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DUHS KARACHI

DUHS Karachi MDCAT 2022 Official Paper

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

📍 Official Admitting Board: Dow University of Health Sciences Karachi 📍 Archive Code: BEAMBE-FLP-DUHS-2022 ⌚ 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

Hepatitis is caused by:

- (A) Protozoans
- (B) Bacteria
- (C) Fungi
- (D) Viruses

Q2. BIO

Syphilis is caused by a bacterium known as:

- (A) Treponema pallidum
- (B) Neisseria gonorrhoeae
- (C) Bacillus anthracis
- (D) Trichomonas vaginalis

Q3. BIO

The presence of remnants of the pelvic girdle in whales and snakes, although they lack functional legs, provides evidence of evolution from:

- (A) Biochemical genetics
- (B) Comparative embryology
- (C) Vestigial organs
- (D) Analogous structures

Q4. BIO

Photosynthetic sulfur bacteria liberate:

- (A) Oxygen
- (B) Carbon dioxide
- (C) Sulfur
- (D) Hydrogen gas

Q5. BIO

The plasma membrane of a living cell is described as being:

- (A) Completely permeable
- (B) Selectively permeable
- (C) Impermeable
- (D) Freely porous

Q6. BIO

Water is the most abundant chemical compound in living organisms, with its proportion in cellular mass generally varying from:

- (A) 10% to 20%
- (B) 30% to 50%
- (C) 50% to 60%
- (D) 70% to 90%

Q7. BIO

The phase of the cardiac cycle in which the bicuspid and tricuspid valves open while the semilunar valves snap shut, producing the second heart sound ('dub'), is known as:

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

Q8. BIO

The classic phenotypic ratio produced in the F_2 generation following Mendel's law of independent assortment is:

- (A) 3:1
- (B) 9:3:3:1
- (C) 1:2:1
- (D) 9:7

Q9. BIO

Triose intermediates and glycerol are directly utilized by the cell in the synthesis of:

- (A) Carbohydrates
- (B) Proteins
- (C) Lipids
- (D) Nucleic acids

Q10. BIO

Chemical substances that act as inhibitors of key enzymes in the human nervous system include:

- (A) Calcium and potassium ions
- (B) Glucose and hexokinase
- (C) Magnesium and manganese ions
- (D) Pesticides such as DDT and parathion

Q11. BIO

The phytohormone primarily responsible for maintaining apical dominance in plants is:

- (A) Auxin
- (B) Gibberellin
- (C) Cytokinin
- (D) Absciscic acid

Q12. BIO

During swallowing, the food bolus is directed safely into the esophagus rather than the trachea due to the action of the:

- (A) Soft palate
- (B) Tongue
- (C) Epiglottis
- (D) Buccal mucosa

Q13. BIO

The net gain of ATP molecules produced per molecule of glucose at the completion of glycolysis is:

- (A) 2 ATP
- (B) 4 ATP
- (C) 6 ATP
- (D) 8 ATP

Q14. BIO

The parasitic and free-living flatworm classes Turbellaria, Trematoda, and Cestoda belong to the phylum:

- (A) Aschelminthes
- (B) Cnidaria
- (C) Platyhelminthes
- (D) Annelida

Q15. BIO

A spikelet inflorescence is a distinguishing botanical characteristic of the family:

- (A) Solanaceae
- (B) Rosaceae
- (C) Fabaceae
- (D) Poaceae

Q16. BIO

In the cross-sectional hexagonal lattice of a skeletal muscle myofibril, each thick myosin filament is surrounded by:

- (A) 2 actin filaments
- (B) 4 actin filaments
- (C) 6 actin filaments
- (D) 8 actin filaments

Q17. BIO

The condensation of two α -D-glucose molecules joined together by an $\alpha(1\rightarrow4)$ glycosidic linkage forms the disaccharide:

- (A) Sucrose
- (B) Lactose
- (C) Maltose
- (D) Cellobiose

Q18. BIO

In *Drosophila melanogaster*, the appearance of the white-eyed phenotype investigated by Thomas Hunt Morgan is due to a:

- (A) Chromosomal inversion
- (B) Spontaneous gene mutation
- (C) Unequal crossing over
- (D) Polyploidy event

Q19. BIO

Enzymes are rapidly inactivated upon direct exposure to ultraviolet light as well as α and β radiation because these rays alter the:

- (A) Quantity of the enzyme
- (B) Three-dimensional shape of the enzyme
- (C) pH of the catalytic medium
- (D) Substrate concentration

Q20. BIO

In the respiratory mechanism of a frog, fresh air is drawn into the buccopharyngeal cavity through the nares while stale air is temporarily held under pressure in the:

- (A) Lungs
- (B) Trachea
- (C) Glottis
- (D) Alveolar ducts

Q21. BIO

Genetic information in a double-stranded DNA molecule is stored fundamentally in the form of:

- (A) Linear genetic code of nucleotide base triplets
- (B) Amino acid sequence
- (C) Double-helical phosphate backbone
- (D) Chromatin histone core

Q22. BIO

Pyruvic acid, the end product of aerobic and anaerobic glycolysis, is an organic acid containing:

- (A) 2 carbon atoms
- (B) 3 carbon atoms
- (C) 4 carbon atoms
- (D) 6 carbon atoms

Q23. BIO

The primary structural polysaccharide comprising the plant cell wall is:

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

Q24. BIO

Which of the following cellular structures represents a plant-like feature found in *Euglena*?

- (A) Pellicle
- (B) Flagellum
- (C) Pyrenoid
- (D) Eye spot

Q25. BIO

Which anatomical region contains specialized neurosecretory cells that synthesize releasing and inhibiting hormones?

- (A) Anterior pituitary gland
- (B) Adrenal cortex
- (C) Hypothalamus
- (D) Thyroid gland

Q26. BIO

The anatomical seat of all conscious perception, reasoning, language, and voluntary movement in the human brain is the:

- (A) Cerebral cortex
- (B) Medulla oblongata
- (C) Cerebellum
- (D) Midbrain tectum

Q27. BIO

The universal and immediate chemical energy currency of all living cells is:

- (A) Nicotinamide adenine dinucleotide (NADH)
- (B) Adenosine triphosphate (ATP)
- (C) Adenosine diphosphate (ADP)
- (D) Phosphoenolpyruvate (PEP)

Q28. BIO

A scorpioid cyme inflorescence, where branching occurs successively on alternate sides to produce a coiled axis, is found in:

- (A) Cotton
- (B) Mulberry
- (C) Sunflower
- (D) Mustard

Q29. BIO

Bacterial cells that possess flagella distributed uniformly all over their outer cell surface are classified as:

- (A) Monotrichous
- (B) Lophotrichous
- (C) Amphitrichous
- (D) Peritrichous

Q30. BIO

The enzyme secreted by the duodenal brush border mucosa that cleaves inactive trypsinogen into active trypsin is:

- (A) Pepsin
- (B) Enterokinase
- (C) Aminopeptidase
- (D) Pancreatic amylase

Q31. BIO

Plant sclerenchyma cells become non-living at functional maturity primarily due to the heavy secondary deposition of:

- (A) Cellulose
- (B) Pectin
- (C) Cutin
- (D) Lignin

Q32. BIO

Rabies is a fatal acute encephalomyelitis caused by a bullet-shaped virus belonging to the family:

- (A) Paramyxoviridae
- (B) Rhabdoviridae
- (C) Picornaviridae
- (D) Retroviridae

Q33. BIO

In the medical acronym AIDS, the letter 'D' stands for:

- (A) Degenerative
- (B) Deficiency
- (C) Different
- (D) Dysfunctional

Q34. BIO

A homeostatic control loop in which the response elicited by effectors counteracts and weakens the initial disruptive stimulus is termed:

- (A) Positive feedback
- (B) Negative feedback
- (C) Static equilibrium
- (D) Thermal dissipation

Q35. BIO

During which specific substage of prophase I of meiosis does genetic recombination through crossing over occur?

- (A) Leptotene
- (B) Zygotene
- (C) Pachytene
- (D) Diplotene

Q36. BIO

In a typical holoenzyme, the non-protein organic co-enzyme moiety constitutes approximately what percentage of the entire enzyme molecule?

- (A) 1%
- (B) 5%
- (C) 10%
- (D) 25%

Q37. BIO

Adjacent deoxyribonucleotides along a single strand of DNA are covalently linked together by:

- (A) Hydrogen bonds
- (B) Phosphodiester bonds
- (C) Peptide bonds
- (D) Disulfide linkages

Q38. BIO

The rapid folding of pinnules in the sensitive plant (*Mimosa pudica*) in response to touch or mechanical vibration is a:

- (A) Theronastic movement
- (B) Nyctinastic movement
- (C) Seismonastic movement
- (D) Photonastic movement

Q39. BIO

Gregor Johann Mendel selected which experimental model organism for his classical hybridization research?

- (A) Garden pea (*Pisum sativum*)
- (B) Sweet pea (*Lathyrus odoratus*)
- (C) Broad bean (*Vicia faba*)
- (D) Wild pea (*Pisum arvense*)

Q40. BIO

Which class of lipids represents the most abundant, concentrated, and rich chemical storage form of energy in both plant and animal tissues?

- (A) Phospholipids
- (B) Acylglycerols
- (C) Carotenoids
- (D) Waxes

Q41. BIO

Organs that perform identical physiological functions in different organismal groups but exhibit different embryonic origins and internal anatomical structures are termed:

- (A) Homologous organs
- (B) Vestigial organs
- (C) Analogous organs
- (D) Atavistic organs

Q42. BIO

The extreme hardness and mechanical strength of nutshells and seed coats are primarily attributable to the presence of:

- (A) Collenchyma cells
- (B) Sclereids
- (C) Parenchyma cells
- (D) Xylem vessel elements

Q43. BIO

The biological term 'virus' is derived from a Latin root word meaning:

- (A) Poison
- (B) Parasite
- (C) Microbe
- (D) Acid

Q44. BIO

In human gross cardiac anatomy, the thick-walled pumping chambers (the ventricles) form the structural region designated as the:

- (A) Base
- (B) Apex
- (C) Superior border
- (D) Coronary sulcus

Q45. BIO

Extremely thin, tubular proteinaceous appendages that facilitate genetic transfer during bacterial conjugation are called:

- (A) Flagella
- (B) Cilia
- (C) Pili
- (D) Capsules

Q46. BIO

Non-pigmented, colourless plastids specialized for the intracellular storage of starch, oils, or proteins in plant cells are known as:

- (A) Chromoplasts
- (B) Chloroplasts
- (C) Leucoplasts
- (D) Amyloplasts only

Q47. BIO

'Evolution is the transformation of the form and mode of existence of an organism in such manner that the descendants differ from their ancestors.' This definition was formulated by:

- (A) Jean-Baptiste Lamarck
- (B) Charles Darwin
- (C) August Weismann
- (D) Walter Zimmermann

Q48. BIO

The uterus communicates with the vaginal canal through a narrow, muscular cylindrical neck bounded by a sphincter known as the:

- (A) Fallopian tube
- (B) Cervix
- (C) Labium majus
- (D) Endometrial fundus

Q49. BIO

The fossilized skeletal tests of marine shelled sarcodines (such as foraminiferans) provide valuable geological clues for locating subterranean deposits of:

- (A) Petroleum
- (B) Potassium salts
- (C) Chromium ore
- (D) Magnesium deposits

Q50. BIO

The spinal cord exits the cranial cavity and descends into the vertebral canal through a large occipital aperture known as the:

- (A) Foramen ovale
- (B) Foramen magnum
- (C) Obturator foramen
- (D) Acetabular notch

Q51. BIO

Endocytosis that involves the ingestion of solid particulate matter into a cell is termed:

- (A) Pinocytosis
- (B) Phagocytosis
- (C) Exocytosis
- (D) Autophagy

Q52. BIO

Plant-like photosynthetic protists are broadly classified as:

- (A) Protozoa
- (B) Slime molds
- (C) Water molds
- (D) Algae

Q53. BIO

When a substrate binds to the active site of an enzyme, it induces a conformational change that enables the enzyme to perform its:

- (A) Analytical function
- (B) Genetic replication
- (C) Structural polymerization
- (D) Catalytic function

Q54. BIO

Gregor Mendel selected how many pairs of contrasting characters in the garden pea for his hybridization experiments?

- (A) Three pairs
- (B) Seven pairs
- (C) Fourteen pairs
- (D) Four pairs

Q55. BIO

The organelle designated as the 'powerhouse of the cell' due to its role in ATP generation is the:

- (A) Ribosome
- (B) Endoplasmic reticulum
- (C) Golgi apparatus
- (D) Mitochondrion

Q56. BIO

The normal tidal volume of human lungs at rest during quiet breathing is approximately:

- (A) 4.0 liters
- (B) 6.0 liters
- (C) 0.5 liters
- (D) 3.0 liters

Q57. BIO

Sensory receptors specialized to detect tissue damage and noxious painful stimuli are known as:

- (A) Baroreceptors
- (B) Chemoreceptors
- (C) Proprioceptors
- (D) Nociceptors

Q58. BIO

The classic phenotypic ratio obtained in the F_2 generation of a Mendelian monohybrid cross for a single trait with complete dominance is:

- (A) 1:2:1
- (B) 3:1
- (C) 9:3:3:1
- (D) 1:1

Q59. BIO

The selective breeding of wild ancestral species by humans to propagate desirable agricultural and physical traits provides direct evidence for evolution known as:

- (A) Domestication
- (B) Natural selection
- (C) Genetic drift
- (D) Speciation by geographic isolation

Q60. BIO

Unbranched amylose molecules consist of hundreds of D-glucose subunits joined together exclusively by:

- (A) $\alpha(1 \rightarrow 2)$ glycosidic linkages
- (B) $\alpha(1 \rightarrow 6)$ glycosidic linkages
- (C) $\alpha(1 \rightarrow 4)$ glycosidic linkages
- (D) $\beta(1 \rightarrow 4)$ glycosidic linkages

Q61. BIO

Marine biogenic structures that protect coastlines from storm surges, provide habitat for diverse organisms, and contribute to carbon fixation are:

- (A) Kelp forests
- (B) Coral reefs
- (C) Abyssal trenches
- (D) Hydrothermal vents

Q62. BIO

The specific localized pocket or groove on an enzyme molecule where catalytic conversion occurs is the:

- (A) Allosteric site
- (B) Active site
- (C) Co-enzyme cleft
- (D) Prosthetic surface

Q63. BIO

The light-dependent reactions of oxygenic photosynthesis occur specifically across the:

- (A) Outer chloroplast membrane
- (B) Stroma
- (C) Inner mitochondrial cristae
- (D) Thylakoid membranes

Q64. BIO

Following ovulation, the ruptured ovarian follicle transforms into a temporary yellow endocrine gland known as the:

- (A) Corpus albicans
- (B) Corpus luteum
- (C) Graafian follicle
- (D) Zona pellucida

Q65. BIO

The giant African land snail (*Achatina fulica*) poses a severe ecological and economic threat primarily as a destructive:

- (A) Agricultural pest
- (B) Parasitoid of honeybees
- (C) Vector of plant viruses
- (D) Predator of silkworms

Q66. BIO

The primary carboxylating enzyme responsible for fixing carbon dioxide in the Calvin cycle of C_3 plants is:

- (A) PEP carboxylase
 - (B) Carbonic anhydrase
 - (C) Pyruvate kinase
 - (D) RuBisCO
-

Q67. BIO

A degenerative joint disorder characterized by cartilage breakdown, abnormal calcium deposition, and joint inflammation is:

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

Q68. BIO

The average number of hemoglobin molecules packaged within a single mature human erythrocyte (RBC) is approximately:

- (A) 280 million
 - (B) 150 million
 - (C) 380 million
 - (D) 180 million
-

CHEM SECTION: CHEMISTRY

Questions 69 to 122 (54 MCQs)

Q69. CHEM

For an exothermic reversible reaction, decreasing the system temperature causes the equilibrium constant (K_c) to:

- (A) Increase
- (B) Decrease
- (C) Remain unchanged
- (D) Fall to zero

Q70. CHEM

Viscosity is a fundamental physical property that quantifies a fluid's:

- (A) Resistance to flow
- (B) Specific gravity
- (C) Vapor pressure at equilibrium
- (D) Surface tension

Q71. CHEM

Acetone (propan-2-one) gives a characteristic yellow crystalline precipitate when reacted under alkaline conditions with:

- (A) Fehling's solution
- (B) Tollens' reagent
- (C) Lucas reagent
- (D) Iodine and aqueous sodium hydroxide

Q72. CHEM

The Rydberg formula $\bar{\nu} = R_H \left(\frac{1}{2^2} - \frac{1}{n^2} \right)$, where $n > 2$, calculates the wavenumbers for the spectral lines of the:

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

Q73. CHEM

The mathematical equation of the first law of thermodynamics, $q = \Delta E + w$, simplifies under constant volume conditions to:

- (A) $q_v = \Delta E$
- (B) $q_v = \Delta E + w$
- (C) $q_v = \Delta E + P\Delta V$
- (D) $q_v = P\Delta V$

Q74. CHEM

The electrolysis of an aqueous dilute hydrochloric acid solution using inert electrodes yields:

- (A) Cl_2 at the cathode and H_2 at the anode
- (B) H_2 at the cathode and O_2 at the anode
- (C) H_2 at the anode and O_2 at the cathode
- (D) O_2 at the cathode and H_2 at the anode

Q75. CHEM

The Ostwald process for the industrial manufacture of nitric acid involves the primary catalytic oxidation of:

- (A) H_2S
- (B) NH_3
- (C) SO_2
- (D) HCl

Q76. CHEM

The net dipole moment of carbon dioxide (CO_2) is zero because its molecular geometry is:

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

Q77. CHEM

Sodium nitrate (NaNO_3) and calcium carbonate (CaCO_3) both form trigonal crystals. Because they share the same crystalline form, they are termed:

- (A) Allotropes
- (B) Enantiomers
- (C) Isomers
- (D) Isomorphs

Q78. CHEM

Nylon-6,6 is synthesized industrially as a:

- (A) Addition polymer of hexanedioic acid and 1,6-diaminohexane
- (B) Condensation polymer of hexanedioic acid and 1,6-diaminohexane
- (C) Addition polymer of ethene and hexanedioic acid
- (D) Condensation polymer of terephthalic acid and ethylene glycol

Q79. CHEM

In an ethene molecule ($\text{H}_2\text{C} = \text{CH}_2$), each carbon atom exhibits which hybridization state?

- (A) sp
- (B) sp^2
- (C) sp^3
- (D) dsp^2

Q80. CHEM

The kinetic molecular theory (KMT) was formulated primarily to provide a theoretical basis explaining the:

- (A) Atomic numbers of gaseous elements
- (B) Chemical bonding within gas molecules
- (C) Macroscopic physical behavior of gases
- (D) Nuclear stability of noble gases

Q81. CHEM

When 2-chloropropane is heated with metallic sodium in dry ether, 2,3-dimethylbutane is formed. This transformation is an example of the:

- (A) Catalytic hydrogenation
- (B) Dehydrohalogenation
- (C) Wurtz reaction
- (D) Kolbe electrolytic reaction

Q82. CHEM

A chemical reaction in a closed vessel achieves dynamic equilibrium when:

- (A) The rate of the forward reaction exceeds the backward reaction
- (B) The rate of the backward reaction exceeds the forward reaction
- (C) Concentrations of reactants and products remain constant, and forward and backward rates are equal
- (D) Reactant concentrations fall to zero as products reach maximum concentration

Q83. CHEM

The addition of a positive catalyst accelerates the rate of a chemical reaction primarily because the:

- (A) Activation energy decreases
- (B) Activation energy increases
- (C) Enthalpy change of reaction increases
- (D) Collision frequency decreases

Q84. CHEM

The photochemical combination reaction $\text{H}_2(g) + \text{Cl}_2(g) \xrightarrow{h\nu} 2\text{HCl}(g)$ carried out over water proceeds as which order of reaction?

- (A) First order
- (B) Second order
- (C) Half order
- (D) Zero order

Q85. CHEM

Under identical conditions of temperature and pressure, the ratio of the rates of diffusion of hydrogen gas (H_2) to oxygen gas (O_2) is:

- (A) 1:2
- (B) 1:4
- (C) 2:1
- (D) 4:1

Q86. CHEM

When a Grignard reagent such as methylmagnesium iodide (CH_3MgI) reacts with methyl iodide (CH_3I), the primary hydrocarbon product is:

- (A) Ethane
- (B) Methane
- (C) Propane
- (D) Butane

Q87. CHEM

The IUPAC systematic name for oxalic acid, $\text{HOOC} - \text{COOH}$, is:

- (A) Acetic acid
- (B) Formic acid
- (C) Ethanedioic acid
- (D) Propanedioic acid

Q88. CHEM

Finely pulverized calcium carbonate (CaCO_3) reacts significantly faster with acid than large marble chips due to an increase in:

- (A) Activation energy
- (B) Surface area
- (C) Gas volume
- (D) Equilibrium constant

Q89. CHEM

The chemical oxidation of potassium manganate (K_2MnO_4) using chlorine gas is used industrially to manufacture:

- (A) K_2CrO_4
- (B) MnO_2
- (C) KMnO_4
- (D) Mn_2O_7

Q90. CHEM

Unlike aliphatic ketones, aliphatic aldehydes can be oxidized to carboxylic acids by:

- (A) Only strong oxidizing agents
- (B) Only mild oxidizing agents
- (C) Both mild and strong oxidizing agents
- (D) Neither mild nor strong oxidizing agents

Q91. CHEM

When benzene is subjected sequentially to Friedel-Crafts alkylation with chloromethane, followed by nitration, and then side-chain oxidation, the primary final product is:

- (A) Meta-nitrobenzoic acid
- (B) Ortho- and para-nitrobenzoic acids
- (C) Meta-nitrotoluene
- (D) Ortho-nitrotoluene only

Q92. CHEM

During the industrial electrolysis of brine in a Castner-Kellner cell, the products formed at the electrodes are:

- (A) NaOH and Cl_2 at the cathode, H_2 at the anode
- (B) NaOH and H_2 at the cathode, Cl_2 at the anode
- (C) Na metal at the anode, Cl_2 at the cathode
- (D) H_2 at the anode, O_2 at the cathode

Q93. CHEM

Bakelite is a commercially important thermosetting polymer synthesized by the condensation of:

- (A) Phenol and formaldehyde
- (B) Formaldehyde and acetone
- (C) Phenol and acetaldehyde
- (D) Urea and formaldehyde

Q94. CHEM

Mononitration of phenol using dilute nitric acid at room temperature produces a mixture containing:

- (A) Ortho-nitrophenol and para-nitrophenol
- (B) Meta-nitrophenol only
- (C) Ortho-nitrophenol and meta-nitrophenol
- (D) 2,4,6-trinitrobenzene

Q95. CHEM

Heating chromite ore ($\text{FeO} \cdot \text{Cr}_2\text{O}_3$) with potassium carbonate (K_2CO_3) in the presence of atmospheric oxygen is used to manufacture:

- (A) KMnO_4
- (B) $\text{K}_2\text{Cr}_2\text{O}_7$
- (C) K_2CrO_4
- (D) Cr_2O_3

Q96. CHEM

A chemical substance classified as a strong electrolyte is one that:

- (A) Partially dissociates into ions
- (B) Does not conduct electricity
- (C) Ionizes completely in aqueous solution
- (D) Decomposes into elemental atoms

Q97. CHEM

During ionic crystal lattice formation between a metal and a non-metal, electrostatic stabilization requires that:

- (A) Only the cation achieves noble gas configuration
- (B) Only the anion achieves noble gas configuration
- (C) Both ions achieve noble gas configurations, and electrons lost equal electrons gained
- (D) Covalent electron pairs are shared equally between ions

Q98. CHEM

In structural organic chemistry, a secondary (2°) alcohol is defined by having its hydroxyl-bearing carbon attached directly to:

- (A) No β -carbons
- (B) One β -carbon
- (C) Two β -carbons
- (D) Three β -carbons

Q99. CHEM

Diffusion occurs at an extremely slow rate in crystalline solids compared to liquids and gases because solid particles exhibit only:

- (A) Fast translational motion
- (B) Vibrational motion about fixed mean positions
- (C) Free rotational tumbling
- (D) High molecular fluidity

Q100. CHEM

Real gases show the greatest deviation from ideal gas behavior under which combination of physical conditions?

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

Q101. CHEM

Complete combustion of 3.0 g of carbon in excess oxygen ($\text{C} + \text{O}_2 \rightarrow \text{CO}_2$) produces how many molecules of carbon dioxide?

- (A) 6.022×10^{23} molecules
- (B) 3.011×10^{23} molecules
- (C) 1.505×10^{23} molecules
- (D) 4.515×10^{23} molecules

Q102. CHEM

When an alkyl halide reacts with aqueous sodium hydroxide to yield an alcohol, the reaction proceeds via which mechanistic pathway?

- (A) Nucleophilic substitution (S_N)
- (B) Electrophilic addition (Ad_E)
- (C) Elimination (E1/E2)
- (D) Electrophilic substitution (S_E)

Q103. CHEM

The historic synthesis of which organic compound from inorganic ammonium cyanate by Friedrich Wöhler in 1828 disproved the vital force theory?

- (A) Acetic acid
- (B) Urea
- (C) Methane
- (D) Ethyl acetate

Q104. CHEM

Across a period from left to right in the periodic table, the first ionization energy generally increases primarily due to an increase in:

- (A) Atomic radius
- (B) Principal quantum number
- (C) Effective nuclear charge
- (D) Inner electron shielding

Q105. CHEM

'The total enthalpy change of a chemical reaction is independent of the pathway taken between the initial and final states.' This statement defines:

- (A) Le Chatelier's principle
- (B) Hess's law
- (C) Gay-Lussac's law
- (D) Raoult's law

Q106. CHEM

Controlled oxidation of a primary (1°) alcohol using pyridinium chlorochromate (PCC) yields a/an:

- (A) Aldehyde
- (B) Ketone
- (C) Carboxylic acid
- (D) Ester

Q107. CHEM

The nucleophilic substitution reaction of a primary alcohol with a dry halogen acid (such as HCl in the presence of anhydrous ZnCl_2) yields a:

- (A) Secondary alcohol
- (B) Tertiary alkyl halide
- (C) Secondary alkyl halide
- (D) Primary alkyl halide

Q108. CHEM

Acetophenone ($\text{C}_6\text{H}_5 - \text{CO} - \text{CH}_3$) is chemically categorized as a/an:

- (A) Aliphatic aldehyde
- (B) Phenol
- (C) Aliphatic ketone
- (D) Aromatic ketone

Q109. CHEM

The unimolecular nucleophilic substitution mechanism ($\text{S}_\text{N}1$) is characterized by a:

- (A) Single-step concerted displacement
- (B) Two-step mechanism with a carbocation intermediate
- (C) Fast rate-determining heterolysis step
- (D) Complete Walden inversion of configuration

Q110. CHEM

The trivial common name for the six-carbon unbranched carboxylic acid, hexanoic acid ($\text{CH}_3(\text{CH}_2)_4\text{COOH}$), is:

- (A) Adipic acid
- (B) Propionic acid
- (C) Butyric acid
- (D) Caproic acid

Q111. CHEM

Which option accurately summarizes the physical characteristics of gamma (γ) rays?

- (A) Positively charged helium nuclei, least penetrating, deflected by magnetic fields
- (B) High penetrating power, speed equal to that of light, undeflected in magnetic fields, shorter wavelength than X-rays
- (C) Negatively charged electrons, moderately penetrating, deflected toward the north magnetic pole
- (D) Neutral nucleons, zero charge, velocity less than the speed of light, easily absorbed by paper

Q112. CHEM

In aqueous solution chemistry, comparing the ion product (Q_{sp}) to the solubility product constant (K_{sp}) enables one to predict whether:

- (A) The boiling point will increase
- (B) Diffusion will cease
- (C) Precipitation will occur
- (D) The solvent will freeze

Q113. CHEM

In polypeptide and protein structures, individual α -amino acid residues are covalently linked together by:

- (A) Glycosidic linkages
- (B) Ester linkages
- (C) Peptide linkages
- (D) Phosphodiester linkages

Q114. CHEM

The ratio of the atomic mass of a standard hydrogen atom (^1H) to that of a carbon-12 atom (^{12}C) is approximately:

- (A) One-sixth
- (B) One-twelfth
- (C) Half
- (D) Double

Q115. CHEM

The industrial petroleum process known as catalytic reforming is carried out to:

- (A) Increase engine knocking
- (B) Increase the octane number of gasoline
- (C) Crack heavy gas oil into kerosene
- (D) Remove heavy paraffin waxes

Q116. CHEM

The chemical product obtained from the acid-catalyzed addition of two molecules of ethyl alcohol to one molecule of formaldehyde is an:

- (A) Aldol
- (B) Acetal
- (C) Ester
- (D) Ether

Q117. CHEM

The industrial metallurgical extraction of metallic sodium via electrolysis of molten sodium chloride is carried out in a:

- (A) Down's cell
- (B) Castner-Kellner cell
- (C) Nelson's diaphragm cell
- (D) Solvay tower

Q118. CHEM

A falling raindrop or small liquid droplet assumes a spherical shape primarily because of:

- (A) Viscous air drag
- (B) Surface tension
- (C) Vapor pressure
- (D) Gravitational acceleration

Q119. CHEM

The catalytic hydrogenation of polyunsaturated vegetable oils at elevated temperature in the presence of a nickel catalyst yields:

- (A) Soaps
- (B) Alkyl halides
- (C) Alkenes
- (D) Saturated solid fats

Q120. CHEM

Benzyl alcohol ($\text{C}_6\text{H}_5\text{CH}_2\text{OH}$) is classified structurally as an:

- (A) Aromatic alcohol
- (B) Phenol
- (C) Aliphatic ether
- (D) Alicyclic alcohol

Q121. CHEM

The industrial ammonia-soda (Solvay) process is designed for the large-scale commercial production of:

- (A) Nitric acid (HNO_3)
- (B) Hydrochloric acid (HCl)
- (C) Soda ash (Na_2CO_3)
- (D) Calcium chloride (CaCl_2)

Q122. CHEM

According to quantum mechanics, the third principal energy level ($n = 3$, the M shell) contains which types of atomic orbitals?

- (A) s orbitals only
- (B) s and p orbitals only
- (C) s, p, d, and f orbitals
- (D) s, p, and d orbitals

PHY SECTION: PHYSICS

Questions 123 to 176 (54 MCQs)

Q123. PHY

When external load resistors of different values are connected across the terminals of a real battery with internal resistance r :

- (A) Both its emf and terminal potential difference remain strictly constant
- (B) Its emf changes, but its terminal potential difference remains constant
- (C) Its emf remains constant, but its terminal potential difference changes with current
- (D) Both its emf and terminal potential difference drop to zero

Q124. PHY

The minimum threshold energy of an incident photon required to create an electron-positron pair in the electric field of a heavy nucleus is:

- (A) 0.511 MeV
- (B) 2.04 MeV
- (C) 1.02 MeV
- (D) 1.02 keV

Q125. PHY

Faraday's law of electromagnetic induction is expressed mathematically as:

- (A) $E = -N \frac{\Delta I}{\Delta t}$
- (B) $E = -N \frac{\Delta \Phi}{\Delta t}$
- (C) $E = N \frac{\Delta \Phi}{\Delta t}$
- (D) $E = -\frac{\Delta I}{\Delta t}$

Q126. PHY

A cyclist negotiating a flat, unbanked circular track skids outward primarily because:

- (A) The limiting friction is directed opposite to the centripetal force
- (B) The limiting friction is greater than the required centripetal force
- (C) The limiting friction acts perpendicular to the track plane
- (D) The limiting friction is less than the required centripetal force

Q127. PHY

An object is released from rest from a tall cliff and falls freely under gravity. Its downward velocity after 5.0 seconds (taking $g = 9.8 \text{ m/s}^2$) is:

- (A) 4.9 m/s
- (B) 9.8 m/s
- (C) 24.5 m/s
- (D) 49.0 m/s

Q128. PHY

Two transverse traveling waves are described by the equations $y_1 = A_0 \sin(kx - \omega t)$ and $y_2 = A_0 \sin(kx - \omega t - \phi)$. These two waves differ strictly in their:

- (A) Amplitude
- (B) Wavelength
- (C) Angular frequency
- (D) Phase

Q129. PHY

In the electric field-potential gradient equation $E = -\frac{\Delta V}{\Delta r}$, the negative sign indicates that the electric field vector:

- (A) Points in the direction of increasing electric potential
- (B) Points in the direction of decreasing electric potential
- (C) Acts perpendicular to the equipotential surfaces
- (D) Is independent of the potential difference

Q130. PHY

A fast neutron enters a region of uniform magnetic field perpendicular to its direction of motion. The resulting path of the neutron will be a/an:

- (A) Parabola
- (B) Straight line
- (C) Circle
- (D) Helix

Q131. PHY

A battery of electromotive force E has an internal resistance r . When a steady current I is drawn through an external circuit, the terminal potential difference V_t is given by:

- (A) $V_t = E + Ir$
- (B) $V_t = E - Ir$
- (C) $V_t = \frac{E}{I-r}$
- (D) $V_t = Ir - E$

Q132. PHY

The instantaneous electromotive force generated by an alternating current generator with N turns of area A rotating with angular speed ω in a uniform magnetic field B is given by:

- (A) $E = N\omega AB \sin(\omega t)$
- (B) $E = NAB \cos(\omega t)$
- (C) $E = \frac{NBA}{\omega} \sin(\omega t)$
- (D) $E = N\omega^2 AB \cos(\omega t)$

Q133. PHY

A projectile is fired horizontally with an initial speed of 20 m/s from the top of a platform. Neglecting air resistance, its horizontal velocity component after 2.0 seconds will be:

- (A) 10 m/s
- (B) 40 m/s
- (C) 0 m/s
- (D) 20 m/s

Q134. PHY

If R_H is the Rydberg constant for hydrogen, the wavelength (λ) of the first spectral line of the Lyman series is:

- (A) $\frac{3R_H}{4}$
- (B) $\frac{R_H}{4}$
- (C) $\frac{4R_H}{3}$
- (D) $\frac{4}{3R_H}$

Q135. PHY

For any ideal gas, the ratio of molar specific heat at constant pressure to that at constant volume ($\gamma = C_p/C_v$) is always:

- (A) Equal to zero
- (B) Less than one
- (C) Greater than one
- (D) Equal to minus one

Q136. PHY

If both the mass and speed of a moving particle are doubled, its kinetic energy will increase by a factor of:

- (A) 8 times
- (B) 4 times
- (C) 16 times
- (D) 2 times

Q137. PHY

The electric field intensity in the region between two closely spaced, oppositely charged parallel metal plates of surface charge density σ is:

- (A) $\frac{\sigma}{2\epsilon_0}$
- (B) $\frac{2\sigma}{\epsilon_0}$
- (C) $\frac{\sigma}{\epsilon_0}$
- (D) $\frac{2\sigma}{\sigma}$

Q138. PHY

A block of mass $m = 6.0$ kg slides with speed $v = 4.0$ m/s across a frictionless surface. It explodes into two pieces. One piece of mass $m_1 = 2.0$ kg moves forward at $v_1 = 8.0$ m/s. What is the velocity of the second piece?

- (A) 4.0 m/s
- (B) 1.0 m/s
- (C) 3.0 m/s
- (D) 2.0 m/s

Q139. PHY

The sound intensity level corresponding to the threshold of human hearing (faintest audible sound at 1 kHz) is defined as:

- (A) 10 decibels
- (B) 0 decibels
- (C) 60 decibels
- (D) 120 decibels

Q140. PHY

Two capacitors with capacitances of $2 \mu\text{F}$ and $4 \mu\text{F}$ are connected in series across a voltage source. Their equivalent capacitance is:

- (A) $6.00 \mu\text{F}$
- (B) $0.75 \mu\text{F}$
- (C) $1.33 \mu\text{F}$
- (D) $8.00 \mu\text{F}$

Q141. PHY

Which of the following physical phenomena provided the earliest definitive experimental proof for the particle (photon) nature of light?

- (A) Young's double-slit interference
- (B) Photoelectric effect
- (C) Diffraction through a circular aperture
- (D) Polarization by reflection

Q142. PHY

The electrical thermal energy (Joule heat) dissipated in an ohmic resistor of resistance R carrying current I for time t is given by:

- (A) $I R t$
- (B) $I^2 R$
- (C) $V^2 R t$
- (D) $I^2 R t$

Q143. PHY

One kilowatt-hour (1 kWh) of electrical energy is equivalent to:

- (A) 3.6×10^6 J
- (B) 3.6×10^3 J
- (C) 3.6×10^5 J
- (D) 36×10^{-6} J

Q144. PHY

The derived physical unit 'joule per coulomb' (J/C) defines the SI unit:

- (A) Volt
- (B) Ampere
- (C) Ohm
- (D) Tesla

Q145. PHY

According to the statistical law of radioactive decay, the instantaneous rate of nuclear disintegration (activity, $-dN/dt$) is directly proportional to the:

- (A) Surrounding temperature
- (B) Density of the sample
- (C) Ambient atmospheric pressure
- (D) Number of radioactive nuclei present

Q146. PHY

Parasitic eddy current energy losses in the core of an alternating current transformer are minimized primarily by:

- (A) Using a thick solid copper core
- (B) Increasing the secondary winding turns
- (C) Using a solid soft iron block
- (D) Using a laminated core of insulated iron sheets

Q147. PHY

The absolute gravitational potential energy U of an object of mass m at the surface of the Earth (with zero potential chosen at infinity) is given by:

- (A) $U = -\frac{GmM_E}{R_E}$
 (B) $U = \frac{GmM_E}{R_E}$
 (C) $U = -\frac{GmM_E}{R_E^2}$
 (D) $U = -\frac{GM_E}{R_E}$

Q148. PHY

The speed of an electromagnetic wave (photon) in free space is defined in terms of vacuum permeability (μ_0) and permittivity (ϵ_0) as:

- (A) $c = \frac{1}{\sqrt{\mu_0\epsilon_0}}$
 (B) $c = \sqrt{\mu_0\epsilon_0}$
 (C) $c = \frac{1}{\mu_0\epsilon_0}$
 (D) $c = \frac{1}{2}\mu_0\epsilon_0$

Q149. PHY

A particle of charge q moves with velocity v parallel to a uniform magnetic field B . The magnitude of the magnetic force acting on the particle is:

- (A) qvB
 (B) $-qvB$
 (C) $\frac{qB}{v}$
 (D) 0

Q150. PHY

Two resistors of resistance $5\ \Omega$ and $10\ \Omega$ are connected in parallel across a DC supply. If the potential difference across the $5\ \Omega$ resistor is 20 V, the current through the $10\ \Omega$ resistor is:

- (A) 4.0 A
 (B) 0.5 A
 (C) 10.0 A
 (D) 2.0 A

Q151. PHY

A helicopter of total weight W is ascending vertically at a constant velocity with zero acceleration. The upward aerodynamic lift force F acting on the helicopter is:

- (A) $F > W$
 (B) $F < W$
 (C) $F = W$
 (D) $F = 0$

Q152. PHY

When a sound wave travels across a boundary from one medium into another of different acoustic density, which wave characteristic remains strictly unchanged?

- (A) Pitch (frequency)
 (B) Velocity
 (C) Amplitude
 (D) Wavelength

Q153. PHY

For the most efficient transmission of electrical power through long-distance overhead grid cables, electricity should be transferred using:

- (A) Low current and high voltage
 (B) High current and high voltage
 (C) High current and low voltage
 (D) Low current and low voltage

Q154. PHY

When an object moves along a straight line with uniform (constant) velocity, its:

- (A) Instantaneous velocity is equal to its average velocity
 (B) Average velocity is zero
 (C) Instantaneous velocity is greater than its average velocity
 (D) Instantaneous acceleration is non-zero

Q155. PHY

During the uniform rotation of a rigid circular disc about a fixed central axis, every particle on the disc possesses the same:

- (A) Constant linear velocity
 (B) Constant angular velocity
 (C) Constant tangential acceleration
 (D) Constant linear momentum

Q156. PHY

A proton of charge $1.6 \times 10^{-19}\ \text{C}$ is accelerated from rest through an electric potential difference of 20 V. The kinetic energy gained by the proton is:

- (A) $-3.2 \times 10^{-18}\ \text{J}$
 (B) $3.2 \times 10^{-18}\ \text{J}$
 (C) $3.2 \times 10^{19}\ \text{J}$
 (D) Zero

Q157. PHY

In a mechanical stationary (standing) wave, the spatial distance between two consecutive antinodes is equal to:

- (A) $\frac{\lambda}{4}$
 (B) λ
 (C) $\frac{\lambda}{2}$
 (D) 2λ

Q158. PHY

A uniform conducting copper wire of electrical resistivity ρ is cut into two equal halves. The resistivity of each individual half will be:

- (A) The same (ρ)
 (B) Halved ($\rho/2$)
 (C) Doubled (2ρ)
 (D) One-fourth ($\rho/4$)

Q159. PHY

An ideal elastic spring with spring constant K is cut into three equal, identical segments. The spring constant of each individual segment is:

- (A) K
- (B) $\frac{K}{3}$
- (C) $\frac{K}{2}$
- (D) $3K$

Q160. PHY

Four identical electrochemical cells, each possessing an electromotive force of 3.0 V, are connected in series aiding. The net emf of the battery combination is:

- (A) 12.0 V
- (B) 3.0 V
- (C) 9.0 V
- (D) 1.33 V

Q161. 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 external force
- (B) Total work done
- (C) Net external torque
- (D) Moment of inertia

Q162. PHY

Which proportional relationship represents the fundamental defining criterion for simple harmonic motion (SHM)?

- (A) $a \propto x$
- (B) $a \propto -x$
- (C) $a = -x^2$
- (D) $a \propto v$

Q163. PHY

A body moves in a circular path of radius r with constant speed and period T . Its centripetal acceleration a_c is expressed as:

- (A) $a_c = \frac{4\pi r^2}{T}$
- (B) $a_c = \frac{4\pi^2 r}{T^2}$
- (C) $a_c = \frac{4\pi r}{T}$
- (D) $a_c = \frac{4\pi^2 r^2}{T}$

Q164. PHY

According to the Bohr model of the hydrogen atom, the kinetic energy of the electron in its ground state orbit (first Bohr radius) is:

- (A) +13.6 eV
- (B) -13.6 eV
- (C) +27.2 eV
- (D) +13.6 J

Q165. PHY

Lenz's law of electromagnetic induction is a direct manifestation of which fundamental conservation law?

- (A) Conservation of electric charge
- (B) Conservation of linear momentum
- (C) Conservation of angular momentum
- (D) Conservation of energy

Q166. PHY

The mechanical power (rate of doing work) exerted by a force $\vec{F}$ on an object moving with instantaneous velocity $\vec{v}$ is zero when the angle θ between them is:

- (A) 0°
- (B) 45°
- (C) 60°
- (D) 90°

Q167. PHY

The half-life ($T_{1/2}$) of a radioactive nuclide is related to its decay constant (λ) by the expression:

- (A) $T_{1/2} = 0.693 \times \lambda$
- (B) $T_{1/2} = \frac{\lambda}{0.693}$
- (C) $T_{1/2} = \sqrt{\frac{0.693}{\lambda}}$
- (D) $T_{1/2} = \frac{0.693}{\lambda}$

Q168. PHY

Two identical positive point charges of 1.0 C each are placed in vacuum separated by a distance of 1.0 m. The repulsive electrostatic force between them is:

- (A) 1.0 N
- (B) 8.85×10^{-12} N
- (C) 6.67×10^{-11} N
- (D) 9.0×10^9 N

Q169. PHY

In the historic nuclear transmutation reaction ${}^{14}_7\text{N} + {}^4_2\text{He} \rightarrow {}^{17}_8\text{O} + X$, the emitted particle X is a/an:

- (A) Proton (${}^1_1\text{H}$)
- (B) Neutron (${}^1_0\text{n}$)
- (C) Beta particle (${}^0_{-1}\text{e}$)
- (D) Alpha particle (${}^4_2\text{He}$)

Q170. PHY

To reduce the width of the depletion layer and lower the potential barrier of a p-n junction diode, the applied external voltage must be:

- (A) Forward biasing
- (B) Reverse biasing
- (C) Zero biasing
- (D) Alternating breakover voltage

Q171. PHY

A charged particle of mass m and charge q enters a magnetic field B with velocity v at an angle θ . The radius of curvature of its resulting helical path is given by:

- (A) $r = \frac{mv}{qB}$
 (B) $r = \frac{mv \cos \theta}{qB}$
 (C) $r = \frac{mv \sin \theta}{qB}$
 (D) $r = \frac{qB}{mv \sin \theta}$

Q172. PHY

The specific heat capacity of a substance in SI units is measured in:

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

Q173. PHY

The mathematical formulation of the first law of thermodynamics relating change in internal energy (ΔU), heat added (ΔQ), and work done by the system (ΔW) is:

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

Q174. PHY

The angular momentum of a rotating body increases uniformly from 0 to $720 \text{ J} \cdot \text{s}$ in a time interval of 4.0 seconds. The magnitude of the net applied torque is:

- (A) $2880 \text{ N} \cdot \text{m}$
 (B) $180 \text{ N} \cdot \text{m}$
 (C) $360 \text{ N} \cdot \text{m}$
 (D) $90 \text{ N} \cdot \text{m}$

Q175. PHY

An aircraft traveling through the atmosphere at a speed exceeding the local speed of sound ($\text{Mach} > 1$) is operating in which aerodynamic regime?

- (A) Subsonic
 (B) Supersonic
 (C) Infrasonic
 (D) Ultrasonic

Q176. PHY

A dielectric slab with a relative permittivity of $\epsilon_r = 2.0$ is inserted between the parallel plates of a $20 \mu\text{F}$ capacitor. Its capacitance will:

- (A) Remain unchanged
 (B) Be halved
 (C) Be doubled
 (D) Increase fourfold

ENG SECTION: ENGLISH

Questions 177 to 194 (18 MCQs)

Q177. ENG

Fill in the blank with the appropriate preposition:

We saw an exciting cricket match _____ the school stadium.

- (A) over
- (B) of
- (C) at
- (D) on

Q178. ENG

Select the correct verb form to complete the sentence:

I _____ an appointment with the dentist soon.

- (A) making
- (B) had make
- (C) will make
- (D) made

Q179. ENG

Identify the segment containing a grammatical error in the sentence:

Due to (A) his negligence (C), he failed (D) in the examination (B).

- (A) Due to
- (B) in the examination
- (C) his negligence
- (D) he failed

Q180. ENG

Which sentence employs capital letters correctly according to standard conventions?

- (A) I will be moving to China.
- (B) I will be moving To china.
- (C) i will be moving to China.
- (D) I will be Moving to china.

Q181. ENG

Fill in the blanks with the appropriate indefinite articles:

To climb _____ tree is not to climb _____ mountain.

- (A) a / a
- (B) an / an
- (C) a / an
- (D) the / an

Q182. ENG

Identify the correct replacement for the underlined segment:

I've lived in Barcelona since six years.

- (A) has six years
- (B) since six years ago
- (C) at six years
- (D) for six years

Q183. ENG

Select the option displaying the correct orthographic spelling of the word:

- (A) Comittee
- (B) Commitee
- (C) Committee
- (D) Committey

Q184. ENG

Complete the sentence using the correct possessive form:

To _____, Anne was on time for her math class.

- (A) everybodys' surprise
- (B) everybody surprise
- (C) everybody's surprise
- (D) every-body surprise

Q185. ENG

Select the sentence that contains a clear grammatical error in tense or syntax:

- (A) She showed us five different shades of blue paint.
- (B) She was approached, but she declined the offer.
- (C) When I go the museum, I wore comfortable shoes.
- (D) There are seven floors in this building.

Q186. ENG

Identify the segment containing an error in subject-verb agreement:

Scientist now hope (A) that cloning can successfully be conducted (B) in human beings in the near future (C).

- (A) Scientist now hope
- (B) successfully be conducted
- (C) in the near future
- (D) No error

Q187. ENG

Fill in the blanks with the correct articles:

_____ apple _____ day keeps _____ doctor away.

- (A) An / a / the
- (B) The / a / a
- (C) An / the / the
- (D) A / a / the

Q188. ENG

Fill in the blank with the appropriate preposition:

She climbed _____ the ladder to paint the upper section of the wall.

- (A) to
- (B) up
- (C) of
- (D) in

Q189. ENG

Complete the sentence using the appropriate verb tenses:

Charles _____ his father in the family shop until school _____ next month.

- (A) is helping, starts
- (B) helped, was starting
- (C) has helped, is starting
- (D) was helping, will start

Q190. ENG

Fill in the blank with the grammatically correct auxiliary verb:

The teacher _____ completed this chapter ahead of schedule.

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

Q191. ENG

Select the appropriate non-finite verb form to complete the sentence:

One must consider all evidence before _____ the matter.

- (A) decided
- (B) decides
- (C) decide
- (D) deciding

Q192. ENG

Read the following passage to answer the question:

'But man is not destined to vanish. He can be killed, but he cannot be destroyed, because his soul is deathless and his spirit is irrepressible. Therefore, though the situation seems dark in the context of the confrontation between the superpowers, the silver lining is provided by an amazing phenomenon that the very nations which have spent incalculable resources and energy for the production of deadly weapons are desperately trying to find out how they might never be used. They threaten each other, intimidate each other and go to the brink, but before the fatal hour arrives, they withdraw from the brink.'

Which of the following serves as the most appropriate title for this passage?

- (A) The Mounting Cost of Modern Armaments
- (B) Man's Desire to Survive Inhibits the Use of Deadly Weapons
- (C) Confrontation Between Nuclear Superpowers
- (D) The Inevitable Destruction of Human Civilization

Q193. ENG

Read the passage below:

'But man is not destined to vanish. He can be killed, but he cannot be destroyed, because his soul is deathless and his spirit is irrepressible. Therefore, though the situation seems dark in the context of the confrontation between the superpowers, the silver lining is provided by an amazing phenomenon that the very nations which have spent incalculable resources and energy for the production of deadly weapons are desperately trying to find out how they might never be used. They threaten each other, intimidate each other and go to the brink, but before the fatal hour arrives, they withdraw from the brink.'

The primary conclusion expressed by the author is that:

- (A) Man's ultimate destiny remains uncertain and obscured
- (B) Superpower arsenals will inevitably be deployed in war
- (C) Human society will survive despite the serious threat of total annihilation
- (D) Deadly weapons are produced exclusively for economic trade

Q194. ENG

In the context of the passage, the word 'irrepressible' most nearly means:

- (A) Harmful
- (B) Incompatible
- (C) Oppressive
- (D) Unrestrainable

LOGIC SECTION: LOGICAL REASONING

Questions 195 to 200 (6 MCQs)

Q195. LOGIC

P, Q, R, S, and T are members of a family. P is the daughter of Q; Q is the son of R; R is the father of S; and T is the daughter of P. Which of the following statements is deductively true?

- (A) R is the uncle of P
- (B) R is the grandfather of P
- (C) P and R are sisters
- (D) Q is the daughter of S

Q196. LOGIC

Identify the next alphanumeric term in the sequential pattern:

7C, 10F, 14J, 19O, ?

- (A) 23Q
- (B) 26N
- (C) 24P
- (D) 25U

Q197. LOGIC

Most lucrative jobs in Pakistan require a university degree, but many emerging roles demand specialized applied skills. For workers in those positions, basic competence in reading, communication, and practical mathematics plays a major role in securing employment and building a career.

Which conclusion is most directly supported by the passage?

- (A) University education has become completely worthless in the modern economy
- (B) Every student should abandon formal college to pursue technical trades
- (C) Skills in reading, communication, and mathematics play a major role in developing a successful career
- (D) Employment agencies should assume full responsibility for secondary mathematics instruction

Q198. LOGIC

After seven years of proposals from the environmental department, the provincial legislature has passed an antipollution ordinance. Analysis of the statutory language suggests it has the potential to be one of the most comprehensive environmental bills in provincial history.

Which of the following can be logically deduced from the passage?

- (A) Industrial pollution is no longer a problem in the province
- (B) To achieve its intended reduction in pollution, the legislation must now be enforced
- (C) The ordinance will immediately eliminate all environmental contamination without further administrative action
- (D) The environmental department will be dissolved following passage of the bill

Q199. LOGIC

Following the company election, the newly elected chairperson addressed the workforce: 'The responsibility of management is to serve and not to dominate the workers.'

Which of the following is a necessary underlying assumption behind the chairperson's statement?

- (A) Management possesses the power or capacity to dominate the workers
- (B) Domination of workers by management is an organizational virtue
- (C) Company unions should be disbanded immediately
- (D) The preceding administration never made mistakes

Q200. LOGIC

Influenza spreads around the world rapidly due to commercial air travel. While patients with severe symptoms usually cancel travel plans, infected individuals can fly during the asymptomatic incubation phase before symptoms appear, spreading the virus on crowded flights.

Which intervention would most effectively reduce the contribution of air travel to the global spread of influenza during a pandemic?

- (A) Refusing air travel permits to all elderly individuals and young children
- (B) Requiring all air passengers to wash their hands immediately prior to boarding
- (C) Requiring air travelers to receive verified influenza vaccinations well in advance of their travel date
- (D) Prohibiting only those travelers who show visible fever or coughing symptoms at the gate

OFFICIAL VERIFIED ANSWER KEY

DUHS Karachi MDCAT 2022 Official Paper - Rapid Self-Grading Grid

[Online Portal >](#)

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

BIOLOGY
05. Acellular Life

Hepatitis is caused by:

CORE CONCEPT & DERIVATION

Hepatitis refers to inflammation of the liver parenchyma, primarily caused by specific hepatotropic viral agents.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Primary infectious hepatitis in humans is caused by hepatotropic viruses designated as Hepatitis A, B, C, D, and E viruses.
- These viral agents possess varying genomic configurations (RNA or DNA) and different routes of transmission, targeting hepatocytes.

Why other options are incorrect:

- Option A:** Protozoans such as *Entamoeba histolytica* cause amoebic liver abscesses, not classic viral hepatitis.
- Option B:** Bacteria can produce secondary pyogenic liver infections or cholangitis, but primary hepatitis is viral in etiology.
- Option C:** Fungi cause systemic opportunistic mycoses in immunocompromised hosts, not standard hepatitis.

Question #2 Key: (A)

BIOLOGY
14. Reproduction

Syphilis is caused by a bacterium known as:

CORE CONCEPT & DERIVATION

Syphilis is a chronic, sexually transmitted systemic infection caused by a specialized helical spirochete.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The causative organism of syphilis is *Treponema pallidum*, a microaerophilic spirochete characterized by corkscrew motility.
- Transmission occurs via direct sexual contact or transplacentally from mother to fetus (congenital syphilis).

Why other options are incorrect:

- Option B:** *Neisseria gonorrhoeae* is a Gram-negative diplococcus that causes gonorrhea, not syphilis.
- Option C:** *Bacillus anthracis* is an endospore-forming rod that causes anthrax.
- Option D:** *Trichomonas vaginalis* is a flagellated protozoan parasite that causes trichomoniasis.

Question #3 Key: (C)

BIOLOGY
16. Evolution

The presence of remnants of the pelvic girdle in whales and snakes, although they lack function...

CORE CONCEPT & DERIVATION

Vestigial organs are anatomical structures that have lost most or all of their ancestral function through evolutionary reduction.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Whales and primitive snakes possess reduced, non-functional pelvic girdles and hindlimb bones embedded within their musculature.
- These rudimentary structures indicate descent from four-limbed tetrapod ancestors that used pelvic bones for locomotion.

Why other options are incorrect:

- Option A:** Biochemical genetics provides evidence via DNA, RNA, and protein sequence homologies.
- Option B:** Comparative embryology analyzes developmental similarities across embryonic stages among diverse species.
- Option D:** Analogous structures share similar functions but possess different developmental origins, reflecting convergent evolution.

Question #4 Key: (C)

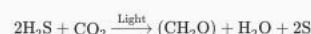
BIOLOGY
04. Bioenergetics

Photosynthetic sulfur bacteria liberate:

CORE CONCEPT & DERIVATION

Anoxygenic photosynthetic bacteria utilize electron donors other than water during light-dependent reactions, preventing oxygen evolution.

Formula / Rule / Reaction:



Solution:

- Purple and green sulfur bacteria split hydrogen sulfide (H_2S) instead of water (H_2O) as a source of reducing equivalents.
- The oxidation of H_2S yields elemental sulfur granules rather than molecular oxygen.

Why other options are incorrect:

- Option A:** Oxygen is liberated exclusively by oxygenic phototrophs (plants, algae, and cyanobacteria) via water photolysis.
- Option B:** Carbon dioxide is consumed as a carbon substrate during dark reactions, not liberated.
- Option D:** Hydrogen gas acts as a possible reducing donor in certain hydrogen bacteria, but is not the liberated byproduct.

Question #5 Key: (B)BIOLOGY
01. Cell

The plasma membrane of a living cell is described as being:

CORE CONCEPT & DERIVATION

The fluid mosaic plasma membrane regulates intracellular composition by permitting differential passage of solutes.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The hydrophobic core of the phospholipid bilayer permits small, nonpolar molecules to diffuse freely while restricting polar and charged particles.
- Transmembrane transport proteins provide regulated entry for specific ions and hydrophilic metabolites, making the barrier selectively permeable.

Why other options are incorrect:

- Option A:** A completely permeable boundary would equalize intracellular and extracellular contents, destroying homeostasis.
- Option C:** An impermeable boundary would prevent nutrient uptake, waste elimination, and cell survival.
- Option D:** Freely porous membranes exist only in dead or disrupted structures, not healthy cellular membranes.

Question #6 Key: (D)BIOLOGY
02. Biomolecules

Water is the most abundant chemical compound in living organisms, with its proportion in cellul...

CORE CONCEPT & DERIVATION

Water constitutes the primary aqueous solvent necessary for biochemical reactions and cellular hydration.

Formula / Rule / Reaction:

Water content $\approx$ 70% to 90% of total wet cellular mass

Solution:

- According to the Sindh Textbook Board syllabus, water accounts for 70% to 90% of the total body weight in most active living organisms.
- Dense tissues like bone contain approximately 20% water, whereas brain and soft tissues exceed 85%, creating this biological range.

Why other options are incorrect:

- Option A:** 10% to 20% corresponds to dehydrated biological structures like dormant seeds or dried spores.
- Option B:** 30% to 50% is significantly below the minimum threshold required for active metabolic cellular processes.
- Option C:** 50% to 60% approximates whole-body water percentage in adult mammals with high adipose stores, but underestimates direct cellular mass.

Question #7 Key: (A)BIOLOGY
07. Circulation / Transport

The phase of the cardiac cycle in which the bicuspid and tricuspid valves open while the semilu...

CORE CONCEPT & DERIVATION

The second heart sound (S₂, 'dub') is generated by the abrupt closure of the aortic and pulmonary semilunar valves at the onset of ventricular relaxation.

Formula / Rule / Reaction:

Ventricular pressure < Arterial pressure $\Rightarrow$ Semilunar valves close (S₂)

Ventricular pressure < Atrial pressure $\Rightarrow$ AV valves open

Solution:

- During ventricular diastole, the ventricular myocardium relaxes, causing intraventricular pressure to drop below arterial pressure.
- Backflow of arterial blood closes the semilunar valves (producing S₂), and as ventricular pressure declines further below atrial pressure, the AV valves open to initiate filling.
- Note on board errata:* Some keys marked Atrial diastole because the atria remain relaxed during early filling; however, physiologically and per STB, valve closure producing S₂ is the hallmark of ventricular diastole.

Why other options are incorrect:

- Option B:** Ventricular systole closes AV valves (producing S₁, 'lub') and opens semilunar valves to eject blood.
- Option C:** Atrial systole represents late ventricular filling, during which semilunar valves remain closed without generating S₂.
- Option D:** Isovolumetric contraction occurs with all four cardiac valves closed, generating peak ventricular pressure.

Question #8 Key: (B)BIOLOGY
15. Inheritance / Variation & Genetics

The classic phenotypic ratio produced in the [Formula] generation following Mendel's law of ind...

CORE CONCEPT & DERIVATION

Mendel's law of independent assortment governs the inheritance of two unlinked, non-interacting gene pairs on non-homologous chromosomes.

Formula / Rule / Reaction:

$$(3:1) \times (3:1) = 9:3:3:1$$

Solution:

- In a dihybrid cross involving two heterozygous individuals (AaBb $\times$ AaBb), four distinct gametic types are formed in equal frequencies.
- Random gamete fusion in a 16-box Punnett square produces 9 double dominant, 3 dominant-recessive recombinant, 3 recessive-dominant recombinant, and 1 double recessive phenotype.

Why other options are incorrect:

- Option A:** 3:1 is the monohybrid phenotypic ratio demonstrating the law of segregation.
- Option C:** 1:2:1 is the monohybrid genotypic ratio or incomplete dominance phenotypic ratio.
- Option D:** 9:7 is a modified dihybrid ratio resulting from complementary gene interaction.

Question #9 Key: (C)BIOLOGY
02. Biomolecules

Triose intermediates and glycerol are directly utilized by the cell in the synthesis of:

CORE CONCEPT & DERIVATION

Lipid biosynthesis integrates three-carbon glycolytic intermediates for the construction of glycerol backbones and fatty acid chains.

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

- The triose phosphate dihydroxyacetone phosphate (DHAP) is reduced to glycerol-3-phosphate, providing the structural backbone of acylglycerols.
- Triose-derived acetyl-CoA units serve as precursors for fatty acid elongation, uniting with glycerol to synthesize neutral lipids and phospholipids.

Why other options are incorrect:

- **Option A:** Carbohydrate synthesis proceeds via gluconeogenesis from various precursors, but glycerol specifically functions as a lipid precursor.
- **Option B:** Proteins are polymers of amino acids synthesized through translation, not directly from glycerol.
- **Option D:** Nucleic acids require pentose sugars (ribose/deoxyribose), purine/pyrimidine bases, and phosphate groups.

Question #10 Key: (D)BIOLOGY
12. Nervous Coordination

Chemical substances that act as inhibitors of key enzymes in the human nervous system include:

CORE CONCEPT & DERIVATION

Organophosphate and organochlorine compounds function as potent neurotoxic inhibitors of critical neurotransmitter-hydrolyzing enzymes.

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

- Parathion is an organophosphate insecticide that phosphorylates the active site serine residue of acetylcholinesterase, blocking acetylcholine degradation.
- DDT interferes with voltage-gated sodium channels and associated axonal ATPases, causing uncontrolled neuronal firing and paralysis.

Why other options are incorrect:

- **Option A:** Calcium and potassium are essential physiological electrolytes mediating action potentials and neurotransmitter exocytosis.
- **Option B:** Glucose is the primary fuel for brain metabolism, and hexokinase is the standard glycolytic enzyme.
- **Option C:** Magnesium and manganese are physiological enzyme cofactors (activators), not neurotoxic inhibitors.

Question #11 Key: (A)BIOLOGY
17. Biotechnology

The phytohormone primarily responsible for maintaining apical dominance in plants is:

CORE CONCEPT & DERIVATION

Apical dominance is the physiological suppression of lateral axillary bud outgrowth exerted by the terminal apical shoot tip.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Auxins (principally indole-3-acetic acid, IAA) synthesized in the shoot apical meristem are transported basipetally down the stem.
- High basipetal auxin concentrations maintain dormant axillary buds; decapitation of the shoot tip eliminates auxin supply and promotes lateral branching.

Why other options are incorrect:

- **Option B:** Gibberellins induce internodal stem elongation, seed germination, and mobilization of endosperm reserves.
- **Option C:** Cytokinins stimulate cell division and act antagonistically to auxins by promoting axillary bud outgrowth.
- **Option D:** Absciscic acid regulates stomatal closure and establishes seed dormancy in response to environmental stress.

Question #12 Key: (C)BIOLOGY
06. Digestion/Nutrition

During swallowing, the food bolus is directed safely into the esophagus rather than the trachea...

CORE CONCEPT & DERIVATION

Deglutition involves reflex coordination of pharyngeal structures to prevent pulmonary aspiration of ingested solids and liquids.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- During swallowing, the larynx moves anteriorly and superiorly, while the cartilaginous epiglottis folds downward over the laryngeal inlet (glottis).
- This mechanical deflection prevents food from entering the trachea and channels the bolus into the relaxed upper esophagus.

Why other options are incorrect:

- **Option A:** The soft palate elevates to seal off the nasopharynx, preventing regurgitation into the nasal cavity.
- **Option B:** The tongue manipulates food into a bolus and pushes it into the oropharynx, but does not guard the glottis.
- **Option D:** The buccal mucosa forms the inner epithelial lining of the cheeks and plays no mechanical role in laryngeal protection.

Question #13 Key: (A)BIOLOGY
04. Bioenergetics

The net gain of ATP molecules produced per molecule of glucose at the completion of glycolysis...

CORE CONCEPT & DERIVATION

Glycolysis converts glucose into pyruvate, yielding ATP through substrate-level phosphorylation while consuming ATP in its preparatory phase.

Formula / Rule / Reaction:

$$\text{Net ATP} = \text{Gross ATP produced (4)} - \text{ATP invested (2)} = 2 \text{ ATP}$$

Solution:

- Preparatory phase: 2 ATP molecules are consumed by hexokinase and phosphofructokinase-1.
- Payoff phase: 4 ATP molecules are produced (2 by phosphoglycerate kinase and 2 by pyruvate kinase).
- Subtracting investment from production yields a net gain of exactly 2 ATP molecules per glucose.

Why other options are incorrect:

- **Option B:** 4 ATP represents the gross yield of substrate-level phosphorylation prior to subtracting the 2 consumed ATP.
- **Option C:** 6 ATP includes theoretical oxidative phosphorylation yields from cytosolic NADH under specific shuttle mechanisms.
- **Option D:** 8 ATP is an older calculation that combined gross substrate-level ATP and NADH oxidation without deducting investment.

Question #14 Key: (C)BIOLOGY
02. Biomolecules

The parasitic and free-living flatworm classes Turbellaria, Trematoda, and Cestoda belong to th...

CORE CONCEPT & DERIVATION

Phylum Platyhelminthes comprises unsegmented or pseudosegmented, dorsoventrally flattened, triploblastic acoelomate invertebrates.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Turbellaria consists of mostly free-living planarians (e.g., Dugesia).
- Trematoda includes endoparasitic flukes (e.g., Fasciola hepatica).
- Cestoda contains endoparasitic tapeworms (e.g., Taenia solium). All three classes constitute phylum Platyhelminthes.

Why other options are incorrect:

- **Option A:** Phylum Aschelminthes (Nematoda) consists of unsegmented, pseudocoelomate roundworms.
- **Option B:** Phylum Cnidaria comprises diploblastic, radially symmetrical organisms possessing nematocysts (e.g., Hydra, jellyfish).
- **Option D:** Phylum Annelida contains metamerically segmented, true coelomate worms (e.g., earthworms, leeches).

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

A spikelet inflorescence is a distinguishing botanical characteristic of the family:

CORE CONCEPT & DERIVATION

The Poaceae (Gramineae) family exhibits a specialized, condensed racemose inflorescence unit termed a spikelet.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- A typical grass spikelet consists of a central axis (rachilla) bearing two sterile basal bracts called glumes.
- Above the glumes are one or more florets, each enclosed by an outer lemma and an inner palea, unique to Poaceae.

Why other options are incorrect:

- **Option A:** Solanaceae characteristically displays solitary or cymose inflorescences (e.g., in Solanum).
- **Option B:** Rosaceae features solitary, racemose, corymbose, or panicle floral arrangements with hypanthia.
- **Option C:** Fabaceae displays racemose racemes, often with typical zygomorphic papilionaceous flowers.

Question #16 Key: (C)BIOLOGY
11. Support & Movement

In the cross-sectional hexagonal lattice of a skeletal muscle myofibril, each thick myosin fila...

CORE CONCEPT & DERIVATION

The A-band zone of overlap in vertebrate skeletal sarcomeres displays an organized geometric array of thick and thin filaments.

Formula / Rule / Reaction:

$$\text{Lattice ratio in overlap zone} = 1 \text{ thick filament} : 6 \text{ thin filaments}$$

Solution:

- When viewed in cross-section within the A-band, myofilaments are positioned in a hexagonal lattice.
- Each thick myosin filament sits in the center of a hexagon formed by 6 thin actin filaments, maximizing cross-bridge formation.

Why other options are incorrect:

- **Option A:** 2 actin filaments is geometrically insufficient to establish the observed hexagonal symmetry of cross-bridges.
- **Option B:** 4 actin filaments represents a square lattice, which does not match vertebrate skeletal ultrastructure.
- **Option D:** 8 actin filaments does not reflect the structural organization of mammalian sarcomeres.

Question #17 Key: (C)BIOLOGY
02. Biomolecules

The condensation of two [Formula] α -D-glucose molecules joined together by an [Formula] (1[Form...

CORE CONCEPT & DERIVATION

Maltose is a reducing disaccharide produced from the enzymatic cleavage of starch by amylase.

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

- The hydroxyl group on carbon 1 of an α -D-glucose condenses with the hydroxyl group on carbon 4 of a second D-glucose.
- The elimination of a water molecule establishes an $\alpha(1 \rightarrow 4)$ glycosidic bond, defining maltose.

Why other options are incorrect:

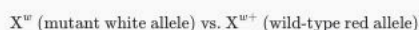
- Option A:** Sucrose is formed by condensation of α -D-glucose and β -D-fructose via an $\alpha, \beta(1 \rightarrow 2)$ bond.
- Option B:** Lactose is composed of β -D-galactose and β -D-glucose linked by a $\beta(1 \rightarrow 4)$ bond.
- Option D:** Cellobiose consists of two β -D-glucose molecules linked by a $\beta(1 \rightarrow 4)$ bond.

Question #18 Key: (B)BIOLOGY
15. Inheritance / Variation & Genetics

In *Drosophila melanogaster*, the appearance of the white-eyed phenotype investigated by Thomas H...

CORE CONCEPT & DERIVATION

The white-eye trait discovered by Morgan represented the first documented X-linked recessive gene mutation in animal genetics.

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

- A spontaneous recessive loss-of-function mutation arose in the white gene located on the X chromosome of a male fly.
- This mutation disabled the ATP-binding cassette transporter required for deposition of red pteridine eye pigments, producing white eyes.

Why other options are incorrect:

- Option A:** Inversions reverse chromosomal segments without necessarily creating the specific white gene null allele.
- Option C:** Unequal crossing over causes gene duplication or deletion (e.g., the Bar eye phenotype in *Drosophila*), not the single-gene white mutation.
- Option D:** Polyploidy involves duplication of whole chromosome sets, which does not explain single-locus Mendelian inheritance.

Question #19 Key: (B)BIOLOGY
03. Enzymes

Enzymes are rapidly inactivated upon direct exposure to ultraviolet light as well as [Formula]...

CORE CONCEPT & DERIVATION

Enzymatic catalytic function relies strictly upon the precise three-dimensional tertiary conformation of its active site.

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

- High-energy ultraviolet and ionizing radiation rupture non-covalent bonds (hydrogen bonds, ionic interactions) and oxidize disulfide linkages.
- Disruption of tertiary folding changes active site geometry, preventing substrate accommodation and abolishing catalytic ability.

Why other options are incorrect:

- Option A:** Total protein quantity (mass of polypeptide chains) remains physically present even after conformational denaturation.
- Option C:** Radiation does not act by altering the external buffer pH of the medium.
- Option D:** The concentration of available substrate remains unaffected; the inactivation is an intrinsic defect of the enzyme molecule.

Question #20 Key: (A)BIOLOGY
09. Respiration / Gaseous Exchange

In the respiratory mechanism of a frog, fresh air is drawn into the buccopharyngeal cavity thro...

CORE CONCEPT & DERIVATION

Anuran amphibians employ a positive-pressure buccal force pump to drive pulmonary ventilation through discrete cyclic phases.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- As the frog lowers its buccal floor with open external nares, fresh air enters the buccopharyngeal cavity.
- During this intake stage, the glottis remains tightly shut, retaining stale pulmonary gas under positive pressure within the lungs until expiration occurs.

Why other options are incorrect:

- Option B:** Frogs lack an elongated trachea; their laryngotracheal chamber opens almost directly into paired sac-like lungs.
- Option C:** The glottis is a muscular slit opening that regulates airflow, not a storage chamber for air.
- Option D:** Amphibian lungs are simple, hollow vascular sacs lacking true mammalian-style branching alveolar ducts.

Question #21 Key: (A)BIOLOGY
02. Biomolecules

Genetic information in a double-stranded DNA molecule is stored fundamentally in the form of:

CORE CONCEPT & DERIVATION

Biological information is encoded in the precise linear sequence of nitrogenous bases along the polynucleotide strand.

Formula / Rule / Reaction:

Triplets of DNA bases $\xrightarrow{\text{Transcription}}$ mRNA Codons $\xrightarrow{\text{Translation}}$ Polypeptide Chain

Solution:

- The specific order of purines (adenine, guanine) and pyrimidines (thymine, cytosine) forms three-letter codons (the genetic code).
- This triplet sequence specifies the linear order of amino acids during protein synthesis, preserving genomic information.

Why other options are incorrect:

- Option B:** Amino acid sequences constitute proteins, which are gene products rather than the storage form of genomic DNA.
- Option C:** The sugar-phosphate backbone provides structural and mechanical stability, not variable coding information.
- Option D:** Histone proteins package and organize DNA into nucleosomes, but do not encode sequence-specific genetic data.

Question #22 Key: (B)BIOLOGY
04. Bioenergetics

Pyruvic acid, the end product of aerobic and anaerobic glycolysis, is an organic acid containin...

CORE CONCEPT & DERIVATION

Glycolysis cleaves a single six-carbon hexose sugar into two equivalent three-carbon carboxylic acid molecules.

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

- Pyruvate consists of a terminal carboxyl group ($-\text{COOH}$), a central ketone carbonyl ($-\text{CO}-$), and a terminal methyl group ($-\text{CH}_3$).
- Counting these functional carbons confirms that pyruvic acid is a 3-carbon intermediate.

Why other options are incorrect:

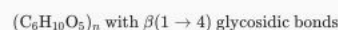
- Option A:** 2-carbon compounds include acetyl-CoA and acetate.
- Option C:** 4-carbon organic acids include oxaloacetate, malate, and succinate in the Krebs cycle.
- Option D:** 6-carbon compounds include glucose, fructose, and citrate.

Question #23 Key: (C)BIOLOGY
02. Biomolecules

The primary structural polysaccharide comprising the plant cell wall is:

CORE CONCEPT & DERIVATION

Plant primary and secondary cell walls consist predominantly of unbranched fibrils of β -D-glucose polymers.

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

- Cellulose chains cross-link via inter-chain hydrogen bonds to form high-tensile microfibrils.
- These microfibrils are embedded in a matrix of hemicellulose and pectin, giving the cell wall mechanical rigidity.

Why other options are incorrect:

- Option A:** Chitin is a polymer of N-acetylglucosamine forming fungal cell walls and arthropod exoskeletons.
- Option B:** Glycogen is the branched storage polysaccharide found in animals and fungi.
- Option D:** Peptidoglycan (murein) forms the cell walls of Eubacteria.

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

Which of the following cellular structures represents a plant-like feature found in Euglena?

CORE CONCEPT & DERIVATION

Euglenoids display mixed animal-like and plant-like characteristics, including algal-type photosynthetic storage structures.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- A pyrenoid is a suborganellar proteinaceous body located within chloroplasts involved in carbon fixation and paramylon (starch-like) synthesis.
- Because pyrenoids are typical components of algal and plant plastids, their presence is a characteristic plant-like feature.

Why other options are incorrect:

- Option A:** The flexible proteinaceous pellicle lies beneath the membrane and functions as an animal-like cellular support structure.
- Option B:** The locomotory flagellum is an animal-like organelle used for active swimming.
- Option D:** The eyespot (stigma) is a sensory organelle found in both animal-like protozoans and motile algae.

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

Which anatomical region contains specialized neurosecretory cells that synthesize releasing and...

CORE CONCEPT & DERIVATION

The hypothalamus integrates the nervous and endocrine systems by secreting regulatory hypophysiotropic neurohormones.

Formula / Rule / Reaction:

Hypothalamus $\xrightarrow{\text{Releasing / Inhibiting Factors}}$ Hypophyseal Portal System $\rightarrow$ Anterior Pituitary

Solution:

- Hypothalamic neurosecretory neurons synthesize regulatory peptides such as TRH, GnRH, GHRH, and somatostatin.
- These hormones enter the hypophyseal portal circulation to control the synthesis and release of anterior pituitary trophic hormones.

Why other options are incorrect:

- Option A:** The anterior pituitary contains endocrine glandular cells that respond to hypothalamic hormones, rather than producing releasing factors.
- Option B:** The adrenal cortex secretes steroid hormones (aldosterone, cortisol) in response to pituitary ACTH.
- Option D:** The thyroid gland secretes thyroxine and calcitonin in response to pituitary TSH.

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

The anatomical seat of all conscious perception, reasoning, language, and voluntary movement in...

CORE CONCEPT & DERIVATION

Higher-order cognitive processing, conscious sensory perception, and voluntary motor planning reside within the cerebral neocortex.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The convoluted gray matter of the cerebral cortex contains primary motor, primary sensory, and multimodal association areas.
- These circuits coordinate conscious thought, volitional motor impulses, language, memory, and cognitive evaluation.

Why other options are incorrect:

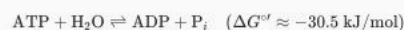
- Option B:** The medulla oblongata regulates involuntary autonomic reflexes (cardiac output, vasomotor tone, respiration).
- Option C:** The cerebellum coordinates muscle synergy, timing, balance, and unconscious motor coordination.
- Option D:** The midbrain tectum coordinates involuntary visual and auditory orienting reflexes.

Question #27 **Key: (B)**BIOLOGY
04. Bioenergetics

The universal and immediate chemical energy currency of all living cells is:

CORE CONCEPT & DERIVATION

High-energy phosphoanhydride bonds in ATP store and release energy to drive endergonic cellular reactions.

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

- ATP acts as the direct coupling intermediate between catabolic exergonic pathways and anabolic endergonic work.
- Its rapid turnover, intermediate phosphate transfer potential, and universal usage establish it as the cellular energy currency.

Why other options are incorrect:

- Option A:** NADH is an electron carrier that donates reducing equivalents to the electron transport chain, rather than acting as a universal direct energy donor.
- Option C:** ADP is the lower-energy hydrolyzed product of ATP dephosphorylation.
- Option D:** PEP has a higher phosphate transfer potential than ATP, but functions as a specialized glycolytic intermediate rather than a general cellular currency.

Question #28 **Key: (A)**BIOLOGY
11. Support & Movement

A scorpioid cyme inflorescence, where branching occurs successively on alternate sides to produ...

CORE CONCEPT & DERIVATION

A scorpioid cyme is a uniparous (monochasial) determinate inflorescence in which successive lateral branches develop on alternate sides, forming a coiled structure.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- According to the Sindh Textbook Board morphology classification, cotton (*Gossypium*) exhibits a scorpioid cymose branching system.
- Each sympodial fruiting branch terminates in a flower, with subsequent growth continuing from an alternate lateral bud.

Why other options are incorrect:

- Option B:** Mulberry displays a catkin inflorescence (a dense, drooping spike of unisexual apetalous flowers).
- Option C:** Sunflower exhibits a head or capitulum inflorescence consisting of ray and disc florets.
- Option D:** Mustard displays an elongated, indeterminate racemose raceme.

Question #29 Key: (D)BIOLOGY
05. Acellular Life

Bacterial cells that possess flagella distributed uniformly all over their outer cell surface are...

CORE CONCEPT & DERIVATION

Bacterial flagellar classification is determined by the number and arrangement of locomotory flagella on the cell wall.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Peritrichous bacteria (from Greek 'peri' meaning around and 'trichos' meaning hair) bear flagella projecting over their entire perimeter.
- Common enteric examples include Escherichia coli, Salmonella enterica, and Proteus vulgaris.

Why other options are incorrect:

- **Option A:** Monotrichous bacteria possess a single polar flagellum (e.g., Vibrio cholerae).
- **Option B:** Lophotrichous bacteria have a cluster or tuft of flagella at one pole (e.g., Pseudomonas fluorescens).
- **Option C:** Amphitrichous bacteria possess flagella originating from both opposite poles (e.g., Spirillum volutans).

Question #30 Key: (B)BIOLOGY
06. Digestion/Nutrition

The enzyme secreted by the duodenal brush border mucosa that cleaves inactive trypsinogen into ...

CORE CONCEPT & DERIVATION

Pancreatic zymogen activation in the small intestine requires an initial mucosal proteolytic cleavage step.

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

- Enterokinase (enteropeptidase) is an enzyme bound to the duodenal mucosal epithelial brush border.
- It cleaves a specific hexapeptide from the N-terminus of pancreatic trypsinogen, producing active trypsin to initiate the digestive cascade.

Why other options are incorrect:

- **Option A:** Pepsin is secreted by gastric chief cells as pepsinogen and operates in an acidic stomach environment.
- **Option C:** Aminopeptidases are exopeptidases that remove N-terminal amino acids from oligopeptides, not zymogen activators.
- **Option D:** Pancreatic amylase hydrolyzes starch into maltose and dextrins.

Question #31 Key: (D)BIOLOGY
01. Cell

Plant sclerenchyma cells become non-living at functional maturity primarily due to the heavy se...

CORE CONCEPT & DERIVATION

Secondary cell wall lignification restricts nutrient diffusion, causing programmed cell death to produce hollow, rigid structural conduits.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Lignin is an impermeable, highly cross-linked complex aromatic polymer deposited into the secondary cell wall matrix.
- Its accumulation waterproofs the wall, blocks symplastic and apoplastic nutrient transport, and leads to protoplast death, leaving a rigid mechanical skeleton.

Why other options are incorrect:

- **Option A:** Cellulose forms the primary flexible wall of living parenchyma and collenchyma cells without inducing cell death.
- **Option B:** Pectin is a hydrated jelly-like matrix polysaccharide found in the middle lamella and living primary walls.
- **Option C:** Cutin forms a waxy hydrophobic surface layer on epidermal cells, but does not cause sclerenchyma cell mortality.

Question #32 Key: (B)BIOLOGY
05. Acellular Life

Rabies is a fatal acute encephalomyelitis caused by a bullet-shaped virus belonging to the fami...

CORE CONCEPT & DERIVATION

Rabies lyssavirus is a neurotropic, enveloped single-stranded negative-sense RNA virus.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The virus causing rabies belongs to the genus Lyssavirus within the family Rhabdoviridae.
- Under electron microscopy, rhabdoviruses exhibit a distinctive bullet-shaped morphology with an enveloped ribonucleoprotein core.

Why other options are incorrect:

- **Option A:** Paramyxoviridae includes measles, mumps, and parainfluenza viruses, which are pleomorphic spheres.
- **Option C:** Picornaviridae includes small, non-enveloped icosahedral viruses such as poliovirus and hepatitis A virus.
- **Option D:** Retroviridae comprises reverse-transcribing spherical enveloped viruses such as HIV.

Question #33 Key: (B)BIOLOGY
05. Acellular Life

In the medical acronym AIDS, the letter 'D' stands for:

CORE CONCEPT & DERIVATION

AIDS denotes the clinical spectrum of advanced infection caused by human immunodeficiency virus (HIV).

Formula / Rule / Reaction:

AIDS = Acquired Immune Deficiency Syndrome

Solution:

- HIV selectively infects and depletes CD4⁺ helper T lymphocytes.
- This progressive loss results in an acquired deficiency of cell-mediated immunity, increasing susceptibility to opportunistic pathogens.

Why other options are incorrect:

- **Option A:** Degenerative is incorrect; the term refers to the immune failure, not general tissue degeneration.
- **Option C:** Different is biologically incorrect in this context.
- **Option D:** Dysfunctional is incorrect; the designated clinical terminology uses deficiency.

Question #34 Key: (B)BIOLOGY
10. Homeostasis

A homeostatic control loop in which the response elicited by effectors counteracts and weakens...

CORE CONCEPT & DERIVATION

Negative feedback loops maintain physiological variables within narrow homeostatic limits by reversing directional shifts.

Formula / Rule / Reaction:

Stimulus ($\uparrow$) $\xrightarrow{\text{Sensor/ Effector}}$ Response ($\downarrow$) $\Rightarrow$ Homeostasis

Solution:

- When a physiological parameter deviates from its set point, receptors trigger effectors to mount a counteractive response.
- Because this output diminishes or opposes the original perturbation, it is designated as negative feedback (e.g., osmoregulation, thermoregulation).

Why other options are incorrect:

- **Option A:** Positive feedback amplifies the initial stimulus, driving the variable further away from the set point (e.g., oxytocin in parturition).
- **Option C:** Static equilibrium refers to stationary balance in physical systems without active continuous regulation.
- **Option D:** Thermal dissipation is a physical process of heat loss, not the broad general feedback loop itself.

Question #35 Key: (C)BIOLOGY
15. Inheritance / Variation & Genetics

During which specific substage of prophase I of meiosis does genetic recombination through cros...

CORE CONCEPT & DERIVATION

Prophase I of meiosis comprises five distinct substages coordinating homologous chromosome pairing and reciprocal genetic exchange.

Formula / Rule / Reaction:

Sequence: Leptotene $\rightarrow$ Zygotene $\rightarrow$ Pachytene $\rightarrow$ Diplotene $\rightarrow$ Diakinesis

Solution:

- During pachytene, synapsis is fully completed through the assembly of the synaptonemal complex between bivalents.
- Recombination nodules facilitate breakage, reciprocal exchange, and rejoining of non-sister chromatid DNA segments (crossing over).

Why other options are incorrect:

- **Option A:** Leptotene involves the initial condensation of chromatin into thin, visible threads.
- **Option B:** Zygotene involves the initial pairing (synapsis) of homologous chromosomes mediated by the synaptonemal complex.
- **Option D:** Diplotene involves the dissolution of the synaptonemal complex, revealing cross-over points as visible chiasmata.

Question #36 Key: (A)BIOLOGY
03. Enzymes

In a typical holoenzyme, the non-protein organic co-enzyme moiety constitutes approximately wha...

CORE CONCEPT & DERIVATION

Holoenzymes consist of a large macromolecular protein component (apoenzyme) and a small, low-molecular-weight non-protein cofactor or coenzyme.

Formula / Rule / Reaction:

Holoenzyme = Apoenzyme ($\approx 99\%$) + Coenzyme ($\approx 1\%$)

Solution:

- Apoenzymes are large globular proteins with molecular weights typically ranging from tens of thousands to hundreds of thousands of daltons.
- Coenzymes are small organic molecules (often vitamin B derivatives) with low molecular weights, contributing roughly 1% of total holoenzyme mass.

Why other options are incorrect:

- **Option B:** 5% overestimates the mass contribution of low-molecular-weight cofactors.
- **Option C:** 10% is inconsistent with the large size disparity between the protein and the coenzyme.
- **Option D:** 25% is biologically inaccurate for enzyme complexes.

Question #37 **Key: (B)**BIOLOGY
02. Biomolecules

Adjacent deoxyribonucleotides along a single strand of DNA are covalently linked together by:

CORE CONCEPT & DERIVATION

The primary structural backbone of a polynucleotide strand is formed by repetitive ester linkages between sugars and phosphates.

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

- DNA polymerase synthesizes polynucleotide chains by catalyzing esterification between the 3'-OH group of the existing deoxypentose and the 5'-alpha-phosphate of an incoming dNTP.
- This forms a continuous covalent sugar-phosphate backbone with 3',5'-phosphodiester linkages.

Why other options are incorrect:

- Option A:** Hydrogen bonds link complementary nitrogenous bases across opposing antiparallel strands, not adjacent nucleotides in a single strand.
- Option C:** Peptide bonds link alpha-amino and alpha-carboxyl groups in proteins.
- Option D:** Disulfide linkages represent covalent bonds between cysteine residues within or between polypeptide chains.

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

The rapid folding of pinnules in the sensitive plant (*Mimosa pudica*) in response to touch or me...

CORE CONCEPT & DERIVATION

Nastic movements are non-directional, reversible plant responses triggered by diffuse external environmental stimuli.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Mechanical touch or vibration generates an action potential that propagates to the specialized motor organ at the leaf base (the pulvinus).
- Rapid potassium and water efflux from abaxial motor cells causes immediate loss of turgor pressure, producing seismonastic drooping.

Why other options are incorrect:

- Option A:** Theronastic movements are induced by variations in ambient temperature (e.g., opening and closing of tulip petals).
- Option B:** Nyctinastic movements are sleep movements governed by diurnal day-night rhythmic light changes.
- Option D:** Photonastic movements represent non-directional responses to light intensity.

Question #39 **Key: (A)**BIOLOGY
15. Inheritance / Variation & Genetics

Gregor Johann Mendel selected which experimental model organism for his classical hybridization...

CORE CONCEPT & DERIVATION

Mendelian genetics was established through controlled hybridization crosses in a self-fertile, true-breeding plant species.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Mendel chose the garden pea (*Pisum sativum*) because it possesses distinct, easily observed contrasting traits.
- Its natural self-pollinating floral anatomy permits easy experimental emasculation and controlled cross-pollination.

Why other options are incorrect:

- Option B:** *Lathyrus odoratus* (sweet pea) was used later by Bateson and Punnett to demonstrate autosomal gene linkage, not by Mendel.
- Option C:** *Vicia faba* (broad bean) is an entirely different legume used in classical mitotic cytology, not Mendel's experiments.
- Option D:** *Pisum arvense* is the wild field pea, whereas Mendel worked specifically with cultivated garden pea varieties.

Question #40 **Key: (B)**BIOLOGY
02. Biomolecules

Which class of lipids represents the most abundant, concentrated, and rich chemical storage for...

CORE CONCEPT & DERIVATION

Triacylglycerols (neutral fats) store energy with minimal hydration mass due to their reduced, non-polar hydrocarbon state.

Formula / Rule / Reaction:

$$\text{Energy Yield} \approx 9.3 \text{ kcal/g (lipids) vs. } 4.1 \text{ kcal/g (carbohydrates)}$$

Solution:

- Acylglycerols (triglycerides) consist of three fatty acid chains esterified to a glycerol backbone.
- Their reduced carbon atoms release more than twice the energy per gram upon complete oxidation compared to carbohydrates or proteins.

Why other options are incorrect:

- Option A:** Phospholipids serve primarily as structural constituents of cellular membranes rather than primary energy reserves.
- Option C:** Carotenoids are tetraterpenoid accessory photosynthetic and protective pigments.
- Option D:** Waxes function as protective, water-repellent surface barriers on leaves, fruits, and animal fur.

Question #41 Key: (C)BIOLOGY
16. Evolution

Organs that perform identical physiological functions in different organismal groups but exhibit...

CORE CONCEPT & DERIVATION

Convergent evolution drives different ancestral lineages to evolve superficially similar morphological adaptations in response to comparable selection pressures.

Formula / Rule / Reaction:

Different structural origins + Similar environmental demand $\Rightarrow$ Analogous organs

Solution:

- Analogous organs share similar functional roles despite fundamentally different developmental origins and anatomical structures.
- Classic examples include the wings of insects (membranous cuticular outgrowths) and the wings of birds (modified endoskeletal forelimbs).

Why other options are incorrect:

- **Option A:** Homologous organs share a common structural plan and embryonic origin, but may carry out divergent functions (e.g., human arm, whale flipper).
- **Option B:** Vestigial organs are non-functional remnants of structures that were fully developed and functional in ancestral species.
- **Option D:** Atavistic organs are rare, sporadic ancestral traits reappearing in individual organisms due to genetic anomalies.

Question #42 Key: (B)BIOLOGY
01. Cell

The extreme hardness and mechanical strength of nutshells and seed coats are primarily attributed to...

CORE CONCEPT & DERIVATION

Sclerenchyma tissue contains specialized isodiametric cells with thick, lignified secondary walls providing localized compressive resistance.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Sclereids (stone cells) are short sclerenchymatous cells possessing thick secondary walls infiltrated with lignin and branched pits.
- Dense clusters of sclereids form the mechanical protective outer layer of nutshells, cherry stones, and legume seed coats.

Why other options are incorrect:

- **Option A:** Collenchyma consists of living cells with localized pectin-cellulose wall thickenings, providing flexible support to growing stems.
- **Option C:** Parenchyma cells have thin primary walls and carry out metabolic storage, photosynthesis, and secretion.
- **Option D:** Xylem vessel elements are specialized for longitudinal water conduction and vertical tensile strength, not seed coat hardness.

Question #43 Key: (A)BIOLOGY
05. Acellular Life

The biological term 'virus' is derived from a Latin root word meaning:

CORE CONCEPT & DERIVATION

Early microbiologists used classical terminology to describe filter-passing infectious fluids prior to understanding submicroscopic virion particles.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The word 'virus' originated directly from the classical Latin noun 'virus', denoting a poisonous, slimy liquid, venom, or toxin.
- Louis Pasteur and early researchers used 'contagium vivum fluidum' and 'virus' to describe sub-microscopic agents capable of causing disease.

Why other options are incorrect:

- **Option B:** Parasite derives from the Greek 'parasitos' (meaning one who eats at another's table), not Latin.
- **Option C:** Microbe derives from the French/Greek 'mikros' and 'bios' (small life).
- **Option D:** Acid comes from the Latin 'acidus' (sour or sharp to taste).

Question #44 Key: (B)BIOLOGY
07. Circulation / Transport

In human gross cardiac anatomy, the thick-walled pumping chambers (the ventricles) form the str...

CORE CONCEPT & DERIVATION

The conical human heart has an inverted anatomical orientation relative to standard geometric cones.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The apex of the heart is directed inferiorly, anteriorly, and to the left, formed entirely by the muscular walls of the ventricles (principally the left ventricle).
- The base of the heart lies opposite the apex, facing superiorly and posteriorly, formed mainly by the thin-walled atria.

Why other options are incorrect:

- **Option A:** The base of the heart is formed by the thin-walled right and left atria and great vessel attachments.
- **Option C:** The superior border of the heart is formed predominantly by the atria and the pulmonary trunk/aorta.
- **Option D:** The coronary sulcus is an external groove marking the boundary between atria and ventricles.

Question #45 Key: (C)BIOLOGY
01. Cell

Extremely thin, tubular proteinaceous appendages that facilitate genetic transfer during bacter...

CORE CONCEPT & DERIVATION

Horizontal gene transfer in Gram-negative bacteria involves surface tubular structures that mediate intercellular contact.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Conjugative pili (specifically the F-pilus or sex pilus) are cylindrical hair-like tubes composed of pilin protein subunits.
- The sex pilus connects a donor (F^+) bacterium to a recipient (F^-) cell, drawing them together to allow plasmid DNA transfer.

Why other options are incorrect:

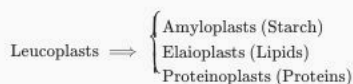
- **Option A:** Flagella are thicker, helical protein filaments composed of flagellin used for rotary motility.
- **Option B:** Cilia are eukaryotic membrane-bound, microtubular (9+2) organelles absent in prokaryotes.
- **Option D:** Capsules are protective outer polysaccharide or poly-D-glutamic acid coats providing phagocytic resistance.

Question #46 Key: (C)BIOLOGY
01. Cell

Non-pigmented, colourless plastids specialized for the intracellular storage of starch, oils, o...

CORE CONCEPT & DERIVATION

Plastids represent a family of plant organelles categorized by pigmentation and metabolic storage specialization.

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

- Leucoplasts are non-pigmented, double-membraned plastids located in non-photosynthetic roots, tubers, and seeds.
- They encompass all subclasses of storage plastids, including amyloplasts, elaioplasts, and aleuroplasts.

Why other options are incorrect:

- **Option A:** Chromoplasts synthesize and accumulate yellow, orange, and red carotenoid pigments in flowers and ripe fruits.
- **Option B:** Chloroplasts contain chlorophyll pigments and carry out light harvesting and photosynthesis.
- **Option D:** Amyloplasts only refers to one specific subtype (starch-storing), excluding fat- and protein-storing leucoplasts.

Question #47 Key: (D)BIOLOGY
16. Evolution

'Evolution is the transformation of the form and mode of existence of an organism in such manne...

CORE CONCEPT & DERIVATION

The introductory section of the Evolution chapter in the Sindh Textbook Board syllabus presents historical formal definitions of organic evolution.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- This statement matches the verbatim definition of organic evolution in the STB Biology XII textbook, credited to Walter Zimmermann (1953).
- Zimmermann's phylogenetic botanical work emphasized morphological transformation across successive descending generations.

Why other options are incorrect:

- **Option A:** Lamarck proposed the inheritance of acquired characters through use and disuse.
- **Option B:** Darwin defined evolution as 'descent with modification' driven by natural selection acting on phenotypic variations.
- **Option C:** August Weismann established the germplasm theory, demonstrating that somatic mutations are not inherited.

Question #48 Key: (B)BIOLOGY
14. Reproduction

The uterus communicates with the vaginal canal through a narrow, muscular cylindrical neck bound...

CORE CONCEPT & DERIVATION

The female reproductive tract features anatomical sphincters to maintain structural separation and regulate gamete or fetal transit.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The cervix uteri forms the narrow inferior portion of the uterus extending into the anterior wall of the vagina.
- Its dense collagenous and muscular wall forms an internal and external os, acting as a sphincter to protect the uterine cavity.

Why other options are incorrect:

- **Option A:** The Fallopian tube (oviduct) connects the periovarian peritoneal space to the superior uterine cavity.
- **Option C:** The labium majus is an external cutaneous fold of the vulva, not a uterine cervical canal.
- **Option D:** The fundus is the rounded, superior-most broad portion of the uterine body lying above the entry of the oviducts.

Question #49 Key: (A)BIOLOGY
01. Cell

The fossilized skeletal tests of marine shelled sarcodines (such as foraminiferans) provide val...

CORE CONCEPT & DERIVATION

Microfossils of calcium-shelled protozoans serve as biostratigraphic markers in petroleum geology and hydrocarbon exploration.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- In the Sindh Textbook Board syllabus (Kingdom Protista), foraminiferan tests accumulated to form thick sedimentary limestone deposits.
- Because specific foraminiferan species flourished during distinctive geological periods associated with hydrocarbon formation, petroleum geologists rely on these microfossils as index markers for oil-bearing strata.

Why other options are incorrect:

- **Option B:** Potassium salts (potash) form via inorganic chemical evaporite deposition in landlocked lakes, not sarcodine accumulation.
- **Option C:** Chromium ore (chromite) forms in ultramafic igneous intrusions, completely unrelated to marine protozoans.
- **Option D:** Magnesium deposits (such as dolomite or magnesite) originate through metamorphic or secondary metasomatic reactions.

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

The spinal cord exits the cranial cavity and descends into the vertebral canal through a large...

CORE CONCEPT & DERIVATION

The brainstem transitions into the spinal cord at the base of the skull through the primary cranial opening.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The foramen magnum is the large oval opening situated in the basilar part of the occipital bone.
- The medulla oblongata extends through this aperture to continue inferiorly as the spinal cord.

Why other options are incorrect:

- **Option A:** The foramen ovale is an opening in the greater wing of the sphenoid bone transmitting the mandibular nerve (V_3).
- **Option C:** The obturator foramen is an opening in the pelvic hip bone between the ischium and pubis.
- **Option D:** The acetabular notch is an interruption in the inferior margin of the hip socket (acetabulum).

Question #51 Key: (B)BIOLOGY
01. Cell

Endocytosis that involves the ingestion of solid particulate matter into a cell is termed:

CORE CONCEPT & DERIVATION

Endocytosis is bulk transport whereby cells engulf extracellular materials by invaginating and pinching off plasma membrane vesicles.

Formula / Rule / Reaction:

Phagocytosis = Cell eating (solids) vs. Pinocytosis = Cell drinking (liquids)

Solution:

- Phagocytosis involves the extension of pseudopodia around large, solid particles such as bacteria, cell debris, or food items.
- The pseudopodia fuse to form an internal membrane-bound phagosome that subsequently merges with lysosomes for hydrolytic digestion.

Why other options are incorrect:

- **Option A:** Pinocytosis refers to non-specific bulk intake of extracellular fluid and dissolved solutes via micro-vesicles.
- **Option C:** Exocytosis is bulk export where secretory vesicles fuse with the plasma membrane to release contents outside the cell.
- **Option D:** Autophagy is the intracellular degradation of the cell's own damaged organelles and macromolecules via autophagosomes.

Question #52 Key: (D)BIOLOGY
01. Cell

Plant-like photosynthetic protists are broadly classified as:

CORE CONCEPT & DERIVATION

Kingdom Protista contains three major polyphyletic assemblages based on modes of nutrition and structural resemblance to higher kingdoms.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Algae are eukaryotic, photosynthetic autotrophs possessing chlorophyll a and accessory pigments within plastids.
- Because they produce oxygen via photolysis and possess cell walls containing cellulose, they represent plant-like protists.

Why other options are incorrect:

- **Option A:** Protozoa are heterotrophic, non-photosynthetic, unicellular animal-like protists (e.g., Amoeba, Paramecium).
- **Option B:** Slime molds (myxomycetes) are fungus-like amoeboid phagotrophic protists.
- **Option C:** Water molds (oomycetes) are filamentous fungus-like saprotrophic protists with cellulosic walls.

Question #53 **Key: (D)**BIOLOGY
03. Enzymes

When a substrate binds to the active site of an enzyme, it induces a conformational change that...

CORE CONCEPT & DERIVATION

The induced-fit model postulates that substrate binding alters active site conformation to position catalytic amino acid side chains correctly.

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

- According to Daniel Koshland's induced-fit model, the active site is flexible rather than completely rigid.
- Substrate binding causes conformational realignment of specific catalytic residues, straining critical bonds to facilitate catalytic turnover.

Why other options are incorrect:

- **Option A:** Enzymes catalyze chemical transformations rather than performing diagnostic analytical evaluations.
- **Option B:** Genetic replication is carried out specifically by DNA polymerases, not a general consequence of substrate binding.
- **Option C:** Structural polymerization applies only to specific synthase enzymes, not the universal outcome of induced-fit.

Question #54 **Key: (B)**BIOLOGY
15. Inheritance / Variation & Genetics

Gregor Mendel selected how many pairs of contrasting characters in the garden pea for his hybrid...

CORE CONCEPT & DERIVATION

Mendelian inheritance was deduced by analyzing discrete, mutually exclusive phenotypic trait variations in *Pisum sativum*.

Formula / Rule / Reaction:

Traits analyzed = 7 distinct characters (each with 2 contrasting allelic forms)

Solution:

- Mendel studied 7 discrete pairs of contrasting traits: seed shape, seed color, pod shape, pod color, flower color, flower position, and stem height.
- Each character exhibited complete dominance without phenotypic blending, enabling rigorous statistical quantification.

Why other options are incorrect:

- **Option A:** Three pairs underrepresents the breadth of Mendel's systematic multi-trait experimental framework.
- **Option C:** Fourteen represents the total number of individual contrasting varieties (lines), which corresponds to seven pairs.
- **Option D:** Four pairs is historically and biologically incorrect.

Question #55 **Key: (D)**BIOLOGY
01. Cell

The organelle designated as the 'powerhouse of the cell' due to its role in ATP generation is t...

CORE CONCEPT & DERIVATION

Cellular respiration couples fuel oxidation to ATP synthesis via the Krebs cycle and oxidative phosphorylation in specialized organelles.

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

- The mitochondrial matrix hosts the tricarboxylic acid (Krebs) cycle and pyruvate decarboxylation, generating NADH and FADH₂.
- The inner mitochondrial cristae house the electron transport chain and ATP synthase, producing the majority of cellular ATP via chemiosmosis.

Why other options are incorrect:

- **Option A:** Ribosomes are ribonucleoprotein complexes responsible for protein translation, consuming ATP and GTP.
- **Option B:** The endoplasmic reticulum coordinates protein translation, folding, lipid biosynthesis, and calcium sequestration.
- **Option C:** The Golgi apparatus modifies, sorts, and packages glycoproteins and glycolipids for secretion or delivery.

Question #56 **Key: (C)**BIOLOGY
09. Respiration / Gaseous Exchange

The normal tidal volume of human lungs at rest during quiet breathing is approximately:

CORE CONCEPT & DERIVATION

Tidal volume (V_T) is the volume of gas inspired or expired during an unforced, quiet respiratory cycle at rest.

Formula / Rule / Reaction:

$$V_T \approx 500 \text{ mL} = 0.5 \text{ L}$$

Solution:

- In a healthy adult human, standard resting tidal volume is approximately 500 mL (0.5 liters).
- Of this 500 mL, roughly 350 mL reaches the alveoli for gas exchange, while 150 mL remains in the conducting anatomical dead space.

Why other options are incorrect:

- **Option A:** 4.0 liters approximates the normal vital capacity (VC) in adult females.
- **Option B:** 6.0 liters represents total lung capacity (TLC) in adult males.
- **Option D:** 3.0 liters approximates inspiratory reserve volume (IRV) or functional residual capacity (FRC).

Question #57 Key: (D)BIOLOGY
12. Nervous Coordination

Sensory receptors specialized to detect tissue damage and noxious painful stimuli are known as:

CORE CONCEPT & DERIVATION

Sensory transducers are categorized based on their responsiveness to specific physical or chemical energy modalities.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Nociceptors are free nerve endings that respond to damaging or potentially damaging mechanical, thermal, or chemical stimuli.
- They release substance P and glutamate, transmitting pain signals via A-delta and C fibers to the spinal cord and brain.

Why other options are incorrect:

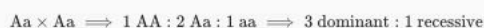
- **Option A:** Baroreceptors are mechanoreceptors located in carotid sinuses and aortic arch that detect blood pressure shifts.
- **Option B:** Chemoreceptors detect chemical concentrations (e.g., arterial P_{O_2} , P_{CO_2} , pH, or olfactory odorants).
- **Option C:** Proprioceptors detect spatial orientation, limb position, and muscle tension (e.g., muscle spindles, Golgi tendon organs).

Question #58 Key: (B)BIOLOGY
15. Inheritance / Variation & Genetics

The classic phenotypic ratio obtained in the [Formula] generation of a Mendelian monohybrid cross...

CORE CONCEPT & DERIVATION

The law of segregation dictates that paired alleles separate randomly during gametogenesis, recombining in predictable ratios upon selfing.

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

- In a monohybrid cross between heterozygous individuals ($Aa \times Aa$), both dominant homozygotes (AA) and heterozygotes (Aa) express the dominant phenotype.
- This produces a phenotypic ratio of 3 dominant individuals to 1 recessive individual.

Why other options are incorrect:

- **Option A:** 1 : 2 : 1 is the monohybrid genotypic ratio, or the phenotypic ratio in incomplete dominance or codominance.
- **Option C:** 9 : 3 : 3 : 1 is the dihybrid phenotypic ratio governing two independently assorting gene loci.
- **Option D:** 1 : 1 is the phenotypic ratio of a heterozygous monohybrid test cross ($Aa \times aa$).

Question #59 Key: (A)BIOLOGY
16. Evolution

The selective breeding of wild ancestral species by humans to propagate desirable agricultural ...

CORE CONCEPT & DERIVATION

Artificial selection acts on heritable phenotypic variations, serving as a direct model for natural evolutionary mechanisms.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Domestication is artificial selection where humans selectively breed individual plants and animals possessing favored phenotypic variations.
- Darwin cited the extensive morphological diversification of domesticated pigeons, dogs, and crops as tangible proof that selection modifies ancestral forms over generations.

Why other options are incorrect:

- **Option B:** Natural selection is differential reproductive success mediated by natural environmental pressures without human intervention.
- **Option C:** Genetic drift refers to stochastic fluctuations in allele frequencies in small populations due to chance sampling events.
- **Option D:** Geographic speciation (allopatric speciation) involves reproductive isolation caused by physical barriers.

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

Unbranched amylose molecules consist of hundreds of D-glucose subunits joined together exclusively...

CORE CONCEPT & DERIVATION

Starch consists of two polysaccharide fractions: linear unbranched amylose and branched amylopectin.

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

- Amylose is a straight-chain polymer where carbon-1 of each α -D-glucopyranose unit links to carbon-4 of the adjacent glucose unit.
- Because it lacks the $\alpha(1 \rightarrow 6)$ branch points found in amylopectin and glycogen, amylose forms a tight, unbranched helical coil.

Why other options are incorrect:

- **Option A:** $\alpha(1 \rightarrow 2)$ bonds link glucose and fructose in sucrose.
- **Option B:** $\alpha(1 \rightarrow 6)$ glycosidic linkages form branch points in amylopectin and glycogen.
- **Option D:** $\beta(1 \rightarrow 4)$ glycosidic linkages form the rigid, unbranched structural chains of cellulose.

Question #61 Key: (B)BIOLOGY
02. Biomolecules

Marine biogenic structures that protect coastlines from storm surges, provide habitat for diver...

CORE CONCEPT & DERIVATION

Scleractinian corals secrete calcium carbonate exoskeletons that create extensive wave-resistant marine ecological barriers.

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

- Coral reefs dissipate destructive ocean wave energy, preventing coastal erosion and protecting shoreline communities.
- Symbiosis between anthozoan polyps and photosynthetic zooxanthellae drives calcium carbonate deposition and primary carbon fixation.

Why other options are incorrect:

- **Option A:** Kelp forests are cold-water brown algal communities that provide habitat, but do not form rigid mineralized reef frameworks.
- **Option C:** Abyssal trenches are deep oceanic fault zones devoid of sunlight and wave dissipation roles.
- **Option D:** Hydrothermal vents are deep chemosynthetic ecosystems driven by sulfur-oxidizing bacteria, unrelated to coastal defense.

Question #62 Key: (B)BIOLOGY
03. Enzymes

The specific localized pocket or groove on an enzyme molecule where catalytic conversion occurs...

CORE CONCEPT & DERIVATION

Enzyme catalytic specificity is governed by a three-dimensional cleft composed of binding and catalytic amino acid residues.

Formula / Rule / Reaction:

Active Site = Binding Residues (orientation) + Catalytic Residues (chemical transformation)

Solution:

- The active site is a specialized geometric crevice formed by polypeptide folding where substrates are selectively bound.
- Within this pocket, functional groups on catalytic side chains lower activation energy and stabilize the transition state.

Why other options are incorrect:

- **Option A:** The allosteric site is a distinct non-catalytic regulatory locus that binds effectors to alter enzyme activity.
- **Option C:** Co-enzyme cleft is not standard biochemical terminology for the general substrate-binding pocket.
- **Option D:** A prosthetic group is a tightly or covalently bound non-protein cofactor, not the catalytic cavity itself.

Question #63 Key: (D)BIOLOGY
04. Bioenergetics

The light-dependent reactions of oxygenic photosynthesis occur specifically across the:

CORE CONCEPT & DERIVATION

Photosynthetic light harvesting and photophosphorylation require a proton-impermeable internal lamellar membrane network.

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

- Photosystems I and II, cytochrome b_6f complexes, and ATP synthase enzymes are integral components of thylakoid membranes.
- Light-driven electron flow pumps protons into the thylakoid lumen, generating the proton motive force that drives ATP generation.

Why other options are incorrect:

- **Option A:** The outer chloroplast membrane contains porins and serves as a semi-permeable protective boundary.
- **Option B:** The aqueous stroma contains soluble enzymes responsible for the light-independent Calvin cycle.
- **Option C:** Mitochondrial cristae house respiratory electron transport, not photosynthetic machinery.

Question #64 Key: (B)BIOLOGY
14. Reproduction

Following ovulation, the ruptured ovarian follicle transforms into a temporary yellow endocrine...

CORE CONCEPT & DERIVATION

Luteinizing hormone (LH) triggers the differentiation of post-ovulatory follicular granulosa and theca cells into luteal tissue.

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

- Under LH stimulation, remaining follicular cells accumulate yellow carotenoid pigments (lutein) and lipid droplets, forming the corpus luteum.
- This temporary endocrine gland secretes progesterone to maintain the secretory endometrium for potential blastocyst implantation.

Why other options are incorrect:

- **Option A:** The corpus albicans is the white fibrous, inactive scar tissue formed after the corpus luteum degenerates.
- **Option C:** The Graafian follicle is the mature, fluid-filled pre-ovulatory ovarian follicle containing the secondary oocyte.
- **Option D:** The zona pellucida is the acellular glycoprotein coat surrounding mammalian oocytes.

Question #65 Key: (A)BIOLOGY
16. Evolution

The giant African land snail (*Achatina fulica*) poses a severe ecological and economic threat pr...

CORE CONCEPT & DERIVATION

Invasive herbivorous mollusks with broad dietary ranges can devastate native plant communities and cultivated crops.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- *Achatina fulica* is a voracious polyphagous invasive snail that consumes more than 500 cultivated plant species.
- Its high reproductive rate and destructive feeding cause heavy economic damage to fruits, vegetables, and ornamentals.

Why other options are incorrect:

- **Option B:** Parasitoids of honeybees include specialized insects like dipteran phorid flies, not terrestrial snails.
- **Option C:** Plant viruses are transmitted predominantly by piercing-sucking hemipteran insects like aphids and whiteflies.
- **Option D:** Snail diets are herbivorous or detritivorous; they do not prey on domestic silkworm larvae.

Question #67 Key: (D)BIOLOGY
11. Support & Movement

A degenerative joint disorder characterized by cartilage breakdown, abnormal calcium deposition...

CORE CONCEPT & DERIVATION

Articular diseases involving structural degeneration of hyaline cartilage and joint capsule inflammation are classified as arthritis.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Arthritis encompasses joint disorders marked by pain, swelling, stiffness, and degeneration of articular cartilage.
- In conditions such as osteoarthritis and calcium pyrophosphate deposition disease, mineralization and cartilage erosion stiffen the joint.

Why other options are incorrect:

- **Option A:** Rickets is defective mineralization of growing bones in children caused by vitamin D deficiency.
- **Option B:** Sciatica is radiating neurogenic pain along the path of the sciatic nerve caused by nerve root compression.
- **Option C:** Spondylosis refers specifically to age-related degenerative changes affecting the vertebral column and intervertebral discs.

Question #66 Key: (D)BIOLOGY
04. Bioenergetics

The primary carboxylating enzyme responsible for fixing carbon dioxide in the Calvin cycle of [...]

CORE CONCEPT & DERIVATION

Atmospheric carbon assimilation into the organic biosphere is initiated by ribulose-1,5-bisphosphate carboxylase/oxygenase.

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

- RuBisCO catalyzes the carboxylation of the five-carbon acceptor ribulose-1,5-bisphosphate using atmospheric CO₂.
- The unstable six-carbon intermediate splits into two molecules of 3-phosphoglycerate (3-PGA), initiating the Calvin cycle.

Why other options are incorrect:

- **Option A:** PEP carboxylase fixes HCO₃⁻ to phosphoenolpyruvate in C₄ and CAM plants, not in the standard C₃ stroma.
- **Option B:** Carbonic anhydrase catalyzes the reversible interconversion of dissolved carbon dioxide and bicarbonate ions.
- **Option C:** Pyruvate kinase carries out the final substrate-level phosphorylation step in glycolysis.

Question #68 Key: (A)BIOLOGY
14. Reproduction

The average number of hemoglobin molecules packaged within a single mature human erythrocyte (R...

CORE CONCEPT & DERIVATION

Erythrocytes shed their nuclei and organelles during erythropoiesis to maximize intracellular hemoglobin packing capacity.

Formula / Rule / Reaction:

Molecules per cell $\approx 280 \times 10^6$ Hemoglobin tetramers (binding $\approx 1.1 \times 10^9$ O₂ molecules)

Solution:

- According to the Sindh Textbook Board Biology XI syllabus, each human red blood cell contains approximately 280 million hemoglobin molecules.
- Each tetrameric hemoglobin carries up to four oxygen molecules, allowing a single RBC to transport over one billion oxygen molecules.

Why other options are incorrect:

- **Option B:** 150 million significantly underestimates the physiological packaging density of hemoglobin.
- **Option C:** 380 million exceeds the normal intracellular packaging limit of mammalian erythrocytes.
- **Option D:** 180 million is below the established textbook standard.

Question #69 Key: (A)

CHEMISTRY
07. Equilibrium

For an exothermic reversible reaction, decreasing the system temperature causes the equilibrium...

CORE CONCEPT & DERIVATION

Temperature is the sole state variable that alters the numerical value of the chemical equilibrium constant.

Formula / Rule / Reaction:

$$\ln\left(\frac{K_2}{K_1}\right) = -\frac{\Delta H^\circ}{R} \left(\frac{1}{T_2} - \frac{1}{T_1}\right) \quad (\text{van 't Hoff equation})$$

Solution:

- In an exothermic reaction, heat is evolved as a product: Reactants $\rightleftharpoons$ Products + Heat ($\Delta H < 0$).
- By Le Chatelier's principle, lowering the temperature shifts the equilibrium in the forward exothermic direction.
- Because forward shift increases product concentration relative to reactants, the value of K_c increases.

Why other options are incorrect:

- Option B:** K_c decreases with cooling only in endothermic reactions ($\Delta H > 0$).
- Option C:** K_c changes with temperature; it remains unchanged only when concentration or pressure varies at constant temperature.
- Option D:** Equilibrium constants remain positive, finite values determined by reaction thermodynamics.

Question #70 Key: (A)

CHEMISTRY
05. Liquids

Viscosity is a fundamental physical property that quantifies a fluid's:

CORE CONCEPT & DERIVATION

Viscosity represents internal friction arising from intermolecular attractive forces as adjacent fluid layers slide over one another.

Formula / Rule / Reaction:

$$F = \eta A \frac{dv}{dx} \Rightarrow \eta = \frac{F/A}{dv/dx} \quad (\text{Newton's law of viscosity})$$

Solution:

- Viscosity (η) measures the internal resistance of a fluid to shear stress, deformation, and laminar flow.
- Strong intermolecular forces (e.g., hydrogen bonding in glycerol) impede layer movement, resulting in high fluid viscosity.

Why other options are incorrect:

- Option B:** Specific gravity is the ratio of the density of a substance to the density of a reference substance (water).
- Option C:** Vapor pressure is the pressure exerted by a vapor in thermodynamic equilibrium with its condensed phase.
- Option D:** Surface tension is the inward force per unit length acting along the surface of a liquid due to unbalanced cohesive forces.

Question #71 Key: (D)

CHEMISTRY
17. Aldehydes & Ketones

Acetone (propan-2-one) gives a characteristic yellow crystalline precipitate when reacted under...

CORE CONCEPT & DERIVATION

The haloform (iodoform) reaction detects the presence of a methyl carbonyl group ($\text{CH}_3 - \text{CO}-$) or a methyl carbinol group.

Formula / Rule / Reaction:



Solution:

- Acetone contains a terminal methyl ketone group ($\text{CH}_3 - \text{C} = \text{O}$).
- Halogenation and base cleavage yield a bright yellow precipitate of triiodomethane (iodoform, CHI_3), confirming a positive iodoform test.

Why other options are incorrect:

- Option A:** Fehling's solution oxidizes aliphatic aldehydes; simple ketones like acetone lack a carbonyl hydrogen and do not react.
- Option B:** Tollens' reagent (ammoniacal silver nitrate) is reduced to a silver mirror by aldehydes, giving a negative result with ketones.
- Option C:** Lucas reagent ($\text{ZnCl}_2/\text{conc. HCl}$) differentiates primary, secondary, and tertiary alcohols, not ketones.

Question #72 Key: (B)

CHEMISTRY
02. Atomic Structure

The Rydberg formula [Formula], where [Formula], calculates the wavenumbers for the spectral l...

CORE CONCEPT & DERIVATION

Atomic emission series in the hydrogen spectrum correspond to electron transitions from higher principal quantum levels to a fixed lower level (n_1).

Formula / Rule / Reaction:

$$\bar{\nu} = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right) \quad \text{For the Balmer series: } n_1 = 2, n_2 = 3, 4, 5, \dots$$

Solution:

- When excited electrons transition to lower energy level $n_1 = 2$, emitted photons fall within the visible spectrum.
- This specific set of transitions defines the Balmer series of hydrogen.

Why other options are incorrect:

- Option A:** The Lyman series corresponds to transitions ending at $n_1 = 1$, emitting in the ultraviolet region.
- Option C:** The Paschen series corresponds to transitions ending at $n_1 = 3$, emitting in the near-infrared region.
- Option D:** The Brackett series corresponds to transitions ending at $n_1 = 4$, emitting in the mid-infrared region.

Question #73 Key: (A)

CHEMISTRY
09. Thermochemistry

The mathematical equation of the first law of thermodynamics, [Formula], simplifies under cons...

CORE CONCEPT & DERIVATION

Pressure-volume work is zero during an isochoric process, meaning added heat changes only internal energy.

Formula / Rule / Reaction:

$$w = P\Delta V \Rightarrow \text{At constant volume, } \Delta V = 0 \Rightarrow w = 0$$

$$q_v = \Delta E + 0 = \Delta E$$

Solution:

- Because the system boundary remains rigid ($\Delta V = 0$), the system does no expansion work on the surroundings.
- Consequently, all heat transferred at constant volume directly changes the internal energy: $q_v = \Delta E$.

Why other options are incorrect:

- Option B:** The work term w must be explicitly set to zero under constant volume conditions.
- Option C:** $P\Delta V$ equals zero because $\Delta V = 0$.
- Option D:** $P\Delta V$ represents expansion work, not the remaining heat term.

Question #74 Key: (B)

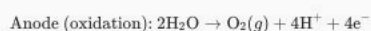
CHEMISTRY
10. Electrochemistry

The electrolysis of an aqueous dilute hydrochloric acid solution using inert electrodes yields:

CORE CONCEPT & DERIVATION

Electrode reactions during electrolysis depend on relative standard reduction and oxidation potentials, as well as species concentrations.

Formula / Rule / Reaction:



Solution:

- At the cathode, hydrogen ions are reduced to form hydrogen gas (H_2).
- In dilute solution, the low concentration of chloride makes the oxidation of water thermodynamically favored over chloride oxidation, releasing oxygen gas (O_2) at the anode.

Why other options are incorrect:

- Option A:** Chlorine evolves at the anode only when concentrated brine or concentrated hydrochloric acid is electrolyzed.
- Option C:** Oxidation occurs at the anode and reduction at the cathode; reversing these assignments violates electrochemical convention.
- Option D:** Protons are positively charged cations that migrate to and are reduced at the negative cathode, not the anode.

Question #75 Key: (B)

CHEMISTRY
16. Alcohols & Phenols

The Ostwald process for the industrial manufacture of nitric acid involves the primary catalytic...

CORE CONCEPT & DERIVATION

Industrial synthesis of nitric acid begins with high-temperature catalytic oxidation of ammonia over a platinum-rhodium catalyst.

Formula / Rule / Reaction:



Solution:

- Ammonia (NH_3) is oxidized by air over a platinum gauze catalyst to produce nitric oxide (NO).
- The resulting NO is cooled, oxidized to nitrogen dioxide (NO_2), and absorbed in water to yield concentrated nitric acid (HNO_3).

Why other options are incorrect:

- Option A:** Oxidation of H_2S is utilized in the Claus process for elemental sulfur recovery.
- Option C:** Catalytic oxidation of SO_2 to SO_3 is used in the Contact process for sulfuric acid production.
- Option D:** Oxidation of HCl to Cl_2 occurs in the Deacon process for chlorine synthesis.

Question #76 Key: (A)

CHEMISTRY
03. Chemical Bonding

The net dipole moment of carbon dioxide ([Formula]) is zero because its molecular geometry is...

CORE CONCEPT & DERIVATION

The net molecular dipole moment is the vector sum of individual polar bond dipoles across the molecule's spatial geometry.

Formula / Rule / Reaction:

$$\mu_{\text{net}} = \vec{\mu}_1 + \vec{\mu}_2 = 0 \quad (\text{where } \vec{\mu}_1 = -\vec{\mu}_2)$$

Solution:

- The carbon atom in CO_2 is sp -hybridized, establishing a linear geometry ($\text{O} = \text{C} = \text{O}$) with a bond angle of 180° .
- Although each $\text{C} = \text{O}$ bond is polar, the two equal bond dipoles act in opposite directions and cancel out, yielding $\mu = 0$.

Why other options are incorrect:

- Option B:** Angular geometry (e.g., H_2O , SO_2) produces unaligned bond dipoles and a net non-zero dipole moment.
- Option C:** Pyramidal geometry (e.g., NH_3) has an uncancelled axial dipole moment.
- Option D:** Tetrahedral geometry applies to five-atom species (e.g., CH_4 , CCl_4), not triatomic molecules.

Question #77 Key: (D)

CHEMISTRY
06. Solids

Sodium nitrate ([Formula]) and calcium carbonate ([Formula]) both form trigonal crystals. B...

CORE CONCEPT & DERIVATION

Isomorphism occurs when distinct chemical compounds share the same crystal lattice structure and atomic ratio stoichiometry.

Formula / Rule / Reaction:

Isomorphism $\Rightarrow$ Different substances + Same crystal system and stoichiometry (1:1:3)

Solution:

- Both NaNO_3 and CaCO_3 possess a 1 : 1 : 3 atomic ratio with similar ionic radius ratios.
- Both crystallize in the trigonal (rhombohedral) system, matching the definition of isomorphous compounds.

Why other options are incorrect:

- Option A:** Allotropy is the existence of a single element in two or more physical forms (e.g., diamond and graphite).
- Option B:** Enantiomers are non-superimposable mirror-image chiral stereoisomers.
- Option C:** Isomers are distinct compounds with identical molecular formulas but different atom connectivity or spatial orientations.

Question #78 Key: (B)

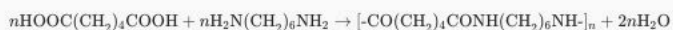
CHEMISTRY
20. Industrial Chemistry

Nylon-6,6 is synthesized industrially as a:

CORE CONCEPT & DERIVATION

Step-growth condensation polymerization joins bifunctional monomers through functional group condensation, eliminating small byproduct molecules.

Formula / Rule / Reaction:



Solution:

- Hexanedioic acid (adipic acid, 6 carbons) reacts with 1,6-diaminohexane (hexamethylenediamine, 6 carbons) to form amide linkages.
- Water molecules are eliminated during reaction, classifying Nylon-6,6 as a condensation polyamide.

Why other options are incorrect:

- Option A:** Synthesis occurs via condensation with elimination of water, not by addition across carbon-carbon double bonds.
- Option C:** Ethene is not a monomer component in polyamide production.
- Option D:** Condensation of terephthalic acid and ethylene glycol produces the polyester polyethylene terephthalate (PET/Dacron), not a nylon.

Question #79 Key: (B)

CHEMISTRY
03. Chemical Bonding

In an ethene molecule ([Formula]), each carbon atom exhibits which hybridization state?

CORE CONCEPT & DERIVATION

Hybridization is determined by the number of steric electron domains (sigma bonds plus lone pairs) around the central atom.

Formula / Rule / Reaction:

$$\text{Steric Number} = 3 \sigma\text{-bonds} + 0 \text{ lone pairs} = 3 \Rightarrow sp^2 \text{ hybridization}$$

Solution:

- Each carbon in ethene forms three σ -bonds (two with hydrogen 1s orbitals and one with the adjacent carbon).
- Mixing one 2s and two 2p orbitals forms three planar sp^2 hybrid orbitals (120° apart), leaving an unhybridized 2p orbital to form a π -bond.

Why other options are incorrect:

- Option A:** sp hybridization occurs with two σ -domains, as in linear ethyne ($\text{HC} \equiv \text{CH}$).
- Option C:** sp^3 hybridization occurs with four σ -domains, as in tetrahedral ethane ($\text{H}_3\text{C} - \text{CH}_3$).
- Option D:** dsp^2 hybridization occurs in four-coordinate square planar transition metal complexes.

Question #80 Key: (C)

CHEMISTRY
04. Gases

The kinetic molecular theory (KMT) was formulated primarily to provide a theoretical basis expl...

CORE CONCEPT & DERIVATION

The kinetic molecular theory relates microscopic particle motion to macroscopic properties (pressure, temperature, volume) via statistical mechanics.

Formula / Rule / Reaction:

$$PV = \frac{1}{3}mN\overline{v^2} = \frac{2}{3}N\left(\frac{1}{2}m\overline{v^2}\right) = \frac{2}{3}E_k$$

Solution:

- KMT models gases as collections of submicroscopic particles in continuous, random, straight-line motion.
- This model accounts for gas laws (Boyle's, Charles's, Avogadro's) and explains diffusion, effusion, and thermal expansion.

Why other options are incorrect:

- Option A:** Atomic numbers reflect nuclear proton counts determined by Moseley's work, not kinetic gas motion.
- Option B:** Chemical bonding and valence electron arrangements are described by molecular orbital and valence bond theories.
- Option D:** Nuclear stability is governed by strong nuclear forces and nuclear shell models.

Question #81 Key: (C)

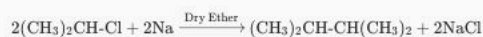
CHEMISTRY
17. Aldehydes & Ketones

When 2-chloropropane is heated with metallic sodium in dry ether, 2,3-dimethylbutane is formed....

CORE CONCEPT & DERIVATION

The Wurtz reaction couples two alkyl halide molecules via sodium-mediated dehalogenation to form higher symmetrical alkanes.

Formula / Rule / Reaction:



Solution:

- Sodium metal donates electrons to isopropyl chloride, generating organometallic intermediates that couple.
- Joining two isopropyl groups forms 2,3-dimethylbutane, matching the definition of the Wurtz reaction.

Why other options are incorrect:

- Option A:** Catalytic hydrogenation adds molecular hydrogen across carbon-carbon double or triple bonds.
- Option B:** Dehydrohalogenation eliminates HX using alcoholic KOH to produce an alkene.
- Option D:** The Kolbe reaction electrolyzes aqueous alkali carboxylates to produce alkanes at the anode.

Question #82 Key: (C)

CHEMISTRY
07. Equilibrium

A chemical reaction in a closed vessel achieves dynamic equilibrium when:

CORE CONCEPT & DERIVATION

Chemical equilibrium is dynamic; forward and reverse reactions proceed at identical rates, stabilizing macroscopic concentrations.

Formula / Rule / Reaction:

$$\text{Rate}_{\text{forward}} = \text{Rate}_{\text{backward}} \Rightarrow \frac{d[\text{Reactants}]}{dt} = \frac{d[\text{Products}]}{dt} = 0$$

Solution:

- Equilibrium does not mean reactions have stopped; both forward and reverse processes continue at matched speeds.
- Because rates are equal, reactant and product concentrations remain constant over time.

Why other options are incorrect:

- Option A:** If the forward rate exceeds the backward rate, the system remains in non-equilibrium net forward progress.
- Option B:** If the backward rate exceeds the forward rate, the system is shifting in reverse toward equilibrium.
- Option D:** Reactant concentrations drop to zero only in irreversible reactions that proceed to completion.

Question #83 Key: (A)

CHEMISTRY
08. Reaction Kinetics

The addition of a positive catalyst accelerates the rate of a chemical reaction primarily because...

CORE CONCEPT & DERIVATION

Catalysts speed up reactions by providing an alternative reaction mechanism with a lower activation energy barrier.

Formula / Rule / Reaction:

$$k = Ae^{-E_a/RT} \Rightarrow E_a \downarrow \Rightarrow k \uparrow$$

Solution:

- A catalyst stabilizes the reaction transition state, lowering the activation energy (E_a).
- Per the Arrhenius equation, lowering E_a exponentially increases the fraction of collisions that overcome the activation barrier.

Why other options are incorrect:

- Option B:** Increasing the activation energy reduces reaction rate, which is the effect of an inhibitor.
- Option C:** The net enthalpy change (ΔH) depends solely on initial and final states; catalysts do not alter ΔH .
- Option D:** Reducing collision frequency would decrease, rather than increase, the overall reaction rate.

Question #84 Key: (D)

CHEMISTRY
08. Reaction Kinetics

The photochemical combination reaction [Formula] carried out over water proceeds as which order...

CORE CONCEPT & DERIVATION

Photochemical reactions where the reaction rate is determined by light intensity rather than reactant concentrations follow zero-order kinetics.

Formula / Rule / Reaction:

$$\text{Rate} = k[\text{H}_2]^0[\text{Cl}_2]^0 = k(I) \quad (\text{where } I \text{ is absorbed light intensity})$$

Solution:

- Over water, reactant gases dissolve to maintain saturated surface layers, making the rate independent of gas-phase concentrations.
- The rate depends solely on the rate of photon absorption, classifying the reaction as zero order overall.

Why other options are incorrect:

- Option A:** First-order reactions have rates directly proportional to a single reactant concentration.
- Option B:** Second-order reactions have rates proportional to the product of two concentrations.
- Option C:** Fractional or half-order kinetics occur in complex surface-catalyzed radical recombinations.

Question #85 Key: (D)

CHEMISTRY
04. Gases

Under identical conditions of temperature and pressure, the ratio of the rates of diffusion of ...

CORE CONCEPT & DERIVATION

Graham's law states that the rate of diffusion of a gas is inversely proportional to the square root of its molar mass.

Formula / Rule / Reaction:

$$\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}$$

Solution:

- Let gas 1 be hydrogen ($M_1 = 2 \text{ g/mol}$) and gas 2 be oxygen ($M_2 = 32 \text{ g/mol}$).

- Applying the formula gives:

$$\frac{r_{\text{H}_2}}{r_{\text{O}_2}} = \sqrt{\frac{32}{2}} = \sqrt{16} = 4$$

- Therefore, hydrogen diffuses four times faster than oxygen, yielding a 4 : 1 ratio.

Why other options are incorrect:

- Option A:** 1 : 2 is the ratio of molar masses without taking the reciprocal square root.
- Option B:** 1 : 4 is the inverse ratio (rate of oxygen relative to hydrogen).
- Option C:** 2 : 1 is the square root of 4, rather than the square root of 16.

Question #86 Key: (A)

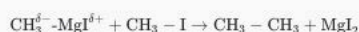
CHEMISTRY
18. Carboxylic Acids

When a Grignard reagent such as methylmagnesium iodide ([Formula]) reacts with methyl iodide ...

CORE CONCEPT & DERIVATION

Organomagnesium reagents act as strong carbanion nucleophiles that undergo substitution reactions with primary alkyl halides.

Formula / Rule / Reaction:



Solution:

- The nucleophilic methyl carbanion (CH_3^-) from the Grignard reagent attacks the methyl carbon of methyl iodide.
- Displacement of the iodide leaving group forms a new carbon-carbon single bond, producing ethane (C_2H_6).

Why other options are incorrect:

- Option B:** Methane forms when methylmagnesium iodide reacts with active hydrogen donors (e.g., H_2O , alcohols), not with alkyl halides.
- Option C:** Propane requires coupling an ethyl Grignard with a methyl halide, or a methyl Grignard with an ethyl halide.
- Option D:** Butane forms from the coupling of ethyl Grignard with ethyl halide.

Question #87 Key: (C)

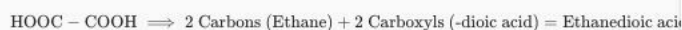
CHEMISTRY
18. Carboxylic Acids

The IUPAC systematic name for oxalic acid, [Formula], is:

CORE CONCEPT & DERIVATION

Dicarboxylic acids are systematically named by appending the suffix '-dioic acid' to the parent alkane name containing both carboxyl carbons.

Formula / Rule / Reaction:



Solution:

- The compound contains two carbon atoms in a continuous chain, defining the parent alkane as ethane.
- Both carbons are carboxylic acid carbons (positions 1 and 2), giving the systematic name ethanedioic acid.

Why other options are incorrect:

- Option A:** Acetic acid is the common name for ethanoic acid (CH_3COOH), a monocarboxylic acid.
- Option B:** Formic acid is the common name for methanoic acid (HCOOH).
- Option D:** Propanedioic acid is the IUPAC name for the three-carbon dicarboxylic acid malonic acid ($\text{HOOC} - \text{CH}_2 - \text{COOH}$).

Question #88 Key: (B)

CHEMISTRY
08. Reaction Kinetics

Finely pulverized calcium carbonate ([Formula]) reacts significantly faster with acid than CaCO_3 .

CORE CONCEPT & DERIVATION

Heterogeneous reaction rates depend directly on the available contact area between solid surfaces and fluid reactants.

Formula / Rule / Reaction:

$$\text{Surface Area} \propto \frac{1}{\text{Particle Radius}} \Rightarrow \text{Collisions per second} \uparrow \Rightarrow \text{Rate} \uparrow$$

Solution:

- Grinding a solid into fine powder exposes a greater number of interior atoms and ions to the surrounding acid solution.
- This higher exposed surface area increases effective collision frequency between H^+ ions and CaCO_3 , accelerating reaction rate.

Why other options are incorrect:

- Option A:** Grinding does not alter the activation energy barrier of the chemical pathway.
- Option C:** Gas volume is a reaction outcome, not a kinetic driver of reaction rate.
- Option D:** Equilibrium constants are governed strictly by temperature, not physical particle size.

Question #89 Key: (C)

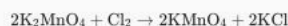
CHEMISTRY
10. Electrochemistry

The chemical oxidation of potassium manganate ([Formula]) using chlorine gas is used industrially...

CORE CONCEPT & DERIVATION

Transition metal oxoanions can be converted to higher oxidation states by treatment with strong oxidizing halogens.

Formula / Rule / Reaction:



Solution:

- In dark-green potassium manganate (K_2MnO_4), manganese is in the +6 oxidation state.
- Chlorine acts as an oxidizing agent, oxidizing manganese to the +7 state to yield deep-purple potassium permanganate (KMnO_4).

Why other options are incorrect:

- Option A:** K_2CrO_4 is a chromium compound derived from chromite ore, unrelated to manganese chemistry.
- Option B:** MnO_2 contains manganese in the +4 state, which would represent reduction rather than oxidation of K_2MnO_4 .
- Option D:** Mn_2O_7 is an unstable, explosive green heptoxide oil formed by reacting KMnO_4 with concentrated H_2SO_4 .

Question #90 Key: (C)

CHEMISTRY
17. Aldehydes & Ketones

Unlike aliphatic ketones, aliphatic aldehydes can be oxidized to carboxylic acids by:

CORE CONCEPT & DERIVATION

Aldehydes have a hydrogen atom directly bound to the carbonyl carbon, making them readily oxidizable without cleaving carbon-carbon bonds.

Formula / Rule / Reaction:



Solution:

- The presence of the aldehydic hydrogen allows conversion to a carboxyl group under mild conditions (e.g., Tollens' or Fehling's reagent).
- They also react readily with vigorous oxidizing agents such as acidified $\text{K}_2\text{Cr}_2\text{O}_7$ and KMnO_4 .
- Ketones lack this hydrogen and resist mild oxidation, reacting only under harsh conditions with C-C bond cleavage.

Why other options are incorrect:

- Option A:** Restricting oxidation to strong agents applies to ketones, not aldehydes.
- Option B:** Aldehydes react with mild reagents, but also react rapidly with strong oxidizing agents.
- Option D:** Aldehydes are among the most readily oxidized organic carbonyl compounds.

Question #91 Key: (B)

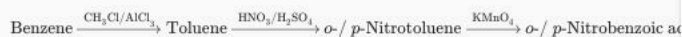
CHEMISTRY
14. Hydrocarbons

When benzene is subjected sequentially to Friedel-Crafts alkylation with chloromethane, followe...

CORE CONCEPT & DERIVATION

Electrophilic aromatic substitution regioselectivity is governed by the directing influence of existing substituents on the benzene ring.

Formula / Rule / Reaction:



Solution:

- Alkylation of benzene yields toluene; the methyl group is an electron-donating ortho/para director.
- Subsequent nitration directs the incoming nitro group to the ortho and para positions, forming ortho- and para-nitrotoluene.
- Subsequent permanganate oxidation converts the alkyl side chain into a carboxylic acid, yielding ortho- and para-nitrobenzoic acids.

Why other options are incorrect:

- Option A:** Meta-nitrobenzoic acid would form if nitration occurred after oxidizing toluene to benzoic acid (since $-\text{COOH}$ is meta-directing).
- Option C:** Meta-nitrotoluene is a minor byproduct because the methyl group is ortho/para-directing.
- Option D:** Nitration yields both ortho and para isomers due to steric accessibility.

Question #92 Key: (B)

CHEMISTRY
10. Electrochemistry

During the industrial electrolysis of brine in a Castner-Kellner cell, the products formed at t...

CORE CONCEPT & DERIVATION

The Castner-Kellner mercury cell separates chlorine evolution from sodium hydroxide formation using a circulating mercury cathode.

Formula / Rule / Reaction:



Solution:

- At the graphite/titanium anodes, chloride ions are oxidized to evolve chlorine gas (Cl_2).
- Sodium amalgam forms and travels to the denuder chamber, where it reacts with water to produce aqueous sodium hydroxide (NaOH) and hydrogen gas (H_2).

Why other options are incorrect:

- Option A:** Chlorine evolves at the positive anode via oxidation, not at the cathode.
- Option C:** Chlorine is formed at the anode, and isolated sodium metal is not the final product.
- Option D:** Brine electrolysis produces chlorine, not oxygen, as the primary anodic product.

Question #93 Key: (A)

CHEMISTRY
20. Industrial Chemistry

Bakelite is a commercially important thermosetting polymer synthesized by the condensation of:

CORE CONCEPT & DERIVATION

Thermosetting phenolic resins form through acid- or base-catalyzed electrophilic aromatic substitution and condensation cross-linking.

Formula / Rule / Reaction:



Solution:

- Formaldehyde acts as a bifunctional methylene bridging agent reacting at the activated ortho and para positions of phenol.
- Initial condensation yields linear novolac, which on heating with hexamethylenetetramine forms a rigid, cross-linked thermosetting plastic (Bakelite).

Why other options are incorrect:

- Option B:** Formaldehyde and acetone condense to form aliphatic aldol products, not Bakelite.
- Option C:** Acetaldehyde is not used in commercial Bakelite manufacturing.
- Option D:** Urea and formaldehyde condense to yield urea-formaldehyde resins, a different class of amino plastics.

Question #94 Key: (A)

CHEMISTRY
16. Alcohols & Phenols

Mononitration of phenol using dilute nitric acid at room temperature produces a mixture contain...

CORE CONCEPT & DERIVATION

The phenolic hydroxyl group (–OH) is a strongly activating, ortho/para-directing substituent in electrophilic aromatic substitution.

Formula / Rule / Reaction:



Solution:

- The lone pair on oxygen delocalizes into the aromatic ring, increasing electron density primarily at the ortho and para positions.
- Electrophilic attack by the nitronium ion (NO_2^+) occurs at these positions, yielding a mixture of ortho-nitrophenol and para-nitrophenol.

Why other options are incorrect:

- Option B:** The meta position remains electron-deficient relative to the activated ortho and para positions.
- Option C:** Meta-nitrophenol is not formed in significant amounts with activating substituents.
- Option D:** 2,4,6-trinitrophenol (picric acid) forms only with concentrated nitric acid in the presence of concentrated sulfuric acid.

Question #95 Key: (C)

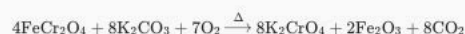
CHEMISTRY
12. Transition Elements

Heating chromite ore ([Formula]) with potassium carbonate ([Formula]) in the presence of at...

CORE CONCEPT & DERIVATION

Oxidative roasting of insoluble Cr(III) ores in alkaline media produces soluble hexavalent chromate salts.

Formula / Rule / Reaction:



Solution:

- Atmospheric oxygen oxidizes chromium from the +3 state in chromite to the +6 state in the presence of alkali.
- The roasted mass yields yellow potassium chromate (K_2CrO_4), which is extracted with water.

Why other options are incorrect:

- Option A:** KMnO_4 is derived from manganese ores like pyrolusite (MnO_2).
- Option B:** Potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$) is produced by subsequent acidification of K_2CrO_4 , not directly during roasting.
- Option D:** Cr_2O_3 is a green reduced oxide, not the product of oxidative roasting.

Question #96 Key: (C)

CHEMISTRY
10. Electrochemistry

A chemical substance classified as a strong electrolyte is one that:

CORE CONCEPT & DERIVATION

Electrolytes are classified as strong or weak based on their degree of electrolytic dissociation (α) in water.

Formula / Rule / Reaction:

$$\text{Strong Electrolyte: } \alpha \approx 1 \quad (100\% \text{ ionization})$$

Solution:

- Strong electrolytes (strong acids, strong bases, soluble ionic salts) dissociate fully into solvated ions in aqueous solution.
- Because of this complete ionization, they show high electrical conductivity even at moderate concentrations.

Why other options are incorrect:

- Option A:** Partial dissociation ($\alpha \ll 1$) defines weak electrolytes (e.g., acetic acid, aqueous ammonia).
- Option B:** Substances that do not conduct electricity in solution are non-electrolytes (e.g., sucrose, urea).
- Option D:** Electrolytes dissociate into solvated cations and anions, not neutral free elemental atoms.

Question #97 Key: (C)

CHEMISTRY
03. Chemical Bonding

During ionic crystal lattice formation between a metal and a non-metal, electrostatic stabilization...

CORE CONCEPT & DERIVATION

Ionic compounds form via complete electron transfer, yielding oppositely charged ions that pack into a stable crystal lattice.

Formula / Rule / Reaction:

Electrons lost by metal = Electrons gained by non-metal $\Rightarrow$ Net crystal charge = 0

Solution:

- The electropositive metal loses valence electrons to achieve the electron configuration of the nearest noble gas.
- The electronegative non-metal accepts these electrons to complete its valence octet, satisfying electrical neutrality across the crystal lattice.

Why other options are incorrect:

- Option A:** Both ions, not just the cation, typically achieve stable closed-shell configurations.
- Option B:** Both partners must attain stable configurations to optimize lattice enthalpy.
- Option D:** Electron sharing is the defining characteristic of covalent bonding, not ionic lattice formation.

Question #98 Key: (C)

CHEMISTRY
16. Alcohols & Phenols

In structural organic chemistry, a secondary ([Formula]) alcohol is defined by having its hydroxyl group bonded to a secondary carbon atom.

CORE CONCEPT & DERIVATION

Alcohols are classified as primary, secondary, or tertiary based on the number of carbon atoms bound to the carbinol (α) carbon.

Formula / Rule / Reaction:

$R_1 - CH(OH) - R_2 \Rightarrow$ Central α -carbon bonded to 2 β -carbons and 1 hydrogen

Solution:

- The carbon atom directly bonded to the $-OH$ group is designated the α -carbon.
- In secondary alcohols (e.g., propan-2-ol), the α -carbon is bonded to two adjacent alkyl carbon atoms (β -carbons).

Why other options are incorrect:

- Option A:** No β -carbons is unique to methanol (CH_3OH).
- Option B:** One β -carbon defines a primary (1°) alcohol (e.g., ethanol, CH_3CH_2OH).
- Option D:** Three β -carbons defines a tertiary (3°) alcohol (e.g., 2-methylpropan-2-ol).

Question #99 Key: (B)

CHEMISTRY
06. Solids

Diffusion occurs at an extremely slow rate in crystalline solids compared to liquids and gases...

CORE CONCEPT & DERIVATION

Kinetic molecular theory states that particles in crystalline solids lack translational mobility due to strong intermolecular lattice forces.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Constituent ions, atoms, or molecules in a solid are locked into fixed lattice positions.
- Their thermal kinetic energy is limited to oscillation and vibration about these mean points, preventing the rapid translational motion needed for fast diffusion.

Why other options are incorrect:

- Option A:** Rapid translational motion is characteristic of gases and permits rapid diffusion.
- Option C:** Unhindered rotational tumbling occurs in gases and non-viscous liquids, not in rigid crystal lattices.
- Option D:** High molecular fluidity is an exclusive property of liquid and gas phases.

Question #100 Key: (B)

CHEMISTRY
04. Gases

Real gases show the greatest deviation from ideal gas behavior under which combination of physical conditions?

CORE CONCEPT & DERIVATION

The ideal gas equation assumes point-mass particles with zero finite volume and no attractive or repulsive intermolecular forces.

Formula / Rule / Reaction:

$$\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT \quad (\text{van der Waals equation})$$

Solution:

- At high pressure, gas molecules are forced close together, making their finite physical volume significant relative to total container volume.
- At low temperature, reduced kinetic energy allows intermolecular attractive forces to pull molecules together, causing maximum deviation from ideality.

Why other options are incorrect:

- Option A:** Low pressure and high temperature is the condition where real gases behave most ideally.
- Option C:** At low pressure, intermolecular distances remain large, minimizing molecular volume deviations.
- Option D:** High temperature imparts high kinetic energy, helping overcome intermolecular attractions even at elevated pressures.

Question #101 Key: (C)

CHEMISTRY
01. Stoichiometry

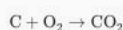
Complete combustion of 3.0 g of carbon in excess oxygen ([Formula]) produces how many molecules...

CORE CONCEPT & DERIVATION

Stoichiometric calculations relate mass of reactants to moles and total representative particles via Avogadro's constant.

Formula / Rule / Reaction:

$$n = \frac{\text{Mass}}{\text{Molar Mass}}, \quad N = n \times N_A$$



Solution:

- Calculate moles of carbon:

$$n = \frac{3.0 \text{ g}}{12.0 \text{ g/mol}} = 0.25 \text{ mol}$$

- According to the balanced reaction equation, 1 mole of carbon yields 1 mole of CO_2 . Therefore, 0.25 mol of carbon yields 0.25 mol of CO_2 .

- Multiply by Avogadro's number:

$$N = 0.25 \times 6.022 \times 10^{23} = 1.505 \times 10^{23} \text{ molecules of } \text{CO}_2$$

Why other options are incorrect:

- Option A:** 6.022×10^{23} molecules corresponds to the complete combustion of 1.0 mol (12.0 g) of carbon.
- Option B:** 3.011×10^{23} molecules corresponds to 0.5 mol (6.0 g) of carbon.
- Option D:** 4.515×10^{23} molecules corresponds to 0.75 mol (9.0 g) of carbon.

Question #102 Key: (A)

CHEMISTRY
14. Hydrocarbons

When an alkyl halide reacts with aqueous sodium hydroxide to yield an alcohol, the reaction proceeds...

CORE CONCEPT & DERIVATION

Alkyl halides possess an electrophilic carbon polarized by a halogen, making them susceptible to nucleophilic attack.

Formula / Rule / Reaction:



Solution:

- The nucleophilic hydroxide ion (OH^-) attacks the partially positive carbon atom bonded to the halogen.
- The halide ion is displaced as a leaving group, substituting an $-\text{OH}$ group for the halogen atom to yield an alcohol.

Why other options are incorrect:

- Option B:** Electrophilic addition occurs across unsaturated carbon-carbon double or triple bonds in alkenes or alkynes.
- Option C:** Elimination occurs predominantly in the presence of strong, bulky bases and hot alcoholic KOH, yielding alkenes.
- Option D:** Electrophilic substitution is characteristic of aromatic systems such as benzene.

Question #103 Key: (B)

CHEMISTRY
13. Fundamental Principles of Organic Chemistry

The historic synthesis of which organic compound from inorganic ammonium cyanate by Friedrich Wöhler...

CORE CONCEPT & DERIVATION

The vital force theory postulated that organic compounds could only be synthesized within living organisms under a mysterious vital force.

Formula / Rule / Reaction:



Solution:

- Wöhler evaporated an aqueous solution of the inorganic salt ammonium cyanate (NH_4OCN) and obtained urea.
- This thermal isomerization proved that organic compounds obey physical and chemical laws and can be produced from inorganic precursors.

Why other options are incorrect:

- Option A:** Acetic acid was synthesized from its elements by Hermann Kolbe in 1845, after Wöhler's breakthrough.
- Option C:** Methane was synthesized from carbon and hydrogen by Marcellin Berthelot in 1856.
- Option D:** Ethyl acetate is an ester synthesized by esterification, unrelated to the overthrow of vitalism.

Question #104 Key: (C)

CHEMISTRY
11. S & P Block Elements

Across a period from left to right in the periodic table, the first ionization energy generally...

CORE CONCEPT & DERIVATION

First ionization energy depends on the net electrostatic attraction exerted by the nucleus on outermost valence electrons.

Formula / Rule / Reaction:

$$Z_{\text{eff}} = Z - S \Rightarrow Z_{\text{eff}} \uparrow \Rightarrow \text{Atomic radius} \downarrow \Rightarrow \text{Ionization Energy} \uparrow$$

Solution:

- Moving across a period, protons are added to the nucleus while electrons enter the same principal valence shell.
- Shielding (S) by inner core electrons remains roughly constant, causing effective nuclear charge (Z_{eff}) to increase and hold valence electrons more tightly.

Why other options are incorrect:

- Option A:** Atomic radius decreases across a period due to greater nuclear pull, which increases ionization energy.
- Option B:** The principal quantum number remains constant across any given period.
- Option D:** Inner electron shielding remains constant because no new inner shells are added across a period.

Question #105 Key: (B)

CHEMISTRY
09. Thermochemistry

The total enthalpy change of a chemical reaction is independent of the pathway taken between t...

CORE CONCEPT & DERIVATION

Enthalpy is a thermodynamic state function; its change depends strictly on initial and final states, not the pathway taken.

Formula / Rule / Reaction:

$$\Delta H_{\text{net}} = \sum \Delta H_{\text{steps}} = \Delta H_1 + \Delta H_2 + \Delta H_3 + \dots$$

Solution:

- Germain Hess established that whether a reaction occurs in a single step or multiple steps, the net enthalpy change remains identical.
- This principle is an application of the law of conservation of energy to chemical thermochemistry.

Why other options are incorrect:

- **Option A:** Le Chatelier's principle predicts how a system at equilibrium responds to external perturbations.
- **Option C:** Gay-Lussac's law relates the pressure and absolute temperature of an ideal gas at constant volume.
- **Option D:** Raoult's law states that the partial vapor pressure of a solution component is proportional to its mole fraction.

Question #106 Key: (A)

CHEMISTRY
17. Aldehydes & Ketones

Controlled oxidation of a primary ([Formula]) alcohol using pyridinium chlorochromate (PCC) y...

CORE CONCEPT & DERIVATION

Mild, anhydrous chromium(VI) oxidizing agents stop the oxidation of primary alcohols at the carbonyl stage without over-oxidation.

Formula / Rule / Reaction:



Solution:

- Pyridinium chlorochromate (PCC) is a mild, non-aqueous oxidizing agent.
- Because the reaction is carried out in anhydrous dichloromethane, no geminal diol hydrate forms, preventing further oxidation to a carboxylic acid and isolating the aldehyde.

Why other options are incorrect:

- **Option B:** Ketones are produced by the oxidation of secondary alcohols, not primary alcohols.
- **Option C:** Carboxylic acids are formed when primary alcohols are oxidized by strong aqueous oxidants like acidified KMnO_4 or $\text{K}_2\text{Cr}_2\text{O}_7$.
- **Option D:** Esters are formed by condensation between carboxylic acids and alcohols, not direct single-substrate oxidation.

Question #107 Key: (D)

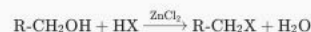
CHEMISTRY
16. Alcohols & Phenols

The nucleophilic substitution reaction of a primary alcohol with a dry halogen acid (such as [F...]

CORE CONCEPT & DERIVATION

Protonation of an alcohol converts the poor leaving group ($-\text{OH}$) into a good leaving group ($-\text{OH}_2^+$), which is displaced by a halide.

Formula / Rule / Reaction:



Solution:

- A primary alcohol ($\text{R-CH}_2\text{OH}$) reacts with a halogen acid through an $\text{S}_{\text{N}}2$ displacement.
- The halide nucleophile attacks the primary carbinol carbon as water leaves, producing a primary alkyl halide without skeletal rearrangement.

Why other options are incorrect:

- **Option A:** The reaction substitutes a halogen for the hydroxyl group; it does not yield an isomeric secondary alcohol.
- **Option B:** Tertiary alkyl halides are produced from tertiary alcohols.
- **Option C:** Secondary alkyl halides are produced from secondary alcohols.

Question #108 Key: (D)

CHEMISTRY
17. Aldehydes & Ketones

Acetophenone ([Formula]) is chemically categorized as a/an:

CORE CONCEPT & DERIVATION

Aromatic ketones contain a carbonyl group bonded directly to at least one aromatic benzene ring.

Formula / Rule / Reaction:



Solution:

- In acetophenone (methyl phenyl ketone), the carbonyl carbon is attached directly to a phenyl ring (C_6H_5) and a methyl group (CH_3).
- Because the carbonyl group is linked directly to an aromatic nucleus, it is classified as an aromatic ketone.

Why other options are incorrect:

- **Option A:** Aliphatic aldehydes possess a $-\text{CHO}$ group attached to an alkyl group or hydrogen.
- **Option B:** Phenols contain an $-\text{OH}$ group bonded directly to an aromatic ring.
- **Option C:** Aliphatic ketones contain a carbonyl group bonded strictly to two aliphatic alkyl groups (e.g., acetone).

Question #109 Key: (B)

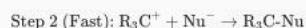
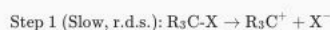
CHEMISTRY
15. Alkyl Halides

The unimolecular nucleophilic substitution mechanism ([Formula]) is characterized by a:

CORE CONCEPT & DERIVATION

The S_N1 mechanism involves step-wise departure of the leaving group to generate a planar carbocation intermediate.

Formula / Rule / Reaction:



Solution:

- Step 1: The substrate undergoes slow, reversible heterolytic cleavage of the C-X bond to form a planar carbocation intermediate.
- Step 2: The nucleophile attacks the flat carbocation from either face rapidly, yielding partial or complete racemization.

Why other options are incorrect:

- Option A:** A single-step concerted process without intermediates defines the bimolecular S_N2 mechanism.
- Option C:** The heterolytic ionization step to form the carbocation is slow, representing the rate-determining step.
- Option D:** Complete Walden inversion is characteristic of the backside attack in the S_N2 mechanism.

Question #110 Key: (D)

CHEMISTRY
18. Carboxylic Acids

The trivial common name for the six-carbon unbranched carboxylic acid, hexanoic acid ([Formula])...

CORE CONCEPT & DERIVATION

Monocarboxylic acids often possess historical common names derived from their initial natural isolation sources.

Formula / Rule / Reaction:



Solution:

- Hexanoic acid (6 carbons) is commonly called caproic acid (derived from the Latin 'caper', meaning goat, referencing its pungent odor in goat milk).
- This matches the established nomenclature in the Sindh Textbook Board organic chemistry syllabus.

Why other options are incorrect:

- Option A:** Adipic acid is the common name for the six-carbon dicarboxylic acid hexanedioic acid.
- Option B:** Propionic acid is the common name for the three-carbon propanoic acid.
- Option C:** Butyric acid is the common name for the four-carbon butanoic acid.

Question #111 Key: (B)

CHEMISTRY
02. Atomic Structure

Which option accurately summarizes the physical characteristics of gamma ([Formula]) rays?

CORE CONCEPT & DERIVATION

Gamma rays are high-energy photons emitted during nuclear de-excitation transitions within unstable nuclei.

Formula / Rule / Reaction:

$$E = h\nu = \frac{hc}{\lambda} \quad (\lambda_\gamma < \lambda_X < 10^{-11} \text{ m})$$

Solution:

- Because gamma rays are uncharged electromagnetic photons, they experience no Lorentz force and travel undeflected through magnetic fields.
- They travel at the speed of light (c), possess very short wavelengths, and have the highest penetrating power among common nuclear emissions.

Why other options are incorrect:

- Option A:** Positively charged helium nuclei describes alpha (α) particles.
- Option C:** High-speed negatively charged electrons describes beta-minus (β^-) particles.
- Option D:** Neutral nucleons of mass number 1 describes free neutrons, not electromagnetic gamma radiation.

Question #112 Key: (C)

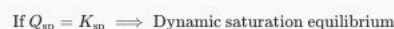
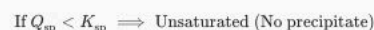
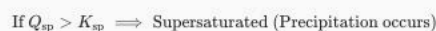
CHEMISTRY
07. Equilibrium

In aqueous solution chemistry, comparing the ion product ([Formula]) to the solubility product...

CORE CONCEPT & DERIVATION

The ion product (Q_{sp}) compared to K_{sp} indicates whether a solution is unsaturated, saturated, or supersaturated.

Formula / Rule / Reaction:



Solution:

- When ionic concentrations are such that Q_{sp} exceeds K_{sp} , excess solute precipitates out of solution until equilibrium is re-established.
- Therefore, K_{sp} serves as a quantitative benchmark to determine precipitation conditions.

Why other options are incorrect:

- Option A:** Boiling point elevation is a colligative property governed by total dissolved solute molality, not the solubility product.
- Option B:** Diffusion rates are governed by Fick's laws and concentration gradients, independent of the K_{sp} threshold.
- Option D:** Freezing point depression is a colligative property dependent on particle molality, not K_{sp} .

Question #113 Key: (C)

CHEMISTRY
19. Macromolecules / Biochemistry

In polypeptide and protein structures, individual [Formula] -amino acid residues are covalently...

CORE CONCEPT & DERIVATION

Proteins are linear polymers of amino acids joined head-to-tail by condensation-derived amide bonds.

Formula / Rule / Reaction:



Solution:

- The α -carboxyl group of one amino acid condenses with the α -amino group of an adjacent amino acid.
- The elimination of a water molecule establishes a rigid, planar amide linkage known as a peptide bond.

Why other options are incorrect:

- Option A:** Glycosidic linkages link monosaccharide units in oligo- and polysaccharides.
- Option B:** Ester linkages join fatty acids to glycerol backbones in lipids.
- Option D:** Phosphodiester linkages connect consecutive nucleotides along nucleic acid strands.

Question #114 Key: (B)

CHEMISTRY
01. Stoichiometry

The ratio of the atomic mass of a standard hydrogen atom ([Formula]) to that of a carbon-12 a...

CORE CONCEPT & DERIVATION

The unified atomic mass unit (amu) is defined as exactly one-twelfth of the mass of a single carbon-12 atom.

Formula / Rule / Reaction:

$$\text{Ratio} = \frac{\text{Atomic mass of } ^1\text{H}}{\text{Atomic mass of } ^{12}\text{C}} = \frac{1.008 \text{ amu}}{12.000 \text{ amu}} \approx \frac{1}{12}$$

Solution:

- A hydrogen-1 atom possesses an atomic mass of roughly 1 amu, while carbon-12 is defined as exactly 12 amu.
- Dividing the two yields a relative mass ratio of one-twelfth.

Why other options are incorrect:

- Option A:** One-sixth would correspond to a ratio of 2 to 12, which represents molecular hydrogen (H_2) or helium.
- Option C:** Half would correspond to a mass of 6 amu (e.g., lithium-6).
- Option D:** Double would require hydrogen to be twice as massive as carbon (24 amu), which is physically impossible.

Question #115 Key: (B)

CHEMISTRY
13. Fundamental Principles of Organic Chemistry

The industrial petroleum process known as catalytic reforming is carried out to:

CORE CONCEPT & DERIVATION

Catalytic reforming rearranges low-octane linear alkanes into high-octane branched alkanes, cycloalkanes, and aromatics.

Formula / Rule / Reaction:



Solution:

- Low-octane naphtha contains predominantly straight-chain alkanes that burn unevenly and cause engine knock.
- Reforming converts these chains into branched and aromatic rings, increasing the fuel's antiknock quality (octane rating).

Why other options are incorrect:

- Option A:** Reforming is designed to suppress and reduce engine knocking, not increase it.
- Option C:** Breaking heavy fractions into lighter fuels is catalytic cracking, not reforming.
- Option D:** Removing paraffin waxes to lower pour point is solvent dewaxing.

Question #116 Key: (B)

CHEMISTRY
17. Aldehydes & Ketones

The chemical product obtained from the acid-catalyzed addition of two molecules of ethyl alcoho...

CORE CONCEPT & DERIVATION

Aldehydes react with alcohols under anhydrous acidic conditions to yield hemiacetals and subsequent acetals.

Formula / Rule / Reaction:



Solution:

- Formaldehyde (methanal) undergoes nucleophilic addition with the first ethanol molecule to form an unstable hemiacetal.
- Subsequent acid-catalyzed substitution with a second ethanol molecule yields diethoxymethane, which is classified as an acetal.

Why other options are incorrect:

- Option A:** An aldol is a β -hydroxy carbonyl compound formed by self-condensation of enolizable carbonyls.
- Option C:** Esters are formed by reacting carboxylic acids with alcohols.
- Option D:** Simple ethers (R-O-R) are prepared by intermolecular dehydration of alcohols alone.

Question #117 Key: (A)

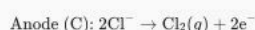
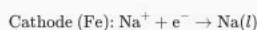
CHEMISTRY
10. Electrochemistry

The industrial metallurgical extraction of metallic sodium via electrolysis of molten sodium ch...

CORE CONCEPT & DERIVATION

Highly electropositive alkali metals cannot be reduced from aqueous solutions and must be extracted from molten anhydrous salts.

Formula / Rule / Reaction:



Solution:

- The Down's cell electrolyzes molten NaCl mixed with CaCl₂ (added to lower the melting point from 801°C to 600°C).
- Liquid sodium metal is produced at the cylindrical iron cathode and collected, while chlorine gas evolves at the central graphite anode.

Why other options are incorrect:

- Option B:** The Castner–Kellner cell electrolyzes aqueous brine using a mercury cathode to produce NaOH, not metallic sodium.
- Option C:** Nelson's cell uses a perforated steel cathode with an asbestos diaphragm to produce aqueous NaOH and chlorine.
- Option D:** The Solvay tower is a gas absorption column used to manufacture sodium bicarbonate, not an electrolytic cell.

Question #118 Key: (B)

CHEMISTRY
05. Liquids

A falling raindrop or small liquid droplet assumes a spherical shape primarily because of:

CORE CONCEPT & DERIVATION

Molecules at a liquid surface experience an inward cohesive pull, driving the surface to contract to the minimum possible area.

Formula / Rule / Reaction:

Surface Energy = $\gamma \Delta A \Rightarrow$ Minimum energy occurs at minimum surface area for a given volume (Solution):

Solution:

- Unbalanced intermolecular cohesive forces at the liquid–gas interface pull surface molecules toward the interior bulk.
- Because a sphere has the lowest surface–area–to–volume ratio of any geometric shape, surface tension forces the droplet into a sphere.

Why other options are incorrect:

- Option A:** Viscous air drag deforms falling drops into flattened oblate spheroids, opposing the spherical shape.
- Option C:** Vapor pressure governs phase equilibrium between the liquid and its vapor, not droplet geometry.
- Option D:** Gravity accelerates the drop downward, but does not provide the inward cohesive force that shapes it into a sphere.

Question #119 Key: (D)

CHEMISTRY
14. Hydrocarbons

The catalytic hydrogenation of polyunsaturated vegetable oils at elevated temperature in the pr...

CORE CONCEPT & DERIVATION

Hydrogenation converts unsaturated liquid triacylglycerols containing double bonds into solid saturated fats.

Formula / Rule / Reaction:



Solution:

- Vegetable oils contain cis-unsaturated fatty acid chains with low melting points that keep them liquid at room temperature.
- Catalytic addition of hydrogen across these C = C double bonds saturates the chains, increasing their melting point to produce solid fat.

Why other options are incorrect:

- Option A:** Soaps are alkali metal salts of fatty acids produced by base-catalyzed ester hydrolysis (saponification).
- Option B:** Alkyl halides are formed by reacting hydrocarbons with halogens or halogen acids.
- Option C:** Alkenes contain carbon–carbon double bonds, which are consumed rather than formed during hydrogenation.

Question #120 Key: (A)

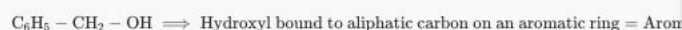
CHEMISTRY
16. Alcohols & Phenols

Benzyl alcohol ([Formula]) is classified structurally as an:

CORE CONCEPT & DERIVATION

Compounds with an –OH group on a side-chain carbon attached to an aromatic ring are aromatic alcohols, not phenols.

Formula / Rule / Reaction:



Solution:

- In benzyl alcohol, the hydroxyl (–OH) group is bonded to an sp³-hybridized benzylic methylene carbon.
- Because the –OH is not directly attached to the aromatic ring, it exhibits alcohol properties rather than phenolic acidity, classifying it as an aromatic alcohol.

Why other options are incorrect:

- Option B:** Phenols contain a hydroxyl group bound directly to an aromatic ring carbon (e.g., C₆H₅OH).
- Option C:** Aliphatic ethers contain an oxygen atom linked between two alkyl groups (R–O–R).
- Option D:** Alicyclic alcohols contain a hydroxyl group attached to a non-aromatic saturated carbocyclic ring (e.g., cyclohexanol).

Question #121 Key: (C)

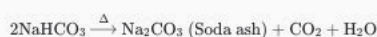
CHEMISTRY
18. Carboxylic Acids

The industrial ammonia-soda (Solvay) process is designed for the large-scale commercial product...

CORE CONCEPT & DERIVATION

The Solvay process produces sodium carbonate from brine, limestone, and ammonia, recycling ammonia internally.

Formula / Rule / Reaction:



Solution:

- Precipitated sodium bicarbonate (NaHCO_3) is filtered and heated in a calciner.
- Thermal decomposition yields anhydrous sodium carbonate, commercially known as soda ash.

Why other options are incorrect:

- **Option A:** Nitric acid is manufactured via the catalytic oxidation of ammonia in the Ostwald process.
- **Option B:** Hydrochloric acid is produced by direct combination of H_2 and Cl_2 or as a chlorination byproduct.
- **Option D:** Calcium chloride is an unmarketable waste byproduct generated during ammonia recovery, not the primary product.

Question #122 Key: (D)

CHEMISTRY
02. Atomic Structure

According to quantum mechanics, the third principal energy level ([Formula], the M shell) con...

CORE CONCEPT & DERIVATION

The azimuthal quantum number (l) ranges from 0 to $n - 1$, defining the subshells present within a principal energy level.

Formula / Rule / Reaction:

$$\text{For } n = 3 \implies l = 0 \text{ (s)}, 1 \text{ (p)}, 2 \text{ (d)}$$

Solution:

- When $n = 3$, the allowed values for l are 0, 1, and 2.
- These values correspond to the 3s, 3p, and 3d subshells, containing a total of $1 + 3 + 5 = 9$ orbitals and accommodating up to 18 electrons.

Why other options are incorrect:

- **Option A:** Only s orbitals ($l = 0$) characterizes the $n = 1$ (K) shell.
- **Option B:** s and p orbitals ($l = 0, 1$) describes the $n = 2$ (L) shell.
- **Option C:** The f subshell ($l = 3$) first appears in the $n = 4$ (N) shell.

Question #123 Key: (C)

PHYSICS
09. Current Electricity

When external load resistors of different values are connected across the terminals of a real b...

CORE CONCEPT & DERIVATION

Electromotive force is an intrinsic chemical property of the cell, while terminal voltage depends on the internal voltage drop.

Formula / Rule / Reaction:

$$V_t = E - Ir = E - \left(\frac{E}{R + r}\right)r$$

Solution:

- The emf (E) is determined solely by the chemical reactions in the cell and remains constant.
- Connecting different load resistances (R) alters the circuit current (I), changing the internal potential drop (Ir) and causing terminal potential difference (V_t) to vary.

Why other options are incorrect:

- **Option A:** Terminal voltage varies with current whenever a real battery has non-zero internal resistance.
- **Option B:** The electromotive force is an intrinsic chemical property and does not vary with external load resistance.
- **Option D:** The terminal voltage drops to zero only during an external short-circuit ($R = 0$).

Question #124 Key: (C)

PHYSICS
14. Dawn of Modern Physics

The minimum threshold energy of an incident photon required to create an electron-positron pair...

CORE CONCEPT & DERIVATION

Pair production requires the incident photon energy to equal at least the combined rest-mass energies of the created electron and positron.

Formula / Rule / Reaction:

$$E_{\min} = 2m_e c^2 = 2 \times 0.511 \text{ MeV} = 1.022 \text{ MeV} \approx 1.02 \text{ MeV}$$

Solution:

- The rest mass of an electron (or positron) is $m_e = 9.11 \times 10^{-31} \text{ kg}$, equivalent to 0.511 MeV.
- To create both an electron and a positron, the incident photon must have a minimum threshold energy of $2 \times 0.511 \text{ MeV} = 1.02 \text{ MeV}$.

Why other options are incorrect:

- **Option A:** 0.511 MeV is the rest-mass energy of a single electron, which violates lepton conservation if created alone.
- **Option B:** 2.04 MeV is double the necessary minimum threshold energy.
- **Option D:** 1.02 keV represents low-energy X-rays, which lack sufficient energy for pair production by a factor of 1,000.

Question #125 Key: (B)PHYSICS
11. Electromagnetic Induction

Faraday's law of electromagnetic induction is expressed mathematically as:

CORE CONCEPT & DERIVATION

The induced electromotive force in a circuit is directly proportional to the time rate of change of magnetic flux linkage.

Formula / Rule / Reaction:

$$\mathcal{E} = -N \frac{\Delta \Phi}{\Delta t} \quad (\text{Faraday's Law with Lenz's Law sign})$$

Solution:

- $\Delta \Phi / \Delta t$ represents the time rate of change of magnetic flux through a single loop.
- Multiplying by the number of turns (N) yields the total induced emf, while the negative sign (from Lenz's law) indicates that the induced emf opposes the change in flux.

Why other options are incorrect:

- **Option A:** $-N(\Delta I / \Delta t)$ describes self-inductance with an incorrect inductance constant (L).
- **Option C:** Omitting the negative sign ignores Lenz's law and the conservation of energy.
- **Option D:** $-\Delta I / \Delta t$ lacks both the number of turns and magnetic flux parameters.

Question #126 Key: (D)PHYSICS
04. Rotational & Circular Motion

A cyclist negotiating a flat, unbanked circular track skids outward primarily because:

CORE CONCEPT & DERIVATION

Circular motion on an unbanked curve requires static friction between tires and the road to supply the necessary centripetal force.

Formula / Rule / Reaction:

$$f_s \leq \mu_s N = \mu_s mg \quad \text{and} \quad F_c = \frac{mv^2}{r}$$

$$\text{Skidding occurs when: } f_{\max} < \frac{mv^2}{r}$$

Solution:

- Static friction directed toward the center of curvature provides the centripetal force required to turn.
- If speed is too high or the friction coefficient is too low, the maximum available friction cannot supply the required centripetal force, and the cyclist skids outward.

Why other options are incorrect:

- **Option A:** Static friction acts toward the center, providing the centripetal force rather than opposing it.
- **Option B:** If limiting friction exceeds the required centripetal force, the turn is completed safely without skidding.
- **Option C:** Friction acts horizontally in the plane of contact, not perpendicular to the track.

Question #127 Key: (D)PHYSICS
02. Force & Motion

An object is released from rest from a tall cliff and falls freely under gravity. Its downward...

CORE CONCEPT & DERIVATION

For an object in free fall from rest near the Earth's surface, velocity increases linearly with elapsed time.

Formula / Rule / Reaction:

$$v_f = v_i + gt \quad (\text{with } v_i = 0)$$

Solution:

- Substitute initial velocity $v_i = 0$, gravitational acceleration $g = 9.8 \text{ m/s}^2$, and time $t = 5.0 \text{ s}$:

$$v_f = 0 + (9.8 \text{ m/s}^2)(5.0 \text{ s}) = 49.0 \text{ m/s}$$

Why other options are incorrect:

- **Option A:** 4.9 m/s results from dividing by time squared or calculating fall distance in the first second.
- **Option B:** 9.8 m/s is the velocity acquired after only 1.0 second of free fall.
- **Option C:** 24.5 m/s is the velocity acquired after 2.5 seconds of free fall.

Question #128 Key: (D)PHYSICS
05. Waves

Two transverse traveling waves are described by the equations [Formula] and [Formula]. These t...

CORE CONCEPT & DERIVATION

The argument of the sinusoidal wave function represents the total phase of a traveling wave at any given coordinate and time.

Formula / Rule / Reaction:

$$\text{Phase Difference } (\Delta \theta) = (kx - \omega t) - (kx - \omega t - \phi) = \phi$$

Solution:

- Both wave functions share identical amplitude (A_0), wavenumber (k), and angular frequency (ω).
- The constant term ϕ shifts the cycle of y_2 relative to y_1 , establishing a constant phase difference.

Why other options are incorrect:

- **Option A:** Both waves have the same peak amplitude factor, A_0 .
- **Option B:** Both waves have the same wavenumber k , meaning their wavelength $\lambda = 2\pi/k$ is identical.
- **Option C:** Both waves have the same angular frequency ω , meaning their temporal frequency $f = \omega/2\pi$ is identical.

Question #129 Key: (B)

PHYSICS
08. Electrostatics

In the electric field-potential gradient equation [Formula], the negative sign indicates that ...

CORE CONCEPT & DERIVATION

The electric field vector is the negative spatial gradient of the electrostatic potential.

Formula / Rule / Reaction:

$$\vec{E} = -\nabla V = -\frac{dV}{dr}\hat{r}$$

Solution:

- Positive electric charges naturally experience a force directed from regions of higher electric potential to lower electric potential.
- Because electric field lines trace the direction of force on a positive test charge, the negative sign confirms that $\vec{E}$ points down the potential gradient.

Why other options are incorrect:

- **Option A:** The field points down the potential gradient; pointing toward increasing potential contradicts the negative sign.
- **Option C:** While $\vec{E}$ is perpendicular to equipotential surfaces, that geometric orientation is dictated by the vector gradient, not the negative sign.
- **Option D:** The magnitude of the electric field depends directly on the potential gradient.

Question #130 Key: (B)

PHYSICS
10. Electromagnetism

A fast neutron enters a region of uniform magnetic field perpendicular to its direction of motion...

CORE CONCEPT & DERIVATION

The magnetic Lorentz force acts exclusively on particles possessing a non-zero net electric charge.

Formula / Rule / Reaction:

$$\vec{F}_B = q(\vec{v} \times \vec{B}) \implies F_B = qvB \sin \theta$$

Solution:

- A neutron is an electrically neutral subatomic particle, so its charge is $q = 0$.
- Substituting $q = 0$ gives $F_B = 0$. With no net magnetic deflecting force, the neutron continues along its original straight-line path per Newton's first law.

Why other options are incorrect:

- **Option A:** Charged particles follow parabolic trajectories in uniform electrostatic fields, not neutral particles in magnetic fields.
- **Option C:** Charged particles follow circular paths when entering a magnetic field perpendicularly.
- **Option D:** Charged particles follow helical paths when entering a magnetic field at an oblique angle.

Question #131 Key: (B)

PHYSICS
09. Current Electricity

A battery of electromotive force [Formula] has an internal resistance [Formula]. When a steady...

CORE CONCEPT & DERIVATION

The terminal voltage across a discharging power source equals its open-circuit emf minus the internal ohmic potential drop.

Formula / Rule / Reaction:

$$E = V_t + V_{\text{internal}} = V_t + Ir \implies V_t = E - Ir$$

Solution:

- As current I flows through the internal electrolyte resistance r , an internal potential drop of Ir develops across the cell.
- This internal loss reduces the voltage available at the external terminals: $V_t = E - Ir$.

Why other options are incorrect:

- **Option A:** $V_t = E + Ir$ applies when a secondary cell is being recharged by an external power source.
- **Option C:** $E/(I - r)$ is dimensionally incorrect.
- **Option D:** $Ir - E$ yields a negative value under normal operating conditions (since $E > Ir$).

Question #132 Key: (A)

PHYSICS
11. Electromagnetic Induction

The instantaneous electromotive force generated by an alternating current generator with [Formula]...

CORE CONCEPT & DERIVATION

Rotating a coil in a magnetic field changes the flux linkage periodically, inducing a sinusoidal electromotive force.

Formula / Rule / Reaction:

$$\Phi(t) = BA \cos(\omega t)$$

$$\mathcal{E} = -N \frac{d\Phi}{dt} = -N \frac{d}{dt}[BA \cos(\omega t)] = N\omega AB \sin(\omega t)$$

Solution:

- The magnetic flux through the rotating loop varies sinusoidally with time: $\Phi(t) = BA \cos(\omega t)$.
- Applying Faraday's law, the time derivative of $\cos(\omega t)$ introduces a factor of $-\omega \sin(\omega t)$, yielding $\mathcal{E} = N\omega AB \sin(\omega t)$.

Why other options are incorrect:

- **Option B:** This expression omits the angular velocity factor ω produced by differentiation.
- **Option C:** Dividing by ω instead of multiplying is dimensionally incorrect for induced emf.
- **Option D:** An ω^2 dependence does not arise from first-order time differentiation of flux.

Question #133 Key: (D)PHYSICS
02. Force & Motion

A projectile is fired horizontally with an initial speed of 20 m/s from the top of a platform. ...

CORE CONCEPT & DERIVATION

In projectile motion without air resistance, vertical and horizontal motions are independent, with zero acceleration in the horizontal axis.

Formula / Rule / Reaction:

$$a_x = 0 \implies v_x(t) = v_{ix} = \text{constant}$$

Solution:

- Gravity acts strictly downward in the vertical direction ($a_y = -g$, $a_x = 0$).
- Because no horizontal force acts on the projectile after launch, its horizontal velocity remains constant at 20 m/s.

Why other options are incorrect:

- **Option A:** 10 m/s incorrectly assumes horizontal deceleration.
- **Option B:** 40 m/s incorrectly treats the horizontal velocity as accelerating.
- **Option C:** Horizontal velocity drops to zero only upon physical impact with a barrier or the ground.

Question #134 Key: (D)PHYSICS
15. Atomic Spectra

If [Formula] is the Rydberg constant for hydrogen, the wavelength ([Formula]) of the first sp...

CORE CONCEPT & DERIVATION

The first line of the Lyman series corresponds to an electron transition from the first excited state ($n_2 = 2$) to the ground state ($n_1 = 1$).

Formula / Rule / Reaction:

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

Solution:

- Substitute $n_1 = 1$ and $n_2 = 2$:

$$\frac{1}{\lambda} = R_H \left(\frac{1}{1^2} - \frac{1}{2^2} \right) = R_H \left(1 - \frac{1}{4} \right) = \frac{3R_H}{4}$$

- Invert the wavenumber to solve for wavelength:

$$\lambda = \frac{4}{3R_H}$$

Why other options are incorrect:

- **Option A:** $3R_H/4$ is the wavenumber ($\bar{\nu} = 1/\lambda$), not the wavelength.
- **Option B:** $R_H/4$ incorrectly uses $1/4$ instead of $1 - 1/4$.
- **Option C:** $4R_H/3$ is dimensionally incorrect for wavelength (reciprocal length).

Question #135 Key: (C)PHYSICS
07. Thermodynamics

For any ideal gas, the ratio of molar specific heat at constant pressure to that at constant vo...

CORE CONCEPT & DERIVATION

Heating a gas at constant pressure requires additional energy to do work during expansion, making C_p greater than C_v .

Formula / Rule / Reaction:

$$C_p - C_v = R \implies C_p = C_v + R \implies \gamma = \frac{C_p}{C_v} = 1 + \frac{R}{C_v} > 1$$

Solution:

- At constant volume, added heat goes entirely into increasing internal energy ($dE = dq_v$).
- At constant pressure, added heat must increase internal energy and perform external work against atmospheric pressure ($P\Delta V$), so $C_p > C_v$ and $\gamma > 1$.

Why other options are incorrect:

- **Option A:** $\gamma = 0$ would require heat capacity at constant pressure to be zero.
- **Option B:** $\gamma < 1$ would imply $C_p < C_v$, violating Mayer's relation ($C_p - C_v = R$).
- **Option D:** Negative heat capacity ratios are unphysical for stable thermodynamic systems.

Question #136 Key: (A)PHYSICS
03. Work & Energy

If both the mass and speed of a moving particle are doubled, its kinetic energy will increase b...

CORE CONCEPT & DERIVATION

Translational kinetic energy is directly proportional to mass and to the square of velocity.

Formula / Rule / Reaction:

$$E_k = \frac{1}{2}mv^2$$

Solution:

- Let the original kinetic energy be $E_{k1} = \frac{1}{2}mv^2$.
- Substitute the new mass $m' = 2m$ and new speed $v' = 2v$:

$$E_{k2} = \frac{1}{2}(2m)(2v)^2 = \frac{1}{2}(2m)(4v^2) = 8\left(\frac{1}{2}mv^2\right) = 8E_{k1}$$
- Therefore, the new kinetic energy is 8 times the original value.

Why other options are incorrect:

- **Option B:** 4 times accounts only for doubling the speed without accounting for the doubled mass.
- **Option C:** 16 times squares both mass and velocity, which is mathematically incorrect.
- **Option D:** 2 times accounts only for doubling mass while keeping speed constant.

Question #137 Key: (C)

PHYSICS
08. Electrostatics

The electric field intensity in the region between two closely spaced, oppositely charged parallel plates is...

CORE CONCEPT & DERIVATION

The net electric field between oppositely charged plates is the vector sum of the uniform fields produced by each charged sheet.

Formula / Rule / Reaction:

$$E_{\text{single sheet}} = \frac{\sigma}{2\epsilon_0} \Rightarrow E_{\text{between}} = \frac{\sigma}{2\epsilon_0} + \frac{\sigma}{2\epsilon_0} = \frac{\sigma}{\epsilon_0}$$

Solution:

- The positively charged plate produces a field $E_+ = \sigma/(2\epsilon_0)$ directed away from itself.
- The negatively charged plate produces an equal field $E_- = \sigma/(2\epsilon_0)$ directed toward itself.
- Between the plates, both fields point in the same direction and reinforce: $E = \sigma/\epsilon_0$. Outside the plates, they cancel to zero.

Why other options are incorrect:

- Option A:** $\sigma/(2\epsilon_0)$ is the electric field produced by a single isolated infinite sheet of charge.
- Option B:** $2\sigma/\epsilon_0$ incorrectly doubles the net field.
- Option D:** ϵ_0/σ is the inverted dimensional reciprocal.

Question #138 Key: (D)

PHYSICS
02. Force & Motion

A block of mass [Formula] slides with speed [Formula] across a frictionless surface. It explodes...

CORE CONCEPT & DERIVATION

In an explosion without external forces, the total linear momentum of the system is strictly conserved.

Formula / Rule / Reaction:

$$p_{\text{initial}} = p_{\text{final}} \Rightarrow mv = m_1v_1 + m_2v_2$$

Solution:

- The mass of the second piece is $m_2 = m - m_1 = 6.0 \text{ kg} - 2.0 \text{ kg} = 4.0 \text{ kg}$.
- Equate initial and final momentum:

$$(6.0 \text{ kg})(4.0 \text{ m/s}) = (2.0 \text{ kg})(8.0 \text{ m/s}) + (4.0 \text{ kg})v_2$$

$$24.0 = 16.0 + 4.0v_2$$

$$4.0v_2 = 8.0 \Rightarrow v_2 = 2.0 \text{ m/s}$$
- Note on board errata:** Some unofficial answer keys marked 4.0 m/s, but conservation of linear momentum strictly requires $v_2 = 2.0 \text{ m/s}$.

Why other options are incorrect:

- Option A:** 4.0 m/s is the initial speed of the unbroken box, not the calculated velocity of piece 2.
- Option B:** 1.0 m/s results from arithmetic errors in the momentum balance.
- Option C:** 3.0 m/s fails the momentum conservation check ($16 + 4(3) = 28 \neq 24$).

Question #139 Key: (B)

PHYSICS
05. Waves

The sound intensity level corresponding to the threshold of human hearing (faintest audible sound) is...

CORE CONCEPT & DERIVATION

Sound intensity level is a logarithmic scale referenced to the human threshold of hearing ($I_0 = 10^{-12} \text{ W/m}^2$).

Formula / Rule / Reaction:

$$\beta = 10 \log_{10} \left(\frac{I}{I_0} \right) \quad (\text{in dB})$$

Solution:

- At the threshold of hearing, the sound intensity is $I = I_0 = 10^{-12} \text{ W/m}^2$.
- Substitute $I = I_0$ into the decibel equation:

$$\beta = 10 \log_{10} \left(\frac{I_0}{I_0} \right) = 10 \log_{10}(1) = 10 \times 0 = 0 \text{ dB}$$

Why other options are incorrect:

- Option A:** 10 dB corresponds to an intensity 10 times greater than the threshold of hearing (e.g., rustling leaves).
- Option C:** 60 dB corresponds to the sound intensity of normal conversational speech.
- Option D:** 120 dB corresponds to the threshold of physical ear discomfort or pain.

Question #140 Key: (C)

PHYSICS
08. Electrostatics

Two capacitors with capacitances of [Formula] and [Formula] are connected in series across a voltage source...

CORE CONCEPT & DERIVATION

For capacitors connected in series, the reciprocal of equivalent capacitance equals the sum of the reciprocals of individual capacitances.

Formula / Rule / Reaction:

$$\frac{1}{C_{\text{eq}}} = \frac{1}{C_1} + \frac{1}{C_2} \Rightarrow C_{\text{eq}} = \frac{C_1 C_2}{C_1 + C_2}$$

Solution:

- Substitute the values $C_1 = 2 \mu\text{F}$ and $C_2 = 4 \mu\text{F}$:

$$C_{\text{eq}} = \frac{2 \times 4}{2 + 4} = \frac{8}{6} = \frac{4}{3} \approx 1.33 \mu\text{F}$$

Why other options are incorrect:

- Option A:** $6.00 \mu\text{F}$ is the equivalent capacitance if connected in parallel ($C_{\text{eq}} = C_1 + C_2 = 2 + 4$).
- Option B:** $0.75 \mu\text{F}$ is the reciprocal value ($1/C_{\text{eq}} = 6/8 = 0.75 \mu\text{F}^{-1}$).
- Option D:** $8.00 \mu\text{F}$ is the product $C_1 C_2$ without dividing by their sum.

Question #141 Key: (B)

PHYSICS
14. Dawn of Modern Physics

Which of the following physical phenomena provided the earliest definitive experimental proof f...

CORE CONCEPT & DERIVATION

Instantaneous ejection of electrons by threshold-frequency light can only be explained by localized photon-electron energy exchanges.

Formula / Rule / Reaction:

$$h\nu = \Phi + K_{\max} = h\nu_0 + \frac{1}{2}mv_{\max}^2 \quad (\text{Einstein's Photoelectric Equation})$$

Solution:

- Classical wave theory predicts that low-intensity light should require time to accumulate energy before ejecting electrons, and that kinetic energy should depend on light intensity.
- Experiments demonstrated instantaneous emission and showed that kinetic energy depends strictly on light frequency, confirming that light delivers energy in discrete packets (photons).

Why other options are incorrect:

- Option A:** Interference demonstrates wave superposition, supporting the wave theory of light.
- Option C:** Diffraction is the bending of waves around obstacles, characteristic of classical waves.
- Option D:** Polarization demonstrates that light is a transverse wave.

Question #142 Key: (D)

PHYSICS
09. Current Electricity

The electrical thermal energy (Joule heat) dissipated in an ohmic resistor of resistance [Formu...

CORE CONCEPT & DERIVATION

Joule's law of heating states that dissipated thermal power in a resistor equals the square of the current multiplied by resistance.

Formula / Rule / Reaction:

$$P = I^2 R \implies H = P \times t = I^2 R t = V I t = \frac{V^2}{R} t$$

Solution:

- Electric power converted to heat per second in a resistor is $P = I^2 R$.
- Multiplying power by elapsed time (t) yields total dissipated thermal energy: $H = I^2 R t$.

Why other options are incorrect:

- Option A:** $I R t = V t$, which is dimensionally incorrect for energy (missing current).
- Option B:** $I^2 R$ represents power (watts), not total accumulated energy (joules).
- Option C:** Using voltage, the correct formula is $(V^2/R)t$, not $V^2 R t$.

Question #143 Key: (A)

PHYSICS
09. Current Electricity

One kilowatt-hour (1 kWh) of electrical energy is equivalent to:

CORE CONCEPT & DERIVATION

A kilowatt-hour is a commercial unit of electrical energy equivalent to consuming one kilowatt of power for one hour.

Formula / Rule / Reaction:

$$1 \text{ kWh} = (10^3 \text{ W}) \times (3600 \text{ s}) = 3.6 \times 10^6 \text{ J}$$

Solution:

- Convert 1 kilowatt to watts: $1 \text{ kW} = 1000 \text{ W} = 1000 \text{ J/s}$.
- Convert 1 hour to seconds: $1 \text{ h} = 60 \times 60 = 3600 \text{ s}$.
- Multiply to find total joules: $1000 \text{ J/s} \times 3600 \text{ s} = 3,600,000 \text{ J} = 3.6 \times 10^6 \text{ J}$ (or $36 \times 10^5 \text{ J}$).

Why other options are incorrect:

- Option B:** $3.6 \times 10^3 \text{ J}$ accounts for only 1 watt-hour, not 1 kilowatt-hour.
- Option C:** $3.6 \times 10^5 \text{ J}$ is off by a factor of 10.
- Option D:** $36 \times 10^{-6} \text{ J}$ involves a negative exponent, which is incorrect.

Question #144 Key: (A)

PHYSICS
08. Electrostatics

The derived physical unit 'joule per coulomb' ([Formula]) defines the SI unit:

CORE CONCEPT & DERIVATION

Electric potential difference is defined as the work done or energy required per unit positive charge to move it between two points.

Formula / Rule / Reaction:

$$V = \frac{W}{q} \implies 1 \text{ Volt (V)} = 1 \text{ Joule per Coulomb (J/C)}$$

Solution:

- Work (W) is measured in joules (J) and charge (q) in coulombs (C).
- Their quotient yields electric potential difference, whose SI unit is the volt (V).

Why other options are incorrect:

- Option B:** The ampere is the unit of electric current, defined as coulombs per second (C/s).
- Option C:** The ohm is the unit of electrical resistance, defined as volts per ampere (V/A).
- Option D:** The tesla is the unit of magnetic flux density, defined as newtons per ampere-meter (N/(A · m)).

Question #145 Key: (D)PHYSICS
16. Nuclear Physics

According to the statistical law of radioactive decay, the instantaneous rate of nuclear disint...

CORE CONCEPT & DERIVATION

Radioactive decay is a spontaneous nuclear process unaffected by environmental factors, with decay rate depending only on population size.

Formula / Rule / Reaction:

$$-\frac{dN}{dt} = \lambda N \implies \text{Activity } (A) \propto N$$

Solution:

- The rate of disintegration is directly proportional to the total number of undecayed radioactive nuclei (N) present at that moment.
- The constant of proportionality is the characteristic decay constant (λ).

Why other options are incorrect:

- Option A:** Nuclear transitions involve mega-electronvolt energy scales and are completely independent of ambient chemical temperature.
- Option B:** Disintegration rate depends on the total count of unstable nuclei, not physical density.
- Option C:** Atmospheric pressure affects only external physical state, having no influence on intranuclear forces.

Question #146 Key: (D)PHYSICS
11. Electromagnetic Induction

Parasitic eddy current energy losses in the core of an alternating current transformer are mini...

CORE CONCEPT & DERIVATION

Alternating magnetic flux induces circulating currents within conductive transformer cores, dissipating energy as heat.

Formula / Rule / Reaction:

$$P_{\text{eddy}} \propto f^2 B_{\text{max}}^2 d^2 \quad (\text{where } d \text{ is sheet lamination thickness})$$

Solution:

- Splitting a solid core into thin iron sheets insulated by varnish restricts eddy currents to small loops within each sheet.
- Because eddy current power loss is proportional to the square of lamination thickness (d^2), laminations reduce overall resistive heating losses.

Why other options are incorrect:

- Option A:** Copper is highly conductive; a thick copper core would permit very large eddy currents and high power losses.
- Option B:** The turns ratio governs voltage transformation, but does not prevent internal core eddy currents.
- Option C:** A solid unlaminated iron block provides broad, low-resistance loops that maximize eddy current heating.

Question #147 Key: (A)PHYSICS
03. Work & Energy

The absolute gravitational potential energy [Formula] of an object of mass [Formula] at the sur...

CORE CONCEPT & DERIVATION

Gravitational potential energy is the work done by an external agent to bring a mass from infinity to its position in an attractive field.

Formula / Rule / Reaction:

$$U(r) = - \int_{\infty}^r \vec{F} \cdot d\vec{r} = - \frac{GmM_E}{r} \implies U(R_E) = - \frac{GmM_E}{R_E}$$

Solution:

- Because gravity is an attractive force and potential energy is set to zero at infinity, potential energy is negative at all finite distances.
- At the Earth's surface ($r = R_E$), the absolute gravitational potential energy is $U = - \frac{GmM_E}{R_E}$.

Why other options are incorrect:

- Option B:** A positive value corresponds to a repulsive force field, which contradicts gravitational attraction.
- Option C:** Dividing by R_E^2 gives the gravitational force ($F = GmM_E/R_E^2$), not potential energy.
- Option D:** Omitting the mass m gives gravitational potential (V_g), not potential energy (U).

Question #148 Key: (A)PHYSICS
12. Alternating Current

The speed of an electromagnetic wave (photon) in free space is defined in terms of vacuum perme...

CORE CONCEPT & DERIVATION

Maxwell's equations demonstrate that electromagnetic waves propagate through vacuum at a speed determined by free-space constants.

Formula / Rule / Reaction:

$$\nabla^2 \vec{E} = \mu_0 \epsilon_0 \frac{\partial^2 \vec{E}}{\partial t^2} \implies v = c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$$

Solution:

- Comparing the electromagnetic wave equation to the general classical wave equation shows that wave velocity is $1/\sqrt{\mu_0 \epsilon_0}$.
- Substituting $\mu_0 = 4\pi \times 10^{-7} \text{ H/m}$ and $\epsilon_0 = 8.854 \times 10^{-12} \text{ F/m}$ yields the speed of light: $c \approx 3.0 \times 10^8 \text{ m/s}$.

Why other options are incorrect:

- Option B:** $\sqrt{\mu_0 \epsilon_0}$ is the reciprocal of speed, giving units of seconds per meter.
- Option C:** $1/(\mu_0 \epsilon_0)$ equals the square of the speed of light (c^2).
- Option D:** $\frac{1}{2} \mu_0 \epsilon_0$ is dimensionally incorrect.

Question #149 Key: (D)PHYSICS
10. Electromagnetism

A particle of charge [Formula] moves with velocity [Formula] parallel to a uniform magnetic field...

CORE CONCEPT & DERIVATION

The magnetic Lorentz force depends on the vector cross product between the velocity vector and the magnetic field vector.

Formula / Rule / Reaction:

$$\vec{F} = q(\vec{v} \times \vec{B}) \implies F = qvB \sin \theta$$

Solution:

- When the particle moves parallel to the magnetic field lines, the angle between $\vec{v}$ and $\vec{B}$ is $\theta = 0^\circ$.
- Because $\sin(0^\circ) = 0$, the magnetic force is zero: $F = qvB \sin(0^\circ) = 0$.

Why other options are incorrect:

- Option A:** qvB is the maximum force, which occurs when the particle moves perpendicular to the field ($\theta = 90^\circ$).
- Option B:** $-qvB$ assumes an antiparallel orientation with an incorrect sign convention.
- Option C:** qB/v is dimensionally incorrect for force.

Question #150 Key: (D)PHYSICS
09. Current Electricity

Two resistors of resistance [Formula] and [Formula] are connected in parallel across a DC supply...

CORE CONCEPT & DERIVATION

In a parallel circuit, all parallel branches share the same potential difference across their terminals.

Formula / Rule / Reaction:

$$V_1 = V_2 = V_{\text{total}}, \quad I_2 = \frac{V_2}{R_2}$$

Solution:

- Because the resistors are in parallel, the potential difference across the 10Ω resistor is also 20 V .
- Applying Ohm's law to the 10Ω branch:

$$I = \frac{V}{R} = \frac{20 \text{ V}}{10 \Omega} = 2.0 \text{ A}$$

Why other options are incorrect:

- Option A:** 4.0 A is the current flowing through the 5Ω resistor ($I = 20/5 = 4 \text{ A}$).
- Option B:** 0.5 A results from inverting the ratio ($10/20$).
- Option C:** 10.0 A corresponds to an incorrect resistance or voltage assignment.

Question #151 Key: (C)PHYSICS
02. Force & Motion

A helicopter of total weight [Formula] is ascending vertically at a constant velocity with zero...

CORE CONCEPT & DERIVATION

According to Newton's first and second laws of motion, an object in uniform motion with zero acceleration experiences zero net external force.

Formula / Rule / Reaction:

$$\sum F_y = ma_y \implies F - W = m(0) = 0 \implies F = W$$

Solution:

- The helicopter ascends at a constant velocity, meaning its acceleration is zero ($a = 0$).
- In dynamic equilibrium, the upward aerodynamic rotor lift force (F) must exactly balance the downward gravitational weight (W).

Why other options are incorrect:

- Option A:** $F > W$ would produce a net upward force, resulting in upward acceleration rather than steady constant-velocity ascent.
- Option B:** $F < W$ would result in a downward net force, causing downward deceleration.
- Option D:** $F = 0$ would leave gravity unbalanced, causing free fall.

Question #152 Key: (A)PHYSICS
05. Waves

When a sound wave travels across a boundary from one medium into another of different acoustic...

CORE CONCEPT & DERIVATION

Wave frequency is determined solely by the periodic oscillation of the source and cannot be altered by changing propagation media.

Formula / Rule / Reaction:

$$v = f\lambda \implies f = \text{constant}, \quad v \propto \lambda$$

Solution:

- As sound enters a new medium, its propagation velocity changes due to differences in elasticity and density.
- To satisfy the wave equation with an invariant source frequency (f), the wavelength (λ) shifts proportionally, while frequency (perceived as pitch) remains constant.

Why other options are incorrect:

- Option B:** Sound velocity depends on the bulk modulus and density of the medium ($v = \sqrt{B/\rho}$) and changes across boundaries.
- Option C:** Amplitude decreases due to partial reflection and acoustic impedance mismatch at the interface.
- Option D:** Wavelength changes in direct proportion to wave speed ($\lambda = v/f$).

Question #153 Key: (A)PHYSICS
11. Electromagnetic Induction

For the most efficient transmission of electrical power through long-distance overhead grid cab...

CORE CONCEPT & DERIVATION

Ohmic power loss along transmission lines is proportional to the square of the transmitted current.

Formula / Rule / Reaction:

$$P = VI \Rightarrow I = \frac{P}{V}, \quad P_{\text{loss}} = I^2 R = \left(\frac{P}{V}\right)^2 R = \frac{P^2 R}{V^2}$$

Solution:

- Stepping up the voltage (V) by a given factor decreases the line current (I) by that same factor for a fixed transmitted power.
- Because Joule heating losses depend on $I^2 R$, transmitting at high voltage and low current minimizes resistive heat dissipation along the cables.

Why other options are incorrect:

- Option B:** High current generates extreme $I^2 R$ thermal losses and causes lines to sag.
- Option C:** Low voltage requires very high current to transmit equivalent power, maximizing heating losses.
- Option D:** Low current paired with low voltage severely restricts total delivered electrical power ($P = VI$).

Question #154 Key: (A)PHYSICS
02. Force & Motion

When an object moves along a straight line with uniform (constant) velocity, its:

CORE CONCEPT & DERIVATION

Uniform velocity requires both speed and directional orientation to remain constant across all time intervals.

Formula / Rule / Reaction:

$$v(t) = \text{constant} \Rightarrow v_{\text{inst}} = \frac{dx}{dt} = \frac{\Delta x}{\Delta t} = v_{\text{avg}}, \quad a = \frac{dv}{dt} = 0$$

Solution:

- Because the velocity vector does not change over time, the instantaneous velocity at any individual moment equals the average velocity over the entire journey.
- Furthermore, because velocity is unchanging, instantaneous acceleration is zero.

Why other options are incorrect:

- Option B:** Average velocity is zero only if net displacement is zero over the time interval.
- Option C:** Instantaneous velocity cannot exceed average velocity in unaccelerated motion.
- Option D:** Instantaneous acceleration must be zero when velocity is uniform.

Question #155 Key: (B)PHYSICS
04. Rotational & Circular Motion

During the uniform rotation of a rigid circular disc about a fixed central axis, every particle...

CORE CONCEPT & DERIVATION

All points within a rigid body sweep out identical angular displacements over any given time interval.

Formula / Rule / Reaction:

$$\omega = \frac{d\theta}{dt} = \text{constant}, \quad v = r\omega$$

Solution:

- Every constituent particle on a rotating disc rotates through the same angle ($\Delta\theta$) in time (Δt).
- Therefore, all particles share an identical angular velocity (ω), even though their linear speeds ($v = r\omega$) scale with radial distance (r).

Why other options are incorrect:

- Option A:** Linear velocity varies with radial position ($v = r\omega$) and constantly changes direction.
- Option C:** In uniform rotation, angular acceleration is zero, meaning tangential acceleration ($a_t = r\alpha$) is zero.
- Option D:** Linear momentum ($p = mv = mr\omega$) varies with radius and continuously changes direction.

Question #156 Key: (B)PHYSICS
08. Electrostatics

A proton of charge [Formula] is accelerated from rest through an electric potential difference ...

CORE CONCEPT & DERIVATION

Work done on a charged particle by an electrostatic field equals the change in its kinetic energy.

Formula / Rule / Reaction:

$$\Delta K = q\Delta V$$

Solution:

- Substitute the charge of a proton $q = 1.6 \times 10^{-19} \text{ C}$ and potential difference $V = 20 \text{ V}$:

$$\Delta K = (1.6 \times 10^{-19} \text{ C}) \times (20 \text{ V}) = 32 \times 10^{-19} \text{ J} = 3.2 \times 10^{-18} \text{ J}$$

Why other options are incorrect:

- Option A:** Gained kinetic energy is a positive scalar; negative signs apply to potential energy changes.
- Option C:** $3.2 \times 10^{19} \text{ J}$ involves an incorrect positive exponent.
- Option D:** Energy gain is non-zero because the charged particle accelerates through a potential gradient.

Question #157 Key: (C)PHYSICS
05. Waves

In a mechanical stationary (standing) wave, the spatial distance between two consecutive antinodes...

CORE CONCEPT & DERIVATION

Standing waves formed by counter-propagating identical waves set up evenly spaced nodes and antinodes.

Formula / Rule / Reaction:

$$\text{Distance between consecutive nodes} = \frac{\lambda}{2}$$

$$\text{Distance between consecutive antinodes} = \frac{\lambda}{2}$$

$$\text{Distance between an adjacent node and antinode} = \frac{\lambda}{4}$$

Solution:

- Antinodes represent positions of maximum displacement occurring twice per full wavelength cycle.
- Therefore, the physical separation between two consecutive antinodes is exactly half a wavelength ($\lambda/2$).

Why other options are incorrect:

- Option A:** $\lambda/4$ is the distance between a consecutive node and antinode.
- Option B:** λ is the distance between alternate antinodes with the same displacement phase.
- Option D:** 2λ encompasses four full half-wavelength segments.

Question #158 Key: (A)PHYSICS
09. Current Electricity

A uniform conducting copper wire of electrical resistivity [Formula] is cut into two equal halves...

CORE CONCEPT & DERIVATION

Resistivity is an intrinsic intensive material property independent of sample geometry and dimensions.

Formula / Rule / Reaction:

$$R = \rho \frac{L}{A} \Rightarrow \rho = \frac{RA}{L} = \text{constant for a given material and temperature}$$

Solution:

- While cutting the wire in half reduces its length and therefore halves its resistance ($R' = R/2$), the intrinsic resistivity (ρ) depends only on material composition and temperature.
- Because the material remains unchanged, the resistivity remains ρ .

Why other options are incorrect:

- Option B:** Halving applies to the total resistance (R), not the intensive material resistivity (ρ).
- Option C:** Resistivity does not increase when dimensions are reduced.
- Option D:** $\rho/4$ is physically incorrect.

Question #159 Key: (D)PHYSICS
05. Waves

An ideal elastic spring with spring constant [Formula] is cut into three equal, identical segments...

CORE CONCEPT & DERIVATION

The spring constant of an elastic spring is inversely proportional to its active unstretched length.

Formula / Rule / Reaction:

$$K \propto \frac{1}{L} \Rightarrow K \times L = \text{constant}$$

Solution:

- Let the original spring have length L and constant K . Cutting it into 3 equal pieces gives each segment a length of $L' = L/3$.

- Applying the inverse relationship:

$$K' L' = K L \Rightarrow K' \left(\frac{L}{3}\right) = K L \Rightarrow K' = 3K$$

Why other options are incorrect:

- Option A:** The spring constant increases because shorter springs are stiffer.
- Option B:** $K/3$ is the equivalent spring constant if three identical springs of constant K were joined in series.
- Option C:** $K/2$ applies to joining two springs in series.

Question #160 Key: (A)PHYSICS
09. Current Electricity

Four identical electrochemical cells, each possessing an electromotive force of 3.0 V, are connected in series...

CORE CONCEPT & DERIVATION

When electrochemical cells are connected in series with matching polarity, their individual electromotive forces add algebraically.

Formula / Rule / Reaction:

$$E_{\text{net}} = E_1 + E_2 + E_3 + E_4 = nE$$

Solution:

- With $n = 4$ identical cells connected in series, each having an emf of $E = 3.0 \text{ V}$:

$$E_{\text{net}} = 4 \times 3.0 \text{ V} = 12.0 \text{ V}$$

Why other options are incorrect:

- Option B:** 3.0 V is the net emf if the cells were connected in parallel.
- Option C:** 9.0 V represents the sum of only three cells.
- Option D:** 1.33 V results from incorrect reciprocal addition.

Question #161 Key: (A)PHYSICS
02. Force & Motion

According to Newton's second law of motion, the time rate of change of linear momentum of a bod...

CORE CONCEPT & DERIVATION

Newton's second law defines net force as the time rate of change of momentum of a mass system.

Formula / Rule / Reaction:

$$\vec{F}_{\text{net}} = \frac{d\vec{p}}{dt} = \frac{d(m\vec{v})}{dt} = m\vec{a} \quad (\text{for constant mass})$$

Solution:

- Linear momentum is $\vec{p} = m\vec{v}$.
- The time derivative $d\vec{p}/dt$ represents the unbalanced net force acting on the body.

Why other options are incorrect:

- Option B:** The time rate of doing work equals power ($P = dW/dt$).
- Option C:** Net torque equals the time rate of change of angular momentum ($\vec{\tau} = d\vec{L}/dt$).
- Option D:** Moment of inertia measures rotational inertia, not the rate of change of linear momentum.

Question #162 Key: (B)PHYSICS
05. Waves

Which proportional relationship represents the fundamental defining criterion for simple harmon...

CORE CONCEPT & DERIVATION

Simple harmonic motion requires an acceleration directly proportional to displacement and directed toward the equilibrium position.

Formula / Rule / Reaction:

$$F = -kx \Rightarrow ma = -kx \Rightarrow a = -\left(\frac{k}{m}\right)x = -\omega^2 x \Rightarrow a \propto -x$$

Solution:

- In SHM, restoring acceleration is directly proportional to displacement from equilibrium (x).
- The negative sign indicates that acceleration is always directed back toward the mean equilibrium position, opposite to displacement.

Why other options are incorrect:

- Option A:** Omitting the negative sign describes unstable divergent motion away from equilibrium.
- Option C:** A non-linear displacement dependence results in anharmonic oscillation.
- Option D:** Acceleration proportional to velocity describes damped motion or terminal drag.

Question #163 Key: (B)PHYSICS
04. Rotational & Circular Motion

A body moves in a circular path of radius [Formula] with constant speed and period [Formula]...

CORE CONCEPT & DERIVATION

Centripetal acceleration is directed toward the center of curvature and can be formulated in terms of orbital period.

Formula / Rule / Reaction:

$$v = \frac{2\pi r}{T}, \quad a_c = \frac{v^2}{r}$$

Solution:

- Substitute the orbital speed expression into the centripetal acceleration formula:

$$a_c = \frac{(2\pi r/T)^2}{r} = \frac{4\pi^2 r^2/T^2}{r} = \frac{4\pi^2 r}{T^2}$$

Why other options are incorrect:

- Option A:** This expression has incorrect dimensions and lacks π^2 and T^2 .
- Option C:** $4\pi r/T$ represents speed, not acceleration.
- Option D:** Retaining r^2 in the numerator fails to cancel the radial denominator.

Question #164 Key: (A)PHYSICS
15. Atomic Spectra

According to the Bohr model of the hydrogen atom, the kinetic energy of the electron in its gro...

CORE CONCEPT & DERIVATION

By the virial theorem for Coulombic systems, kinetic energy is positive and equals the absolute value of total energy.

Formula / Rule / Reaction:

$$E_{\text{total}} = -13.6 \text{ eV}, \quad U = 2E_{\text{total}} = -27.2 \text{ eV}$$

$$K = -E_{\text{total}} = -(-13.6 \text{ eV}) = +13.6 \text{ eV}$$

Solution:

- Total mechanical energy in the ground state is $E_1 = -13.6 \text{ eV}$.
- Because mass and velocity squared are positive quantities, kinetic energy is strictly positive: $K = \frac{1}{2}mv^2 = +13.6 \text{ eV}$.

Why other options are incorrect:

- Option B:** -13.6 eV represents total mechanical energy, not kinetic energy.
- Option C:** +27.2 eV is the magnitude of the potential energy ($U = -27.2 \text{ eV}$).
- Option D:** 13.6 J is unphysically large for a single atom ($1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$).

Question #165 Key: (D)PHYSICS
11. Electromagnetic Induction

Lenz's law of electromagnetic induction is a direct manifestation of which fundamental conserva...

CORE CONCEPT & DERIVATION

The induced current must oppose the flux change that creates it to prevent self-generating energy without mechanical input.

Formula / Rule / Reaction:

$$\text{Work done against magnetic opposition} = \text{Electrical energy generated}$$

Solution:

- If an induced current aided rather than opposed the flux change, a minor initial push would create unbounded magnetic fields and infinite energy.
- Therefore, mechanical work must be expended against the opposing magnetic force to generate electrical energy, fulfilling the law of conservation of energy.

Why other options are incorrect:

- **Option A:** Conservation of charge underlies Kirchhoff's current law, not the directional opposition of induced emf.
- **Option B:** Conservation of linear momentum governs collision dynamics.
- **Option C:** Conservation of angular momentum applies to torque-free rotational systems.

Question #166 Key: (D)PHYSICS
03. Work & Energy

The mechanical power (rate of doing work) exerted by a force [Formula] on an object moving with...

CORE CONCEPT & DERIVATION

Instantaneous mechanical power is the scalar dot product of the applied force vector and velocity vector.

Formula / Rule / Reaction:

$$P = \frac{dW}{dt} = \vec{F} \cdot \vec{v} = Fv \cos \theta$$

Solution:

- When force acts perpendicular to velocity, $\theta = 90^\circ$.
- Because $\cos(90^\circ) = 0$, the rate of doing work is zero ($P = 0$), as seen in uniform circular motion under centripetal forces.

Why other options are incorrect:

- **Option A:** At $\theta = 0^\circ$, $\cos(0^\circ) = 1$, giving maximum positive power.
- **Option B:** At $\theta = 45^\circ$, $P = 0.707Fv \neq 0$.
- **Option C:** At $\theta = 60^\circ$, $P = 0.5Fv \neq 0$.

Question #167 Key: (D)PHYSICS
16. Nuclear Physics

The half-life ([Formula]) of a radioactive nuclide is related to its decay constant ([Formul...

CORE CONCEPT & DERIVATION

Half-life is the time required for half of the initial radioactive nuclei in a sample to undergo decay.

Formula / Rule / Reaction:

$$N(t) = N_0 e^{-\lambda t} \Rightarrow \frac{N_0}{2} = N_0 e^{-\lambda T_{1/2}} \Rightarrow T_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda}$$

Solution:

- Taking the natural logarithm of both sides gives $\ln(1/2) = -\lambda T_{1/2}$.
- Simplifying with $\ln 2 \approx 0.693$ yields $T_{1/2} = 0.693/\lambda$.

Why other options are incorrect:

- **Option A:** Multiplying by λ gives units of s^{-2} , which is dimensionally incorrect for time.
- **Option B:** Inverting the relationship is algebraically incorrect.
- **Option C:** Half-life scales with λ^{-1} , not its square root.

Question #168 Key: (D)PHYSICS
08. Electrostatics

Two identical positive point charges of 1.0 C each are placed in vacuum separated by a distance...

CORE CONCEPT & DERIVATION

Coulomb's law defines the electrostatic force between two stationary point charges in free space.

Formula / Rule / Reaction:

$$F = k \frac{|q_1 q_2|}{r^2} \quad (k = \frac{1}{4\pi\epsilon_0} \approx 8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2)$$

Solution:

- Substitute $q_1 = 1.0 \text{ C}$, $q_2 = 1.0 \text{ C}$, and $r = 1.0 \text{ m}$:

$$F = (9.0 \times 10^9) \frac{(1.0)(1.0)}{(1.0)^2} = 9.0 \times 10^9 \text{ N}$$

Why other options are incorrect:

- **Option A:** 1.0 N ignores Coulomb's constant k .
- **Option B:** 8.85×10^{-12} corresponds to the value of vacuum permittivity ϵ_0 .
- **Option C:** 6.67×10^{-11} corresponds to Newton's universal gravitational constant G .

Question #169 Key: (A)PHYSICS
16. Nuclear Physics

In the historic nuclear transmutation reaction [Formula], the emitted particle [Formula] is a/...

CORE CONCEPT & DERIVATION

Nuclear reactions must satisfy conservation of both total nucleon number (mass number A) and total atomic charge (atomic number Z).

Formula / Rule / Reaction:

$$\sum A_{\text{reactants}} = \sum A_{\text{products}}, \quad \sum Z_{\text{reactants}} = \sum Z_{\text{products}}$$

Solution:

- Conservation of mass number: $14 + 4 = 17 + A_X \Rightarrow 18 = 17 + A_X \Rightarrow A_X = 1$.
- Conservation of atomic number: $7 + 2 = 8 + Z_X \Rightarrow 9 = 8 + Z_X \Rightarrow Z_X = 1$.
- The particle with $A = 1$ and $Z = 1$ is a proton (${}^1_1\text{H}$ or p), as demonstrated in Rutherford's transmutation experiment.

Why other options are incorrect:

- **Option B:** A neutron has $Z = 0$, which fails the atomic number balance ($8 + 0 \neq 9$).
- **Option C:** A beta particle has $A = 0$ and $Z = -1$, failing both conservation sums.
- **Option D:** An alpha particle has $A = 4$ and $Z = 2$, which corresponds to the projectile rather than the product.

Question #170 Key: (A)PHYSICS
13. Electronics

To reduce the width of the depletion layer and lower the potential barrier of a p-n junction di...

CORE CONCEPT & DERIVATION

Forward biasing applies an external electric field opposing the built-in junction potential, driving majority carriers across the barrier.

Formula / Rule / Reaction:

$$V_{\text{net}} = V_{\text{barrier}} - V_{\text{forward}} \Rightarrow \text{Depletion width decreases}$$

Solution:

- In forward biasing, the positive battery terminal connects to the p-type material and the negative terminal to the n-type material.
- This repels majority carriers toward the junction, neutralizing immobilized border ions and narrowing the depletion region to permit conduction.

Why other options are incorrect:

- **Option B:** Reverse biasing pulls majority carriers away from the junction, widening the depletion layer and increasing the barrier height.
- **Option C:** Zero bias leaves the built-in equilibrium depletion width unchanged.
- **Option D:** Breakover voltage triggers avalanche or Zener breakdown under high reverse stress.

Question #171 Key: (C)PHYSICS
10. Electromagnetism

A charged particle of mass [Formula] and charge [Formula] enters a magnetic field [Formula] wit...

CORE CONCEPT & DERIVATION

Only the velocity component perpendicular to magnetic field lines experiences a centripetal deflecting force.

Formula / Rule / Reaction:

$$v_{\perp} = v \sin \theta, \quad F_c = \frac{mv^2}{r} = qv_{\perp}B \Rightarrow r = \frac{mv_{\perp}}{qB}$$

Solution:

- Decompose velocity into components: parallel ($v_{\parallel} = v \cos \theta$) and perpendicular ($v_{\perp} = v \sin \theta$).
- Because only $v_{\perp}$ drives circular motion around the field lines, substitute $v_{\perp} = v \sin \theta$ to get $r = \frac{mv \sin \theta}{qB}$.

Why other options are incorrect:

- **Option A:** $mv/(qB)$ applies only when the velocity is entirely perpendicular to the field ($\theta = 90^\circ$).
- **Option B:** $v \cos \theta$ is the parallel velocity component, which determines the pitch of the helix rather than its radius.
- **Option D:** Inverting the expression yields units of reciprocal meters.

Question #172 Key: (C)PHYSICS
07. Thermodynamics

The specific heat capacity of a substance in SI units is measured in:

CORE CONCEPT & DERIVATION

Specific heat capacity measures the heat energy required to raise the temperature of a unit mass of material by one kelvin.

Formula / Rule / Reaction:

$$Q = mc\Delta T \Rightarrow c = \frac{Q}{m\Delta T} \Rightarrow \frac{\text{Joules}}{(\text{kg})(\text{K})} = \text{J} \cdot \text{kg}^{-1} \cdot \text{K}^{-1}$$

Solution:

- Heat energy Q is in joules (J), mass m is in kilograms (kg), and temperature change ΔT is in kelvins (K).
- Combining these gives the SI unit: $\text{J} \cdot \text{kg}^{-1} \cdot \text{K}^{-1}$.

Why other options are incorrect:

- **Option A:** $\text{J} \cdot \text{kg} \cdot \text{K}$ multiplies the quantities rather than dividing by mass and temperature.
- **Option B:** $\text{J} \cdot \text{kg}^{-1}$ is the unit of specific latent heat.
- **Option D:** $\text{J} \cdot \text{K}^{-1}$ is the unit of total heat capacity.

Question #173 Key: (D)PHYSICS
07. Thermodynamics

The mathematical formulation of the first law of thermodynamics relating change in internal ene...

CORE CONCEPT & DERIVATION

The first law of thermodynamics states that the net change in a system's internal energy equals heat absorbed minus work performed by the system.

Formula / Rule / Reaction:

$$\Delta Q = \Delta U + \Delta W \Rightarrow \Delta U = \Delta Q - \Delta W$$

Solution:

- When heat ΔQ is added to a thermodynamic system, part of it increases internal energy (ΔU) and the remainder performs work (ΔW).
- Rearranging gives the change in internal energy: $\Delta U = \Delta Q - \Delta W$.

Why other options are incorrect:

- Option A:** Work done equals heat added minus internal energy change ($\Delta W = \Delta Q - \Delta U$).
- Option B:** Heat added must equal the sum of internal energy change and work done ($\Delta Q = \Delta U + \Delta W$).
- Option C:** This expression has the signs inverted, violating conservation of energy.

Question #174 Key: (B)PHYSICS
04. Rotational & Circular Motion

The angular momentum of a rotating body increases uniformly from 0 to [Formula] in a time inter...

CORE CONCEPT & DERIVATION

Torque is the rotational analog of force, defined as the time rate of change of angular momentum.

Formula / Rule / Reaction:

$$\tau_{\text{avg}} = \frac{\Delta L}{\Delta t} = \frac{L_f - L_i}{\Delta t}$$

Solution:

- Substitute $L_i = 0$, $L_f = 720 \text{ J} \cdot \text{s}$, and $\Delta t = 4.0 \text{ s}$:

$$\tau = \frac{720 \text{ J} \cdot \text{s} - 0}{4.0 \text{ s}} = 180 \text{ N} \cdot \text{m}$$

Why other options are incorrect:

- Option A:** $2880 \text{ N} \cdot \text{m}$ results from multiplying 720×4 instead of dividing.
- Option C:** $360 \text{ N} \cdot \text{m}$ corresponds to an elapsed time of 2.0 seconds.
- Option D:** $90 \text{ N} \cdot \text{m}$ corresponds to an elapsed time of 8.0 seconds.

Question #175 Key: (B)PHYSICS
05. Waves

An aircraft traveling through the atmosphere at a speed exceeding the local speed of sound ([F...

CORE CONCEPT & DERIVATION

Flight speed regimes are classified by the Mach number ($M = v/v_{\text{sound}}$) relative to the ambient speed of sound.

Formula / Rule / Reaction:

$$\text{Mach Number } (M) = \frac{v}{c_s} \Rightarrow M > 1 = \text{Supersonic}$$

Solution:

- Speeds below the speed of sound ($M < 1$) are subsonic.
- Speeds exceeding the speed of sound ($M > 1$) are classified as supersonic, creating shock waves and sonic booms.

Why other options are incorrect:

- Option A:** Subsonic refers to speeds below the speed of sound ($M < 1$).
- Option C:** Infrasonic describes acoustic sound waves with frequencies below the human auditory threshold ($< 20 \text{ Hz}$).
- Option D:** Ultrasonic describes acoustic sound waves with frequencies above the human auditory threshold ($> 20 \text{ kHz}$).

Question #176 Key: (C)PHYSICS
08. Electrostatics

A dielectric slab with a relative permittivity of [Formula] is inserted between the parallel pl...

CORE CONCEPT & DERIVATION

Inserting a dielectric between capacitor plates reduces the internal electric field, increasing capacitance by a factor of ϵ_r .

Formula / Rule / Reaction:

$$C = \epsilon_r C_0$$

Solution:

- With a relative permittivity of $\epsilon_r = 2.0$, the new capacitance becomes:

$$C = 2.0 \times C_0 = 2.0 \times 20 \mu\text{F} = 40 \mu\text{F}$$
- Therefore, the capacitance is doubled.

Why other options are incorrect:

- Option A:** Capacitance increases whenever a polarizable dielectric medium replaces air.
- Option B:** Capacitance increases rather than decreases when a dielectric is introduced.
- Option D:** Fourfold increase requires a dielectric constant of $\epsilon_r = 4.0$.

Question #177 Key: (C)ENGLISH
03. Parts of Speech, Prepositions & Modifiers

Fill in the blank with the appropriate preposition: We saw an exciting cricket match _____ at....

CORE CONCEPT & DERIVATION

The preposition 'at' is used to specify precise venues, public locations, and event sites.

Formula / Rule / Reaction:

Rule: Use 'at' for designated geographical points, facilities, and sporting venues.

Solution:

- A stadium functions as a specific event venue, requiring 'at': 'at the school stadium'.
- 'In' can describe being inside the enclosed boundary, but 'at' designates attendance at an event site.

Why other options are incorrect:

- **Option A:** 'Over' implies physical suspension or movement above an object.
- **Option B:** 'Of' denotes possession, association, or origin.
- **Option D:** 'On' implies being on top of a surface rather than attending a venue.

Question #178 Key: (C)ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

Select the correct verb form to complete the sentence: I _____ an appointment with the dentist...

CORE CONCEPT & DERIVATION

The temporal adverb 'soon' indicates an action that will take place in the near future, requiring future tense.

Formula / Rule / Reaction:

$\text{[Subject]} + \text{[will]} + \text{[Base Verb (V}_1\text{)]}$ $\rightarrow$ $\text{[Simple Future Tense]}$

Solution:

- The time marker 'soon' establishes a future event.
- 'Will make' provides the grammatically correct simple future construction.

Why other options are incorrect:

- **Option A:** 'Making' is a present participle that requires an auxiliary verb (e.g., 'am making') to form a predicate.
- **Option B:** 'Had make' combines past perfect 'had' with an uninflected base verb, violating past participle requirements.
- **Option D:** 'Made' is past tense, which conflicts with the future marker 'soon'.

Question #179 Key: (B)ENGLISH
05. Active-Passive Voice, Reported Speech & Syntax

Identify the segment containing a grammatical error in the sentence: Due to (A) his negligence ...

CORE CONCEPT & DERIVATION

When 'fail' means to be unsuccessful in a test or course, it functions transitively and takes a direct object without a preposition.

Formula / Rule / Reaction:

Correct: fail + [direct object exam/test] $\rightarrow$ Incorrect: fail in + [exam]

Solution:

- In standard academic English, one says 'failed the examination', not 'failed in the examination'.
- The preposition 'in' is redundant; the corrected sentence reads: 'Due to his negligence, he failed the examination.'

Why other options are incorrect:

- **Option A:** 'Due to' is a correct prepositional phrase introducing the cause of the failure.
- **Option C:** 'His negligence' is a grammatically sound noun phrase acting as the object of 'due to'.
- **Option D:** 'He failed' provides the correct subject and past-tense transitive verb.

Question #180 Key: (A)ENGLISH
06. Punctuation, Capitalization & Reading Comprehension

Which sentence employs capital letters correctly according to standard conventions?

CORE CONCEPT & DERIVATION

The first-person nominative pronoun 'I' and proper nouns designating specific countries must always be capitalized.

Formula / Rule / Reaction:

Rule: Capitalize the first word of a sentence, pronoun 'I', and proper nouns (names, countries, nationalities).

Solution:

- 'I' is capitalized as the sentence-initial first-person pronoun.
- 'China' is capitalized as a proper noun denoting a sovereign nation. Prepositions ('to') and participles ('moving') remain lowercase.

Why other options are incorrect:

- **Option B:** The preposition 'to' is incorrectly capitalized, and the proper noun 'china' is in lowercase.
- **Option C:** The initial pronoun 'i' is incorrectly written in lowercase.
- **Option D:** The common verb 'Moving' is unnecessarily capitalized, and 'china' is in lowercase.

Question #181 Key: (A)ENGLISH
03. Parts of Speech, Prepositions & Modifiers

Fill in the blanks with the appropriate indefinite articles: To climb _____ tree is not to c...

CORE CONCEPT & DERIVATION

The indefinite article 'a' is placed before singular, non-specific countable nouns that begin with a consonant sound.

Formula / Rule / Reaction:

'a' + consonant sound (/t/ in tree, /m/ in mountain)

Solution:

- 'Tree' begins with the consonant sound /t/, requiring the indefinite article 'a'.
- 'Mountain' begins with the consonant sound /m/, requiring the indefinite article 'a'. The parallel structure reads: 'To climb a tree is not to climb a mountain.'

Why other options are incorrect:

- **Option B:** 'An' is used only before initial vowel sounds.
- **Option C:** 'An' cannot precede 'mountain' because it begins with the consonant sound /m/.
- **Option D:** 'The' implies a specific tree, which alters the generic comparative meaning of the proverb.

Question #182 Key: (D)ENGLISH
03. Parts of Speech, Prepositions & Modifiers

Identify the correct replacement for the underlined segment: I've lived in Barcelona since six ...

CORE CONCEPT & DERIVATION

In present perfect structures, 'for' denotes an extended duration of time, while 'since' marks a specific starting point.

Formula / Rule / Reaction:

for + duration of time (e.g., six years) vs. since + starting time point (e.g., 2016)

Solution:

- 'Six years' is a duration rather than a specific starting point on the calendar.
- Therefore, 'since' must be replaced by 'for': 'I've lived in Barcelona for six years.'

Why other options are incorrect:

- **Option A:** 'Has six years' is ungrammatical following a location.
- **Option B:** 'Since six years ago' is redundant and non-standard compared to 'for six years'.
- **Option C:** 'At six years' implies an age milestone, not an elapsed duration of residence.

Question #183 Key: (C)ENGLISH
01. Vocabulary, Synonyms, Antonyms & Spelling

Select the option displaying the correct orthographic spelling of the word:

CORE CONCEPT & DERIVATION

Standard English orthography for this administrative noun features double 'm', double 't', and double 'e'.

Formula / Rule / Reaction:

C - O - M - M - I - T - T - E - E

Solution:

- The word 'Committee' derives from Anglo-French and contains three pairs of doubled letters: double 'm', double 't', and double 'e'.

Why other options are incorrect:

- **Option A:** 'Comittee' incorrectly omits one 'm'.
- **Option B:** 'Commitee' incorrectly omits one 't'.
- **Option D:** 'Committey' incorrectly ends in '-ey'.

Question #184 Key: (C)ENGLISH
06. Punctuation, Capitalization & Reading Comprehension

Complete the sentence using the correct possessive form: To _____, Anne was on time for her ...

CORE CONCEPT & DERIVATION

Singular indefinite pronouns form their possessive case by adding an apostrophe followed by an 's' ('s).

Formula / Rule / Reaction:

Indefinite pronoun (everybody) + 's + noun (surprise)

Solution:

- 'Everybody' is a singular indefinite pronoun.
- Its possessive form takes an apostrophe before the 's': 'everybody's surprise'.

Why other options are incorrect:

- **Option A:** 'Everybodys' places the apostrophe after the 's', which is used for regular plural nouns ending in 's'.
- **Option B:** 'Everybody surprise' omits the possessive marker entirely.
- **Option D:** 'Every-body' is hyphenated non-standardly and lacks the possessive apostrophe.

Question #185 Key: (C)

06. Punctuation, Capitalization & Reading Comprehension

ENGLISH

Select the sentence that contains a clear grammatical error in tense or syntax:

CORE CONCEPT & DERIVATION

Clauses joined within a narrative past-tense context must maintain consistent verb tense and appropriate prepositions.

Formula / Rule / Reaction:

Tense harmony: Past dependent clause ('went') + Past main clause ('wore')

Solution:

- Sentence C shifts from present 'go' to past 'wore', and omits the required directional preposition 'to' after 'go'.
- Corrected version: 'When I went to the museum, I wore comfortable shoes.'

Why other options are incorrect:

- **Option A:** 'She showed us five different shades of blue paint' is fully grammatical.
- **Option B:** 'She was approached, but she declined the offer' demonstrates correct compound passive-active voice coordination.
- **Option D:** 'There are seven floors in this building' correctly matches plural subject 'seven floors' with the plural verb 'are'.

Question #186 Key: (A)

04. Subject-Verb Agreement, Tenses & Conditionals

ENGLISH

Identify the segment containing an error in subject-verb agreement: Scientist now hope (A) that...

CORE CONCEPT & DERIVATION

A third-person singular noun subject requires a singular verb ending in '-s', while a plural subject takes an uninflected base verb.

Formula / Rule / Reaction:

Singular: A scientist hopes \quad vs. \quad Plural: Scientists hope

Solution:

- The error is in Option A ('Scientist now hope'). The subject 'Scientist' is singular, but the verb 'hope' is plural.
- To correct the agreement, either the subject must be pluralized ('Scientists now hope') or the verb must take the singular ending ('A scientist now hopes').

Why other options are incorrect:

- **Option B:** 'Successfully be conducted' is a correct passive modal infinitive construction.
- **Option C:** 'In the near future' is an established prepositional time phrase.
- **Option D:** An error exists in Option A, so 'No error' is incorrect.

Question #187 Key: (A)

03. Parts of Speech, Prepositions & Modifiers

ENGLISH

Fill in the blanks with the correct articles: _____ apple _____ day keeps _____ doctor...

CORE CONCEPT & DERIVATION

Use 'an' before initial vowel sounds, 'a' before singular time units, and 'the' before nouns representing a generic class.

Formula / Rule / Reaction:

'An' + vowel sound (/æ/ in apple) \quad + \quad 'a' + day \quad + \quad 'the' + doctor

Solution:

- 'Apple' begins with the short vowel sound /æ/, requiring 'An'.
- 'Day' is a singular non-specific countable unit, requiring 'a'.
- 'Doctor' refers to the medical profession in a generic sense, taking the definite article 'the': 'An apple a day keeps the doctor away.'

Why other options are incorrect:

- **Option B:** 'The apple' incorrectly specifies a particular fruit rather than any generic apple.
- **Option C:** 'The day' incorrectly refers to a specific calendar day.
- **Option D:** 'A apple' violates the requirement for 'an' before vowel sounds.

Question #188 Key: (B)

03. Parts of Speech, Prepositions & Modifiers

ENGLISH

Fill in the blank with the appropriate preposition: She climbed _____ the ladder to paint th...

CORE CONCEPT & DERIVATION

The directional preposition 'up' indicates movement from a lower to a higher position along a vertical structure.

Formula / Rule / Reaction:

Verb of motion (climb) + directional preposition (up) + structural noun (the ladder)

Solution:

- Ascending a ladder involves upward vertical motion, which is expressed by the phrasal combination 'climbed up the ladder'.

Why other options are incorrect:

- **Option A:** 'Climbed to the ladder' implies moving toward the ladder from elsewhere, not ascending its rungs.
- **Option C:** 'Of' denotes possession or origin, which is ungrammatical with 'climbed'.
- **Option D:** 'In' implies entering an enclosed interior, which does not apply to a ladder.

Question #189 Key: (A)

O4. Subject-Verb Agreement, Tenses & Conditionals

ENGLISH

Complete the sentence using the appropriate verb tenses: Charles _____ his father in the farm...

CORE CONCEPT & DERIVATION

Present continuous describes a temporary action in progress, while simple present describes scheduled calendar events.

Formula / Rule / Reaction:

Temporary activity: Present continuous (is helping) + Scheduled future event: Simple present (starts)

Solution:

- 'Is helping' indicates that Charles is working at the shop temporarily during the break.
- In temporal subordinate clauses introduced by 'until', scheduled future events use the simple present tense ('starts'), not the future tense.

Why other options are incorrect:

- **Option B:** 'Helped, was starting' places the action in the past, conflicting with 'next month'.
- **Option C:** 'Has helped, is starting' is unidiomatic in an 'until' time clause.
- **Option D:** Subordinate time clauses introduced by 'until' do not take modal 'will'.

Question #191 Key: (D)

O4. Subject-Verb Agreement, Tenses & Conditionals

ENGLISH

Select the appropriate non-finite verb form to complete the sentence: One must consider all evil...

CORE CONCEPT & DERIVATION

Prepositions that govern verbs require the gerund form (the '-ing' form functioning as a noun).

Formula / Rule / Reaction:

Preposition (before) + Gerund (verb + ing)

Solution:

- 'Before' acts here as a preposition introducing a temporal phrase.
- Prepositions govern nouns, pronouns, or gerunds, making 'deciding' the grammatically correct choice.

Why other options are incorrect:

- **Option A:** 'Decided' is a past-tense finite verb or past participle that cannot serve as the direct object of 'before'.
- **Option B:** 'Decides' is a finite third-person present verb requiring a nominative subject.
- **Option C:** 'Decide' is a bare infinitive and cannot follow a preposition.

Question #190 Key: (D)

O4. Subject-Verb Agreement, Tenses & Conditionals

ENGLISH

Fill in the blank with the grammatically correct auxiliary verb: The teacher _____ completed...

CORE CONCEPT & DERIVATION

A third-person singular subject requires the singular auxiliary 'has' to form the present perfect tense.

Formula / Rule / Reaction:

Singular Subject (The teacher) + has + Past Participle (completed)

Solution:

- 'The teacher' is a singular third-person noun.
- It requires the singular auxiliary 'has' to form the present perfect tense with the past participle 'completed'.

Why other options are incorrect:

- **Option A:** 'Have' is plural and causes a subject-verb agreement error with 'The teacher'.
- **Option B:** 'Are completed' forms a passive construction that incorrectly treats 'The teacher' as the entity being completed.
- **Option C:** 'Were' is plural and past tense, causing both number and voice errors.

Question #192 Key: (B)

O6. Punctuation, Capitalization & Reading Comprehension

ENGLISH

Read the following passage to answer the question: 'But man is not destined to vanish. He can b...

CORE CONCEPT & DERIVATION

A passage title must capture the central thesis without being overly broad or focused on a single supporting detail.

Formula / Rule / Reaction:

Central Thesis = Humanity's innate will to survive prevents nations from using destructive weapons.

Solution:

- The author argues that despite building deadly weapons and escalating tensions, nations step back from the brink because human survival instincts prevail.
- 'Man's Desire to Survive Inhibits the Use of Deadly Weapons' accurately reflects this core argument.

Why other options are incorrect:

- **Option A:** The economic cost of weapons is mentioned only in passing to emphasize their destructive scale.
- **Option C:** Superpower confrontation is the contextual backdrop, not the central thesis.
- **Option D:** The author directly rejects this view, stating that man is not destined to vanish.

Question #193 Key: (C)ENGLISH
06. Punctuation, Capitalization & Reading Comprehension

Read the passage below: 'But man is not destined to vanish. He can be killed, but he cannot be ...'

CORE CONCEPT & DERIVATION

The primary conclusion is the author's ultimate claim, supported by the evidence and reasoning presented in the text.

Formula / Rule / Reaction:

Premise: Man is not destined to vanish + Nations withdraw from the brink \implies Conclusion: Humanity will survive.

Solution:

- The passage begins with 'man is not destined to vanish' and ends by noting that nations withdraw from the brink of conflict.
- The author's main point is that human society will endure despite the looming threat of nuclear annihilation.

Why other options are incorrect:

- Option A:** The author expresses confidence in human survival rather than viewing the future as uncertain.
- Option B:** The author observes that nations actively seek ways to ensure weapons are never used.
- Option D:** Economic trade in weapons is never discussed in the text.

Question #194 Key: (D)ENGLISH
01. Vocabulary, Synonyms, Antonyms & Spelling

In the context of the passage, the word 'irrepressible' most nearly means:

CORE CONCEPT & DERIVATION

Contextual vocabulary requires determining word meaning from its morphological roots and surrounding rhetorical context.

Formula / Rule / Reaction:

Prefix 'ir-' (not) + 'repress' (hold back/subdue) + suffix '-ible' (capable of) = incapable of being restrained.

Solution:

- 'Irrepressible' describes an inner drive or spirit that cannot be held back, controlled, or defeated.
- In this context, it emphasizes that humanity's resilience cannot be crushed by destructive weapons, making 'unrestrainable' the correct synonym.

Why other options are incorrect:

- Option A:** 'Harmful' means causing injury or damage.
- Option B:** 'Incompatible' means incapable of existing together harmoniously.
- Option C:** 'Oppressive' means burdensome, harsh, or tyrannical.

Question #195 Key: (B)LOGICAL REASONING
13. Blood Relations & Kinship

P, Q, R, S, and T are members of a family. P is the daughter of Q; Q is the son of R; R is the ...

CORE CONCEPT & DERIVATION

Deductive family relationship logic tracks lineage, gender, and generational tiers across defined relational premises.

Formula / Rule / Reaction:

$R \text{ (male, Generation 1)} \rightarrow Q \text{ (male, Generation 2)} \rightarrow P \text{ (female, Generation 3)}$

Solution:

- Premise 1: R is the father of Q (Q is the son of R).
- Premise 2: Q is the parent of P (P is the daughter of Q).
- Because R is the male parent of P's father Q, R is the paternal grandfather of P.

Why other options are incorrect:

- Option A:** R is two generations above P, making him her grandfather, not her uncle.
- Option C:** P and R belong to different generations and cannot be sisters.
- Option D:** Q and S are siblings (both children of R), so Q cannot be the daughter of S.

Question #196 Key: (D)LOGICAL REASONING
08. Letter Series & Coding-Decoding

Identify the next alphanumeric term in the sequential pattern: 7C, 10F, 14J, 19O, ?

CORE CONCEPT & DERIVATION

Alphanumeric series follow paired mathematical and alphabetical progression rules across consecutive terms.

Formula / Rule / Reaction:

Numerical sequence: $+3, +4, +5, +6, \dots$

Alphabetical positions: C (3), F (6), J (10), O (15), ...

Solution:

- Numbers: $7 + 3 = 10$; $10 + 4 = 14$; $14 + 5 = 19$. The next difference is $+6$, giving $19 + 6 = 25$.
- Letters: C (position 3) $\xrightarrow{+3}$ F (6) $\xrightarrow{+4}$ J (10) $\xrightarrow{+5}$ O (15). The next shift is $+6$, giving alphabetical position $15 + 6 = 21$, which corresponds to the letter U.
- Combining both yields 25U.

Why other options are incorrect:

- Option A:** 23Q uses an incorrect increment of $+4$ for the number and $+2$ for the letter.
- Option B:** 26N increments the number by $+7$ and steps the letter backward.
- Option C:** 24P uses $+5$ and $+1$ instead of $+6$.

Question #197 Key: (C)LOGICAL REASONING
04. Argument Evaluation & Ethics

Most lucrative jobs in Pakistan require a university degree, but many emerging roles demand spe...

CORE CONCEPT & DERIVATION

In deductive reasoning, a valid conclusion must be directly supported by the text without introducing unsupported assumptions.

Formula / Rule / Reaction:

Premise: Basic skills in reading, communication, and mathematics are central to job placement and career development.

Solution:

- The passage states that basic competence in reading, communication, and mathematics is instrumental in securing jobs and advancing careers.
- Option C restates this point directly without adding unmentioned claims.

Why other options are incorrect:

- **Option A:** The passage notes that most lucrative jobs still require a university degree, directly contradicting this claim.
- **Option B:** The text does not recommend abandoning formal college education.
- **Option D:** The passage makes no mention of employment agencies taking over school instruction.

Question #198 Key: (B)LOGICAL REASONING
04. Argument Evaluation & Ethics

After seven years of proposals from the environmental department, the provincial legislature ha...

CORE CONCEPT & DERIVATION

Passing legislation is a regulatory prerequisite that requires operational enforcement to produce practical outcomes.

Formula / Rule / Reaction:

Statute passed $\Rightarrow$ Statutory potential exists $\Rightarrow$ Enforcement is necessary for real-world effect

Solution:

- The passage states that the legislation 'promises to be' effective based on its language.
- For a passed bill to realize its potential in practice, it must be actively implemented and enforced by executive authorities.

Why other options are incorrect:

- **Option A:** Passing a bill indicates that pollution remains an active problem requiring regulation, not that it is resolved.
- **Option C:** A law does not eliminate pollution automatically upon passage without implementation.
- **Option D:** The environmental department will be needed to oversee and execute the newly enacted standards.

Question #199 Key: (A)LOGICAL REASONING
01. Identifying Assumptions

Following the company election, the newly elected chairperson addressed the workforce: 'The res...

CORE CONCEPT & DERIVATION

An assumption is an unstated premise that must be true for the speaker's statement to remain meaningful and logically coherent.

Formula / Rule / Reaction:

Admonishing management 'not to dominate' presumes management has the capability to dominate if it chose to do so.

Solution:

- For it to be meaningful to direct management to serve rather than dominate, management must have the institutional capacity to exert dominance over the workforce.
- If management had no power to dominate, the admonition would be meaningless.

Why other options are incorrect:

- **Option B:** The chairperson explicitly rejects domination, treating it as an undesirable outcome rather than a virtue.
- **Option C:** Disbanding unions contradicts the collaborative message delivered to the workforce.
- **Option D:** The statement focuses on guiding future management conduct rather than validating past administrations.

Question #200 Key: (C)LOGICAL REASONING
04. Argument Evaluation & Ethics

Influenza spreads around the world rapidly due to commercial air travel. While patients with se...

CORE CONCEPT & DERIVATION

When pathogens can be transmitted by asymptomatic individuals, screening for active symptoms fails to prevent disease spread.

Formula / Rule / Reaction:

Problem: Transmission during asymptomatic incubation phase \implies Solution: Prior immunization that prevents infection and shedding.

Solution:

- The passage emphasizes that infected travelers fly before symptoms appear, rendering gate-based symptom checks ineffective.
- Mandating vaccination well in advance provides systemic immunity, preventing travelers from contracting and transmitting the virus during transit.

Why other options are incorrect:

- **Option A:** Restricting travel by age does not stop transmission among healthy adult carriers.
- **Option B:** Handwashing does not prevent airborne droplet transmission in an enclosed aircraft cabin.
- **Option D:** The passage notes that travelers fly before symptoms appear, so symptom screening at the gate misses incubating carriers.