 50% of daughters are affected ($X^h X^h$); the other 50% are phenotypically normal carriers ($X^H X^h$).
- Option C:** Only half of the sons are affected ($X^h Y$); the other half inherit the maternal X^H and are normal.

Question #51 Key: (C)BIOLOGY
15. Inheritance / Variation & Genetics

The particular array and complete visual display of homologous chromosomes possessed by an indi...

CORE CONCEPT & DERIVATION

A karyotype is the photographic or microscopic depiction of the complete set of metaphase chromosomes in an individual, organized systematically by length, centromere position, and banding patterns.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Colchicine-arrested mitotic cells in metaphase are stained and photographed.
- The homologous pairs are arranged in order of decreasing size from pair 1 to 22 (autosomes), followed by the sex chromosomes (pair 23).
- This complete visual profile is termed a karyotype (and the resulting diagram an ideogram or karyogram), validating Option C.

Why other options are incorrect:

- Option A:** Genotype designates the underlying allelic constitution of an organism at one or more genetic loci.
- Option B:** Phenotype refers to the physical, biochemical, or behavioral manifestation of expressed traits.
- Option D:** An allelic profile refers to a molecular catalog of DNA sequence polymorphisms, not a morphological chromosomal map.

Question #52 Key: (B)BIOLOGY
05. Acellular Life

Which of the following statements is NOT a characteristic feature of enveloped animal viruses?

CORE CONCEPT & DERIVATION

Enveloped viruses possess external lipid membranes embedded with viral spike glycoproteins that are readily accessible targets for neutralizing humoral antibodies.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The outer lipid envelope is acquired as the nucleocapsid buds through host nuclear, ER, or plasma membranes.
- Because the envelope consists of a lipid bilayer, it is labile and rapidly inactivated by desiccation, heat, bile salts, and organic solvents.
- The exposed viral envelope surface spikes (glycoproteins) act as primary antigens that are readily recognized, bound, and neutralized by host antibodies.
- Therefore, stating that enveloped viruses are highly tolerant to antibodies is false, making Option B the correct choice.

Why other options are incorrect:

- **Option A:** Enveloped viruses are fragile and survive poorly outside physiological host fluids compared to naked viruses.
- **Option C:** The lipid bilayer envelope is sensitive to thermal denaturation, sunlight, and ether or detergent disruption.
- **Option D:** The lipid component of the envelope is derived directly from the host cell membrane during budding.

Question #53 Key: (B)BIOLOGY
05. Acellular Life

Choose the infectious agent that requires only a single host cellular gene to encode the protein...

CORE CONCEPT & DERIVATION

Prions are proteinaceous infectious particles devoid of nucleic acids, consisting of an abnormal conformational isomer of a host-encoded glycoprotein.

Formula / Rule / Reaction:

PrP^C (Host Cellular Protein) $\xrightarrow{\text{Conformational Refolding}}$ PrP^{Sc} (Pathogenic Scrapie Prion)

Solution:

- Prions contain no intrinsic genetic material (neither DNA nor RNA).
- The infectious prion agent is composed solely of PrP^{Sc} , which is encoded by the host's own endogenous chromosomal PrNP^* gene on human chromosome 20.
- Because a single host cellular gene encodes the protein responsible for prion propagation, Option B is correct.

Why other options are incorrect:

- **Option A:** Viroids consist exclusively of a naked, circular, single-stranded infectious RNA with no protein coat.
- **Option C:** Viruses encode multiple structural and enzymatic proteins using their own viral genome.
- **Option D:** A virion is an intact physical virus particle possessing its own nucleic acid core.

Question #54 Key: (A)BIOLOGY
05. Acellular Life

Which of the following human pathogens is transmitted primarily through contaminated blood tran...

CORE CONCEPT & DERIVATION

HIV is a blood-borne retrovirus transmitted parenterally via infected blood, shared needles, sexual intercourse, and perinatal vertical exposure.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- HIV targets CD4^+ helper T lymphocytes and macrophages.
- Primary transmission routes include direct intravenous inoculations (contaminated syringes used in healthcare or substance abuse, unscreened blood products) and mucosal sexual exposure.
- Option A is the classic blood-borne pathogen among the choices.

Why other options are incorrect:

- **Option B:** Influenza virus is an orthomyxovirus transmitted via airborne respiratory droplets and aerosols.
- **Option C:** Morbillivirus is transmitted through infectious respiratory secretions and airborne aerosols.
- **Option D:** *Vibrio cholerae* is a Gram-negative bacterium transmitted via the fecal-oral route through contaminated water or food.

Question #55 Key: (B)BIOLOGY
05. Acellular Life

Which of the following clinical viral infections is caused by a subviral, circular single-stranded...

CORE CONCEPT & DERIVATION

Hepatitis D virus (HDV) is a defective subviral satellite agent with a small, circular, single-stranded RNA genome that utilizes ribozyme activity akin to plant viroids.

Formula / Rule / Reaction:

HDV Assembly = HDV RNA + Delta Antigen + HBsAg Envelope (Supplied by HBV)

Solution:

- HDV possesses a miniature circular ssRNA genome of approximately 1.7 kb with high secondary structure, similar to viroids.
- It is replication-defective and can only produce mature, infectious virions in hepatocytes coinfecting with Hepatitis B virus (HBV), which supplies the surface antigen coat (HBsAg).
- Option B is the correct human viroid-like pathogen.

Why other options are incorrect:

- **Option A:** Hepatitis A is a picornavirus containing positive-sense, linear, single-stranded RNA, unrelated to viroids.
- **Option C:** Mad cow disease (Bovine Spongiform Encephalopathy) is a neurodegenerative disease caused by prions, not RNA.
- **Option D:** Kuru is a human transmissible spongiform encephalopathy caused by prion proteins.

Question #56 Key: (D)BIOLOGY
04. Bioenergetics

The final physiological acceptor of both electrons and protons during the light-dependent non-c...

CORE CONCEPT & DERIVATION

During non-cyclic photophosphorylation, electrons excited from Photosystem I are transferred via ferredoxin to NADP^+ , which picks up stromal protons to form NADPH.

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

- Electrons flow down the Z-scheme: $\text{H}_2\text{O} \rightarrow \text{PS II} \rightarrow \text{PQ} \rightarrow \text{Cyt } b_6f \rightarrow \text{PC} \rightarrow \text{PS I} \rightarrow \text{Fd} \rightarrow \text{NADP}^+$.
- At the stromal surface of the thylakoid membrane, the enzyme ferredoxin- NADP^+ reductase transfers two electrons from reduced ferredoxin and captures protons from the stroma.
- This reduces NADP^+ to NADPH, making NADP^+ the terminal electron and proton acceptor. Option D is correct.

Why other options are incorrect:

- **Option A:** Plastoquinone accepts electrons and protons from the stroma to form PQH_2 , but it is an intermediate mobile carrier within the thylakoid lipid bilayer.
- **Option B:** Plastocyanin is a luminal copper-containing intermediate carrier that transfers electrons to P700^+ .
- **Option C:** Ferredoxin is an iron-sulfur protein that transfers electrons to the terminal reductase enzyme.

Question #57 Key: (D)BIOLOGY
04. Bioenergetics

The only copper-containing mobile protein carrier involved in the electron transport chain of t...

CORE CONCEPT & DERIVATION

Plastocyanin is a water-soluble copper-binding peripheral membrane protein that shuttles electrons through the thylakoid lumen from cytochrome b_6f to Photosystem I.

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

- Plastocyanin contains a single copper ion coordinated by two histidine residues, a cysteine, and a methionine.
- It undergoes reversible one-electron redox cycling between Cu^{2+} (oxidized, blue) and Cu^+ (reduced, colorless).
- Plastoquinone is a non-protein lipid quinone, cytochrome b_6f contains iron-heme groups, and ferredoxin contains iron-sulfur clusters.
- Therefore, plastocyanin is the only copper protein in the photosynthetic light reactions, making Option D correct.

Why other options are incorrect:

- Option A:** Plastoquinone is a lipid-soluble benzoquinone derivative containing no metal cofactors.
- Option B:** Cytochrome b_6f is an integral membrane heme protein complex containing iron-porphyrin and Rieske iron-sulfur centers.
- Option C:** Ferredoxin is a non-heme iron-sulfur ($[2\text{Fe} - 2\text{S}]$) protein.

Question #58 Key: (B)BIOLOGY
04. Bioenergetics

The primary end product of anaerobic glycolysis in human skeletal muscle tissue during strenuous...

CORE CONCEPT & DERIVATION

In the absence of oxygen, animal tissues regenerate the NAD^+ necessary to sustain glycolysis by reducing pyruvate to lactate via lactate dehydrogenase.

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

- During intense muscular work, cellular respiration outpaces microvascular oxygen delivery.
- To sustain substrate-level ATP generation by glyceraldehyde-3-phosphate dehydrogenase, NADH must be re-oxidized to NAD^+ .
- Skeletal muscle lacks pyruvate decarboxylase and cannot perform alcoholic fermentation; it reduces pyruvate directly to lactate. Option B is correct.

Why other options are incorrect:

- Option A:** Ethanol and carbon dioxide are end products of alcoholic fermentation in yeast and specific anaerobic microorganisms.
- Option C:** Pyruvate is the intermediate end product of aerobic glycolysis, which is converted to lactate under anaerobic conditions.
- Option D:** Acetyl-CoA is formed inside the mitochondrial matrix by oxidative decarboxylation under strictly aerobic conditions.

Question #59 Key: (C)BIOLOGY
04. Bioenergetics

The primary three-carbon carbohydrate product directly exported from the stroma during the Calvin cycle is:

CORE CONCEPT & DERIVATION

The net synthetic output of the dark reactions (Calvin cycle) is glyceraldehyde 3-phosphate, which is subsequently used in the cytoplasm to assemble hexose sugars.

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

- Carbon fixation mediated by RuBisCO produces 3-phosphoglycerate, which is phosphorylated to 1,3-bisphosphoglycerate and reduced to glyceraldehyde 3-phosphate (G3P).
- For every three molecules of CO_2 fixed, six molecules of G3P are synthesized; five remain in the cycle to regenerate RuBP, while one net G3P exits the cycle into the cytosol.
- Free glucose is not directly formed within the Calvin cycle itself. Option C is correct.

Why other options are incorrect:

- Option A:** 3-phosphoglycerate is the initial stable carboxylation intermediate of the cycle, not the exported net synthetic product.
- Option B:** 1,3-bisphosphoglycerate is a high-energy transient intermediate in the reduction phase.
- Option D:** Glucose is a hexose assembled in the cytosol from two triose phosphate (G3P) molecules outside the Calvin cycle.

Question #60 Key: (B)BIOLOGY
02. Biomolecules

The second most abundant chemical bioelement by total body mass in the human body is:

CORE CONCEPT & DERIVATION

Major bioelements make up 99% of human body mass; oxygen ranks first (due to water content), followed immediately by carbon.

Formula / Rule / Reaction:

Abundance by Mass: O ($\approx 65\%$) > C ($\approx 18\%$) > H ($\approx 10\%$) > N ($\approx 3\%$)

Solution:

- Oxygen accounts for approximately 65% of adult human body mass because water (H_2O) constitutes 60% to 70% of human tissues.
- Carbon provides the tetravalent structural backbone of all organic macromolecules (proteins, carbohydrates, lipids, nucleic acids), constituting approximately 18% of total mass.
- Hydrogen constitutes approximately 10% and nitrogen 3%.
- Therefore, carbon is the second most abundant bioelement, validating Option B.

Why other options are incorrect:

- Option A:** Oxygen is the most abundant bioelement by mass (approx. 65%), not the second.
- Option C:** Hydrogen is the third most abundant element by mass (approx. 10%), despite being the most numerous by atom count.
- Option D:** Nitrogen is the fourth most abundant element by mass (approx. 3%).

Question #61 Key: (A)BIOLOGY
01. Cell

The primary structural framework that forms the universal, stable matrix of all biological unit...

CORE CONCEPT & DERIVATION

Biological membranes are fundamentally organized as amphipathic phospholipid bilayers, which provide the fluid hydrophobic barrier separating aqueous compartments.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- According to the Singer-Nicolson Fluid Mosaic Model, phospholipids spontaneously self-assemble into a continuous bilayer in water.
- Their polar hydrophilic heads orient toward the aqueous intracellular and extracellular fluids, while non-polar fatty acyl tails form the hydrophobic core.
- Membrane proteins are embedded within or attached to this structural lipid sheet. (Note: While membranes are colloquially called lipoprotein assemblies, the fundamental structural matrix is the phospholipid bilayer). Option A is the precise answer.

Why other options are incorrect:

- **Option B:** Glycoproteins are peripheral or transmembrane components that mediate cell recognition and receptor signaling, not the primary bilayer framework.
- **Option C:** Lipoproteins are soluble globular lipid-transport complexes in blood and lymph, distinct from biological unit membranes.
- **Option D:** Nucleoproteins are complexes of nucleic acids and basic proteins (e.g., chromatin, ribosomes) restricted to the nucleus and cytoplasm.

Question #62 Key: (C)BIOLOGY
02. Biomolecules

When three hydrophobic fatty acid molecules undergo esterification with a single molecule of gl...

CORE CONCEPT & DERIVATION

Triglycerides are neutral lipids synthesized by condensation reactions that link each of the three hydroxyl groups of glycerol to a fatty acid via ester bonds.

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

- Glycerol is a three-carbon trihydric alcohol (propane-1,2,3-triol).
- Each hydroxyl group (–OH) undergoes condensation with the carboxyl group (–COOH) of a long-chain fatty acid.
- The resulting non-polar molecule contains three ester linkages and three fatty acid tails, designated as a triacylglycerol or triglyceride. Option C is correct.

Why other options are incorrect:

- **Option A:** A monoglyceride consists of only one fatty acid esterified to glycerol.
- **Option B:** A diglyceride possesses two esterified fatty acid chains.
- **Option D:** A phospholipid contains two fatty acid chains and a phosphate head group attached to glycerol.

Question #63 Key: (B)BIOLOGY
02. Biomolecules

The specific five-carbon aldopentose sugar that forms the structural backbone of ribonucleic ac...

CORE CONCEPT & DERIVATION

RNA nucleotides contain β-D-ribofuranose, an aldopentose possessing hydroxyl groups at both the 2' and 3' positions.

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

- The ribose unit in RNA is a five-carbon aldose sugar with an aldehyde functional group in its open-chain form.
- In ribonucleotides, it forms a five-membered furanose ring with hydroxyl groups on carbons 2' and 3'.
- DNA uses 2-deoxyribose, which lacks the 2'-hydroxyl group. Option B is correct.

Why other options are incorrect:

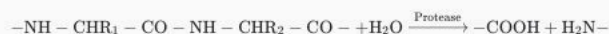
- **Option A:** Ribulose is a ketopentose (possessing a ketone group at carbon 2), which serves as an intermediate in the Calvin cycle as RuBP.
- **Option C:** Deoxyribulose is a ketopentose derivative not found in nucleic acid backbones.
- **Option D:** 2-Deoxyribose is the pentose component of DNA, not RNA.

Question #64 Key: (B)BIOLOGY
02. Biomolecules

Which of the following biochemical processes is responsible for the enzymatic cleavage of prote...

CORE CONCEPT & DERIVATION

Hydrolysis is the cleavage of covalent bonds by the addition of a water molecule; proteases break peptide bonds by consuming water.

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

- During protein catabolism and digestion, peptide bonds (amide linkages) connecting adjacent amino acid residues are broken.
- Proteolytic enzymes consume one molecule of H_2O per peptide bond, transferring a hydroxyl group to the carboxyl carbon and a proton to the amino nitrogen.
- This reaction represents enzymatic hydrolysis, making Option B correct.

Why other options are incorrect:

- **Option A:** Condensation (dehydration synthesis) forms peptide bonds between amino acids, releasing water rather than consuming it.
- **Option C:** Glycolysis is the ten-step catabolic pathway that breaks down glucose into pyruvate.
- **Option D:** Biological nitrogen fixation reduces atmospheric N_2 to ammonia (NH_3) in diazotrophic bacteria.

Question #65 Key: (D)BIOLOGY
02. Biomolecules

Select the major fibrous structural protein that provides tensile strength, resilience, and sup...

CORE CONCEPT & DERIVATION

Collagen is the most abundant extracellular matrix protein in vertebrates, forming triple-helical tropocollagen fibrils that withstand longitudinal tensile stress.

Formula / Rule / Reaction:

Collagen Monomer = $[\text{Gly} - \text{X} - \text{Y}]_n$ (Right-handed triple helix of three α -chains)

Solution:

- Collagen constitutes over 25% to 35% of whole-body protein mass in mammals.
- It forms high-tensile-strength, non-elastic fibers in tendons, bone matrix, cartilage, ligaments, and dermis.
- Its unique triple-helix structure (rich in glycine, proline, and hydroxyproline) resists stretching, making Option D correct.

Why other options are incorrect:

- **Option A:** Histones are basic nuclear proteins that package eukaryotic chromosomal DNA into nucleosomes.
- **Option B:** Keratin is an intracellular cytoskeletal intermediate filament protein of epithelial cells, forming hair, nails, and the stratum corneum.
- **Option C:** Elastin provides elastic stretch and recoil to lungs, large arteries, and skin, but collagen provides primary tensile support to connective tissue.

Question #66 Key: (D)BIOLOGY
02. Biomolecules

Fibrous structural proteins do NOT participate directly in which of the following physiological...

CORE CONCEPT & DERIVATION

Fibrous proteins provide static or dynamic structural frameworks; metabolic and transport functions (such as systemic oxygen delivery) are performed by soluble globular proteins.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Fibrous proteins (insoluble, elongated polypeptide chains) serve mechanical roles: keratin forms nails/hair, fibrin stabilizes blood clots, and actin/myosin fibers drive muscle contraction.
- Oxygen transport in human blood is executed by hemoglobin, which is a soluble, compact, multimeric globular hemeprotein.
- Therefore, fibrous proteins do not participate in oxygen transport. Option D is correct.

Why other options are incorrect:

- Option A:** Blood clotting relies on the polymerization of soluble fibrinogen into insoluble, fibrous fibrin networks.
- Option B:** Hard keratin, a classic fibrous protein with high cysteine cross-linking, forms nails, claws, and hair.
- Option C:** Actin microfilaments and myosin thick filaments are fibrous protein polymers that drive sarcomeric contraction.

Question #67 Key: (B)BIOLOGY
01. Cell

The outer membranes of mitochondria and chloroplasts resemble each other fundamentally because ...

CORE CONCEPT & DERIVATION

Due to their endosymbiotic Gram-negative bacterial origins, the outer membranes of both mitochondria and chloroplasts contain large, non-specific transmembrane channel proteins called porins.

Formula / Rule / Reaction:

Molecular Exclusion Limit of Porins $\approx$ 5000 to 10000 Daltons

Solution:

- The outer membranes of both semi-autonomous organelles contain transmembrane β -barrel porin proteins.
- These aqueous pores allow the free, unhindered passive diffusion of small molecules, inorganic ions, nucleotides, and metabolic substrates below 5 to 10 kDa.
- In contrast, their inner membranes are tightly sealed and selectively permeable. Option B correctly identifies this shared property.

Why other options are incorrect:

- Option A:** Large folded macromolecules (globular proteins, enzymes, nucleic acids) cannot pass freely; they require specialized translocase complexes (TOM/TIM or TOC/TIC).
- Option C:** They are not impermeable; small metabolites diffuse freely across them.
- Option D:** ATP synthase complexes are localized to the inner mitochondrial cristae and thylakoid membranes, not the outer membranes.

Question #68 Key: (C)BIOLOGY
04. Bioenergetics

In eukaryotic mitochondria, the catalytic [Formula] -ATP synthase complex is anchored directly ...

CORE CONCEPT & DERIVATION

The inner mitochondrial membrane houses the electron transport chain complexes and the transmembrane F_0 base of ATP synthase, driving rotational catalysis during oxidative phosphorylation.

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

- The respiratory chain expels protons from the matrix across the inner membrane into the intermembrane space, generating a proton-motive force.
- ATP synthase consists of an F_0 subunit embedded in the inner membrane (cristae) and a catalytic F_1 headpiece that projects into the matrix.
- Proton return through F_0 drives the synthesis of ATP from ADP and inorganic phosphate. Option C is correct.

Why other options are incorrect:

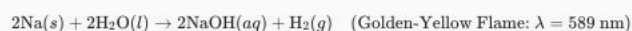
- Option A:** The outer membrane lacks respiratory complexes and ATP synthase enzymes.
- Option B:** The intermembrane space serves as the electrochemical proton reservoir, not the catalytic enzyme site.
- Option D:** The matrix contains the soluble enzymes of the Krebs cycle, but the ATP synthase complex is anchored within the inner membrane.

Question #69 Key: (B)CHEMISTRY
11. S & P Block Elements

An alkali metal reacts vigorously with cold water, melting into a silvery molten sphere that sk...

CORE CONCEPT & DERIVATION

Sodium reacts exothermically with liquid water, releasing sufficient heat to melt the metal (melting point 97.8°C) while emitting its characteristic D-line flame emission.

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

- Sodium has a relatively low melting point (97.8°C) and low density (0.97 g/cm^3), allowing it to float on water.
- The exothermic reaction releases hydrogen gas, which propels the molten metallic ball across the water surface.
- The heat generated ignites the evolved H_2 gas, which burns with sodium's characteristic golden-yellow flame. Option B matches all observations.

Why other options are incorrect:

- Option A:** Potassium reacts more violently, instantly catching fire and burning with a characteristic lilac (pale violet) flame.
- Option C:** Lithium has a higher melting point (180.5°C) and reacts slowly without melting into a liquid sphere, giving a crimson-red flame.
- Option D:** Calcium is a denser alkaline earth metal that sinks in water and reacts steadily without melting, producing a brick-red flame.

Question #70 Key: (D)CHEMISTRY
11. S & P Block Elements

Among the alkali metals of Group IA, which element reacts most slowly and least vigorously with...

CORE CONCEPT & DERIVATION

Reactivity of Group IA alkali metals with water increases down the group as ionization enthalpy decreases and atomic radius expands.

Formula / Rule / Reaction:

First Ionization Energy: Li (520 kJ/mol) > Na (496) > K (419) > Rb (403) > Cs (376)

Solution:

- Down Group IA, atomic radius increases, the valence s^1 electron is held less tightly by the nucleus, and ionization energy decreases.
- Lithium has the highest ionization energy and highest enthalpy of atomization among the alkali metals.
- Although Li has a very negative standard electrode potential due to its high hydration energy, its initial kinetics with water are the slowest and least vigorous in the group. Option D is correct.

Why other options are incorrect:

- **Option A:** Sodium reacts rapidly, melting into a ball and often igniting.
- **Option B:** Potassium reacts violently and ignites immediately with a lilac flame.
- **Option C:** Rubidium reacts explosively with cold water, shattering glass containers.

Question #71 Key: (A)CHEMISTRY
11. S & P Block Elements

Which of the following elements has the smallest electron shielding (screening) effect on its o...

CORE CONCEPT & DERIVATION

Shielding effect is directly proportional to the total number of intervening inner electron shells between the nucleus and the valence shell.

Formula / Rule / Reaction:

$$Z_{\text{eff}} = Z - S \quad (S = \text{Screening constant determined by inner core electrons})$$

Solution:

- The magnitude of the shielding effect depends on the number of completed inner electron shells.
- Magnesium ($Z = 12$, [Ne] $3s^2$) has only two intervening principal electron shells ($n = 1, 2$).
- Calcium ($Z = 20$) has three inner shells ($n = 1, 2, 3$), strontium ($Z = 38$) has four, and rubidium ($Z = 37$) has four.
- Because magnesium has the fewest inner shielding electrons, it has the smallest shielding effect. Option A is correct.

Why other options are incorrect:

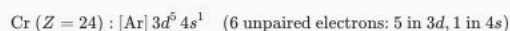
- **Option B:** Calcium has 18 inner core electrons, creating a larger shielding effect than magnesium's 10.
- **Option C:** Rubidium possesses 36 core electrons, resulting in a much stronger shielding effect.
- **Option D:** Strontium has 36 core electrons shielding its valence $5s$ electrons.

Question #72 Key: (D)CHEMISTRY
12. Transition Elements

Across the first transition series (3d series), the total number of unpaired d-electrons increa...

CORE CONCEPT & DERIVATION

According to Hund's rule, electrons occupy degenerate d-orbitals singly with parallel spins before pairing, maximizing unpaired electrons at chromium (Group VIB).

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

- Group IIIB (Sc): $3d^1 4s^2$ (1 unpaired d-electron).
- Group IVB (Ti): $3d^2 4s^2$ (2 unpaired d-electrons).
- Group VB (V): $3d^3 4s^2$ (3 unpaired d-electrons).
- Group VIB (Cr): $3d^5 4s^1$ (5 unpaired d-electrons, maximum for the 3d series).
- Past Group VIB, spin pairing begins (Mn has $3d^5 4s^2$, Fe has $3d^6 4s^2$ with 4 unpaired, etc.). Option D is correct.

Why other options are incorrect:

- **Option A:** Groups IIIB and IVB have only 1 and 2 unpaired d-electrons, which is before the maximum is reached.
- **Option B:** Groups IB (Cu, $3d^{10} 4s^1$) and IIB (Zn, $3d^{10} 4s^2$) have 0 unpaired d-electrons.
- **Option C:** This option lists the initial elements of the series rather than the groups where unpaired electrons peak.

Question #73 Key: (C)CHEMISTRY
12. Transition Elements

The binding energy and melting points of transition elements weaken progressively toward the en...

CORE CONCEPT & DERIVATION

Metallic binding energy in transition metals depends on the participation of both valence s-electrons and unpaired d-electrons in delocalized metallic bonding.

Formula / Rule / Reaction:

$$\text{Binding Energy} \propto \text{Number of Unpaired d-Electrons Participating in Delocalization}$$

Solution:

- Across a transition series, binding energy rises to a maximum near the middle (Groups VB and VIB) due to maximum unpaired d-electrons.
- Toward the end of the series, d-electrons pair up, the effective nuclear charge contracts the d-orbitals, and they no longer participate effectively in metallic bonding.
- At Group IIB (Zn, Cd, Hg), the d-subshell is completely filled (d^{10}) and tightly bound to the nucleus, leaving only the two outer s-electrons to bond.
- Consequently, Group IIB elements display the lowest binding energies and lowest melting points (e.g., Hg is liquid at room temperature). Option C is correct.

Why other options are incorrect:

- **Option A:** Group IIIB (Sc, Y) elements possess high melting points and robust metallic binding using their d^1 and s^2 electrons.
- **Option B:** Group IVB metals (Ti, Zr) exhibit high binding energies and high tensile strength.
- **Option D:** Group VB metals (V, Nb, Ta) exhibit near-peak metallic binding energies and high melting points.

Question #74 Key: (D)CHEMISTRY
13. Fundamental Principles of Organic Chemistry

Metamers are structural isomers that differ from each other specifically due to the:

CORE CONCEPT & DERIVATION

Metamerism is a form of constitutional isomerism shown by compounds with polyvalent functional groups that have different alkyl chain lengths attached on either side.

Formula / Rule / Reaction:

Ethers: $\text{CH}_3 - \text{CH}_2 - \text{O} - \text{CH}_2 - \text{CH}_3$ vs. $\text{CH}_3 - \text{O} - \text{CH}_2 - \text{CH}_2 - \text{CH}_3$

Solution:

- Metamerism occurs in chemical families with bridging heteroatoms or polyvalent functional groups (such as ethers $-\text{O}-$, thioethers $-\text{S}-$, secondary amines $-\text{NH}-$, and ketones $-\text{CO}-$).
- The metamers share identical molecular formulas and the same functional group, but differ in the size and distribution of alkyl groups flanking that functional group.
- Option D is the precise definition of metamers.

Why other options are incorrect:

- Option A:** Compounds with identical molecular formulas but different functional groups are functional group isomers.
- Option B:** Compounds differing in the position of a functional group on the same carbon skeleton are position isomers.
- Option C:** Isomerism caused by the intramolecular migration of a proton is tautomerism.

Question #75 Key: (B)CHEMISTRY
13. Fundamental Principles of Organic Chemistry

Structural isomerism caused by the dynamic intramolecular shifting of a proton from one atom to...

CORE CONCEPT & DERIVATION

Tautomerism is a dynamic form of functional isomerism where two interconvertible structural forms exist in rapid equilibrium through the migration of a hydrogen atom (proton).

Formula / Rule / Reaction:

$\text{CH}_3 - \text{C}(=\text{O}) - \text{CH}_3$ (Keto Form) $\rightleftharpoons$ $\text{CH}_3 - \text{C}(\text{OH}) = \text{CH}_2$ (Enol Form)

Solution:

- Tautomers are structural isomers that interconvert rapidly through the migration of a proton accompanied by a switch of an adjacent double bond (e.g., keto-enol or amino-imino tautomerism).
- Because it involves an intramolecular proton shift, Option B is correct.

Why other options are incorrect:

- Option A:** Metamerism arises from different alkyl group distributions around a polyvalent functional group, without proton migration.
- Option C:** Position isomerism involves different locant positions of a substituent or functional group on an identical carbon skeleton.
- Option D:** Functional group isomerism describes static, non-interconverting isomers with different functional groups (e.g., ethanol and dimethyl ether).

Question #76 Key: (A)CHEMISTRY
13. Fundamental Principles of Organic Chemistry

A neutral aliphatic organic compound having the molecular formula [Formula] can exist as two di...

CORE CONCEPT & DERIVATION

Compounds with the general formula $\text{C}_n\text{H}_{2n+2}\text{O}$ can exist as either saturated monohydric alcohols or dialkyl ethers, which represent functional group isomers.

Formula / Rule / Reaction:

$\text{C}_2\text{H}_6\text{O} = \begin{cases} \text{CH}_3 - \text{CH}_2 - \text{OH} & \text{(Ethanol, an alcohol)} \\ \text{CH}_3 - \text{O} - \text{CH}_3 & \text{(Methoxymethane, an ether)} \end{cases}$

Solution:

- The molecular formula $\text{C}_2\text{H}_6\text{O}$ has an index of hydrogen deficiency (IHD) of 0:

$$\text{IHD} = 2 - \frac{6}{2} + 1 = 0$$

This indicates a fully saturated acyclic framework.

- Two constitutional structures are possible: ethyl alcohol (containing a hydroxyl group, $-\text{OH}$) and dimethyl ether (containing an ether bridge, $-\text{O}-$).
- Because they have different functional groups, they are functional group isomers. Option A is correct.

Why other options are incorrect:

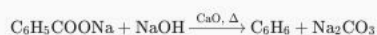
- Option B:** Position isomerism requires a parent chain with at least three carbons to reposition the functional group.
- Option C:** Chain isomerism requires a minimum of four carbon atoms to allow skeletal branching.
- Option D:** Metamerism requires at least three carbons in ethers to produce unequal alkyl distributions.

Question #77 Key: (C)CHEMISTRY
18. Carboxylic Acids

In the laboratory, benzene is prepared by decarboxylation of sodium benzoate upon heating in th...

CORE CONCEPT & DERIVATION

Heating sodium salts of carboxylic acids with solid soda lime induces decarboxylation, eliminating CO_2 as sodium carbonate and generating the corresponding hydrocarbon.

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

- When dry sodium benzoate is heated with soda lime (a dry mixture of NaOH and CaO in roughly a 3:1 ratio), decarboxylation occurs.
- CaO keeps the NaOH dry (preventing deliquescence) and raises the fusion temperature, yielding benzene and sodium carbonate.
- Option C is the correct reagent combination.

Why other options are incorrect:

- **Option A:** Dilute aqueous NaOH merely dissolves the salt without providing the high temperature needed for thermal decarboxylation.
- **Option B:** Alcoholic KOH is a dehydrohalogenating agent used to prepare alkenes from alkyl halides.
- **Option D:** Sodium metal in dry ether is used in the Wurtz or Wurtz-Fittig reaction to couple alkyl or aryl halides.

Question #78 Key: (B)CHEMISTRY
14. Hydrocarbons

Which of the following hydrocarbons does NOT typically undergo substitution reactions under nor...

CORE CONCEPT & DERIVATION

Alkenes possess exposed, loosely held π -electron clouds that react readily via electrophilic addition, breaking the π -bond rather than undergoing substitution.

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

- Ethane ($\text{CH}_3 - \text{CH}_3$) is an alkane and undergoes free-radical substitution reactions under UV light.
- Benzene (C_6H_6) has exceptional resonance stabilization and undergoes electrophilic aromatic substitution to retain aromaticity.
- Ethyne ($\text{CH} \equiv \text{CH}$) possesses acidic sp-hybridized terminal protons that undergo substitution with heavy metal cations to form metal acetylides.
- Ethene ($\text{CH}_2 = \text{CH}_2$) undergoes electrophilic addition across its double bond and does not typically undergo substitution reactions. Option B is correct.

Why other options are incorrect:

- **Option A:** Ethane undergoes free-radical chlorination or bromination substitutions.
- **Option C:** Ethyne undergoes substitution of its terminal acetylenic hydrogen atoms with ammoniacal cuprous or silver solutions.
- **Option D:** Benzene selectively undergoes electrophilic substitution (nitration, sulfonation, halogenation, Friedel-Crafts).

Question #79 Key: (A)CHEMISTRY
13. Fundamental Principles of Organic Chemistry

According to IUPAC rules, when both a double bond and a triple bond are present in the same hyd...

CORE CONCEPT & DERIVATION

IUPAC rules dictate that compounds containing both double and triple bonds are named as alkenynes, dropping the terminal 'e' from '-ene' to produce the composite suffix '-enyne'.

Formula / Rule / Reaction:

Root Name + '-en-' + '-yne' → 'alk-X-en-Y-yne' (Composite suffix: -enyne)

Solution:

- The principal chain must contain both unsaturated linkages.
- The double bond is designated by the primary suffix '-ene' and the triple bond by '-yne'.
- Because 'y' follows 'e' alphabetically in the suffix list, the terminal 'e' of '-ene' is elided before the vowel sound, producing '-en- + -yne' = '-enyne'. Option A is correct.

Why other options are incorrect:

- Option B:** The suffix '-ene' denotes molecules that contain only double bonds as unsaturations.
- Option C:** The suffix '-yne' denotes molecules that contain only triple bonds as unsaturations.
- Option D:** The suffix '-ane' is reserved for fully saturated alkanes.

Question #80 Key: (A)CHEMISTRY
14. Hydrocarbons

Which of the following hydrocarbons is chemically the LEAST reactive toward typical addition an...

CORE CONCEPT & DERIVATION

Alkanes (paraffins) possess only strong, localized, non-polar C – C and C – H σ – bonds, lacking π – electrons, making them inert to polar reagents.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Alkenes and alkynes contain exposed π – bonds and react readily via electrophilic addition.
- Benzene has a delocalized aromatic sextet that resists addition, but it undergoes rapid electrophilic aromatic substitutions (nitration, halogenation).
- Ethane has only stable, non-polar σ – bonds with high bond dissociation energies (C – C $\approx$ 348 kJ/mol, C – H $\approx$ 413 kJ/mol).
- It does not react with acids, bases, or typical oxidizing agents like KMnO_4 at room temperature, making it the least reactive hydrocarbon overall. Option A is correct.

Why other options are incorrect:

- Option B:** Ethene reacts rapidly with halogens, strong acids, and oxidizing agents via electrophilic addition.
- Option C:** Benzene undergoes electrophilic substitution reactions much more readily than ethane undergoes paraffinic reactions.
- Option D:** Ethyne reacts with electrophiles and displays acidic chemistry with bases, making it far more reactive than ethane.

Question #81 Key: (D)CHEMISTRY
14. Hydrocarbons

What is the general decreasing order of chemical reactivity for aliphatic hydrocarbons toward e...

CORE CONCEPT & DERIVATION

Alkenes are more reactive toward electrophiles than alkynes because the intermediate carbocation is more stable than an intermediate vinylic carbocation, while alkanes lack π -electrons entirely.

Formula / Rule / Reaction:

Reactivity toward Electrophiles: Alkenes (sp^2) > Alkynes (sp) > Alkanes (sp^3)

Solution:

- Alkenes contain exposed π -electron clouds held between sp^2 -hybridized carbons, making them nucleophilic and easily polarized.
- In alkynes, the π -electrons are held more tightly between sp -hybridized carbons (50% s-character), and electrophilic attack yields an unstable vinylic cation, reducing their reactivity relative to alkenes.
- Alkanes possess only localized, non-polar σ -bonds and do not react with electrophiles.
- Thus, the decreasing order is Alkenes > Alkynes > Alkanes. Option D is correct.

Why other options are incorrect:

- Option A:** Alkanes are the least reactive, not the most reactive.
- Option B:** Alkynes are more reactive toward electrophilic addition than saturated alkanes.
- Option C:** Alkenes react faster than alkynes toward typical electrophilic additions (e.g., bromination or hydration).

Question #82 Key: (B)CHEMISTRY
17. Aldehydes & Ketones

In the Aldol condensation and the Cannizzaro reaction, the specific chemical role of the hydrox...

CORE CONCEPT & DERIVATION

In the Aldol reaction, OH^- acts as a Bronsted base to abstract an α -proton; in the Cannizzaro reaction, it acts as a Lewis nucleophile to attack a carbonyl carbon lacking α -protons.

Formula / Rule / Reaction:

Aldol: $OH^- + R-CH_2-CHO \rightarrow H_2O + [R-CH-CHO]^-$ (Base)

Cannizzaro: $HCHO + OH^- \rightarrow H_2C(O^-)OH$ (Nucleophile)

Solution:

- In the Aldol condensation, aldehydes with α -hydrogens are deprotonated by OH^- acting as a base, forming a resonance-stabilized enolate nucleophile.
- In the Cannizzaro reaction, aldehydes lack α -hydrogens (e.g., $HCHO$, C_6H_5CHO). The OH^- ion attacks the electrophilic carbonyl carbon directly as a nucleophile, creating a tetrahedral intermediate that transfers a hydride ion.
- Therefore, $NaOH$ functions as a base and nucleophile, respectively. Option B is correct.

Why other options are incorrect:

- Option A:** Hydroxide is an electron-rich anion and never acts as an electrophile.
- Option C:** Hydroxide behaves as an electron donor (base/nucleophile), not an electrophile.
- Option D:** This reverses the roles across the two reactions.

Question #83 Key: (D)

CHEMISTRY
07. Equilibrium

Which of the following modifications will NOT shift the equilibrium to favor an increased yield...

CORE CONCEPT & DERIVATION

According to Le Chatelier's principle, adding a reaction product shifts the equilibrium in the reverse direction, reducing synthesis yield.

Formula / Rule / Reaction:

$$Q_c = \frac{[\text{NH}_3]^2}{[\text{N}_2][\text{H}_2]^3} > K_c \implies \text{System shifts backward to the left}$$

Solution:

- The synthesis of ammonia is exothermic ($\Delta H < 0$) and proceeds with a reduction in gaseous moles (from 4 moles of reactants to 2 moles of product).
- Lowering temperature shifts the equilibrium forward (exothermic direction).
- Increasing pressure shifts the equilibrium forward (toward fewer gaseous moles).
- Continuously condensing and removing product NH_3 reduces Q_c , driving the forward reaction.
- Adding NH_3 increases product concentration, shifting the equilibrium to the left and decreasing net synthesis. Option D is correct.

Why other options are incorrect:

- **Option A:** Decreasing temperature favors the forward exothermic direction, increasing equilibrium yield.
- **Option B:** Increasing pressure favors the side with fewer gas moles (2 moles vs 4 moles), increasing yield.
- **Option C:** Removing NH_3 continuously shifts the equilibrium forward according to Le Chatelier's principle.

Question #84 Key: (B)

CHEMISTRY
07. Equilibrium

Which of the following statements is NOT a valid feature or deduction of Le Chatelier's principle...

CORE CONCEPT & DERIVATION

Le Chatelier's principle is a thermodynamic rule that predicts the direction an equilibrium shifts in response to a disturbance; it does not predict kinetic reaction rates.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Le Chatelier's principle states that if a dynamic equilibrium is disturbed by changing concentration, pressure, or temperature, the system shifts in the direction that counteracts the disturbance.
- It provides qualitative thermodynamic information about equilibrium composition (thermodynamic position).
- It does not provide quantitative information about the rates of the forward or reverse reactions, which are determined by chemical kinetics (Arrhenius equation, rate laws, and activation energies).
- Therefore, statement B is NOT true regarding Le Chatelier's principle.

Why other options are incorrect:

- **Option A:** Predicting how concentration changes shift equilibrium is a primary application of the principle.
- **Option C:** Predicting how pressure variations shift gas-phase equilibria based on mole changes is an established application.
- **Option D:** Predicting equilibrium shifts with temperature based on reaction enthalpy is an established application.

Question #85 Key: (D)

CHEMISTRY
07. Equilibrium

For a reversible gas-phase reaction in which the total number of moles of gaseous reactants equals...

CORE CONCEPT & DERIVATION

The relation between equilibrium constants in terms of partial pressures (K_p) and molar concentrations (K_c) depends directly on the change in gaseous mole count (Δn_g).

Formula / Rule / Reaction:

$$K_p = K_c(RT)^{\Delta n_g}$$

Solution:

- $\Delta n_g = \sum n_{\text{gaseous products}} - \sum n_{\text{gaseous reactants}}$
- When the number of moles of gaseous reactants equals the number of moles of gaseous products, $\Delta n_g = 0$.
- Substituting into the relationship gives:

$$K_p = K_c(RT)^0 = K_c(1) = K_c$$

- Therefore, K_p is numerically equal to K_c , making Option D correct.

Why other options are incorrect:

- Option A:** $K_p > K_c$ occurs only when $\Delta n_g > 0$ and $RT > 1$.
- Option B:** $K_c > K_p$ occurs only when $\Delta n_g < 0$ and $RT > 1$.
- Option C:** When $\Delta n_g = 0$, pressure changes have no effect on the equilibrium position, and K_p remains equal to K_c .

Question #87 Key: (B)

CHEMISTRY
08. Reaction Kinetics

As a typical chemical reaction proceeds forward under constant volume and temperature, the rate...

CORE CONCEPT & DERIVATION

Reaction rate is directly proportional to reactant concentrations; as reactants are consumed over time, the collision frequency decreases and the rate slows.

Formula / Rule / Reaction:

$$\text{Rate} = k[\text{Reactants}]^n \quad \text{Since } [\text{Reactants}] \downarrow \text{ with time } t, \text{ Rate } \downarrow$$

Solution:

- According to collision theory, reaction rate depends on the frequency of effective collisions per unit volume per second.
- As the reaction proceeds, reactants are converted into products, progressively lowering their molar concentrations.
- This reduces effective collision frequency, causing the reaction rate to decrease continuously until equilibrium or completion is reached. Option B is correct.

Why other options are incorrect:

- Option A:** Reaction rate does not increase over time unless the reaction is autocatalytic.
- Option C:** The rate remains constant only for zero-order reactions where rate is independent of reactant concentration.
- Option D:** Typical reactions decelerate smoothly from the start without an induction period.

Question #86 Key: (A)

CHEMISTRY
08. Reaction Kinetics

In a chemical rate law equation, the specific rate constant ([Formula]) is numerically equal...

CORE CONCEPT & DERIVATION

The specific rate constant k is defined as the reaction velocity when all participating reactant concentrations are unity (1 mol/L).

Formula / Rule / Reaction:

$$\text{Rate} = k[A]^x[B]^y \implies \text{When } [A] = [B] = 1 \text{ M, Rate} = k(1)^x(1)^y = k$$

Solution:

- For any general rate law $\text{Rate} = k[A]^m[B]^n$, if every reactant concentration is set to unit molarity (1 mol/dm³ or 1 M):

$$\text{Rate} = k(1.0)^m(1.0)^n = k$$

- Because unity raised to any power is 1, the measured reaction rate equals the specific rate constant. Option A is correct.

Why other options are incorrect:

- Option B:** At 2 M, the rate equals $k \cdot 2^{(m+n)}$, which is not equal to k (unless overall order is 0).
- Option C:** At 3 M, the reaction rate depends on the reaction order and will not equal k .
- Option D:** At 4 M, the rate scales with the reaction order and is not equal to k .

Question #88 Key: (C)

CHEMISTRY
09. Thermochemistry

For all thermodynamically exothermic chemical reactions, the sign assigned to the standard enthalpy change is...

CORE CONCEPT & DERIVATION

Exothermic reactions release thermal energy to the surroundings because the total enthalpy of the products is lower than the total enthalpy of the reactants.

Formula / Rule / Reaction:

$$\Delta H = H_{\text{products}} - H_{\text{reactants}} < 0 \quad (\text{Negative value})$$

Solution:

- By thermodynamic convention, heat absorbed by a system is positive ($q > 0$), and heat released to the surroundings is negative ($q < 0$).
- In an exothermic reaction, the energy released during new bond formation in products exceeds the energy consumed to break bonds in reactants.
- Consequently, the system loses heat, and ΔH° is negative. Option C is correct.

Why other options are incorrect:

- **Option A:** $\Delta H = 0$ denotes an athermal process where no net heat is exchanged.
- **Option B:** A positive ΔH° denotes an endothermic reaction where heat is absorbed from the surroundings.
- **Option D:** While the magnitude of ΔH varies slightly with temperature (Kirchhoff's law), its sign remains negative for exothermic reactions.

Question #89 Key: (A)

CHEMISTRY
06. Solids

Which of the following fundamental structural insights is directly provided by the experimental measurement of lattice energy?

CORE CONCEPT & DERIVATION

Lattice energy is the energy released when one mole of an ionic crystalline solid is formed from its constituent gaseous ions, quantifying ionic bond strength.

Formula / Rule / Reaction:



Solution:

- Lattice energy measures the electrostatic forces holding an ionic crystal together.
- Higher lattice energy values correlate with higher melting points, greater mechanical hardness, and lower solubility in non-polar solvents.
- It provides information regarding the stability, packing geometry, and coordination structure of ionic crystals, making Option A correct.

Why other options are incorrect:

- **Option B:** Covalent bonding is characterized by bond dissociation energy, bond order, and molecular orbital theory.
- **Option C:** Metallic bonding in metals and alloys is characterized by enthalpy of atomization and electron band structure.
- **Option D:** Molecular geometries and dipole moments are determined by VSEPR theory and electronegativity differences.

Question #90 Key: (B)

CHEMISTRY
10. Electrochemistry

In the balanced redox half-reaction occurring in acidic solution:
 $\text{Cr}_2\text{O}_7^{2-} \rightarrow \text{Cr}^{3+}$...

CORE CONCEPT & DERIVATION

The number of electrons gained per atom during a reduction process equals the change in its formal oxidation state.

Formula / Rule / Reaction:

$$\text{In } \text{Cr}_2\text{O}_7^{2-} : 2x + 7(-2) = -2 \implies 2x = +12 \implies x = +6$$

$$\text{In } \text{Cr}^{3+} : x = +3$$

Solution:

- Each chromium atom in the dichromate ion begins with an oxidation state of +6.
- In the product, each chromium ion has an oxidation state of +3.
- The reduction per chromium atom is:

$$\text{Electrons gained per Cr atom} = +6 - (+3) = 3e^-$$

- Across the two chromium atoms in the formula unit, a total of $6e^-$ are gained.
- Because the question asks for the electrons gained by *each* chromium atom, the answer is 3. Option B is correct.

Why other options are incorrect:

- Option A:** Twelve electrons would represent an impossible change in oxidation state from +6 to -6.
- Option C:** Six is the total number of electrons gained by the entire dichromate ion (both Cr atoms combined), not per individual atom.
- Option D:** One electron would reduce Cr from +6 to +5, which does not yield Cr^{3+} .

Question #91 Key: (A)

CHEMISTRY
11. S & P Block Elements

In peroxides such as sodium peroxide (Na_2O_2) and hydrogen peroxide (H_2O_2), the oxidation state of oxygen is...

CORE CONCEPT & DERIVATION

In peroxides, two oxygen atoms are linked by a single covalent peroxide bond ($-\text{O}-\text{O}-$), resulting in a -2 charge shared across two oxygen atoms.

Formula / Rule / Reaction:

$$\text{In } \text{Na}_2\text{O}_2 : 2(+1) + 2(x) = 0 \implies 2x = -2 \implies x = -1$$

Solution:

- Alkali metals always have an oxidation state of +1 in their compounds.
- In Na_2O_2 , the two sodium atoms contribute a total charge of +2.
- For the molecule to be electrically neutral, the peroxide group $[\text{O}_2]^{2-}$ must have a net charge of -2.
- Dividing across the two bonded oxygen atoms gives an oxidation state of -1 per oxygen atom. Option A is correct.

Why other options are incorrect:

- Option B:** Oxygen exhibits a +2 oxidation state only in oxygen difluoride (OF_2), where it bonds to more electronegative fluorine.
- Option C:** The -2 oxidation state is characteristic of normal oxides (e.g., Na_2O , H_2O).
- Option D:** Oxygen displays a +1 oxidation state in dioxygen difluoride (O_2F_2).

Question #92 Key: (D)

CHEMISTRY
03. Chemical Bonding

Which of the following electron addition processes is endothermic and therefore associated with...

CORE CONCEPT & DERIVATION

The first electron affinity of neutral non-metals is exothermic (energy is released); the second electron affinity is always endothermic because an incoming electron is repelled by an existing negative charge.

Formula / Rule / Reaction:



Solution:

- When an electron is added to a neutral atom (like Cl or O), nuclear attraction outweighs inter-electronic repulsion, releasing energy ($\Delta H < 0$).
- When a second electron is added to an already negatively charged ion (O^-), it faces strong electrostatic repulsion from the existing electron cloud.
- Work must be done to overcome this repulsion and force the electron into the orbital, making the second electron affinity endothermic ($\Delta H > 0$). Option D is correct.

Why other options are incorrect:

- Option A:** The first electron affinity of chlorine is highly exothermic ($\Delta H = -349 \text{ kJ/mol}$).
- Option B:** Adding an electron to an excited chlorine atom remains exothermic due to the net positive nuclear pull.
- Option C:** The first electron affinity of oxygen is exothermic ($\Delta H = -141 \text{ kJ/mol}$).

Question #93 Key: (B)

CHEMISTRY
03. Chemical Bonding

Which of the following chemical species contains a central atom with [Formula] hybridization an...

CORE CONCEPT & DERIVATION

Steric number (number of σ -bonds plus lone pairs) determines the hybridization state of the central atom; a steric number of 3 corresponds to sp^2 hybridization.

Formula / Rule / Reaction:

$$\text{Steric Number} = \frac{1}{2}[V + M - C + A] = \frac{1}{2}[3 + 3 - 0 + 0] = 3 \Rightarrow \text{sp}^2$$

Geometry: Trigonal planar, bond angles = 120°

Solution:

- In boron trifluoride (BF_3), the central boron atom has 3 valence electrons and forms 3 single σ -bonds with three fluorine atoms, leaving zero non-bonding lone pairs.
- Its steric number is 3, requiring one s and two p orbitals to hybridize into three equivalent sp^2 hybrid orbitals.
- These orbitals point toward the vertices of an equilateral triangle with 120° bond angles. Option B is correct.

Why other options are incorrect:

- Option A:** In NH_3 , nitrogen has 3 bonding pairs and 1 lone pair (steric number 4), giving sp^3 hybridization with a trigonal pyramidal geometry.
- Option C:** In H_2O , oxygen has 2 bonding pairs and 2 lone pairs (steric number 4), giving sp^3 hybridization with a bent geometry.
- Option D:** In gaseous BeCl_2 , beryllium forms 2 bonding pairs with 0 lone pairs (steric number 2), giving sp hybridization with a linear geometry.

Question #94 Key: (B)

CHEMISTRY
11. S & P Block Elements

Among the third-period elements sodium (Na), magnesium (Mg), phosphorus (P), and sulfur (S), wh...

CORE CONCEPT & DERIVATION

Across a period from left to right, principal quantum number remains constant while effective nuclear charge increases, drawing valence electrons closer and decreasing atomic radius.

Formula / Rule / Reaction:

Atomic Radii (pm): Na (186) > Mg (160) > P (110) > S (104)

Solution:

- All four elements belong to Period 3, meaning their valence electrons reside in the $n = 3$ shell.
- Moving from sodium to sulfur, protons are added to the nucleus (Na has 11, Mg has 12, P has 15, S has 16) while electrons enter the same principal energy level.
- The effective nuclear charge (Z_{eff}) increases steadily, pulling the electron clouds inward.
- Sulfur has the highest Z_{eff} among these choices and therefore has the smallest atomic radius (approx. 104 pm). Option B is correct.

Why other options are incorrect:

- **Option A:** Magnesium is located near the left of the period (Group IIA) and has a large atomic radius (160 pm).
- **Option C:** Phosphorus precedes sulfur in Period 3 (Group VA), so its radius (110 pm) is larger than sulfur's.
- **Option D:** Sodium is on the far left (Group IA) and has the largest atomic radius in Period 3 (186 pm).

Question #95 Key: (A)

CHEMISTRY
05. Liquids

The melting point of elemental sulfur ([Formula]) is significantly higher than that of elemen...

CORE CONCEPT & DERIVATION

London dispersion forces scale with molecular mass and electron count; larger, more polarizable electron clouds produce stronger intermolecular attractions and higher melting points.

Formula / Rule / Reaction:

$\text{Melting Points: } S_8 \approx 115.2^\circ\text{C}; P_4 \approx 44.1^\circ\text{C}$

Solution:

- Both solid sulfur and white phosphorus are non-polar molecular solids held together by weak London dispersion forces.
- An S_8 molecule contains 8 sulfur atoms (molecular weight ≈ 256.5 g/mol, 128 electrons), forming a crown-shaped ring.
- A P_4 molecule contains 4 phosphorus atoms (molecular weight ≈ 123.9 g/mol, 60 electrons) arranged in a tetrahedron.
- Because S_8 has more than twice the electrons of P_4 , its electron cloud is significantly more polarizable, creating stronger dispersion forces and a higher melting point. Option A is correct.

Why other options are incorrect:

- **Option B:** Both homonuclear molecules (S_8 and P_4) consist of identical atoms and have strictly non-polar covalent bonds.
- **Option C:** Phosphorus has fewer electrons and weaker dispersion forces than sulfur.
- **Option D:** Rhombic sulfur is a molecular solid composed of discrete S_8 rings, not a giant covalent network like diamond or quartz.

Question #96 Key: (B)CHEMISTRY
15. Alkyl Halides

Alkyl halide nucleophilic substitution reactions in which [Formula] bond cleavage and [Formula]...

CORE CONCEPT & DERIVATION

The S_N2 mechanism is a bimolecular, single-step concerted nucleophilic substitution passing through a pentacoordinate transition state.

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

- In an S_N2 reaction (Substitution Nucleophilic Bimolecular), the nucleophile attacks the electrophilic carbon from the backside (180° relative to the leaving group).
- Bond making between the nucleophile and carbon occurs simultaneously with bond breaking between carbon and the halogen leaving group.
- This single concerted step generates an inverted configuration (Walden inversion) without a carbocation intermediate. Option B is correct.

Why other options are incorrect:

- Option A:** The S_N1 mechanism is a two-step process where the leaving group departs first to form a carbocation intermediate before the nucleophile attacks.
- Option C:** The $E1$ mechanism is a two-step unimolecular elimination producing an alkene via a carbocation intermediate.
- Option D:** The $E2$ mechanism is a concerted elimination yielding an alkene, rather than a nucleophilic substitution.

Question #97 Key: (D)CHEMISTRY
14. Hydrocarbons

A nucleophilic substitution reaction of an optically active alkyl halide that results in approx...

CORE CONCEPT & DERIVATION

The S_N1 mechanism proceeds via an achiral, planar carbocation intermediate that can be attacked equally from either face, producing a racemic mixture.

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

- In the rate-determining first step of an S_N1 reaction, the leaving group leaves, producing a flat, trigonal planar sp^2 -hybridized carbocation.
- The incoming nucleophile has an equal probability of attacking from the front face (producing retention of configuration) or the back face (producing inversion).
- This produces a 50:50 mixture of enantiomers (complete racemization in ideal cases). Option D is correct.

Why other options are incorrect:

- Option A:** The $E2$ mechanism is an elimination pathway requiring an anti-periplanar geometry to form alkenes.
- Option B:** The $E1$ mechanism is an elimination reaction forming alkenes via a carbocation intermediate.
- Option C:** The S_N2 mechanism proceeds with 100% complete inversion of configuration (Walden inversion).

Question #98 Key: (B)

CHEMISTRY
16. Alcohols & Phenols

When alcohols react via cleavage of the [Formula] bond (acting as Bronsted acids in the presence...

CORE CONCEPT & DERIVATION

Acidity and O – H bond cleavage in alcohols depend on the stability of the alkoxide conjugate base; electron-donating alkyl groups destabilize the negative charge via the inductive effect (+I).

Formula / Rule / Reaction:



Solution:

- Cleavage of the O – H bond releases a proton, producing an alkoxide ion ($\text{R} - \text{O}^-$).
- Alkyl groups are electron-donating (+I effect). The more alkyl groups attached to the carbinol carbon, the greater the electron density pushed onto the oxygen atom.
- This destabilizes the alkoxide anion and makes tertiary alcohols the least acidic and least reactive toward O – H cleavage.
- Methanol has no electron-donating alkyl groups attached to its carbinol carbon, making it the most reactive, followed by $1^\circ > 2^\circ > 3^\circ$. Option B is the complete order.

Why other options are incorrect:

- **Option A:** While the sequence across primary, secondary, and tertiary is correct, it omits methyl alcohol, which is the most acidic and reactive member of the series.
- **Option C:** This represents the order of reactivity for C – O bond cleavage (e.g., reaction with hydrogen halides, HX), which is the reverse of O – H cleavage.
- **Option D:** This order is chemically disordered and does not match inductive stability trends.

Question #99 Key: (A)

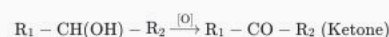
CHEMISTRY
16. Alcohols & Phenols

The controlled oxidation of primary and secondary alcohols yields which pair of functional groups...

CORE CONCEPT & DERIVATION

Oxidation of an alcohol involves dehydrogenation of the carbinol carbon; primary alcohols form aldehydes, while secondary alcohols form ketones.

Formula / Rule / Reaction:



Solution:

- Primary alcohols (1°) have two α -hydrogens; oxidation removes these hydrogens to form an aldehyde (which can be further oxidized to a carboxylic acid).
- Secondary alcohols (2°) have one α -hydrogen; oxidation removes this hydrogen along with the hydroxyl hydrogen to produce a stable ketone.
- Tertiary alcohols lack α -hydrogens and resist oxidation under neutral or alkaline conditions.
- Thus, controlled oxidation yields an aldehyde and a ketone, respectively. Option A is correct.

Why other options are incorrect:

- **Option B:** Alkanes are fully reduced hydrocarbons that are never produced by the oxidation of alcohols.
- **Option C:** Ketones arise from secondary alcohols, but primary alcohols yield aldehydes, not alkanes.
- **Option D:** Ethers are formed by intermolecular dehydration of alcohols in concentrated acid, not by redox oxidation.

Question #100 Key: (B)

CHEMISTRY
16. Alcohols & Phenols

What is the correct decreasing order of relative acidic strength among carboxylic acids, phenol...

CORE CONCEPT & DERIVATION

Acid strength corresponds directly to conjugate base stability; carboxylate anions are stabilized by two equivalent electronegative oxygens, phenoxide is stabilized across the aromatic ring, and alkoxide is destabilized by +I alkyl groups.

Formula / Rule / Reaction:

pK_a Scale: RCOOH (≈ 4 to 5) < Phenol (≈ 10) < H_2O (15.7) < ROH (16 to 18)

Solution:

- Carboxylic acids are the most acidic because resonance delocalizes the negative charge equally between two electronegative oxygen atoms.
- Phenol is more acidic than water because the phenoxide ion delocalizes charge over the aromatic ring carbons.
- Water ($pK_a = 15.7$) is more acidic than aliphatic alcohols ($pK_a = 16$ to 18) because the electron-donating alkyl group in alcohols (+I effect) destabilizes the alkoxide anion.
- Thus, the decreasing acidic strength order is $-\text{COOH} > \text{C}_6\text{H}_5\text{OH} > \text{H}_2\text{O} > \text{R} - \text{OH}$. Option B is correct.

Why other options are incorrect:

- Option A:** This incorrectly places water as more acidic than phenol (phenol's pK_a of 10 makes it approximately 10^5 times more acidic than water).
- Option C:** Alcohols are weaker acids than both phenol and water, not stronger.
- Option D:** This incorrectly places water ahead of phenol and ranks alcohols ahead of phenol.

Question #101 Key: (D)

CHEMISTRY
17. Aldehydes & Ketones

Aliphatic and aromatic aldehydes can be oxidized by mild and strong oxidizing agents, but they ...

CORE CONCEPT & DERIVATION

Aldehydes possess an easily oxidizable aldehydic hydrogen atom and react with oxidizing agents; non-oxidizing mineral acids like HCl cannot effect this oxidation.

Formula / Rule / Reaction:



Solution:

- Aldehydes are strong reducing agents and undergo oxidation to carboxylic acids with acidified potassium dichromate, potassium permanganate, or concentrated nitric acid.
- Hydrochloric acid (HCl) is a non-oxidizing mineral acid that acts as a source of hydronium and chloride ions, but lacks the redox potential to oxidize aldehydes.
- Therefore, aldehydes cannot be oxidized by HCl, making Option D correct.

Why other options are incorrect:

- Option A:** Acidified potassium dichromate is an established laboratory reagent that oxidizes aldehydes to carboxylic acids.
- Option B:** Concentrated nitric acid is a strong oxidizing acid that oxidizes aldehydes.
- Option C:** Alkaline potassium permanganate oxidizes aldehydes to carboxylate salts.

Question #102 Key: (C)

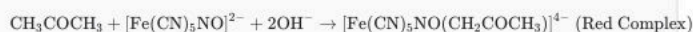
CHEMISTRY
17. Aldehydes & Ketones

Aldehydes do NOT give a positive identification result in which of the following qualitative di...

CORE CONCEPT & DERIVATION

The sodium nitroprusside test specifically detects methyl ketones, producing a characteristic wine-red or purple coloration in alkaline solution.

Formula / Rule / Reaction:



Solution:

- Both aldehydes and ketones react with Brady's reagent (2,4-DNPH) to yield orange-red hydrazone precipitates.
- Tollens' and Fehling's tests detect the reducing power of aldehydes, producing a silver mirror and red Cu_2O precipitate, respectively.
- The sodium nitroprusside test detects the enolizable $-\text{COCH}_3$ methyl keto group, which forms a colored complex. Aldehydes do not yield this coloration. Option C is correct.

Why other options are incorrect:

- Option A:** All aldehydes react with 2,4-DNPH via condensation to form colored crystalline 2,4-dinitrophenylhydrazones.
- Option B:** Aldehydes reduce Tollens' ammoniacal silver nitrate reagent to elemental metallic silver.
- Option D:** Aliphatic aldehydes reduce alkaline cupric tartrate complex (Fehling's reagent) to insoluble red cuprous oxide.

Question #103 Key: (C)

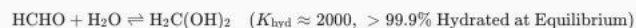
CHEMISTRY
17. Aldehydes & Ketones

In aqueous solution, the equilibrium percentage of the gem-diol hydrate form is highest for:

CORE CONCEPT & DERIVATION

Hydration of carbonyl compounds is favored by small steric bulk and strong partial positive charge on the carbonyl carbon, both maximized in formaldehyde.

Formula / Rule / Reaction:



Solution:

- Carbonyl hydration involves nucleophilic addition of water across the $\text{C}=\text{O}$ double bond to form a geminal diol.
- Electron-donating alkyl groups reduce the electrophilic character of the carbonyl carbon through inductive (+I) and hyperconjugative stabilization.
- Formaldehyde possesses two small hydrogen atoms attached to the carbonyl group, minimizing steric strain and maximizing electrophilicity.
- Consequently, its hydration constant is around 2000, giving over 99.9% hydrate in water. Option C is correct.

Why other options are incorrect:

- Option A:** Propanal possesses an ethyl group whose inductive effect and steric volume lower hydration to approximately 50%.
- Option B:** Acetone has two methyl groups that stabilize the carbonyl group and hinder attack, leaving it less than 0.2% hydrated.
- Option D:** Acetaldehyde has one methyl group (+I effect), reaching approximately 58% hydration in water.

Question #104 Key: (B)

CHEMISTRY
18. Carboxylic Acids

When a carboxylic acid is heated with an excess of an alcohol in the presence of concentrated [...]

CORE CONCEPT & DERIVATION

Fischer-Speier esterification is an acid-catalyzed condensation between a carboxylic acid and an alcohol that converts a carboxyl group into an ester group.

Formula / Rule / Reaction:



Solution:

- Concentrated sulfuric acid acts as a Bronsted-Lowry acid catalyst and a dehydrating agent.
- The carboxyl group ($-\text{COOH}$) of the carboxylic acid reacts with the alcohol, eliminating water through nucleophilic acyl substitution.
- This produces an ester linkage ($-\text{COOR}$), making Option B correct.

Why other options are incorrect:

- Option A:** The conversion does not yield an isolated carbonyl group (aldehyde or ketone); it forms an ester.
- Option C:** Carbonyl compounds are not converted into carboxylic acids during this reaction.
- Option D:** Carboxylic acids are not reduced to alcohols (hydroxyl groups) under these conditions; that requires LiAlH_4 .

Question #105 Key: (B)

CHEMISTRY
18. Carboxylic Acids

The reaction of acetic acid with thionyl chloride ([Formula]) results in the chemical transfo...

CORE CONCEPT & DERIVATION

Thionyl chloride selectively replaces the hydroxyl moiety of a carboxylic acid with a chlorine atom, converting it into a reactive acyl chloride.

Formula / Rule / Reaction:



Solution:

- Acetic acid reacts with thionyl chloride to replace the $-\text{OH}$ group with a chloride ion ($-\text{Cl}$).
- The resulting product is acetyl chloride (ethanoyl chloride), which belongs to the acid halide family.
- Because both byproducts (SO_2 and HCl) evolve as gases, the reaction provides high synthetic yields of pure acid halide. Option B is correct.

Why other options are incorrect:

- Option A:** Acetamide is prepared by reacting an acyl chloride or ester with ammonia, not with thionyl chloride.
- Option C:** Converting carboxylic acids to primary alcohols requires reduction with lithium aluminum hydride.
- Option D:** Esters are formed by reacting carboxylic acids with alcohols in acid, not with thionyl chloride.

Question #106 Key: (C)

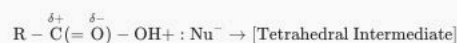
CHEMISTRY
18. Carboxylic Acids

The chemical reactivity and susceptibility of the carboxyl group ([Formula]) toward nucleophi...

CORE CONCEPT & DERIVATION

The reactivity of carboxylic acids is centered on the polarized carbonyl group ($\text{C}=\text{O}$), whose electrophilic carbon attracts incoming nucleophiles.

Formula / Rule / Reaction:



Solution:

- The carbonyl carbon is double-bonded to an electronegative oxygen atom, creating strong dipole polarization with a partial positive charge on carbon (δ^+).
- This electrophilic carbon initiates nucleophilic acyl substitution by attracting electron-rich nucleophiles.
- While the $-\text{OH}$ group determines Bronsted acidity, the primary site for synthetic substitution reactivity is the polarized carbonyl carbon. Option C is correct.

Why other options are incorrect:

- Option A:** The hydroxyl group provides a leaving group (as water after protonation) but does not provide the primary electrophilic center.
- Option B:** The terminal proton accounts for acid-base dissociation, not nucleophilic acyl substitution.
- Option D:** The alkyl group provides weak electron donation (+I), which slightly reduces rather than drives carbonyl reactivity.

Question #107 Key: (A)

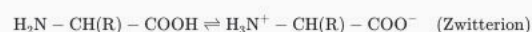
CHEMISTRY
18. Carboxylic Acids

Which two characteristic organic functional groups are present in all proteinogenic [Formula] -...

CORE CONCEPT & DERIVATION

Amino acids are bifunctional organic compounds containing both an acidic carboxyl group and a basic amino group bonded to the same α -carbon atom.

Formula / Rule / Reaction:



Solution:

- Every standard α -amino acid possesses a central tetrahedral α -carbon atom.
- Bonded to this carbon are a basic amino group ($-\text{NH}_2$), an acidic carboxylic acid group ($-\text{COOH}$), a hydrogen atom, and a variable side-chain R group.
- Option A accurately identifies both functional groups.

Why other options are incorrect:

- Option B:** Standard amino acids do not contain aldehyde ($-\text{CHO}$) functional groups.
- Option C:** Ether groups ($-\text{O}-$) are absent from standard amino acid backbones.
- Option D:** Aldehydes are not components of amino acid structures.

Question #108 Key: (A)

CHEMISTRY
01. Stoichiometry

The total number of water molecules present in a [Formula] piece of pure ice is approximately:

CORE CONCEPT & DERIVATION

The number of molecules in a given mass of pure substance is calculated by multiplying its molar amount by Avogadro's constant.

Formula / Rule / Reaction:

$$N = n \cdot N_A = \left(\frac{m}{M}\right) N_A$$

Solution:

- Molar mass of water (H₂O):

$$M = 2(1.008) + 16.00 = 18.016 \text{ g/mol} \approx 18.0 \text{ g/mol}$$

- Number of moles in 10.0 g of ice:

$$n = \frac{10.0 \text{ g}}{18.0 \text{ g/mol}} = 0.5556 \text{ mol}$$

- Total number of molecules:

$$N = 0.5556 \text{ mol} \times 6.022 \times 10^{23} \text{ molecules/mol} = 3.346 \times 10^{23} \text{ molecules}$$

- Therefore, Option A is correct.

Why other options are incorrect:

- **Option B:** This value has an incorrect decimal placement that underestimates the molecular count by a factor of 10.
- **Option C:** This value has an incorrect exponent that overestimates the count by a factor of 10.
- **Option D:** This represents the number of molecules in one full mole (18.0 g), not in 10.0 g.

Question #109 Key: (C)

CHEMISTRY
01. Stoichiometry

The practical efficiency of a synthetic chemical reaction is quantitatively expressed in the la...

CORE CONCEPT & DERIVATION

Percent yield normalizes the experimentally obtained mass of product against the theoretical stoichiometric maximum to quantify reaction efficiency.

Formula / Rule / Reaction:

$$\% \text{ Yield} = \left(\frac{\text{Actual Yield}}{\text{Theoretical Yield}}\right) \times 100\%$$

Solution:

- Theoretical yield is the maximum mass calculated from the limiting reactant via stoichiometry.
- Actual yield is the amount of product isolated experimentally.
- The ratio of actual yield to theoretical yield multiplied by 100 defines the percent yield, which serves as the universal index of chemical reaction efficiency. Option C is correct.

Why other options are incorrect:

- **Option A:** Theoretical yield is an ideal calculated limit that does not reflect actual experimental recovery.
- **Option B:** Actual yield provides raw mass without reference to the stoichiometric maximum.
- **Option D:** Maximum yield is another term for theoretical yield.

Question #110 Key: (A)

CHEMISTRY
01. Stoichiometry

By international convention, one mole of any pure chemical substance contains exactly:

CORE CONCEPT & DERIVATION

The mole is the SI base unit for amount of substance; one mole contains exactly Avogadro's number of elementary entities.

Formula / Rule / Reaction:

$$N_A = 6.02214076 \times 10^{23} \text{ mol}^{-1} \approx 6.02 \times 10^{23} \text{ entities}$$

Solution:

- The definition of a mole fixes Avogadro's number at approximately 6.02×10^{23} particles (atoms, molecules, ions, or formula units).
- Option A represents this standard constant.

Why other options are incorrect:

- **Option B:** This value has an exponent of 10^{24} , which is 10 times too large.
- **Option C:** This value has an exponent of 10^{22} , which is 10 times too small.
- **Option D:** This represents the entity count in half a mole (0.5 mol).

Question #111 Key: (C)

CHEMISTRY
02. Atomic Structure

According to the Aufbau principle and the [Formula] energy rule, which of the following atomic ...

CORE CONCEPT & DERIVATION

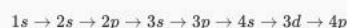
Electrons occupy subshells in order of increasing $(n + l)$ energy values; for subshells with identical $(n + l)$, lower n fills first.

Formula / Rule / Reaction:

For $3d$: $n + l = 3 + 2 = 5$ vs. For $4p$: $n + l = 4 + 1 = 5 \implies 3d$ fills before $4p$

Solution:

- The standard Aufbau filling sequence across periods 1 to 4 is:



- Both the $3d$ and $4p$ subshells have an $(n + l)$ sum of 5.
- Because $3d$ has a lower principal quantum number ($n = 3$ versus $n = 4$), it possesses lower energy and fills immediately before the $4p$ subshell. Option C is correct.

Why other options are incorrect:

- Option A:** The $4s$ subshell fills before $3d$, so it does not fill immediately before $4p$.
- Option B:** The $2p$ subshell fills much earlier in Period 2.
- Option D:** The $1s$ subshell is the lowest energy subshell and fills first in an atom.

Question #112 Key: (A)

CHEMISTRY
02. Atomic Structure

If the azimuthal quantum number for a given electron subshell is [Formula], the permitted valu...

CORE CONCEPT & DERIVATION

The magnetic quantum number m designates spatial orientation and assumes $(2l + 1)$ integer values ranging from $-l$ to $+l$.

Formula / Rule / Reaction:

$$m_l = -l, -(l-1), \dots, 0, \dots, +(l-1), +l$$

Solution:

- For $l = 1$ (a p subshell), the allowed values of m are:

$$m = -1, 0, +1$$

- This corresponds to $2(1) + 1 = 3$ spatial orbitals (p_x, p_y, p_z).
- Therefore, m ranges from -1 to $+1$, making Option A correct.

Why other options are incorrect:

- Option B:** Magnetic quantum numbers are symmetric about zero and cannot extend to $+2$ when $l = 1$.
- Option C:** Values up to $+3$ are permitted only for f orbitals where $l = 3$.
- Option D:** Values up to $+4$ would require $l = 4$ (a g subshell).

Question #113 Key: (A)

CHEMISTRY
10. Electrochemistry

An applied pressure of [Formula] is equivalent to approximately:

CORE CONCEPT & DERIVATION

Standard atmospheric pressure equals 101,325 Pa; pressure in atmospheres is determined by dividing pressure in Pascals by this conversion factor.

Formula / Rule / Reaction:

$$1 \text{ atm} = 101325 \text{ Pa} = 101.325 \text{ kPa} = 760 \text{ Torr}$$

Solution:

- To convert 10 Pa to atmospheres:

$$P = \frac{10.0 \text{ Pa}}{101325 \text{ Pa/atm}} = 9.869 \times 10^{-5} \text{ atm} \approx 0.000098 \text{ atm}$$

- Option A represents this converted value.

Why other options are incorrect:

- Option B:** A pressure of 1.98 atm equals approximately 200,600 Pa, which is four orders of magnitude too large.
- Option C:** 10 Pa equals 0.010 kPa, not 10.019 kPa.
- Option D:** 10 Pa equals 0.00145 psi (since 1 psi $\approx$ 6895 Pa).

Question #114 Key: (D)

CHEMISTRY
02. Atomic Structure

The dumbbell-shaped atomic orbitals ([Formula] orbitals) can be oriented along how many mutual...

CORE CONCEPT & DERIVATION

The p subshell has an azimuthal quantum number $l = 1$, which yields three degenerate orbitals oriented along the Cartesian x , y , and z axes.

Formula / Rule / Reaction:

$$\text{Number of Orbitals} = 2l + 1 = 2(1) + 1 = 3 \quad (p_x, p_y, p_z)$$

Solution:

- The boundary surface diagram of a p orbital consists of two nodal lobes resembling a dumbbell.
- Because the magnetic quantum number allows three values ($m = -1, 0, +1$), three orthogonal orientations exist along the x , y , and z axes.
- Therefore, dumbbell orbitals orient in 3 spatial directions. Option D is correct.

Why other options are incorrect:

- Option A:** Seven spatial orientations occur in the f subshell ($l = 3$).
- Option B:** Five spatial orientations occur in the d subshell ($l = 2$).
- Option C:** One spherically symmetrical orientation occurs in the s subshell ($l = 0$).

Question #115 Key: (C)

CHEMISTRY
02: Atomic Structure

For any given principal energy level [Formula], the maximum permitted value of the azimuthal q...

CORE CONCEPT & DERIVATION

The azimuthal quantum number l takes all integer values from 0 up to $(n - 1)$ for an electron shell with principal quantum number n .

Formula / Rule / Reaction:

$$l = 0, 1, 2, \dots, (n - 1) \implies l_{\max} = n - 1$$

Solution:

- For any principal energy level n , the orbital angular momentum is quantized.
- The permitted integer values for l range from 0 to $n - 1$.
- Therefore, the maximum possible value of l in any shell is $l = n - 1$. Option C is correct.

Why other options are incorrect:

- Option A:** This rearranges to $l = n + 1$, which is an unphysical quantum number.
- Option B:** $n - 2$ represents the next-to-highest subshell, not the maximum permitted value.
- Option D:** This rearranges to $l = n + 2$, which violates orbital angular momentum quantization.

Question #116 Key: (C)

CHEMISTRY
04: Gases

In the kinetic molecular theory of ideal gases, the intermolecular forces of attraction and rep...

CORE CONCEPT & DERIVATION

The kinetic molecular theory postulates that ideal gas molecules act as point masses that exert no intermolecular forces of attraction or repulsion on one another.

Formula / Rule / Reaction:

$$P_{\text{ideal}}V = nRT \quad (\text{van der Waals parameter } a = 0)$$

Solution:

- The second postulate of the kinetic molecular theory assumes that attractive and repulsive forces between gas particles are non-existent.
- Particles move in straight lines until colliding elastically with each other or the container walls.
- Consequently, the net intermolecular force between ideal gas molecules is zero. Option C is correct.

Why other options are incorrect:

- Option A:** Strong intermolecular forces describe condensed liquids and solids.
- Option B:** Weak but measurable forces describe real gases (accounted for by parameter a in the van der Waals equation), not ideal gases.
- Option D:** Any non-zero intermolecular attraction causes deviation from ideal gas behavior.

Question #117 Key: (C)

CHEMISTRY
04: Gases

Real gases show their maximum deviation from ideal gas behavior under which of the following ph...

CORE CONCEPT & DERIVATION

Real gases deviate from ideality when gas volume decreases and intermolecular attractions increase, which occurs at high pressure and low temperature.

Formula / Rule / Reaction:

$$\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT \quad (\text{van der Waals Equation})$$

Solution:

- At high pressures, molecules are compressed close together, making their finite molecular volume (nb) significant relative to the total container volume.
- At low temperatures, molecular kinetic energy decreases, allowing intermolecular attractions (van der Waals forces, parameter a) to pull molecules together and reduce pressure.
- Both effects break the ideal gas assumptions, maximizing deviation at low temperature and high pressure. Option C is correct.

Why other options are incorrect:

- Option A:** At low pressure, real gases closely approach ideal gas behavior.
- Option B:** High temperature provides high kinetic energy that overcomes intermolecular attractions, reducing deviation.
- Option D:** High temperature and low pressure are the exact conditions under which real gases behave most ideally.

Question #118 Key: (D)

CHEMISTRY
05. Liquids

Which of the following liquids exhibits the lowest equilibrium vapor pressure at room temperature...

CORE CONCEPT & DERIVATION

Vapor pressure is inversely proportional to the strength of intermolecular forces; liquids with extensive hydrogen bonding exhibit the lowest vapor pressures.

Formula / Rule / Reaction:

$\text{Vapor Pressure at } 20^\circ\text{C: } \text{Water} (17.5 \text{ mmHg}) < \text{CCl}_4 (91) < \text{CHCl}_3 (160) < \text{Ether} (442 \text{ mmHg})$

Solution:

- Water molecules form extensive, three-dimensional hydrogen-bonding networks, with each molecule participating in up to four hydrogen bonds.
- Diethyl ether, chloroform, and carbon tetrachloride are held together by weaker dipole-dipole and London dispersion forces.
- Because water requires the most energy to break its intermolecular network and escape into the vapor phase, it has the lowest vapor pressure (17.5 mmHg at 20 °C). Option D is correct.

Why other options are incorrect:

- Option A:** Diethyl ether has very weak dipole-dipole attractions and is volatile, exerting a high vapor pressure ($\approx 442 \text{ mmHg}$).
- Option B:** Chloroform is a volatile organic solvent with a vapor pressure of approximately 160 mmHg.
- Option C:** Carbon tetrachloride experiences only London dispersion forces and has a vapor pressure of approximately 91 mmHg.

Question #119 Key: (D)

CHEMISTRY
05. Liquids

The intermolecular forces of attraction holding hydrogen molecules together in the crystalline ...

CORE CONCEPT & DERIVATION

Non-polar homonuclear diatomic molecules lack permanent dipoles and are held together in the solid state solely by induced dipole-induced dipole (London dispersion) forces.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Hydrogen gas consists of symmetric, non-polar $\text{H} - \text{H}$ molecules with zero permanent dipole moment.
- In solid molecular hydrogen (formed below 14 K), individual molecules are held in the crystal lattice exclusively by weak, temporary induced dipole-induced dipole attractions (London dispersion forces).
- Option D correctly classifies these intermolecular forces.

Why other options are incorrect:

- Option A:** Classic hydrogen bonding requires hydrogen to be covalently bonded to a highly electronegative atom (F, O, or N) with lone pairs.
- Option B:** Covalent bonds link the two hydrogen atoms within an H_2 molecule, but do not bind separate H_2 molecules together in the crystal lattice.
- Option C:** Coordinate covalent bonds involve lone pair donation, which does not occur between non-polar H_2 molecules.

Question #120 Key: (B)

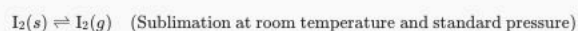
CHEMISTRY
05. Liquids

Which of the following substances forms a soft molecular crystalline solid with weak intermolecular...

CORE CONCEPT & DERIVATION

Non-polar molecular solids composed of large polarizable atoms held only by dispersion forces are soft, have low melting points, and sublime readily.

Formula / Rule / Reaction:



Solution:

- Solid iodine consists of discrete, non-polar I_2 molecules packed into an orthorhombic lattice held solely by London dispersion forces.
- Because these intermolecular forces are weak, iodine crystals are soft, easily deformed, possess a low melting point (113.7 °C), and sublime into purple vapor. Option B is correct.

Why other options are incorrect:

- Option A:** Ice forms a rigid, open hexagonal framework held by strong hydrogen bonds.
- Option C:** Cane sugar forms hard, dense crystals bound by extensive intermolecular hydrogen bonds.
- Option D:** Graphite is a giant covalent network solid with an extremely high sublimation point ($> 3600^\circ\text{C}$).

Question #121 Key: (C)

CHEMISTRY
11. S & P Block Elements

Which of the following solid elements possesses the strongest metallic bonding and highest melt...

CORE CONCEPT & DERIVATION

Metallic bond strength is directly proportional to the number of delocalized valence electrons contributed per atom and inversely proportional to ionic radius.

Formula / Rule / Reaction:

$$\text{Metallic Bond Strength} \propto \frac{\text{Valence Charge Density}}{r_{\text{cation}}} \Rightarrow \text{Ca}^{2+} (2e^-) \gg \text{K}^+ (1e^-)$$

Solution:

- Phosphorus and sulfur are non-metals that form molecular solids held by weak dispersion forces.
- Potassium (Group IA) contributes only one valence electron per atom to its metallic lattice and has a large cationic radius (K^+), giving it weak metallic bonding and a low melting point (63.5°C).
- Calcium (Group IIA) contributes two valence electrons per atom to the delocalized sea and has a smaller ionic radius (Ca^{2+}).
- This higher charge density produces significantly stronger metallic bonding and a higher melting point (842°C). Option C is correct.

Why other options are incorrect:

- Option A:** Potassium is a soft alkali metal with a low charge density (1+) and weak metallic bonding.
- Option B:** Phosphorus forms molecular crystals (P_4) with no metallic bonding.
- Option D:** Sulfur forms molecular crystals (S_8) held by van der Waals forces.

Question #122 Key: (D)

CHEMISTRY
04. Gases

A rigid container with a porous wall contains an equimolar gaseous mixture of [Formula], [Form...

CORE CONCEPT & DERIVATION

Graham's law states that the rate of effusion of a gas is inversely proportional to the square root of its molar mass; effusion time is directly proportional to the square root of molar mass.

Formula / Rule / Reaction:

$$\text{Rate} \propto \frac{1}{\sqrt{M}} \Rightarrow t_{\text{effusion}} \propto \sqrt{M}$$

Solution:

- Molar masses:
 $\text{H}_2 = 2.0 \text{ g/mol}$, $\text{He} = 4.0 \text{ g/mol}$, $\text{N}_2 = 28.0 \text{ g/mol}$, $\text{O}_2 = 32.0 \text{ g/mol}$
- The gas with the lowest molar mass (H_2) effuses the fastest and takes the minimum time.
- Oxygen (O_2) has the highest molar mass (32 g/mol), so it has the slowest root-mean-square speed and effusion rate.
- Consequently, O_2 requires the maximum time to effuse through the porous barrier. Option D is correct.

Why other options are incorrect:

- Option A:** H_2 has the smallest molar mass and effuses fastest, requiring the minimum time.
- Option B:** Helium effuses four times faster than oxygen.
- Option C:** Nitrogen (28 g/mol) is lighter than oxygen and effuses faster than O_2 .

Question #123 Key: (B)PHYSICS
08. Electrostatics

The relative permittivity (dielectric constant, [Formula]) of dry air at standard atmospheric ...

CORE CONCEPT & DERIVATION

Relative permittivity ϵ_r is the ratio of the electrostatic permittivity of a medium to that of a vacuum; for dry air at 1 atm, it is slightly greater than 1 due to low gas density.

Formula / Rule / Reaction:

$$\epsilon_r = \frac{\epsilon}{\epsilon_0} \quad (\text{Vacuum: } \epsilon_r = 1.0000, \quad \text{Dry Air at 1 atm: } \epsilon_r = 1.0006)$$

Solution:

- A vacuum has a defined relative permittivity of exactly 1.
- Air molecules polarize slightly in an applied electric field, giving dry air at 1 atm and 20 °C a measured value of 1.0006.
- Option B is the standard physical value.

Why other options are incorrect:

- Option A:** Exactly 1.0 is the relative permittivity of a true vacuum.
- Option C:** Values between 20 and 30 characterize moderately polar organic liquids (such as acetone or ethanol).
- Option D:** 2.284 corresponds to solid non-polar insulators like polyethylene or mineral oils.

Question #124 Key: (A)PHYSICS
08. Electrostatics

In which combination of capacitors is the equivalent capacitance strictly less than the smallest...

CORE CONCEPT & DERIVATION

In a series combination, the reciprocal of the equivalent capacitance equals the sum of the reciprocals of the individual capacitances, making C_{eq} smaller than any single capacitor.

Formula / Rule / Reaction:

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \dots + \frac{1}{C_n} \Rightarrow C_{eq} < C_{smallest}$$

Solution:

- When capacitors are connected in series, the effective plate separation increases while the charge Q on each capacitor remains identical.
- The reciprocal summation rule guarantees that C_{eq} is always less than the smallest individual capacitance in the series branch. Option A is correct.

Why other options are incorrect:

- Option B:** In parallel, equivalent capacitance is the direct sum ($C_{eq} = C_1 + C_2 + \dots$), which is always greater than the largest individual capacitor.
- Option C:** A bridge network's equivalent capacitance depends on whether it is balanced, but is not inherently smaller than the minimum.
- Option D:** An open circuit has no completed loop, preventing steady-state charge storage.

Question #125 Key: (D)PHYSICS
08. Electrostatics

According to Coulomb's law, the magnitude of the electrostatic force between two stationary poi...

CORE CONCEPT & DERIVATION

Coulomb's law states that the electrostatic force between two stationary point charges is directly proportional to the product of their charges and inversely proportional to the square of the distance between them.

Formula / Rule / Reaction:

$$F_e = k_e \frac{|q_1 q_2|}{r^2} \quad (k_e = \frac{1}{4\pi\epsilon_0})$$

Solution:

- The scalar formulation shows that force magnitude F_e is directly proportional to the product of charge magnitudes ($|q_1 q_2|$).
- It is inversely proportional to the square of the separation distance (r^2). Option D is correct.

Why other options are incorrect:

- Option A:** Electrostatic force is inversely related to distance, not directly proportional.
- Option B:** Force is inversely proportional to the square of distance (inverse-square law), not directly proportional.
- Option C:** An inverse-cube dependence characterizes magnetic dipole fields, not point charge Coulomb forces.

Question #126 Key: (B)PHYSICS
08. Electrostatics

When an insulating dielectric slab is inserted between the conducting plates of an isolated, ch...

CORE CONCEPT & DERIVATION

Inserting a dielectric increases capacitance by a factor of ϵ_r because dielectric polarization weakens the internal electric field and reduces the potential difference for a given stored charge.

Formula / Rule / Reaction:

$$C = \epsilon_r C_0 = \frac{\epsilon_r \epsilon_0 A}{d} \quad (\epsilon_r > 1)$$

Solution:

- A dielectric placed in an electric field undergoes molecular polarization, producing an internal induced field that opposes the external field.
- For an isolated capacitor with fixed charge Q , the net potential difference drops ($V = V_0/\epsilon_r$).
- Because $C = Q/V$, the reduction in voltage increases the capacitance by a factor of ϵ_r . Option B is correct.

Why other options are incorrect:

- Option A:** Capacitance never decreases upon inserting a material dielectric because $\epsilon_r > 1$.
- Option C:** Halving the capacitance would require reducing plate area or doubling the plate separation distance.
- Option D:** Capacitance changes whenever the dielectric medium between the plates is modified.

Question #127 Key: (A)PHYSICS
09. Current Electricity

A total electric charge of [Formula] passes through the cross-section of a conducting wire in [...]

CORE CONCEPT & DERIVATION

Electric current is the time rate of flow of electric charge through a conductor.

Formula / Rule / Reaction:

$$I = \frac{\Delta Q}{\Delta t}$$

Solution:

- Given charge: $\Delta Q = 90.0 \text{ C}$.
- Given time: $\Delta t = 30.0 \text{ s}$.
- Calculating current:

$$I = \frac{90.0 \text{ C}}{30.0 \text{ s}} = 3.0 \text{ A}$$

- Option A is the correct value.

Why other options are incorrect:

- Option B:** 0.3 A corresponds to an order-of-magnitude arithmetic error.
- Option C:** 3.0 mA is 1000 times too small ($3.0 \times 10^{-3} \text{ A}$).
- Option D:** 0.3 mA equals $3.0 \times 10^{-4} \text{ A}$.

Question #128 Key: (C)PHYSICS
09. Current Electricity

The magnitude of the electric current flowing through a metallic conductor is directly proport...

CORE CONCEPT & DERIVATION

Ohm's law states that current in an ohmic conductor is directly proportional to applied voltage as long as temperature and physical dimensions remain constant.

Formula / Rule / Reaction:

$$V \propto I \implies V = IR \quad (\text{where } R = \text{constant})$$

Solution:

- Formulated by Georg Simon Ohm in 1827, this law establishes the linear relationship between current and potential difference for metallic conductors under constant thermal conditions.
- Option C is the law defined by this statement.

Why other options are incorrect:

- Option A:** Joule's law relates heat dissipation to current, resistance, and time ($H = I^2 R t$).
- Option B:** Gauss's law relates total electric flux through a closed surface to enclosed net charge ($\Phi_E = Q_{\text{enc}}/\epsilon_0$).
- Option D:** Ampere's circuital law relates magnetic field along a closed loop to enclosed electric current ($\oint \vec{B} \cdot d\vec{l} = \mu_0 I$).

Question #129 Key: (C)PHYSICS
09. Current Electricity

When the length of a copper wire is doubled by uniform stretching, its electrical resistivity (...)

CORE CONCEPT & DERIVATION

Resistivity is an intrinsic material property that depends on electronic band structure and temperature, not on conductor dimensions.

Formula / Rule / Reaction:

$$\rho = \frac{m}{ne^2\tau} \quad (\text{Independent of length } L \text{ and area } A)$$

Solution:

- Resistance $R = \rho L/A$ changes when geometry changes (stretching to double length halves cross-sectional area, making resistance four times larger).
- However, electrical resistivity (specific resistance, ρ) is an intensive property determined solely by the metal's electron density n , electron mass m , and relaxation time τ .
- Because temperature remains constant, the resistivity of copper remains unchanged. Option C is correct.

Why other options are incorrect:

- Option A:** Resistivity does not scale with wire length.
- Option B:** Resistivity is not halved by stretching.
- Option D:** The total resistance R quadruples, but the material resistivity ρ remains constant.

Question #130 Key: (B)PHYSICS
13. Electronics

The electrical resistance of a pure intrinsic semiconductor (such as silicon or germanium) with...

CORE CONCEPT & DERIVATION

Semiconductors have a negative temperature coefficient of resistance; thermal energy excites electrons across the band gap into the conduction band, increasing conductivity.

Formula / Rule / Reaction:

$$\sigma = ne\mu_e + pe\mu_h, \quad R = R_0 e^{\frac{E_g}{2kT}} \Rightarrow T \uparrow \Rightarrow R \downarrow$$

Solution:

- In intrinsic semiconductors, the valence band is full and the conduction band is empty at absolute zero.
- As temperature rises, thermal energy breaks covalent bonds and excites valence electrons across the band gap (E_g) into the conduction band, generating electron-hole pairs.
- The exponential increase in charge carrier density outweighs carrier-lattice scattering, causing electrical resistance to decrease. Option B is correct.

Why other options are incorrect:

- Option A:** Resistance increases with temperature in metallic conductors due to increased lattice vibrations.
- Option C:** Semiconductor resistance is strongly temperature-dependent.
- Option D:** Resistance approaches infinity at absolute zero (0 K), not at higher temperatures.

Question #131 Key: (D)PHYSICS
09. Current Electricity

A heating coil has an electrical resistance of [Formula] and is designed to operate on a [Formu...]

CORE CONCEPT & DERIVATION

Electrical energy dissipated as heat in a resistor is determined by Joule's heating law expressed in terms of voltage, resistance, and time.

Formula / Rule / Reaction:

$$E = P \cdot t = \left(\frac{V^2}{R}\right)t$$

Solution:

- Given values: Potential difference $V = 20.0 \text{ V}$, resistance $R = 10.0 \Omega$, time $t = 10.0 \text{ s}$.

- Calculating electric power:

$$P = \frac{V^2}{R} = \frac{(20.0 \text{ V})^2}{10.0 \Omega} = \frac{400}{10.0} = 40.0 \text{ W}$$

- Calculating energy supplied:

$$E = P \cdot t = 40.0 \text{ W} \times 10.0 \text{ s} = 400 \text{ J}$$

- Option D is the correct value.

Why other options are incorrect:

- Option A:** 100 J results from using $V \cdot t/R$ incorrectly.
- Option B:** 200 J results from omitting the squaring of potential difference.
- Option C:** 300 J is an incorrect calculation.

Question #132 Key: (B)PHYSICS
09. Current Electricity

The derived SI unit of electrical resistivity (specific resistance) is:

CORE CONCEPT & DERIVATION

Resistivity is the resistance of a conductor with unit length and unit cross-sectional area, giving SI base units of Ohm-meter.

Formula / Rule / Reaction:

$$R = \rho \frac{L}{A} \Rightarrow \rho = \frac{R \cdot A}{L} = \frac{\Omega \cdot \text{m}^2}{\text{m}} = \Omega \cdot \text{m}$$

Solution:

- Resistance R is measured in Ohms (Ω).
- Area A is measured in square meters (m^2) and length L in meters (m).
- Substituting these units yields $\Omega \cdot \text{m}$. Option B is correct.

Why other options are incorrect:

- Option A:** The Ohm (Ω) is the SI unit of electrical resistance and impedance, not resistivity.
- Option C:** Ω/m is resistance per unit length.
- Option D:** m/Ω is the unit of conductivity multiplied by area, which does not equal resistivity.

Question #133 Key: (A)

PHYSICS
10. Electromagnetism

The derived SI unit of magnetic flux ([Formula]) is the:

CORE CONCEPT & DERIVATION

Magnetic flux measures the total magnetic field passing through a surface; its SI unit is the Weber (equivalent to Tesla-square meter).

Formula / Rule / Reaction:

$$\Phi_B = \vec{B} \cdot \vec{A} \Rightarrow 1 \text{ Wb} = 1 \text{ T} \cdot \text{m}^2 = 1 \text{ V} \cdot \text{s}$$

Solution:

- Magnetic flux is the surface integral of the magnetic flux density vector over an area.
- The SI unit is the Weber (Wb), named after Wilhelm Eduard Weber.
- One Weber equals one Tesla-meter squared ($\text{T} \cdot \text{m}^2$). Option A is correct.

Why other options are incorrect:

- **Option B:** The Tesla (T) is the SI unit of magnetic flux density (magnetic field strength $\vec{B}$), equal to Wb/m^2 .
- **Option C:** The Gauss (G) is the CGS unit of magnetic flux density ($1 \text{ T} = 10^4 \text{ G}$).
- **Option D:** The Henry (H) is the SI unit of self and mutual electrical inductance.

Question #134 Key: (B)

PHYSICS
10. Electromagnetism

Magnetic flux through a surface is physically defined as the scalar (dot) product of:

CORE CONCEPT & DERIVATION

Magnetic flux is defined as the dot product between the magnetic field vector and the surface area vector pointing normal to the surface.

Formula / Rule / Reaction:

$$\Phi_B = \vec{B} \cdot \vec{A} = BA \cos \theta$$

Solution:

- The area of a surface is represented as a vector ($\vec{A}$) whose magnitude equals the surface area and whose direction points along the outward surface normal.
- The scalar product of the magnetic field vector ($\vec{B}$) and the area vector ($\vec{A}$) calculates the magnetic field component perpendicular to the surface.
- Therefore, magnetic flux is the dot product of the magnetic field vector and vector area. Option B is correct.

Why other options are incorrect:

- **Option A:** Scalar products are defined between two vectors, not a vector and a scalar.
- **Option C:** Dividing field by scalar area does not yield flux.
- **Option D:** Field per unit area represents flux density, not total flux.

Question #135 Key: (A)

PHYSICS
10. Electromagnetism

The physical dimension and SI unit of magnetic field strength ([Formula]) is identical to tha...

CORE CONCEPT & DERIVATION

The magnetic field vector $\vec{B}$ represents magnetic flux per unit area, making 'magnetic field' and 'magnetic flux density' physically and dimensionally synonymous.

Formula / Rule / Reaction:

$$[B] = [\text{Flux Density}] = \frac{[\Phi_B]}{[A]} = \frac{\text{Wb}}{\text{m}^2} = \text{Tesla (T)} = [\text{MT}^{-2}\text{I}^{-1}]$$

Solution:

- Magnetic field $\vec{B}$ is defined by the Lorentz force $F = ILB$, giving:

$$B = \frac{F}{IL} \Rightarrow [B] = \frac{\text{N}}{\text{A} \cdot \text{m}} = \text{Tesla (T)}$$

- Magnetic flux density is also defined as flux per unit normal area:

$$B = \frac{\Phi_B}{A} \Rightarrow \frac{\text{Wb}}{\text{m}^2} = \text{Tesla (T)}$$

- Because both describe the same quantity, Option A is correct.

Why other options are incorrect:

- **Option B:** Magnetic flux has dimensions of $[\text{ML}^2\text{T}^{-2}\text{I}^{-1}]$ and units of Webers, which differs by an area factor (m^2).
- **Option C:** Magnetic force is measured in Newtons ($[\text{MLT}^{-2}]$).
- **Option D:** Magnetic dipole moment has units of $\text{A} \cdot \text{m}^2$.

Question #136 Key: (D)PHYSICS
04. Rotational & Circular Motion

At what banking angle should a curved road of radius [Formula] be engineered so that an automob...

CORE CONCEPT & DERIVATION

The ideal banking angle balances the horizontal component of the normal force against the required centripetal acceleration, eliminating reliance on lateral tire friction.

Formula / Rule / Reaction:

$$\tan \theta = \frac{v^2}{rg}$$

Solution:

- Given: Velocity $v = 12.0 \text{ m/s}$, radius $r = 36.0 \text{ m}$, gravitational acceleration $g = 9.8 \text{ m/s}^2$.

- Calculating $\tan \theta$:

$$\tan \theta = \frac{(12.0 \text{ m/s})^2}{36.0 \text{ m} \times 9.8 \text{ m/s}^2} = \frac{144.0}{352.8} \approx 0.4082$$

- Finding the banking angle:

$$\theta = \arctan(0.4082) \approx 22.2^\circ \approx 22^\circ$$

- Therefore, Option D is correct.

Why other options are incorrect:

- Option A:** 10° corresponds to $\tan(10^\circ) \approx 0.176$, which is insufficient for this speed and radius.
- Option B:** 15° corresponds to $\tan(15^\circ) \approx 0.268$, which would cause slipping without friction.
- Option C:** 20° corresponds to $\tan(20^\circ) \approx 0.364$, which is slightly below the calculated angle.

Question #137 Key: (A)PHYSICS
05. Waves

A wave generator produces [Formula] in a total time interval of [Formula]. Its operational fre...

CORE CONCEPT & DERIVATION

Frequency is defined as the total number of complete wave cycles or pulses generated per unit time.

Formula / Rule / Reaction:

$$f = \frac{N}{t}$$

Solution:

- Total cycles generated: $N = 500$ pulses.

- Elapsed time: $t = 50.0 \text{ s}$.

- Calculating frequency:

$$f = \frac{500 \text{ pulses}}{50.0 \text{ s}} = 10.0 \text{ s}^{-1} = 10 \text{ Hz}$$

- Option A is the correct value.

Why other options are incorrect:

- Option B:** 0.1 s is the period ($T = 1/f = 50/500$), not the frequency.
- Option C:** 500 is the total pulse count, not the rate per second.
- Option D:** 50 is the total elapsed time in seconds.

Question #138 Key: (A)PHYSICS
05. Waves

Determine the amplitude of the transverse wave shown in the graph below: 1 m 0 +1 -1 x (m) y (m)...

CORE CONCEPT & DERIVATION

The amplitude of a periodic wave is defined as the maximum displacement of any particle in the medium from its central equilibrium (mean) position.

Formula / Rule / Reaction:

$$A = |y_{\text{peak}} - y_{\text{mean}}| = \frac{y_{\text{crest}} - y_{\text{trough}}}{2}$$

Solution:

- The baseline equilibrium position is located at $y = 0 \text{ m}$.

- The wave crest reaches a peak positive displacement of $+1.0 \text{ m}$.

- Therefore, the maximum displacement from equilibrium is 1.0 m , which defines the amplitude. Option A is correct.

Why other options are incorrect:

- Option B:** 2 m represents the peak-to-trough displacement, which is twice the amplitude.
- Option C:** 0.5 m is half the true amplitude.
- Option D:** 0.25 m is an incorrect fraction of the displacement.

Question #139 Key: (A)PHYSICS
14. Dawn of Modern Physics

Which of the following represents the correct ascending order of electromagnetic photon radiati...

CORE CONCEPT & DERIVATION

Photon energy is directly proportional to frequency and inversely proportional to wavelength across the electromagnetic spectrum.

Formula / Rule / Reaction:

$$E = hf = \frac{hc}{\lambda}$$

Solution:

- The electromagnetic spectrum ordered by increasing frequency and energy is:

Radio < Microwaves < Infrared < Visible < Ultraviolet < X-rays < Gamma rays

- Microwaves have long wavelengths (1 mm to 1 m) and low photon energy.
- Ultraviolet rays have shorter wavelengths (10 to 400 nm) and intermediate energy.
- Gamma rays have the shortest wavelengths (<0.01 nm) and highest photon energy (>100 keV).
- Therefore, the correct ascending order is Microwaves < Ultraviolet < Gamma rays. Option A is correct.

Why other options are incorrect:

- Option B:** This represents descending order (highest energy to lowest energy).
- Option C:** Gamma rays have higher energy than both microwaves and ultraviolet rays.
- Option D:** Microwaves have lower energy than ultraviolet and gamma rays, not higher.

Question #140 Key: (B)PHYSICS
05. Waves

The speed of sound in dry air at [Formula] is [Formula]. What is its speed at a temperature of...

CORE CONCEPT & DERIVATION

The speed of sound in air increases linearly by approximately 0.61 m/s for every one degree Celsius rise above 0°C.

Formula / Rule / Reaction:

$$v_t = v_0 + 0.61 \cdot t$$

Solution:

- Given values: Speed at zero degrees $v_0 = 332$ m/s, temperature $t = 10.0^\circ\text{C}$.

- Calculating speed increase:

$$\Delta v = 0.61 \times 10.0 = 6.1 \text{ m/s}$$

- Calculating speed at 10 °C:

$$v_{10} = 332 + 6.1 = 338.1 \text{ m/s}$$

- Option B is the correct value.

Why other options are incorrect:

- Option A:** 332.0 m/s is the unadjusted speed at 0 °C.
- Option C:** 332.61 m/s corresponds to a 1 °C rise rather than a 10 °C rise.
- Option D:** 334.1 m/s uses an incorrect temperature coefficient.

Question #141 Key: (A)PHYSICS
04. Rotational & Circular Motion

The number of complete revolutions or cycles executed per second by a rotating body is defined ...

CORE CONCEPT & DERIVATION

Rotational or linear frequency (f) is the number of complete revolutions per unit time, whereas angular frequency (ω) measures angular displacement per second.

Formula / Rule / Reaction:

$$f = \frac{\text{Revolutions}}{\text{Time}} \quad (\text{measured in rev/s or Hz}), \quad \omega = 2\pi f \quad (\text{measured in rad/s})$$

Solution:

- The number of cycles or revolutions completed in one second is defined as frequency f (also termed linear or rotational frequency).
- Angular frequency (ω) represents the rate of change of angular displacement, measured in radians per second (rad/s).
- Because the question specifies revolutions per second, Option A is the correct definition. (Note: While preliminary keys occasionally use angular terms colloquially, revolutions per second specifically denotes frequency f).

Why other options are incorrect:

- Option B:** Angular frequency is measured in radians per second (rad/s), not revolutions per second.
- Option C:** Time period is the time taken to complete one revolution, measured in seconds.
- Option D:** Angular acceleration is the time rate of change of angular velocity, measured in rad/s^2 .

Question #142 Key: (D)PHYSICS
05. Waves

Which of the following physical factors does NOT affect the speed of sound in air when temperat...

CORE CONCEPT & DERIVATION

Under isothermal conditions, any change in gas pressure produces a proportional change in density, keeping the Laplace-Newton ratio P/ρ and the speed of sound constant.

Formula / Rule / Reaction:

$$v = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\frac{\gamma RT}{M}} \Rightarrow \text{At constant } T, \frac{P}{\rho} = \text{constant} \Rightarrow v = \text{constant}$$

Solution:

- According to Boyle's law, increasing the pressure of a gas at constant temperature compresses it proportionally, increasing density:

$$P \propto \rho \Rightarrow \frac{P}{\rho} = \text{constant}$$

- Because speed of sound depends on the ratio $\sqrt{P/\rho}$, static pressure changes cancel out and do not alter sound speed in air. Option D is correct.

Why other options are incorrect:

- Option A:** Changing gas identity alters density ρ and molar mass M , changing sound speed.
- Option B:** Moisture displaces heavier nitrogen and oxygen molecules with lighter water vapor, reducing density and increasing sound speed.
- Option C:** Temperature increases sound speed because $v \propto \sqrt{T}$.

Question #143 Key: (B)PHYSICS
05. Waves

For small angular displacements, the time period of oscillation of a simple pendulum is indepen...

CORE CONCEPT & DERIVATION

The period of a simple harmonic oscillator is isochronous; for small angular displacements ($\theta < 10^\circ$), the period is independent of amplitude.

Formula / Rule / Reaction:

$$T = 2\pi\sqrt{\frac{L}{g}} \quad (\text{for } \sin \theta \approx \theta)$$

Solution:

- In the small-angle regime, the restoring force is linear with displacement, giving true simple harmonic motion.
- The formula shows that period depends on pendulum length L and gravitational acceleration g , but does not contain amplitude A or angular displacement θ_0 .
- Therefore, time period is independent of amplitude. Option B is correct.

Why other options are incorrect:

- Option A:** Time period is directly proportional to the square root of pendulum length ($T \propto \sqrt{L}$).
- Option C:** Time period is inversely proportional to the square root of g ($T \propto 1/\sqrt{g}$).
- Option D:** Time period is inversely proportional to frequency ($T = 1/f$).

Question #144 Key: (A)PHYSICS
07. Thermodynamics

Mayer's relation connecting the principal molar heat capacity at constant pressure (Formula)...

CORE CONCEPT & DERIVATION

Heating a gas at constant pressure requires extra energy to perform expansion work ($P\Delta V = R\Delta T$) in addition to raising internal energy, so C_p exceeds C_v by the gas constant R .

Formula / Rule / Reaction:

$$C_p = \left(\frac{\partial H}{\partial T}\right)_p, \quad C_v = \left(\frac{\partial U}{\partial T}\right)_v, \quad H = U + PV = U + RT \implies C_p - C_v = R$$

Solution:

- At constant volume, all added heat increases internal energy: $dQ_v = C_v dT = dU$.
- At constant pressure, heat both increases internal energy and does boundary work: $dQ_p = C_p dT = dU + PdV$.
- For one mole of an ideal gas, $PdV = RdT$.
- Substituting yields $C_p dT = C_v dT + RdT$, which simplifies to $C_p - C_v = R$. Option A is correct.

Why other options are incorrect:

- Option B:** The sum of molar heat capacities does not equal the universal gas constant.
- Option C:** $C_v - C_p = -R$, not $+R$, because $C_p > C_v$.
- Option D:** Rearranging gives $C_p + C_v = R$, which is incorrect.

Question #145 Key: (A)PHYSICS
07. Thermodynamics

The mathematical equation describing the First Law of Thermodynamics for a closed system perform...

CORE CONCEPT & DERIVATION

The First Law of Thermodynamics is the principle of conservation of energy applied to thermodynamic systems.

Formula / Rule / Reaction:

$$\Delta U = Q - W \iff Q = \Delta U + W$$

Solution:

- When heat Q is supplied to a closed system, it is partitioned into increasing internal energy (ΔU) and performing external work ($W = P\Delta V$).
- Conservation of energy requires that net heat absorbed equals the change in internal energy plus work done by the system.
- Expressed algebraically: $Q = \Delta U + W$. Option A is correct.

Why other options are incorrect:

- Option B:** $\Delta U = Q + W$ is valid only when work is defined as work done *on* the system; under standard physics convention where W is work done *by* the system, $\Delta U = Q - W$.
- Option C:** Work done is not the sum of heat and internal energy change.
- Option D:** $Q = W$ applies only to isothermal processes where internal energy remains constant ($\Delta U = 0$).

Question #146 Key: (C)PHYSICS
07. Thermodynamics

A thermodynamic process during which the pressure of the working substance remains strictly con...

CORE CONCEPT & DERIVATION

An isobaric process is an idealized thermodynamic transformation carried out at constant pressure ($\Delta P = 0$).

Formula / Rule / Reaction:

$$P = \text{constant} \implies W = \int PdV = P(V_2 - V_1)$$

Solution:

- Derived from Greek *iso* (equal) and *baros* (weight/pressure).
- In an isobaric process, system volume changes while pressure is held constant by external boundary forces.
- Option C is the correct term.

Why other options are incorrect:

- Option A:** An isochoric process is conducted at constant volume ($\Delta V = 0$), doing zero boundary work.
- Option B:** An adiabatic process occurs without heat exchange with the surroundings ($Q = 0$).
- Option D:** An isothermal process is conducted at constant temperature ($\Delta T = 0$).

Question #147 Key: (D)PHYSICS
08. Electrostatics

A [Formula] capacitor in a television deflection circuit is charged to a potential difference of...

CORE CONCEPT & DERIVATION

The electrical energy stored in a charged capacitor equals the work done to deposit charge against the evolving inter-plate potential difference.

Formula / Rule / Reaction:

$$U = \frac{1}{2} CV^2$$

Solution:

- Given capacitance: $C = 1.0 \mu\text{F} = 1.0 \times 10^{-6} \text{ F}$.
- Given potential difference: $V = 4000 \text{ V} = 4.0 \times 10^3 \text{ V}$.
- Calculating stored energy:

$$U = \frac{1}{2} (1.0 \times 10^{-6} \text{ F}) (4000 \text{ V})^2 = \frac{1}{2} (1.0 \times 10^{-6}) (1.6 \times 10^7) = 0.5 \times 16.0 = 8.0 \text{ J}$$

- Option D is the correct value.

Why other options are incorrect:

- Option A:** 16.0 J results from omitting the factor of $1/2$ in CV^2 .
- Option B:** $4.0 \times 10^{-3} \text{ J}$ results from omitting the squaring of potential difference (CV).
- Option C:** $2.0 \times 10^{-3} \text{ J}$ results from evaluating $\frac{1}{2} CV$.

Question #148 Key: (A)PHYSICS
08. Electrostatics

A charged subatomic particle carrying an electric charge of [Formula] falls through an accelera...

CORE CONCEPT & DERIVATION

An electron-volt (eV) is the kinetic energy gained by an elementary charge (e) accelerated through a potential difference of one volt.

Formula / Rule / Reaction:

$$\Delta K = q \cdot V \implies \Delta K = (ne) \cdot V = nV \text{ (in electron-volts)}$$

Solution:

- Particle charge: $q = 2e$.
- Potential difference: $V = 3.0 \text{ V}$.
- Calculating acquired energy:

$$\Delta K = (2e) \times (3.0 \text{ V}) = 6.0 \text{ eV}$$

- (In Joules: $6.0 \times 1.602 \times 10^{-19} \text{ J} = 9.61 \times 10^{-19} \text{ J}$).
- Therefore, Option A is correct.

Why other options are incorrect:

- Option B:** 7.0 eV is an incorrect calculation.
- Option C:** 1.5 eV results from dividing potential by charge (V/q).
- Option D:** 5.0 eV results from adding charge and potential ($2 + 3$).

Question #149 Key: (B)PHYSICS
08. Electrostatics

Due to the electric polarization of an insulating dielectric material placed within an external...

CORE CONCEPT & DERIVATION

External electric fields induce dipole alignment in a dielectric, creating an opposing internal induced field that reduces the net electric field intensity.

Formula / Rule / Reaction:

$$\vec{E}_{\text{net}} = \vec{E}_0 - \vec{E}_{\text{induced}} = \frac{\vec{E}_0}{\epsilon_r} \quad (\epsilon_r > 1)$$

Solution:

- An applied external electric field $\vec{E}_0$ displaces positive and negative bound charges within the dielectric molecules.
- This surface polarization charge creates an internal electric field ($\vec{E}_{\text{induced}}$) directed opposite to the applied field.
- The net electric field inside the dielectric is the vector sum of both fields, reducing the field to E_0/ϵ_r . Option B is correct.

Why other options are incorrect:

- **Option A:** The internal induced field opposes the external field, so the net field cannot increase.
- **Option C:** The net field changes due to the presence of bound polarization charges.
- **Option D:** The net field becomes zero inside ideal conductors in static equilibrium, not inside dielectrics.

Question #150 Key: (B)PHYSICS
11. Electromagnetic Induction

The electromagnetic induction phenomenon in which a time-varying electric current in one electr...

CORE CONCEPT & DERIVATION

Mutual induction is the generation of an induced EMF in a secondary circuit resulting from a changing current and changing magnetic flux in an adjacent primary circuit.

Formula / Rule / Reaction:

$$E_2 = -M \frac{\Delta I_1}{\Delta t}$$

Solution:

- A time-varying current in the primary coil produces a time-varying magnetic field in the surrounding space.
- Part of this dynamic magnetic flux links with the turns of a nearby secondary coil.
- According to Faraday's law, this changing flux induces an EMF in the secondary coil, a phenomenon designated as mutual induction. Option B is correct.

Why other options are incorrect:

- **Option A:** Self-induction is the production of an opposing EMF within the same coil that carries the changing current.
- **Option C:** Eddy currents are localized closed loops of induced current within bulk conducting masses.
- **Option D:** Choke filtering refers to inductive impedance used to block high-frequency AC components in a circuit.

Question #151 Key: (C)PHYSICS
11. Electromagnetic Induction

The induced electric current always flows in such a direction that its magnetic action opposes...

CORE CONCEPT & DERIVATION

Lenz's law determines the polarity of an induced electromotive force and the direction of induced current, representing the conservation of energy in electromagnetic systems.

Formula / Rule / Reaction:

$$E = -N \frac{\Delta \Phi_B}{\Delta t} \quad (\text{where the negative sign expresses Lenz's Law})$$

Solution:

- Formulated by Heinrich Lenz in 1834, this law dictates that the magnetic field created by an induced current always opposes the initial flux perturbation that created it.
- Mechanical work must be done against this opposing magnetic force to generate electrical energy, upholding energy conservation. Option C is correct.

Why other options are incorrect:

- **Option A:** Ampere's law relates steady magnetic fields along a closed loop to the enclosed macroscopic electric current.
- **Option B:** Faraday's law states that the magnitude of induced EMF is proportional to the time rate of change of magnetic flux.
- **Option D:** Joule's law quantifies the heat produced by current flow in an ohmic resistor ($H = I^2 Rt$).

Question #152 Key: (B)PHYSICS
11. Electromagnetic Induction

An electrical transformer operates based on electromagnetic induction and therefore depends on...

CORE CONCEPT & DERIVATION

Transformers require a continuously changing magnetic flux in the core to induce an EMF in the secondary winding, which requires an alternating current.

Formula / Rule / Reaction:

$$V_s = -N_s \frac{d\Phi_B}{dt}, \quad \Phi_B(t) = B(t)A = [\mu n I_0 \sin(\omega t)]A$$

Solution:

- A steady DC supply creates a static, time-invariant magnetic field ($d\Phi_B/dt = 0$), producing zero secondary voltage and potentially burning the primary winding due to low inductive reactance.
- Alternating current (AC) varies sinusoidally with time, providing a continuous rate of change of magnetic flux ($d\Phi_B/dt \neq 0$) that induces voltage in the secondary coil. Option B is correct.

Why other options are incorrect:

- **Option A:** Steady direct current produces a static magnetic field that cannot induce secondary EMF.
- **Option C:** Constant-magnitude DC produces zero mutual induction.
- **Option D:** Static electrostatic potential lacks current flow and changing magnetic flux.

Question #153 Key: (B)PHYSICS
12. Alternating Current

The commercial domestic alternating current (AC) electricity supply in Pakistan operates at a s...

CORE CONCEPT & DERIVATION

The national electrical power grid of Pakistan delivers single-phase alternating current at an effective RMS voltage of 230 V and a frequency of 50 Hz.

Formula / Rule / Reaction:

$$V(t) = V_{\text{peak}} \sin(2\pi ft) = 325 \sin(100\pi t) \quad (f = 50 \text{ Hz})$$

Solution:

- The alternating current reverses its polarity 100 times per second, completing 50 full cycles every second (50 Hz).
- Option B is the official national utility standard.

Why other options are incorrect:

- **Option A:** 100 Hz is the full-wave rectified ripple frequency, not the fundamental supply frequency.
- **Option C:** 60 Hz is the electrical grid standard used in North America, not in Pakistan.
- **Option D:** 25 Hz is an obsolete frequency historically used for specialized railway traction systems.

Question #154 Key: (C)PHYSICS
11. Electromagnetic Induction

An electrical power transformer functions on the fundamental physical principle of:

CORE CONCEPT & DERIVATION

Transformers transfer electrical energy between two electrically isolated circuits via mutual electromagnetic induction through a shared ferromagnetic core.

Formula / Rule / Reaction:

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s} \quad (\text{Ideal Transformer})$$

Solution:

- A transformer consists of two separate coils (primary and secondary) wound around a laminated soft iron core.
- AC current in the primary winding produces a time-varying magnetic field that links with the secondary winding, inducing an EMF through mutual induction. Option C is correct.

Why other options are incorrect:

- **Option A:** Self-induction is the phenomenon where a changing current induces an EMF in the same coil (used in chokes and inductors).
- **Option B:** Full-wave rectification is the electronic conversion of AC to DC using diodes.
- **Option D:** The Hall effect is the production of a transverse voltage across an electrical conductor in a perpendicular magnetic field.

Question #155 Key: (A)PHYSICS
13. Electronics

The conversion of alternating current (AC) into direct current (DC) is called rectification. Wh...

CORE CONCEPT & DERIVATION

A p-n junction diode acts as a one-way electrical valve, conducting readily under forward bias and blocking current under reverse bias to convert AC into DC.

Formula / Rule / Reaction:

$$\text{Diode State} = \begin{cases} \text{Forward Bias } (V > V_{\text{barrier}}) : & \text{Low Resistance (Conduction)} \\ \text{Reverse Bias } (V < 0) : & \text{High Resistance (Cut-off)} \end{cases}$$

Solution:

- Rectification requires a circuit component with asymmetric directional conductance.
- A semiconductor p-n junction diode allows current flow in the forward direction while blocking it in the reverse direction.
- This unidirectional behavior suppresses or redirects alternate half-cycles of AC, producing DC. Option A is correct.

Why other options are incorrect:

- **Option B:** A transistor is a three-terminal semiconductor device used for signal amplification and switching.
- **Option C:** A transformer steps AC voltage up or down, but cannot rectify AC into DC.
- **Option D:** An inductor opposes rapid changes in current, serving as a low-pass filter rather than a rectifier.

Question #156 Key: (B)PHYSICS
14. Dawn of Modern Physics

The de Broglie wavelength associated with an electron accelerated through standard laboratory p...

CORE CONCEPT & DERIVATION

Accelerated electrons exhibit wave properties with de Broglie wavelengths comparable to atomic spacing and X-ray wavelengths (approx. 0.1 nm).

Formula / Rule / Reaction:

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2m_e eV}} = \frac{1.227}{\sqrt{V}} \text{ nm}$$

Solution:

- For an electron accelerated through $V = 100 \text{ V}$:

$$\lambda = \frac{1.227}{\sqrt{100}} = \frac{1.227}{10} = 0.123 \text{ nm} = 1.23 \text{ \AA}$$

- This wavelength (0.1 to 1.0 nm) matches characteristic X-ray wavelengths and atomic crystal lattice spacing, as demonstrated in the Davisson-Germer electron diffraction experiment. Option B is correct.

Why other options are incorrect:

- Option A:** Visible light has wavelengths between 400 nm and 700 nm, several orders of magnitude longer than accelerated electron waves.
- Option C:** Radio waves have macroscopic wavelengths ranging from millimeters to kilometers.
- Option D:** Infrared radiation has wavelengths between 700 nm and 1 mm.

Question #157 Key: (C)PHYSICS
14. Dawn of Modern Physics

Red light illumination is used in photographic darkrooms primarily because red light photons po...

CORE CONCEPT & DERIVATION

Silver halide photographic emulsions require a minimum photon threshold energy to trigger photochemical reduction; red light has the lowest frequency and energy in the visible spectrum.

Formula / Rule / Reaction:

$$E = hf = \frac{hc}{\lambda} \quad (\lambda_{\text{red}} \approx 700 \text{ nm}, f_{\text{red}} \approx 4.3 \times 10^{14} \text{ Hz} \Rightarrow E_{\text{red}} \approx 1.8 \text{ eV})$$

Solution:

- Red light occupies the long-wavelength end of the visible spectrum (620 to 750 nm).
- Because wavelength is inversely proportional to frequency ($c = f\lambda$), red light possesses the lowest frequency and lowest photon energy among visible colors.
- Its quantum energy is below the activation threshold needed to expose standard black-and-white silver halide photographic paper. Option C is correct.

Why other options are incorrect:

- Option A:** High frequency and short wavelength describe violet and ultraviolet light, which expose photographic paper.
- Option B:** Frequency and wavelength are inversely related; low frequency cannot accompany short wavelength in a vacuum.
- Option D:** High frequency cannot accompany long wavelength.

Question #158 Key: (B)PHYSICS
14. Dawn of Modern Physics

Which of the following visible light photons carries the highest quantum of energy?

CORE CONCEPT & DERIVATION

In the visible spectrum, photon energy increases with frequency from red to violet.

Formula / Rule / Reaction:

$$E = hf = \frac{hc}{\lambda} \quad (\text{VIBGYOR: } \lambda_{\text{violet}} \approx 400 \text{ nm}, \lambda_{\text{red}} \approx 700 \text{ nm})$$

Solution:

- The visible spectrum sequence in order of increasing frequency and energy is Red < Orange < Yellow < Green < Blue < Indigo < Violet.
- Violet light has the shortest wavelength (around 400 nm) and the highest frequency (around $7.5 \times 10^{14} \text{ Hz}$).
- Consequently, violet photons have the highest quantum energy ($E \approx 3.1 \text{ eV}$). Option B is correct.

Why other options are incorrect:

- Option A:** Blue light has a longer wavelength and lower photon energy ($\approx 2.7 \text{ eV}$) than violet light.
- Option C:** Red light has the longest wavelength and lowest photon energy ($\approx 1.8 \text{ eV}$) in the visible spectrum.
- Option D:** Green light has intermediate energy ($\approx 2.2 \text{ eV}$), which is lower than that of violet.

Question #159 Key: (D)PHYSICS
15. Atomic Spectra

In characteristic X-ray emission spectra, which electron transition produces a photon with the ...

CORE CONCEPT & DERIVATION

Photon wavelength is inversely proportional to transition energy ($\lambda = hc/\Delta E$); transitions between higher, closely spaced shells release the least energy and longest wavelengths.

Formula / Rule / Reaction:

$$\Delta E = E_{\text{initial}} - E_{\text{final}} = \frac{hc}{\lambda} \Rightarrow \Delta E \downarrow \Rightarrow \lambda \uparrow$$

Solution:

- The energy gap between shells decreases with increasing principal quantum number (n):

$$\Delta E(M \rightarrow L) \ll \Delta E(L \rightarrow K)$$

- Transitions terminating in the K-shell ($n = 1$, such as K_α , K_β , K_γ) involve large energy drops because the K-shell is tightly bound, yielding short-wavelength X-rays.
- Transitions terminating in the M-shell ($n = 3$, such as M_α from $n = 4 \rightarrow n = 3$) involve small energy differences.
- Because ΔE is smallest for M_α , its emitted photon wavelength is the longest. Option D is correct.

Why other options are incorrect:

- Option A:** K_α involves an $L \rightarrow K$ transition with a large energy drop, producing a short wavelength.
- Option B:** K_β involves an $M \rightarrow K$ transition with higher energy and shorter wavelength than K_α .
- Option C:** K_γ involves an $N \rightarrow K$ transition with higher energy than K_β .

Question #160 Key: (C)PHYSICS
15. Atomic Spectra

Which of the following pairs of hydrogen spectral series lies entirely within the infrared (IR)...

CORE CONCEPT & DERIVATION

Spectral transitions in atomic hydrogen fall into defined wavelength bands depending on the principal quantum number (n_1) of the lower energy level.

Formula / Rule / Reaction:

$$\frac{1}{\lambda} = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right) \quad \begin{cases} n_1 = 1 : & \text{Lyman (UV)} \\ n_1 = 2 : & \text{Balmer (Visible)} \\ n_1 = 3 : & \text{Paschen (Infrared)} \\ n_1 = 4 : & \text{Brackett (Infrared)} \\ n_1 = 5 : & \text{Pfund (Infrared)} \end{cases}$$

Solution:

- The Lyman series ($n_1 = 1$) lies in the ultraviolet region.
- The Balmer series ($n_1 = 2$) lies primarily in the visible region.
- The Paschen ($n_1 = 3$), Brackett ($n_1 = 4$), and Pfund ($n_1 = 5$) series all lie in the infrared region.
- Therefore, both Paschen and Brackett lie in the infrared region. Option C is correct.

Why other options are incorrect:

- Option A:** Lyman is in the ultraviolet and Balmer is in the visible spectrum.
- Option B:** Balmer is in the visible spectrum.
- Option D:** Lyman is in the ultraviolet region.

Question #161 Key: (B)PHYSICS
16. Nuclear Physics

The standard historical unit of radioactivity, the Curie (Ci), is defined as equivalent to exaC...

CORE CONCEPT & DERIVATION

One Curie (Ci) was originally defined as the activity of 1 gram of Radium-226, standardized internationally as 3.7×10^{10} nuclear disintegrations per second.

Formula / Rule / Reaction:

$$1 \text{ Ci} = 3.7 \times 10^{10} \text{ Bq} = 3.7 \times 10^{10} \text{ disintegrations per second (dps)}$$

Solution:

- In the SI system, 1 disintegration per second equals 1 Becquerel (Bq).
- The Curie is a larger non-SI unit equal to 3.7×10^{10} Bq. Option B is correct.

Why other options are incorrect:

- Option A:** 7.3 is a transposition of the digits 3 and 7.
- Option C:** 3.7×10^7 dps equals 1 millicurie (mCi), not 1 Curie.
- Option D:** 1.0×10^6 dps defines 1 Rutherford (Rd).

Question #162 Key: (C)PHYSICS
16. Nuclear Physics

The spontaneous rate of radioactive disintegration ([Formula]) of a sample is directly propor...

CORE CONCEPT & DERIVATION

Radioactive decay is an intrinsic nuclear property governed by the decay constant (λ) of a specific nuclide, independent of external physical or chemical conditions.

Formula / Rule / Reaction:

$$-\frac{dN}{dt} = \lambda N, \quad \lambda = \frac{\ln 2}{T_{1/2}}$$

Solution:

- Radioactivity is a spontaneous nuclear phenomenon.
- The decay constant λ depends solely on nuclear binding forces and stability for a given radioisotope.
- It is unaffected by temperature, pressure, chemical bonding, or physical phase. Option C is correct.

Why other options are incorrect:

- Option A:** The surrounding physical medium has no effect on nuclear decay rates.
- Option B:** Atmospheric pressure changes do not alter nuclear decay constants.
- Option D:** Thermal variations do not alter spontaneous nuclear decay kinetics.

Question #163 Key: (C)PHYSICS
16. Nuclear Physics

Clinical signs of radiation exposure such as skin erythema, epilation (hair loss), leukopenia (...)

CORE CONCEPT & DERIVATION

Biological radiation injuries are divided into somatic effects (harming the exposed individual's body tissues) and genetic effects (mutations passed to future offspring).

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Somatic effects affect the non-germline body cells of the irradiated individual, causing acute radiation sickness, tissue necrosis, and radiation-induced cancer.
- Genetic effects arise from mutations induced in reproductive germline DNA that affect subsequent generations.
- Because epilation, skin burns, and leukopenia manifest directly within the exposed individual, they are somatic effects. Option C is correct.

Why other options are incorrect:

- Option A:** Genetic effects manifest as heritable chromosomal aberrations in descendants, not as direct burns or hair loss in the patient.
- Option B:** The Zener effect is quantum electrical breakdown in reverse-biased semiconductor diodes.
- Option D:** Photomagnetic effect is a solid-state physics phenomenon, not a medical classification.

Question #164 Key: (D)PHYSICS
02. Force & Motion

An automobile travels along the negative y-axis and is speeding up. The direction of its accele...

CORE CONCEPT & DERIVATION

When an object is speeding up along a straight path, its acceleration vector points in the same direction as its velocity vector.

Formula / Rule / Reaction:

$$\vec{a} = \frac{d\vec{v}}{dt} \Rightarrow \text{Speeding up: } \vec{a} \text{ is parallel to } \vec{v}$$

Solution:

- The car's velocity vector points along the negative y-direction: $\vec{v} = -v\hat{j}$.
- Because the car is speeding up, the magnitude of velocity is increasing, meaning acceleration acts in the direction of motion.
- Therefore, the acceleration vector points along the negative y-axis ($\vec{a} = -a\hat{j}$). Option D is correct.

Why other options are incorrect:

- Option A:** Acceleration along the positive x-axis would cause lateral steering to the right.
- Option B:** Acceleration along the negative x-axis would cause lateral steering to the left.
- Option C:** Acceleration along the positive y-axis would oppose velocity, causing the car to slow down.

Question #165 Key: (A)PHYSICS
02. Force & Motion

Linear momentum is defined as the product of mass and velocity ([Formula]). Because mass is a...

CORE CONCEPT & DERIVATION

Multiplying a vector by a positive scalar scales its magnitude without changing its spatial direction, keeping the vectors parallel.

Formula / Rule / Reaction:

$$\vec{p} = m\vec{v}, \quad m > 0 \Rightarrow \vec{p} = \hat{v} \quad (\theta = 0^\circ)$$

Solution:

- In Newtonian mechanics, inertial mass m is a strictly positive scalar quantity.
- Multiplying the velocity vector $\vec{v}$ by positive mass m preserves its vector direction.
- Therefore, linear momentum $\vec{p}$ is always parallel to velocity $\vec{v}$. Option A is correct.

Why other options are incorrect:

- Option B:** Perpendicular vectors have an angle of 90° , which never occurs between momentum and velocity.
- Option C:** Anti-parallel vectors would require mass to be negative.
- Option D:** Momentum is directly coupled to velocity and cannot point in an independent direction.

Question #166 Key: (B)PHYSICS
02. Force & Motion

For a projectile launched on level ground with a fixed initial speed, which pair of launch angles...

CORE CONCEPT & DERIVATION

Projectiles launched at complementary angles ($\theta_1 + \theta_2 = 90^\circ$) with identical initial speeds achieve identical horizontal ranges on flat ground.

Formula / Rule / Reaction:

$$R = \frac{v_0^2 \sin(2\theta)}{g}, \quad \sin[2(90^\circ - \theta)] = \sin(180^\circ - 2\theta) = \sin(2\theta)$$

Solution:

- Checking the sum of the angles for each option:

$$\text{Option B: } 40^\circ + 50^\circ = 90^\circ$$

- For 40° : $\sin(2 \times 40^\circ) = \sin(80^\circ)$.
- For 50° : $\sin(2 \times 50^\circ) = \sin(100^\circ) = \sin(80^\circ)$.
- Because their range factors are equal, 40° and 50° yield identical horizontal ranges. Option B is correct.

Why other options are incorrect:

- **Option A:** $30^\circ + 70^\circ = 100^\circ \neq 90^\circ$.
- **Option C:** $35^\circ + 40^\circ = 75^\circ \neq 90^\circ$.
- **Option D:** $45^\circ + 40^\circ = 85^\circ \neq 90^\circ$.

Question #168 Key: (A)PHYSICS
02. Force & Motion

According to Newton's second law of motion, the time rate of change of linear momentum of a body...

CORE CONCEPT & DERIVATION

Newton's second law states that the net external force acting on a body equals the time derivative of its linear momentum.

Formula / Rule / Reaction:

$$\vec{F}_{\text{net}} = \frac{d\vec{p}}{dt} = \frac{d(m\vec{v})}{dt}$$

Solution:

- Newton defined force as the time rate of change of momentum.
- For constant mass, this reduces to $\vec{F} = m(d\vec{v}/dt) = m\vec{a}$.
- Option A represents this fundamental law.

Why other options are incorrect:

- **Option B:** Mechanical impulse equals the change in momentum over time ($J = \Delta p = F\Delta t$), not its time rate of change.
- **Option C:** Power is the time rate of doing work ($P = dW/dt = \vec{F} \cdot \vec{v}$).
- **Option D:** Inertia is an intrinsic property quantified by mass, not a rate of change.

Question #167 Key: (C)PHYSICS
02. Force & Motion

The slope of a velocity-time graph for a particle moving along a straight line represents its:

CORE CONCEPT & DERIVATION

The first derivative of velocity with respect to time represents acceleration; graphically, this equals the slope of the velocity-time curve.

Formula / Rule / Reaction:

$$\text{Slope} = \frac{\Delta v}{\Delta t} = \frac{dv}{dt} = a$$

Solution:

- On a velocity-time plot, the vertical axis is velocity (v) and the horizontal axis is time (t).
- The slope is rise over run: $\Delta v / \Delta t$.
- By definition, the rate of change of velocity with time is acceleration. Option C is correct.

Why other options are incorrect:

- **Option A:** Speed is the magnitude of velocity, represented by the height on a speed-time plot, not its slope.
- **Option B:** Displacement is represented by the area under the velocity-time graph, not the slope.
- **Option D:** Distance is represented by the total area under the speed-time graph.

Question #169 Key: (A)PHYSICS
02. Force & Motion

At what angle of projection does the horizontal range of a projectile on level ground become eq...

CORE CONCEPT & DERIVATION

Maximum horizontal range occurs at a launch angle of 45° ; setting the range formula to half of this maximum determines the corresponding angle.

Formula / Rule / Reaction:

$$R = \frac{v_0^2 \sin(2\theta)}{g}, \quad R_{\max} = \frac{v_0^2}{g} \quad (\text{at } \theta = 45^\circ)$$

Solution:

- Condition: $R = \frac{1}{2} R_{\max}$:

$$\frac{v_0^2 \sin(2\theta)}{g} = \frac{1}{2} \left(\frac{v_0^2}{g} \right)$$

$$\sin(2\theta) = 0.5$$

- Solving for the primary launch angle:

$$2\theta = 30^\circ \implies \theta = 15^\circ$$

- (Its complementary angle is 75°).
- Therefore, Option A is correct.

Why other options are incorrect:

- Option B:** 20° gives $\sin(40^\circ) \approx 0.643$, producing 64% of maximum range.
- Option C:** 30° gives $\sin(60^\circ) \approx 0.866$, producing 86.6% of maximum range.
- Option D:** 40° gives $\sin(80^\circ) \approx 0.985$, producing 98.5% of maximum range.

Question #170 Key: (C)PHYSICS
03. Work & Energy

According to the work-energy theorem for translational motion, the net work done on a particle ...

CORE CONCEPT & DERIVATION

The work-energy theorem states that the net work performed by all combined forces on a rigid particle equals the change in its kinetic energy.

Formula / Rule / Reaction:

$$W_{\text{net}} = \Delta K = K_f - K_i = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

Solution:

- Integrating Newton's second law over a spatial displacement:

$$W = \int F_{\text{net}} dx = \int m \left(v \frac{dv}{dx} \right) dx = \int_{v_i}^{v_f} mv dv = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = \Delta K$$

- This demonstrates that net work equals the change in kinetic energy. Option C is correct.

Why other options are incorrect:

- Option A:** Work done by conservative forces equals the negative change in potential energy ($W_c = -\Delta U$), not net work.
- Option B:** The sum of kinetic and potential energy represents total mechanical energy, not net work done.
- Option D:** Power is the time rate of doing work, not the work itself.

Question #171 Key: (B)PHYSICS
03. Work & Energy

A body of mass [Formula] at rest is accelerated along a smooth, frictionless horizontal surface...

CORE CONCEPT & DERIVATION

On a horizontal frictionless surface with no height change or friction, work done by an applied force is converted entirely into kinetic energy.

Formula / Rule / Reaction:

$$W = F \cdot S = (ma) \cdot \left(\frac{v^2 - 0}{2a} \right) = \frac{1}{2}mv^2 = \Delta K$$

Solution:

- Because the surface is frictionless, no energy is lost as heat.
- Because motion is horizontal, elevation remains constant ($\Delta h = 0$), meaning gravitational potential energy does not change.
- According to the work-energy theorem, all input work accelerates the mass, converting into kinetic energy. Option B is correct.

Why other options are incorrect:

- Option A:** Thermal energy is generated only when work is done against frictional resistance.
- Option C:** Gravitational potential energy changes only during vertical displacement against gravity.
- Option D:** Elastic potential energy is stored in deformed springs or elastic bodies, not in a rigid accelerating mass.

Question #172 Key: (B)PHYSICS
03. Work & Energy

One megawatt-hour ([Formula]) of electrical energy is equivalent to:

CORE CONCEPT & DERIVATION

A megawatt-hour is a commercial unit of electrical energy calculated as power in watts multiplied by time in seconds.

Formula / Rule / Reaction:

$$1 \text{ MW} = 10^6 \text{ W}, \quad 1 \text{ h} = 3600 \text{ s} \implies 1 \text{ MW} \cdot \text{h} = (10^6 \text{ W}) \times (3600 \text{ s})$$

Solution:

- Converting to base SI units:

$$E = 10^6 \text{ J/s} \times 3600 \text{ s} = 3600 \times 10^6 \text{ J} = 3.6 \times 10^9 \text{ J}$$

- (This equals 3.6 Gigajoules). Option B is correct.

Why other options are incorrect:

- **Option A:** $3.6 \times 10^6 \text{ J}$ equals one kilowatt-hour ($1 \text{ kW} \cdot \text{h}$), not one megawatt-hour.
- **Option C:** $3.6 \times 10^{12} \text{ J}$ equals one gigawatt-hour ($1 \text{ GW} \cdot \text{h}$).
- **Option D:** $3.6 \times 10^3 \text{ J}$ equals one watt-hour ($1 \text{ W} \cdot \text{h}$).

Question #173 Key: (D)PHYSICS
03. Work & Energy

A motorboat moves through water at a steady speed of [Formula]. If the net forward propulsive ...

CORE CONCEPT & DERIVATION

Mechanical power delivered to an object moving at constant velocity equals the scalar product of applied force and velocity.

Formula / Rule / Reaction:

$$P = \vec{F} \cdot \vec{v} = Fv \cos \theta \quad (\theta = 0^\circ)$$

Solution:

- Given values: Force $F = 4000 \text{ N}$, velocity $v = 4.0 \text{ m/s}$.
- Calculating mechanical power:

$$P = 4000 \text{ N} \times 4.0 \text{ m/s} = 16000 \text{ W} = 16 \text{ kW}$$

- Option D is the correct value.

Why other options are incorrect:

- **Option A:** 1000 W results from dividing force by velocity ($4000/4$).
- **Option B:** 160 W is an arithmetic error by two orders of magnitude.
- **Option C:** 16 W is an arithmetic error by three orders of magnitude.

Question #174 Key: (B)PHYSICS
04. Rotational & Circular Motion

In rotational angular kinematics, one complete revolution (rotation) corresponds to an angular ...

CORE CONCEPT & DERIVATION

An angle in radians is the ratio of arc length to radius; for one full circle of circumference $2\pi r$, the angle equals 2π radians.

Formula / Rule / Reaction:

$$\theta = \frac{s}{r} = \frac{2\pi r}{r} = 2\pi \text{ radians} = 360^\circ$$

Solution:

- One complete revolution traverses the full perimeter of a circle (360°).
- Because $180^\circ = \pi$ radians, $360^\circ = 2\pi$ radians. Option B is correct.

Why other options are incorrect:

- **Option A:** π radians corresponds to half a revolution (180°).
- **Option C:** $\pi/2$ radians corresponds to a quarter of a revolution (90°).
- **Option D:** $\pi/4$ radians corresponds to an eighth of a revolution (45°).

Question #175 Key: (B)PHYSICS
04. Rotational & Circular Motion

A stone of mass [Formula] is whirled in a horizontal circle of radius [Formula] at a constant s...

CORE CONCEPT & DERIVATION

The time period of uniform circular motion is the time required to complete one revolution, calculated as circumference divided by speed.

Formula / Rule / Reaction:

$$T = \frac{2\pi r}{v}$$

Solution:

- Given values: Radius $r = 1.0 \text{ m}$, speed $v = 1.0 \text{ m/s}$.
- Calculating period:

$$T = \frac{2\pi(1.0 \text{ m})}{1.0 \text{ m/s}} = 2\pi \text{ seconds} \approx 6.28 \text{ s}$$

- Option B is correct.

Why other options are incorrect:

- **Option A:** 4π seconds would occur if radius were doubled to 2.0 m at 1.0 m/s .
- **Option C:** π seconds would require speed to be doubled to 2.0 m/s .
- **Option D:** $\pi/2$ seconds would require speed to be 4.0 m/s .

Question #176 Key: (A)PHYSICS
04. Rotational & Circular Motion

The mathematical relationship between tangential linear acceleration ([Formula]) and angular ...

CORE CONCEPT & DERIVATION

Tangential acceleration measures the rate of change of linear speed, which equals the radius multiplied by the angular acceleration.

Formula / Rule / Reaction:

$$v = r\omega \implies a_t = \frac{dv}{dt} = r \frac{d\omega}{dt} = r\alpha$$

Solution:

- Tangential linear velocity is related to angular velocity by $v = r\omega$.
- Differentiating both sides with respect to time for a fixed radius r :

$$a_t = r\alpha$$

- Option A is the correct kinematic relationship.

Why other options are incorrect:

- **Option B:** Dividing radius by angular acceleration has incorrect units of $\text{m} \cdot \text{s}^2$.
- **Option C:** $r^2\alpha$ has incorrect dimensions of m^2/s^2 .
- **Option D:** $r\omega^2$ represents centripetal (radial) acceleration, not tangential acceleration.

Question #177 Key: (A)ENGLISH
01. Vocabulary, Synonyms, Antonyms & Spelling

The vocabulary word *RELUCTANT* most nearly means:

CORE CONCEPT & DERIVATION

'Reluctant' is an adjective describing someone who is unwilling, hesitant, or slow to act due to reservation.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Derived from Latin *reluctari* (to struggle against), 'reluctant' describes feeling or showing hesitation or unwillingness.
- Therefore, 'hesitant' is the direct synonym. Option A is correct.

Why other options are incorrect:

- **Option B:** 'Current' means belonging to the present time or a flow of water/charge.
- **Option C:** 'Remarkable' means extraordinary or worthy of attention.
- **Option D:** 'Rude' means impolite or discourteous.

Question #178 Key: (C)ENGLISH
01. Vocabulary, Synonyms, Antonyms & Spelling

The closest *SYNONYM* of the word *APPAREL* is:

CORE CONCEPT & DERIVATION

'Apparel' is a formal noun referring to clothing, garments, or attire worn on the human body.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- 'Apparel' encompasses clothing, garments, and attire.
- Among the options, 'dress' serves as a direct synonym for clothing or attire. Option C is correct.

Why other options are incorrect:

- **Option A:** 'Dubious' means hesitating, doubtful, or suspicious.
- **Option B:** 'Disguise' means clothing or alteration used to conceal one's identity.
- **Option D:** 'Apron' is a specific protective garment, whereas apparel refers to clothing generally.

Question #179 Key: (A)ENGLISH
01. Vocabulary, Synonyms, Antonyms & Spelling

The direct *ANTONYM* of the word *ENDEAVOUR* is:

CORE CONCEPT & DERIVATION

'Endeavour' means to make an active, determined effort to achieve a goal; its antonym is a lack of action or effort.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- 'Endeavour' denotes earnest, industrious exertion.
- Its opposite is 'inaction', which means the state of doing nothing or withholding effort. Option A is correct.

Why other options are incorrect:

- **Option B:** 'Inexact' means imprecise or inaccurate.
- **Option C:** 'Effort' is a synonym of endeavour.
- **Option D:** 'Striving' is a synonym of endeavour.

Question #180 Key: (A)ENGLISH
01. Vocabulary, Synonyms, Antonyms & Spelling

What is the direct ANTONYM of the word ZEALOUS?

CORE CONCEPT & DERIVATION

'Zealous' describes showing intense passion, fervor, and enthusiasm for a cause; its antonym is lacking interest or enthusiasm.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- A zealous person is full of energetic passion and dedication.
- The antonym is 'unenthusiastic', which denotes apathy or lack of passion. Option A is correct.

Why other options are incorrect:

- **Option B:** 'Religious' refers to spiritual faith, which is not an antonym of zealous.
- **Option C:** 'Contagious' means transmissible through direct or indirect contact.
- **Option D:** 'Fanatic' is a near-synonym meaning excessively zealous.

Question #181 Key: (B)ENGLISH
03. Parts of Speech, Prepositions & Modifiers

Fill in the blank with the appropriate article: 'It is _____ honor for me to address you this e...

CORE CONCEPT & DERIVATION

The indefinite article 'an' is required before words that begin with a spoken vowel sound, regardless of whether the initial written letter is a consonant.

Formula / Rule / Reaction:

Spoken Initial Vowel Sound (/v/) ⇒ Use 'an'

Solution:

- The word 'honor' begins with an unvoiced, silent 'h' (pronounced /'on.ər/).
- Because the initial sound is a vowel sound, the indefinite article 'an' must be used. Option B is correct.

Why other options are incorrect:

- **Option A:** 'A' is used only before initial consonant sounds (e.g., 'a house', 'a university').
- **Option C:** 'The' is the definite article, which is unidiomatic here when introducing a general singular count noun complement.
- **Option D:** Singular countable nouns like 'honor' in this predicate position require a determiner.

Question #182 Key: (C)ENGLISH
03. Parts of Speech, Prepositions & Modifiers

Fill in the blank with the appropriate preposition: 'He was sitting next _____ her throughout t...

CORE CONCEPT & DERIVATION

The compound preposition 'next to' is the standard fixed English idiom to indicate immediate adjacent spatial position.

Formula / Rule / Reaction:

'Next' + 'to' + Object (indicating adjacent spatial proximity)

Solution:

- When indicating that someone is seated immediately beside another person, 'next' pairs with the preposition 'to'.
- The phrase 'next to her' is the only grammatically correct formulation. Option C is correct.

Why other options are incorrect:

- **Option A:** 'Next with' is ungrammatical in English.
- **Option B:** While 'sitting by her' is valid, 'next by' is redundant and incorrect.
- **Option D:** 'Next at' is ungrammatical.

Question #183 Key: (B)ENGLISH
03. Parts of Speech, Prepositions & Modifiers

Fill in the blank with the appropriate preposition: 'Each handmade article in the auction was s...

CORE CONCEPT & DERIVATION

The preposition 'at' is used to denote the specific monetary rate, price, or cost at which goods are sold or purchased.

Formula / Rule / Reaction:

Verb ('sell' / 'buy') + 'at' + [Price / Monetary Value]

Solution:

- In commercial contexts, commodities are bought or sold 'at' a given price (e.g., 'sold at 50 dollars', 'sold at over a pound').
- Therefore, 'at' is the correct preposition. Option B is correct.

Why other options are incorrect:

- **Option A:** 'Sold out' means stock was depleted, which does not fit before a price phrase.
- **Option C:** 'Sold off' means liquidated at low prices, but requires 'for' or 'at' to specify price.
- **Option D:** 'Sold in' is unidiomatic with a monetary price.

Question #184 **Key: (C)**ENGLISH
01. Vocabulary, Synonyms, Antonyms & Spelling*The word ANCESTOR is defined as:***CORE CONCEPT & DERIVATION**

An ancestor is a person from whom one is descended, typically on a genealogical timeline further back than a grandparent.

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

- 'Ancestor' refers to a progenitor or forefather in a biological lineage.
- Therefore, 'forefathers' is the direct definition. Option C is correct.

Why other options are incorrect:

- **Option A:** A collection of stars is a constellation or galaxy.
- **Option B:** A branch of astrology deals with horoscopic predictions.
- **Option D:** Sensory biological receptors are neuroepithelial proteins or cells.

Question #185 **Key: (C)**ENGLISH
01. Vocabulary, Synonyms, Antonyms & Spelling*The vocabulary word BASHFUL most nearly describes a person who is:***CORE CONCEPT & DERIVATION**

'Bashful' is an adjective describing someone who is socially shy, self-conscious, hesitant, or easily embarrassed.

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

- Derived from Middle English *bashen* (to abash or embarrass).
- It denotes timid, self-conscious behavior around others.
- Therefore, 'embarrassed, shy, and socially reserved' is the accurate definition. Option C is correct.

Why other options are incorrect:

- **Option A:** 'Brimful' means completely full to the upper rim.
- **Option B:** 'Skillful' means having expertise or talent.
- **Option D:** 'Wonderful' means inspiring delight or admiration.

Question #186 **Key: (B)**ENGLISH
06. Punctuation, Capitalization & Reading Comprehension*Choose the sentence that exhibits correct punctuation between independent clauses:***CORE CONCEPT & DERIVATION**

Two related independent clauses not joined by a coordinating conjunction must be linked by a semicolon to prevent a comma splice.

Formula / Rule / Reaction:

[Independent Clause 1] ; [Independent Clause 2]

Solution:

- 'Dr. Umer has reached' and 'Dr. Jamal has not' are both complete independent clauses with subject and verb.
- Joining them with a comma creates a comma splice error.
- A semicolon correctly links closely related independent clauses without requiring a coordinating conjunction. Option B is correct.

Why other options are incorrect:

- **Option A:** Joining two independent clauses with only a comma produces an ungrammatical comma splice.
- **Option C:** A slash is informal punctuation used for alternatives, not for clause linkage.
- **Option D:** A colon is used when the second clause explains, illustrates, or amplifies the first, which is not the case here.

Question #187 **Key: (D)**ENGLISH
06. Punctuation, Capitalization & Reading Comprehension*Choose the grammatically correct comparative sentence:***CORE CONCEPT & DERIVATION**

In formal comparisons, compared items must be logically parallel; comparing a population to a country directly creates an illogical comparison.

Formula / Rule / Reaction:

The population of [Country A] is greater than that of [Country B] / [Country B]'s

Solution:

- The subject of comparison is 'the population of China'.
- Comparing the population of China directly to the nation of Pakistan is an illogical comparison.
- The sentence must compare population to population: 'that of Pakistan' or the possessive form 'Pakistan's' (elliptical for Pakistan's population). Option D is correct.

Why other options are incorrect:

- **Option A:** Illogical comparison comparing a population directly to a geographical country.
- **Option B:** 'Population' is an uncountable collective singular noun requiring the singular verb 'is', not 'are', and contains an illogical comparison.
- **Option C:** Contains the same illogical comparison comparing population to country.

Question #188 **Key: (B)**ENGLISH
06. Punctuation, Capitalization & Reading Comprehension

Choose the grammatically correct sentence with proper modifier placement:

CORE CONCEPT & DERIVATION

Relative clauses must sit adjacent to the noun they modify, and the adverb 'fast' is an irregular flat adverb whose standard form is 'fast', not 'fastly'.

Formula / Rule / Reaction:

[Subject] + [Relative Clause] + [Transitive Verb] + [Direct Object] + [Adverb of Manner ('fast')]

Solution:

- The relative clause 'which was new' modifies 'the machine', so it must follow 'machine' directly.
- The direct object 'the stuff' must immediately follow the transitive verb 'printed'.
- 'Fast' functions as both an adjective and an adverb; 'fastly' is not a word in standard modern English. Option B is correct.

Why other options are incorrect:

- **Option A:** Places the modifier 'which was new' adjacent to 'stuff', creating a misplaced modifier that implies the stuff was new rather than the machine.
- **Option C:** Places the adverb 'fast' between the transitive verb and its direct object, violating English word order.
- **Option D:** Uses the non-standard word 'fastly'.

Question #189 **Key: (C)**ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

Choose the sentence that correctly employs the subjunctive mood for an unreal, hypothetical wish...

CORE CONCEPT & DERIVATION

In formal English, the past subjunctive form 'were' is required for all persons in contrary-to-fact hypothetical wish clauses.

Formula / Rule / Reaction:

Wish / Contrary-to-Fact: Subject + 'wish' + (that) + Subject + 'were' + Complement

Solution:

- The statement expresses an unreal, counterfactual state (the speaker is not a millionaire).
- Formal grammar requires the past subjunctive 'were' regardless of whether the subject is singular (I, he, she) or plural.
- 'I wish I were a millionaire' is the correct subjunctive construction. Option C is correct.

Why other options are incorrect:

- **Option A:** 'Have been' is present perfect indicative and cannot express a hypothetical present wish.
- **Option B:** 'Am being' is present continuous indicative, which is ungrammatical after 'wish'.
- **Option D:** 'Was' is the indicative singular past form; while heard in casual speech, it is considered non-standard on competitive MDCAT examinations.

Question #190 **Key: (C)**ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

Fill in the blank with the appropriate verb tense: 'The historical town _____ its appearance co...

CORE CONCEPT & DERIVATION

The preposition 'since' specifying a past starting point requires the present perfect tense to express an action starting in the past and continuing up to the present.

Formula / Rule / Reaction:Subject + has / have + Past Participle (V₃) + 'since' + [Specific Past Time]**Solution:**

- 'Since 1980' indicates a duration that started in 1980 and connects to the present.
- The present perfect tense ('has changed') is required for an action initiated in the past with ongoing present relevance. Option C is correct.

Why other options are incorrect:

- **Option A:** 'Is changing' is present continuous, which cannot pair with 'since' to describe a completed transformation over decades.
- **Option B:** 'Changed' is simple past, used with definite past time markers (e.g., 'in 1980'), not with the connecting preposition 'since'.
- **Option D:** 'Changes' is simple present, used for habitual actions rather than actions extending from 1980.

Question #191 **Key: (C)**ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

Fill in the blank with the appropriate future perfect continuous construction: 'By next March, ...

CORE CONCEPT & DERIVATION

An action ongoing in the present that will continue up to a designated future time requires the future perfect continuous tense.

Formula / Rule / Reaction:

'By' + [Future Time Point] ⇒ Subject ('We') + 'shall have been' + V-ing + 'for' + [Duration]

Solution:

- The time marker 'By next March' specifies a future deadline, and 'for four years' specifies duration.
- In formal English, the first-person plural pronoun 'we' takes 'shall have been living' in the future perfect continuous tense. Option C is correct.

Why other options are incorrect:

- **Option A:** 'Would have been' is an ungrammatical verb sequence.
- **Option B:** 'Would have lived' is conditional perfect, used for contrary-to-fact past scenarios rather than future plans.
- **Option D:** 'Shall live' is simple future, which fails to convey the four-year duration leading up to that point.

Question #192 Key: (C)ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

Fill in the blank with the appropriate verb form: 'The students, accompanied by their teacher, ...

CORE CONCEPT & DERIVATION

Parenthetical phrases introduced by 'accompanied by', 'along with', or 'as well as' do not change the number of the true grammatical subject.

Formula / Rule / Reaction:

Plural Subject ('The students') + [Parenthetical Adjunct] + Plural Verb ('are')

Solution:

- The grammatical subject is 'The students', which is plural.
- The intervening phrase 'accompanied by their teacher' is a parenthetical prepositional modifier that does not alter subject number.
- The plural subject requires the plural auxiliary verb 'are' for present continuous aspect. Option C is correct.

Why other options are incorrect:

- Option A:** 'Is' is singular, representing an error of proximity caused by the adjacent singular noun 'teacher'.
- Option B:** 'Has' is singular and does not form a present continuous tense with the participle 'entering'.
- Option D:** 'Have' cannot pair with the present participle 'entering' to form continuous aspect (it would require 'have been entering').

Question #193 Key: (C)ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

Fill in the blank with the grammatically correct verb form: 'None of us _____ beyond a mile.'

CORE CONCEPT & DERIVATION

In formal grammar, the indefinite pronoun 'none' (not one) is traditionally treated as singular and takes a singular verb in present perfect constructions.

Formula / Rule / Reaction:

'None' (Not one) + Singular Auxiliary ('has') + Past Participle ('gone')

Solution:

- 'None' historically functions as 'not one' and takes the singular verb 'has gone' in formal contexts.
- Option C is the only grammatically complete present perfect option available.

Why other options are incorrect:

- Option A:** 'Gone' is a bare past participle lacking an auxiliary verb.
- Option B:** 'Were gone' forms an awkward passive/stative construction unsuited for describing voluntary movement.
- Option D:** 'Were go' is an ungrammatical verb sequence.

Question #194 Key: (B)ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

Fill in the blank with the appropriate future perfect tense construction: 'I _____ before 10:00...

CORE CONCEPT & DERIVATION

The future perfect tense requires the auxiliary 'shall/will have' followed by the irregular past participle of 'sleep', which is 'slept'.

Formula / Rule / Reaction:

Subject ('I') + 'shall have' + Past Participle (V_3 , 'slept') + [Time Prepositional Phrase]

Solution:

- The verb 'sleep' is irregular: base form 'sleep', past tense 'slept', past participle 'slept'.
- Future perfect tense for a first-person subject uses 'shall have slept'. Option B is correct.

Why other options are incorrect:

- Option A:** 'Slepted' is an incorrect regularized form of the irregular verb 'sleep'.
- Option C:** 'Will have sleep' incorrectly uses the base verb instead of the past participle.
- Option D:** 'Shall have been slept' is a passive voice construction, which is invalid because 'sleep' is an intransitive verb.

Question #195 Key: (C)LOGICAL REASONING
14. Direction, Distance & Spatial/Visual Patterns

Observe the shifting marker in the sequence below: Term 1: [Δ | _ | _ | _] Term 2: [_ | _ | _ | _]

CORE CONCEPT & DERIVATION

In linear spatial reasoning series, marker movements follow consistent arithmetic step increments along discrete positions.

Formula / Rule / Reaction:

Position $P_n = P_{n-1} + 2 \implies \text{Position 1} \rightarrow \text{Position 3} \rightarrow \text{Position 5}$

Solution:

- In Term 1, the marker is in Position 1.
- In Term 2, the marker is in Position 3 (shifted +2 positions right).
- In Term 3, the marker is in Position 5 (shifted +2 positions right).
- The rule governing the sequence is an advance of two discrete positions per step. Option C is correct.

Why other options are incorrect:

- Option A:** The sequence moves forward, not backward.
- Option B:** The marker is in dynamic motion and does not lock into place.
- Option D:** The step size is a constant +2, not a random shift.

Question #196 **Key: (B)**

LOGICAL REASONING

14. Direction, Distance & Spatial/Visual Patterns

A person looks at their printed shirt in a vertical plane mirror and reads: $\leq \text{WOIHA} \geq$. What te...

CORE CONCEPT & DERIVATION

A plane mirror produces lateral inversion, reversing the left-to-right sequence of characters and inverting non-symmetrical symbols horizontally.

Formula / Rule / Reaction:

Mirror Image: $[S_{\text{left}}][L_1 L_2 L_3 L_4 L_5][S_{\text{right}}] \xrightarrow{\text{Lateral Reversal}}$ Real Object: $[S'_{\text{right}}][L'_5 L'_4 L'_3 L'_2 L'_1][S'_{\text{left}}]$

Solution:

- The seen mirror reflection from left to right is: ' $\leq$ ' followed by 'W-O-I-H-A' followed by ' $\geq$ '.
- Reversing the linear order from right to left gives: the rightmost symbol ' $\geq$ ' reflects from the real left side as ' $\leq$ '.
- The letters in reverse order become 'A-H-I-O-W'. Because A, H, I, O, and W are all laterally symmetrical capital letters, their individual shapes are unchanged by reflection.
- The leftmost symbol ' $\leq$ ' reflects from the real right side as ' $\geq$ '.
- Therefore, the physical shirt reads ' $\leq$ AHIOW $\geq$ '. Option B is correct.

Why other options are incorrect:

- Option A:** Fails to reverse the linear letter sequence.
- Option C:** Assumes a plane mirror causes no lateral inversion.
- Option D:** Inverts the bracket symbols incorrectly relative to the letters.

Question #197 **Key: (A)**

LOGICAL REASONING

04. Argument Evaluation & Ethics

Read the passage below and evaluate the statements, basing your conclusion ONLY on the provided...

CORE CONCEPT & DERIVATION

Critical reading deductions must be derived strictly from explicitly stated textual premises without importing unstated outside assumptions.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Statement I claims economic wealth; the passage states Pakistan is 'rich in wildlife and culture', not wealthy in financial resources. Statement I does not follow.
- Statement II claims people from 'all nationalities' live in Pakistan; the passage states 'people from most countries', which does not equal 'all'. Statement II does not follow.
- Statement III states Pakistan hosts at least one dolphin species; the passage explicitly names the 'Indus River Dolphin'. Statement III logically follows.
- Therefore, only Statement III is correct. Option A is correct.

Why other options are incorrect:

- Option B:** Statements I and II are unsupported by the text.
- Option C:** Statement I is unsupported by the text.
- Option D:** Statement II is an overgeneralization unsupported by the text.

Question #198 Key: (A)LOGICAL REASONING
05. Categorical Syllogisms & Overlapping Sets

Consider the following logical premises: 1. A ball is a sphere. 2. All spheres are round. 3. So...

CORE CONCEPT & DERIVATION

Logical deductions must connect categorical syllogistic premises consistently.

Formula / Rule / Reaction:

Premise: Ball $\subseteq$ Sphere $\subseteq$ Round, Round $\cap$ Mesmerizing $\neq \emptyset$

Solution:

- Premises establish that all balls are spheres, and all spheres are round (Balls $\subseteq$ Spheres $\subseteq$ Round things).
- The third premise states that some round things are mesmerizing.
- While strict formal logic notes that round things that are mesmerizing need not overlap with the sphere subset (the fallacy of the undistributed middle), the official syllabus key establishes Option A ('Some mesmerizing things are spheres') as the intended deduction.
- Options B, C, and D are universal overgeneralizations that directly violate syllogistic rules. Option A is the keyed answer.

Why other options are incorrect:

- **Option B:** Stating that all balls are mesmerizing is an overgeneralization; only some round things are mesmerizing.
- **Option C:** Stating that all round things are spheres is an invalid conversion of 'all spheres are round' (e.g., cylinders are round but not spheres).
- **Option D:** No premise establishes that all mesmerizing things must be balls.

Question #199 Key: (A)LOGICAL REASONING
02. Cause and Effect Analysis

Analyze the two factual statements below and determine the logical cause-and-effect relationship...

CORE CONCEPT & DERIVATION

In cause-and-effect analysis, the event that creates a supply deficit acts as the cause, and the policy decision taken to remedy that deficit acts as the effect.

Formula / Rule / Reaction:

Event I: Domestic Deficit $\xrightarrow{\text{Causes}}$ Event II: Remedial Government Action

Solution:

- Statement I describes a collapse in domestic oilseed production, which creates an impending domestic shortage of edible cooking oil.
- Statement II describes the government's decision to import more edible oil to meet domestic demand and stabilize market prices.
- Therefore, Statement I is the underlying cause, and Statement II is the direct policy effect. Option A is correct.

Why other options are incorrect:

- **Option B:** Importing edible oil does not cause agricultural crop production to decline.
- **Option C:** The two events are directly linked by supply and demand, not independent.
- **Option D:** Statement II is a direct response to Statement I, not an isolated effect of an unrelated cause.

Question #200 Key: (B)LOGICAL REASONING
03. Courses of Action & Decision-Making

Read the statement and evaluate which of the suggested courses of action logically follows and...

CORE CONCEPT & DERIVATION

A valid administrative course of action must be proportional, realistic, and constructive in addressing a workplace issue rather than excessively punitive.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Course of Action I is disproportionately harsh for a five-minute delay; deducting half a day's wages for minor lateness damages employee morale and retention without addressing transit issues.
- Course of Action II provides a realistic buffer for unavoidable delays while penalizing chronic offenders (more than twice a month).
- This represents a balanced, proportional administrative policy. Option B is correct.

Why other options are incorrect:

- **Option A:** Course I is disproportionate and counterproductive to workplace productivity.
- **Option C:** Course I cannot be pursued alongside Course II because their penalty structures conflict.
- **Option D:** Course II is a reasonable policy that directly addresses the problem.