

**BEAMBEPREP**

PAKISTAN ENTRANCE EXAMINATION ENGINE

**SCAN TO SOLVE LIVE**Timer, instant scoring, and  
percentile ranks on  
beambeprep.com

DUHS KARACHI

## DUHS Karachi MDCAT 2023 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-2023   Duration: 200 Minutes (3h 20m)

**200**

TOTAL QUESTIONS

**200m**

OFFICIAL DURATION

**+1 / 0.00**

ZERO NEGATIVE MARKING

**200**

MAXIMUM MARKS

### EXAMINATION BLUEPRINT & SUBJECT WEIGHTAGE

**Biology****68 MCQs**

34.0% weight

**Chemistry****54 MCQs**

27.0% weight

**Physics****54 MCQs**

27.0% weight

**English****18 MCQs**

9.0% weight

**Logical Reasoning****6 MCQs**

3.0% weight

## BIO SECTION: BIOLOGY

Questions 1 to 68 (68 MCQs)

Q1. BIO

Which of the following best characterizes the viruses with un-enveloped plus-strand RNA?

- (A) Lacking envelope
- (B) Having DNA
- (C) Act indirectly
- (D) Enveloped

Q2. BIO

Through which of the following animals does rabies predominantly spread to humans?

- (A) Cat
- (B) Fox
- (C) Dog
- (D) Pig

Q3. BIO

The type of hepatitis that passes vertically from mother to her child during pregnancy and childbirth is:

- (A) Hepatitis A
- (B) Hepatitis B
- (C) Hepatitis C
- (D) Hepatitis D

Q4. BIO

A virus enters the host body and produces DNA from an RNA template. Which enzyme is required for this process?

- (A) Transcriptase
- (B) Reverse transcriptase
- (C) Oxidoreductase
- (D) Ligase

Q5. BIO

Which of the following is the end product of alcoholic anaerobic respiration?

- (A) Methyl alcohol
- (B) Acetaldehyde
- (C) Formaldehyde
- (D) Ethyl alcohol

Q6. BIO

What is the primary physiological importance of the Krebs cycle?

- (A) Production of amino acids
- (B) Production of vitamins
- (C) Production of ATP molecules through oxidative phosphorylation
- (D) Production of pyruvic acid

Q7. BIO

The initial carbon dioxide acceptor in the Calvin cycle is:

- (A) RuBP
- (B) RuMP
- (C) PGA
- (D) PGAL

Q8. BIO

Anaerobic respiration, compared to aerobic respiration, produces:

- (A) More ATPs
- (B) Less ATPs
- (C) Equal ATPs
- (D) Does not produce ATPs

Q9. BIO

In carbohydrates, hydrogen and oxygen are mostly present in the ratio of 2:1, which is why they are historically called:

- (A) Carbon monoxide
- (B) Carbon dioxide
- (C) Hydrated carbons
- (D) Trioses

Q10. BIO

How much of a temperature rise ( $^{\circ}\text{C}$ ) is observed, as per the definition of specific heat capacity, when 1 calorie of heat energy is added to 1 gram of water?

- (A)  $1^{\circ}\text{C}$
- (B)  $2^{\circ}\text{C}$
- (C)  $3^{\circ}\text{C}$
- (D)  $10^{\circ}\text{C}$

Q11. BIO

Which chemical compound maintains approximately the same percentage (around 70%) in both bacterial and mammalian cells?

- (A) Carbohydrates
- (B) Proteins
- (C) Lipids
- (D) Water

Q12. BIO

Glyceraldehyde and dihydroxyacetone are classic examples of which group of carbohydrates?

- (A) Trioses
- (B) Tetroses
- (C) Pentoses
- (D) Hexoses

Q13. BIO

A compound formed by an ester bond between one molecule of fatty acid and one molecule of long-chain alcohol is classified as a:

- (A) Saturated acylglycerol
- (B) Unsaturated acylglycerol
- (C) Phospholipid
- (D) Wax

Q14. BIO

Lysozyme represents which basic structural level of proteins?

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

Q15. BIO

Which of the following compounds is regarded as the common precursor for the biosynthesis of steroid hormones like testosterone, progesterone, and estrogens?

- (A) Wax
- (B) Cholesterol
- (C) Phospholipid
- (D) Acylglycerol

**Q16. BIO**

Which organelle is designated as the powerhouse of the cell?

- (A) Ribosome
- (B) Golgi apparatus
- (C) Mitochondrion
- (D) Chloroplast

**Q17. BIO**

A phospholipid molecule has a hydrophilic head and two hydrophobic tails. Where are the fatty acid tails situated in the plasma membrane?

- (A) At the outer surface of the membrane
- (B) In the interior of the membrane
- (C) In the exterior aqueous medium
- (D) Spanning completely across the membrane

**Q18. BIO**

Which of the following congenital lysosomal storage diseases typically leads to progressive neurodegeneration and death by the age of three years?

- (A) Pompe disease
- (B) Gaucher disease
- (C) Tay-Sachs disease
- (D) Krabbe disease

**Q19. BIO**

Which of the following terms best describes the functional permeability of the plasma membrane?

- (A) Completely permeable
- (B) Impermeable
- (C) Freely permeable
- (D) Semipermeable

**Q20. BIO**

What is the cementing intercellular layer that holds the primary walls of two adjacent plant cells together called?

- (A) Primary cell wall
- (B) Secondary cell wall
- (C) Middle lamella
- (D) Plasma membrane

**Q21. BIO**

The structure and arrangement of membrane proteins embedded within a dynamic lipid bilayer was proposed by the:

- (A) Lock and key model
- (B) Induced fit model
- (C) Fluid mosaic model
- (D) Unit membrane model

**Q22. BIO**

Which of the following physiological functions is primarily associated with lysosomes?

- (A) Protein synthesis
- (B) Processing and packaging
- (C) Intracellular digestion
- (D) Lipid synthesis

**Q23. BIO**

Approximately how long does it take for a complete action potential cycle to occur in a typical neuron?

- (A) A few minutes
- (B) A few milliseconds
- (C) A few hours
- (D) A few seconds

**Q24. BIO**

Which specific part of the limbic system in the human brain is involved in the consolidation of short-term memory into long-term memory?

- (A) Hippocampus
- (B) Cerebellum
- (C) Cerebrum
- (D) Pons

**Q25. BIO**

A reflex arc that involves only a single sensory neuron and a single motor neuron with one central synapse is termed a:

- (A) Chemical synapse
- (B) Monosynaptic reflex
- (C) Polysynaptic reflex arc
- (D) Synaptic cleft

**Q26. BIO**

Which ion influx is required at the presynaptic terminal to trigger the exocytosis of neurotransmitter vesicles into the synaptic cleft?

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

**Q27. BIO**

Which of the following biological functions does dopamine serve in the human nervous system?

- (A) Transmission blocker
- (B) Neurotransmitter
- (C) General anesthetic
- (D) Sedative

**Q28. BIO**

Which major division of the human brain is responsible for higher cognitive functions such as conscious thought, reasoning, and abstract problem-solving?

- (A) Medulla oblongata
- (B) Cerebellum
- (C) Cerebrum
- (D) Hypothalamus

**Q29. BIO**

What stage of embryonic development is formed when the blastula folds inward (invaginates)?

- (A) Morula
- (B) Blastocoel
- (C) Blastopore
- (D) Gastrula

**Q30. BIO**

Which biological phenomenon describes a life cycle where an asexual form produces a sexual form and vice versa?

- (A) Colonial organization
- (B) Alternation of generations
- (C) Parasitism
- (D) Polymorphism

**Q31. BIO**

Which of the following represents the red coral reef material historically used by Hakeems in preparing eastern medicines?

- (A) Diamond
- (B) Emerald
- (C) Ruby
- (D) Marjan

**Q32. BIO**

Evolutionary progress toward the development of organ systems in cnidarians is first indicated by the presence of a gastrovascular cavity (enteron) and a:

- (A) Rudimentary network of nerves
- (B) Bilateral symmetry
- (C) Coelomic cavity
- (D) Organ-level organization

**Q33. BIO**

What is the optimum pH for the catalytic activity of pepsin in the human stomach?

- (A) 3.0
- (B) 2.0
- (C) 2.5
- (D) 1.4

**Q34. BIO**

At equilibrium, a scientist added more substrate and observed a transient increase in the reaction rate, which soon declined and remained unaffected by further substrate additions. What was the cause?

- (A) The enzyme ceased functioning permanently
- (B) Feedback inhibition due to accumulation of end product
- (C) Free enzyme active sites exceeded substrate molecules
- (D) The substrate molecules were degraded

**Q35. BIO**

Penicillin blocks the active site of the transpeptidase enzyme that bacteria use to cross-link peptidoglycan in their cell walls. This is an example of:

- (A) Competitive inhibition
- (B) Non-competitive inhibition
- (C) Feedback inhibition
- (D) Allosteric activation

**Q36. BIO**

The three-dimensional conformation and catalytic geometry of an enzyme's active site is altered when an inhibitor binds to a site other than the active site. This mechanism is called:

- (A) Irreversible substrate binding
- (B) Competitive reversible inhibition
- (C) Substrate-level phosphorylation
- (D) Non-competitive inhibition

**Q37. BIO**

A chemical substance that binds to an enzyme in place of the natural substrate but is not converted into a product is an:

- (A) Accelerator
- (B) Inhibitor
- (C) Coenzyme
- (D) Activator

**Q38. BIO**

Which of the following transitional fossil organisms provides definitive evidence for the evolutionary lineage connecting reptiles to birds?

- (A) Mammals
- (B) Fishes
- (C) Archaeopteryx
- (D) Arthropods

**Q39. BIO**

The ancient fossil bird Archaeopteryx possessed teeth, clawed wing fingers, and a long tail containing 20 vertebrae. These structural features demonstrate that birds evolved from:

- (A) Insects
- (B) Pisces
- (C) Amphibians
- (D) Reptiles

**Q40. BIO**

Artificial selection in animal and plant breeding provides compelling evidence for evolution. This process of human-guided selection is also known as:

- (A) Vestigial development
- (B) Domestication
- (C) Spontaneous mutation
- (D) Homology

**Q41. BIO**

Carolus Linnaeus, the renowned Swedish botanist and taxonomist, was an ardent proponent of which doctrine regarding the origin of species?

- (A) Catastrophism
- (B) Inheritance of acquired characteristics
- (C) Natural selection
- (D) Special creation

**Q42. BIO**

What is the total volume of blood pumped per minute by the left ventricle into the systemic circulation called?

- (A) Cardiac output
- (B) Stroke volume
- (C) Systolic volume
- (D) End-diastolic volume

**Q43. BIO**

Which digestive enzyme is synthesized and secreted in an inactive state (as a zymogen) to prevent the self-digestion of the cells producing it?

- (A) Lactase
- (B) Sucrase
- (C) Maltase
- (D) Pepsin

**Q44. BIO**

The carnivorous adaptation observed in insectivorous plants is primarily an evolutionary response to soils deficient in:

- (A) Nitrogen
- (B) Potassium
- (C) Sulphur
- (D) Calcium

**Q45. BIO**

In nutritional and ecological terms, the insectivorous plant sundew (*Drosera*) is categorized as:

- (A) Completely autotrophic
- (B) Exclusively heterotrophic
- (C) Holozoic
- (D) Partially autotrophic and partially heterotrophic

**Q46. BIO**

Which of the following statements is anatomically and functionally correct regarding the semilunar valves of the human heart?

- (A) Present in veins to prevent backward flow
- (B) Present in arteries to regulate jerks in pulsations
- (C) Present in capillaries to regulate the flow of blood
- (D) Present at the base of the aorta and pulmonary artery to prevent backflow into the ventricles

**Q47. BIO**

The average total lung capacity of an adult human is approximately 5 litres. What proportion or percentage of this capacity is represented by the vital capacity during maximum deep inspiration?

- (A) 10% (0.1)
- (B) 40% (0.4)
- (C) 60% (0.6)
- (D) 80% (0.8)

**Q48. BIO**

In ecological and trophic classification, the earthworm is classified as a:

- (A) Detritivore
- (B) Fluid feeder
- (C) Macrophagous predator
- (D) Microphagous suspension feeder

**Q49. BIO**

Photosynthetic sulfur bacteria utilize hydrogen sulfide ( $H_2S$ ) instead of water as an electron donor and consequently liberate:

- (A) Sulphur
- (B) Phosphorus
- (C) Calcium
- (D) Magnesium

**Q50. BIO**

Which of the following genetically engineered bacteria is widely utilized in biotechnology to produce human insulin and human growth hormone?

- (A) *Streptococcus pneumoniae*
- (B) *Escherichia coli*
- (C) *Rhizobium leguminosarum*
- (D) *Nostoc commune*

**Q51. BIO**

The bacterial cell wall is chemically composed of:

- (A) Cellulose and pectin
- (B) Cellulose and cutin
- (C) Hemicellulose and chitin
- (D) Amino acids and sugars

**Q52. BIO**

Which of the following extrachromosomal genetic elements serves as an essential vector in recombinant DNA technology?

- (A) Plastid
- (B) Plasmid
- (C) Nucleoid
- (D) Pilus

**Q53. BIO**

Membranous infoldings of the bacterial plasma membrane that assist in cell division and initiate DNA replication are called:

- (A) Mesosomes
- (B) Peroxisomes
- (C) Glyoxysomes
- (D) Nucleosomes

**Q54. BIO**

During human embryonic development, the testes originate inside the abdominal cavity. In which anatomical structure do they normally descend and reside before birth?

- (A) Peritoneal sac
- (B) Scrotum
- (C) Inguinal pouch
- (D) Seminal vesicle

**Q55. BIO**

During the process of ovulation, which anatomical structure captures and draws the secondary oocyte released from the ovary into the reproductive tract?

- (A) Oviducts
- (B) Uterus
- (C) Vagina
- (D) Ureter

**Q56. BIO**

Following ovulation, the collapsed, ruptured Graafian follicle transforms under the influence of luteinizing hormone into the:

- (A) Corpus callosum
- (B) Corpus albicans
- (C) Corpus luteum
- (D) Corpus atresia

**Q57. BIO**

In humans, rabbits, and other placental mammals, fertilization of the ovum typically takes place in the:

- (A) Ovary
- (B) Uterine cavity
- (C) Cervix
- (D) Fallopian tube

**Q58. BIO**

The corpus luteum in female mammals is located in the:

- (A) Brain, where it connects the cerebral hemispheres
- (B) Ovary, where it produces progesterone
- (C) Heart, where it initiates arterial contractions
- (D) Skin, where it acts as a mechanical receptor

**Q59. BIO**

In the human axial skeleton, the ribs are articulated to the thoracic vertebrae through:

- (A) Fixed (fibrous) joints
- (B) Freely movable (synovial ball-and-socket) joints
- (C) Suture joints
- (D) Partially movable (cartilaginous / gliding) joints

**Q60. BIO**

Which internal cavities are present at diarthrodial joints and contain a viscous fluid that reduces friction between articulating cartilages?

- (A) Synovial cavities
- (B) Cerebral ventricles
- (C) Acetabular notches
- (D) Pleural cavities

**Q61. BIO**

Which type of muscle tissue forms the tunica media of blood vessels and regulates their luminal diameter?

- (A) Smooth muscle
- (B) Striated skeletal muscle
- (C) Cardiac muscle
- (D) Voluntary muscle

**Q62. BIO**

When Gregor Mendel crossed two true-breeding homozygous pea plants with contrasting traits, the phenotype of the resulting  $F_1$  hybrid generation appeared to be:

- (A) That of the recessive parent
- (B) That of the dominant parent
- (C) An intermediate blending of both traits
- (D) A mosaic of half dominant and half recessive phenotypes

**Q63. BIO**

In a dihybrid cross between \**Pisum sativum*\* plants producing Yellow/Round seeds and Green/Wrinkled seeds, the  $F_2$  generation yields four distinct phenotypes in the ratio  $9/16 : 3/16 : 3/16 : 1/16$ . Which specific proportions confirm that independent assortment has occurred?

- (A)  $9/16$  and  $1/16$
- (B)  $6/16$  and  $3/16$
- (C)  $2/16$  and  $3/16$
- (D)  $3/16$  and  $3/16$

**Q64. BIO**

An orthopedic radiograph of a patient's stiff, crippled joint reveals erosion and hardening of articular cartilage due to abnormal calcium salt deposition. The patient is suffering from:

- (A) Disc slip
- (B) Spondylosis
- (C) Arthritis
- (D) Sciatica

**Q65. BIO**

Which of the following inherited disorders is characterized by a failure of the physiological blood clotting mechanism, leading to uncontrolled hemorrhage?

- (A) Color blindness
- (B) Hemophilia
- (C) Diabetes mellitus
- (D) Alkaptonuria

**Q66. BIO**

In human genetics, multiple allelism is classically demonstrated by the inheritance of:

- (A) ABO blood groups
- (B) Phenylketonuria
- (C) Color blindness
- (D) Sickle cell anemia

**Q67. BIO**

Polygenic inheritance, where multiple independent pairs of genes exert an additive effect on a single quantitative trait, forms the genetic basis of:

- (A) Codominance
- (B) Incomplete dominance
- (C) Continuous variation
- (D) Discontinuous variation

**Q68. BIO**

Mr. X and Mrs. X both possess the heterozygous genotype  $I^A i$  for the ABO blood group. What is the expected probability of their offspring possessing blood group 'A' and blood group 'O'?

- (A) Blood Group 'A' = 1.00, Blood Group 'O' = 0.00
- (B) Blood Group 'A' = 0.75, Blood Group 'O' = 0.25
- (C) Blood Group 'A' = 0.50, Blood Group 'O' = 0.50
- (D) Blood Group 'A' = 0.25, Blood Group 'O' = 0.75

## CHEM SECTION: CHEMISTRY

Questions 69 to 122 (54 MCQs)

Q69. CHEM

Which of the following chemical processes converts ethyl alcohol into acetaldehyde in the laboratory?

- (A) Polymerization
- (B) Dehydrogenation (or controlled oxidation)
- (C) Esterification
- (D) Catalytic hydrogenation

Q70. CHEM

Which organic product is predominantly formed when excess ethyl alcohol is heated with concentrated  $\text{H}_2\text{SO}_4$  at a low temperature ( $140^\circ\text{C}$ )?

- (A) Diethyl ether
- (B) Dimethyl ether
- (C) Ethene
- (D) Acetylene

Q71. CHEM

Which of the following compounds gives a positive iodoform test (yellow precipitate of  $\text{CHI}_3$ ) upon treatment with  $\text{I}_2$  and aqueous  $\text{Na}_2\text{CO}_3$ ?

- (A) Methanol
- (B) Acetic acid
- (C) Acetic anhydride
- (D) Acetone

Q72. CHEM

Which of the following organic carboxylic acids is formed when formaldehyde is oxidized with acidified potassium dichromate ( $\text{K}_2\text{Cr}_2\text{O}_7/\text{H}_2\text{SO}_4$ )?

- (A) Methanol
- (B) Methanoic acid
- (C) Acetone
- (D) Acetaldehyde

Q73. CHEM

Dry distillation of which of the following calcium salts of carboxylic acids produces acetone in the laboratory?

- (A) Calcium acetate
- (B) Calcium formate
- (C) Calcium propionate
- (D) Calcium benzoate

Q74. CHEM

Dehydrohalogenation of alkyl halides by a strong base occurs via E1 or E2 mechanisms. How many mechanistic steps are involved in E1 and E2 eliminations, respectively?

- (A) E1 is a two-step mechanism, and E2 is a one-step mechanism
- (B) E1 and E2 both occur in a single concerted step
- (C) E1 and E2 both occur in two discrete steps
- (D) E1 is a one-step mechanism, and E2 is a two-step mechanism

Q75. CHEM

Which of the following haloalkanes is an example of a tertiary ( $3^\circ$ ) alkyl halide?

- (A) 2-Chlorobutane
- (B) 1-Chloro-2-methylpentane
- (C) 2-Bromo-3-methylbutane
- (D) 2-Bromo-2-methylbutane

Q76. CHEM

According to Bohr's atomic model, the radius of the first orbit of hydrogen is  $0.53 \text{ \AA}$ . Which principal energy level ( $n$ ) corresponds to an orbit with a radius of  $4.77 \text{ \AA}$ ?

- (A) First orbit ( $n = 1$ )
- (B) Second orbit ( $n = 2$ )
- (C) Third orbit ( $n = 3$ )
- (D) Fourth orbit ( $n = 4$ )

Q77. CHEM

Which of the following atomic subshells possesses only a single spatial orientation in a magnetic field?

- (A) p subshell
- (B) s subshell
- (C) d subshell
- (D) f subshell

Q78. CHEM

What is the rest mass of a single proton relative to an electron?

- (A) Equal to 1836 electrons
- (B) Equal to a positron
- (C) Equal to an electron
- (D) Equal to 1836 neutrons

Q79. CHEM

Which of the following subatomic properties differs among the isoelectronic ions  $\text{Na}^+$  ( $Z = 11$ ),  $\text{Mg}^{2+}$  ( $Z = 12$ ), and  $\text{Al}^{3+}$  ( $Z = 13$ )?

- (A) Number of electron shells
- (B) Total number of electrons
- (C) Ground-state electronic configuration
- (D) Number of protons in the nucleus

Q80. CHEM

What is the systematic IUPAC name of stearic acid ( $\text{C}_{17}\text{H}_{35}\text{COOH}$ )?

- (A) Hexanoic acid
- (B) Octadecanoic acid
- (C) Octanoic acid
- (D) Hexadecanoic acid

Q81. CHEM

Which of the following carboxylic acids is formed when acetone is oxidized under vigorous conditions with concentrated nitric acid or acidified  $\text{KMnO}_4$ ?

- (A) Formic acid
- (B) Ethanoic acid
- (C) Propanoic acid
- (D) Butyric acid

Q82. CHEM

What is the systematic IUPAC name of  $\alpha, \beta$ -dimethylvaleric acid?

- (A) 2,3-Dimethylhexanoic acid
- (B) 3,4-Dimethylhexanoic acid
- (C) 3,4-Dimethylpentanoic acid
- (D) 2,3-Dimethylpentanoic acid

**Q83. CHEM**

What volume of oxygen gas ( $O_2$ ) at STP is stoichiometrically required for the complete combustion of  $500\text{ dm}^3$  of ethene ( $C_2H_4$ )?

- (A)  $500\text{ dm}^3$
- (B)  $1000\text{ dm}^3$
- (C)  $1500\text{ dm}^3$
- (D)  $2000\text{ dm}^3$

**Q84. CHEM**

An element has a valence shell electronic configuration of  $4s^2 4p^1$ . To which periodic group does this element belong?

- (A) Group I-B
- (B) Group II-B
- (C) Group I-A
- (D) Group III-A

**Q85. CHEM**

Calcium ( $Z = 20$ ) combines with chlorine ( $Z = 17$ ) to form an ionic compound. What is the empirical chemical formula of calcium chloride?

- (A)  $CaCl$
- (B)  $CaCl_2$
- (C)  $Ca_2Cl_2$
- (D)  $Ca_2Cl$

**Q86. CHEM**

Carbon dioxide ( $CO_2$ ) and sulfur dioxide ( $SO_2$ ) are triatomic triatomic oxides. Which of the following statements correctly describes their molecular geometries and net dipole moments?

- (A) Both  $CO_2$  and  $SO_2$  are linear and non-polar
- (B)  $CO_2$  is angular and polar;  $SO_2$  is linear and non-polar
- (C)  $CO_2$  is linear and non-polar;  $SO_2$  is angular and polar
- (D) Both  $CO_2$  and  $SO_2$  are angular and polar

**Q87. CHEM**

What hybridization state is exhibited by the carbon atoms in an ethyne (acetylene,  $C_2H_2$ ) molecule?

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

**Q88. CHEM**

For which of the following gaseous equilibrium reactions does the equilibrium constant  $K_p$  equal  $K_c$ ?

- (A)  $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$
- (B)  $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$
- (C)  $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$
- (D)  $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

**Q89. CHEM**

Which of the following reaction conditions will shift the equilibrium to favor the maximum yield of ammonia ( $NH_3$ ) in the industrial Haber-Bosch process?

- (A) Increasing the reaction temperature
- (B) Decreasing the concentration of reactants
- (C) Decreasing the total system pressure
- (D) Decreasing the reaction temperature

**Q90. CHEM**

Which of the following statements is true for any reversible chemical reaction that has attained dynamic equilibrium?

- (A) The rate of the forward reaction is greater than the rate of the backward reaction
- (B) The rate of the forward reaction is less than the rate of the backward reaction
- (C) The rate of the forward reaction is equal to the rate of the backward reaction
- (D) All chemical reactions have completely ceased

**Q91. CHEM**

When benzene reacts with isopropyl chloride in the presence of anhydrous  $AlCl_3$  as a Lewis acid catalyst, isopropylbenzene (cumene) is formed. What is this reaction called?

- (A) Friedel-Crafts acylation
- (B) Friedel-Crafts alkylation
- (C) Halogenation of benzene
- (D) Sulfonation of benzene

**Q92. CHEM**

Benzene is subjected sequentially to: (1) Friedel-Crafts alkylation with  $CH_3Cl/AlCl_3$ , (2) Nitration with concentrated  $HNO_3/H_2SO_4$ , and (3) Vigorous oxidation with  $KMnO_4/H_2SO_4$ . The final products are:

- (A) m-Nitrobenzoic acid
- (B) o-Nitrobenzoic acid and p-nitrobenzoic acid
- (C) m-Nitrotoluene
- (D) o-Nitrotoluene and p-nitrotoluene

**Q93. CHEM**

Isopropyl chloride is structurally classified as a:

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

**Q94. CHEM**

What is the primary organic product obtained when toluene is heated with acidified potassium permanganate ( $KMnO_4$ )?

- (A) o-Nitrotoluene
- (B) p-Nitrotoluene
- (C) Benzaldehyde
- (D) Benzoic acid

**Q95. CHEM**

What is the systematic IUPAC name of chloroform ( $CHCl_3$ )?

- (A) Chloromethane
- (B) Dichloromethane
- (C) Trichloromethane
- (D) Tetrachloromethane

**Q96. CHEM**

Catalytic vapor-phase oxidation of benzene with air over vanadium pentoxide ( $V_2O_5$ ) at  $450^\circ C$  produces:

- (A) Acetylene
- (B) Phenol
- (C) Toluene
- (D) Maleic anhydride

**Q97. CHEM**

What is the oxidation state of manganese (Mn) in potassium manganate ( $K_2MnO_4$ )?

- (A) +2
- (B) +4
- (C) +6
- (D) +7

**Q98. CHEM**

In the standard electrochemical series based on IUPAC reduction potentials, what is the sign of the standard electrode potential ( $E^\circ$ ) for all active metals positioned above hydrogen?

- (A) Zero
- (B) Negative
- (C) Positive
- (D) Greater than +1.0 V

**Q99. CHEM**

On the basis of their fundamental carbon skeleton structure, organic compounds are broadly divided into:

- (A) Carbon compounds and non-carbon compounds
- (B) Open-chain (acyclic) and closed-chain (cyclic) compounds
- (C) Homocyclic and heterocyclic compounds exclusively
- (D) Aromatic and non-benzenoid compounds exclusively

**Q100. CHEM**

Which of the following sets correctly lists the three structural chain isomers of pentane ( $C_5H_{12}$ )?

- (A) n-Pentane, 2-methylbutane, and 2,2-dimethylpropane
- (B) n-Pentane, 2-methylbutane, and 2,3-dimethylbutane
- (C) n-Pentane, 3-methylbutane, and 2,2-dimethylpentane
- (D) n-Pentane, 2-methylpentane, and 2,2-dimethylpropane

**Q101. CHEM**

Which structural isomerism is exhibited between propanal and propanone (acetone)?

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

**Q102. CHEM**

According to Boyle's law, the graphical plot of gas volume (V) versus applied pressure (P) at constant temperature is a:

- (A) Straight line passing through the origin
- (B) Curve that becomes linear at high pressures
- (C) Horizontal straight line parallel to the pressure axis
- (D) Non-linear smooth curve (rectangular hyperbola)

**Q103. CHEM**

A sample of nitrogen gas occupies  $1.0 \text{ dm}^3$  at  $1.0 \text{ atm}$  and  $25^\circ\text{C}$ . If the pressure is increased to  $2.0 \text{ atm}$  while the temperature is raised to  $50^\circ\text{C}$ , the new volume of the gas will be:

- (A)  $0.542 \text{ dm}^3$
- (B)  $2.000 \text{ dm}^3$
- (C)  $3.000 \text{ dm}^3$
- (D)  $4.000 \text{ dm}^3$

**Q104. CHEM**

Which of the following temperatures corresponds to absolute zero on the Celsius scale?

- (A)  $-273.16^\circ\text{C}$
- (B)  $-273.16 \text{ K}$
- (C)  $0^\circ\text{C}$
- (D)  $32^\circ\text{F}$

**Q105. CHEM**

An organic compound contains 40.0% Carbon, 6.67% Hydrogen, and 53.3% Oxygen by mass. What is the empirical formula of the compound?

- (A)  $CH_3O$
- (B)  $C_2H_3O$
- (C)  $CH_2O$
- (D)  $C_2H_2O$

**Q106. CHEM**

Given the balanced reaction:  $CS_2 + 3 O_2 \rightarrow CO_2 + 2 SO_2$ . If 7.6 g of  $CS_2$  reacts with 12.8 g of  $O_2$ , which substance is the limiting reactant?

- (A)  $CS_2$
- (B)  $O_2$
- (C)  $CO_2$
- (D)  $SO_2$

**Q107. CHEM**

Water rises spontaneously in a narrow glass capillary tube primarily because:

- (A) Cohesive forces equal adhesive forces
- (B) Adhesive forces between water and glass exceed cohesive forces among water molecules
- (C) Cohesive forces among water molecules exceed adhesive forces
- (D) Atmospheric pressure pushes the liquid upward without surface forces

**Q108. CHEM**

Which of the following physical variables directly determines the temperature at which a liquid boils?

- (A) External (atmospheric) pressure
- (B) Surrounding ambient temperature
- (C) Volume of the liquid container
- (D) Total mass of liquid present

**Q109. CHEM**

Human enzymes typically exhibit optimum activity between  $37^\circ\text{C}$  and  $50^\circ\text{C}$ . If the temperature is raised significantly above  $50^\circ\text{C}$ , the enzyme permanently loses its catalytic activity due to:

- (A) Hydrolysis of all primary peptide bonds
- (B) Reversible low-temperature freezing
- (C) Irreversible thermal denaturation of its tertiary structure
- (D) Competitive active-site saturation

**Q110. CHEM**

The controlled oxidation of secondary propyl alcohol (propan-2-ol) with acidified potassium dichromate yields:

- (A) Acetone
- (B) Acetaldehyde
- (C) Ethyl alcohol
- (D) n-Propyl alcohol

**Q111. CHEM**

Which of the following biological compounds contains both an amino group ( $-\text{NH}_2$ ) and a carboxyl group ( $-\text{COOH}$ ) attached to the same carbon skeleton, classifying it as an amino acid?

- (A) Benzoic acid
- (B) Palmitic acid
- (C) Aspartic acid
- (D) Aniline

**Q112. CHEM**

What is the overall order of a chemical reaction if its specific reaction rate constant ( $k$ ) is expressed in units of  $\text{s}^{-1}$ ?

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

**Q113. CHEM**

Which of the following best characterizes the reaction kinetics of aqueous ionic reactions between inorganic electrolytes?

- (A) Very slow, requiring days for completion
- (B) Moderately slow, with measurable activation barriers
- (C) Extremely fast, occurring almost instantaneously
- (D) Non-spontaneous under all physical conditions

**Q114. CHEM**

What is the general periodic trend in metallic character as one descends a group of p-block elements?

- (A) Decreases progressively
- (B) Increases progressively
- (C) Remains constant
- (D) Fluctuates irregularly without a pattern

**Q115. CHEM**

A superoxide of an alkali metal ( $M$  belonging to Group I–A) possesses which of the following general empirical formulas?

- (A)  $M_2O$
- (B)  $M_2O_3$
- (C)  $MO_2$
- (D)  $M_2O_2$

**Q116. CHEM**

Which pair of elements differs markedly from the other members of their respective periodic groups due to unusually small atomic size and exceptionally high charge density?

- (A) Potassium and Calcium
- (B) Sodium and Magnesium
- (C) Cesium and Barium
- (D) Lithium and Beryllium

**Q117. CHEM**

Which of the following solids is classified as a three-dimensional network covalent crystal?

- (A)  $\text{NaCl}$
- (B)  $\text{KI}$
- (C)  $\text{MgBr}_2$
- (D) Diamond

**Q118. CHEM**

The lattice points of a molecular crystal (such as solid iodine or dry ice) are held together by:

- (A) Electrostatic ionic bonds
- (B) Metallic electron-sea attractions
- (C) Continuous network covalent bonds
- (D) Intermolecular van der Waals forces

**Q119. CHEM**

According to classical thermodynamics, what is the mathematical expression for the First Law of Thermodynamics when work ( $w$ ) is defined as work done by the system on the surroundings?

- (A)  $\Delta E = q + w$
- (B)  $\Delta E = -q - w$
- (C)  $\Delta E = -q + w$
- (D)  $\Delta E = q - w$

**Q120. CHEM**

According to the First Law of Thermodynamics at constant pressure, the change in enthalpy ( $\Delta H$ ) of a system is equal to:

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

**Q121. CHEM**

Why do transition metals readily form non-stoichiometric interstitial compounds with small non-metallic elements like hydrogen, carbon, nitrogen, and boron?

- (A) Due to the presence of unpaired d-electrons only
- (B) Due to electronic transitions between split d-orbitals
- (C) Due to vacant interstitial voids (holes) in their close-packed crystal lattices
- (D) Due to their low standard reduction potentials

**Q122. CHEM**

In coordination chemistry, the ligand diethylenetriamine (dien) acts as a:

- (A) Bidentate ligand
- (B) Tridentate ligand
- (C) Pentadentate ligand
- (D) Hexadentate ligand

## PHY SECTION: PHYSICS

Questions 123 to 176 (54 MCQs)

## Q123. PHY

In the emission spectrum of atomic hydrogen, which spectral series occurs in the far-ultraviolet region of the electromagnetic spectrum?

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

## Q124. PHY

Ohm's law ( $V = IR$ ) is strictly valid for a metallic conductor only if its:

- (A) Temperature approaches infinity
- (B) Temperature increases continuously with current
- (C) Length decreases inversely with current
- (D) Physical state, especially temperature, remains constant

## Q125. PHY

A direct current (DC) that maintains a constant magnitude and unidirectional flow over time is termed a:

- (A) Eddy current
- (B) Surge current
- (C) Leakage current
- (D) Steady current

## Q126. PHY

In an electrical circuit containing a real chemical battery connected to an external load resistor ( $R$ ), the internal resistance ( $r$ ) of the battery behaves as if it is:

- (A) Connected in parallel with the external load
- (B) Connected in series with the external load
- (C) Completely disconnected from the load circuit
- (D) Negligible under all load conditions

## Q127. PHY

The potential difference measured across the external output terminals of a battery when an active current ( $I$ ) is drawn by an external load is defined as the:

- (A) Electromotive force (EMF)
- (B) Back EMF
- (C) Internal potential gradient
- (D) Terminal potential difference (terminal voltage)

## Q128. PHY

An energy expenditure rate of 1 Joule per second (1 J/s) is equivalent to:

- (A) 1 Kelvin
- (B) 1 Newton
- (C) 1 Tesla
- (D) 1 Watt

## Q129. PHY

According to the de Broglie hypothesis and quantum electrodynamics, what is the momentum ( $p$ ) of a photon having wavelength  $\lambda$ ?

- (A)  $h\lambda$
- (B)  $h/\lambda$
- (C)  $\lambda/h$
- (D)  $h^2/\lambda^2$

## Q130. PHY

If monochromatic light possesses a wavelength of  $3.0 \times 10^{-7}$  m, what is its frequency in a vacuum?

- (A)  $1.0 \times 10^{13}$  Hz
- (B)  $1.0 \times 10^{14}$  Hz
- (C)  $1.0 \times 10^{15}$  Hz
- (D)  $1.0 \times 10^{16}$  Hz

## Q131. PHY

According to Planck's quantum theory, the energy carried by an individual photon is determined solely by its:

- (A) Frequency
- (B) Beam intensity
- (C) Wave amplitude
- (D) Propagation speed in vacuum

## Q132. PHY

The operational principle of an electrical transformer is based upon:

- (A) Self-induction
- (B) Mutual induction
- (C) Motional EMF
- (D) Magnetic torque

## Q133. PHY

An ideal step-down transformer has 500 turns on its primary winding and 250 turns on its secondary winding. If an alternating voltage  $V_p$  is applied across the primary, the secondary output voltage ( $V_s$ ) will be:

- (A) Half of the input voltage
- (B) Equal to the input voltage
- (C) Double the input voltage
- (D) Zero

## Q134. PHY

The magnetic flux passing perpendicularly through a unit surface area is defined as the:

- (A) Total magnetic field line count
- (B) Magnetic dipole moment
- (C) Magnetic vector potential
- (D) Magnetic flux density (B)

## Q135. PHY

The scalar (dot) product of magnetic induction ( $B$ ) and the area vector ( $A$ ) of a flat surface equals the:

- (A) Magnetic flux
- (B) Magnetic permeability
- (C) Magnetic field intensity
- (D) Magnetic pole strength

## Q136. PHY

Conceptually, the magnetic flux passing through an oriented planar surface provides a quantitative measure of the:

- (A) Effective area occupied by the magnet
- (B) Total electrical charge circulating in the magnet
- (C) Rate of change of magnetic Lorentz forces
- (D) Total number of magnetic lines of force traversing the surface

**Q137. PHY**

The rate of change of electric potential with respect to spatial distance ( $-\Delta V/\Delta r$ ) is termed the:

- (A) Potential gradient
- (B) Surface charge density
- (C) Permittivity of free space
- (D) Electrostatic flux density

**Q138. PHY**

The amount of kinetic energy acquired by an electron when accelerated across an electrostatic potential difference of exactly 1 Volt is defined as:

- (A) 1 keV
- (B) 1 MeV
- (C) 1 GeV
- (D) 1 eV

**Q139. PHY**

Which fundamental law of physics establishes that the electrostatic force between two stationary point charges is directly proportional to the product of their charges and inversely proportional to the square of the distance between them?

- (A) Ohm's law
- (B) Lenz's law
- (C) Coulomb's law
- (D) Ampere's law

**Q140. PHY**

Physically, the electric field surrounding an isolated point charge represents the:

- (A) Physical radius of the atomic nucleus
- (B) Region of space within which electrostatic forces can be exerted on other charges
- (C) Orbital trajectory followed by circulating electrons
- (D) Velocity of charge propagation through a vacuum

**Q141. PHY**

The electric field intensity unit of 1 Newton per Coulomb (1 N/C) is dimensionally and physically identical to:

- (A) 1 Volt per meter (1 V/m)
- (B) 1 Joule per Coulomb (1 J/C)
- (C) 1 Coulomb per square meter (1 C/m<sup>2</sup>)
- (D) 1 Ohm per second (1  $\Omega$ /s)

**Q142. PHY**

What is the linear acceleration produced when a net horizontal force of 10 N acts upon a body of mass 0.5 kg resting on a frictionless surface?

- (A) 40 m/s<sup>2</sup>
- (B) 5 m/s<sup>2</sup>
- (C) 10 m/s<sup>2</sup>
- (D) 20 m/s<sup>2</sup>

**Q143. PHY**

The time rate of change of linear momentum of a moving body equals the net:

- (A) Acceleration
- (B) Force
- (C) Velocity
- (D) Work

**Q144. PHY**

Ionizing nuclear radiations (such as alpha, beta, and gamma rays) are biologically hazardous because they damage cellular components primarily by:

- (A) Producing reactive ions and free radicals within cellular water and biomolecules
- (B) Raising the overall macro-temperature of tissues
- (C) Directly decreasing cellular mass without chemical alteration
- (D) Inducing spontaneous non-thermal cellular freezing

**Q145. PHY**

In uniform circular motion, what kinematic change causes centripetal acceleration to act on the moving body?

- (A) Change in the magnitude of velocity
- (B) Continuous change in the mass of the body
- (C) Continuous variation in the speed of the body
- (D) Continuous change in the direction of the velocity vector

**Q146. PHY**

One radian is an SI derived angular unit equivalent to approximately how many degrees?

- (A) 0.573°
- (B) 5.73°
- (C) 57.3°
- (D) 573°

**Q147. PHY**

A bicycle wheel accelerates uniformly from rest, achieving an angular velocity of 6.28 rad/s in 2.0 seconds. What is its angular acceleration?

- (A) 1.00 rad/s<sup>2</sup>
- (B) 1.50 rad/s<sup>2</sup>
- (C) 3.14 rad/s<sup>2</sup>
- (D) 6.28 rad/s<sup>2</sup>

**Q148. PHY**

For an object executing circular motion of radius  $r$ , the ratio of its tangential linear velocity ( $v$ ) to the orbital radius ( $r$ ) equals its:

- (A) Angular displacement ( $\theta$ )
- (B) Angular velocity ( $\omega$ )
- (C) Angular acceleration ( $\alpha$ )
- (D) Angular momentum ( $L$ )

**Q149. PHY**

The pressure-volume ( $P$ - $V$ ) indicator diagram for which classical gas law is geometrically identical to the isotherm of an isothermal thermodynamic process?

- (A) Boyle's law
- (B) Charles's law
- (C) Avogadro's law
- (D) Gay-Lussac's law

**Q150. PHY**

When sudden heavy rain wets a highway, a moving car is prone to skidding primarily because:

- (A) The drive force of the engine decreases instantly
- (B) Frictional grip is drastically reduced, preventing the tires from maintaining directional stability and balance
- (C) The car's forward motion becomes completely independent of external forces
- (D) The gross weight of the vehicle increases due to rain droplet collection

**Q151. PHY**

Which of the following technological applications operates directly on the principle of the Doppler effect?

- (A) Holographic imaging
- (B) Measuring the speed of automobiles using radar speed guns
- (C) Determining the speed of light in optical fibers
- (D) Total internal reflection in endoscopes

**Q152. PHY**

Which of the following wave phenomena can be exhibited by longitudinal sound waves in an elastic medium?

- (A) Plane polarization
- (B) Photoelectric emission
- (C) Electromagnetic radiation
- (D) Superposition and interference

**Q153. PHY**

Which thermodynamic state variable or property of a system remains strictly constant during an adiabatic process?

- (A) Temperature of the gas
- (B) Volume of the gas
- (C) Pressure of the gas
- (D) Total heat content (no heat exchange occurs,  $Q = \text{constant}$ )

**Q154. PHY**

According to Gauss's law, the net electric flux traversing a closed Gaussian surface enclosing an isolated point charge ( $q$ ) is:

- (A) Inversely proportional to the enclosed charge
- (B) Dependent on the spatial location of the charge within the boundary
- (C) Completely independent of the geometric shape and size of the enclosing surface
- (D) Zero under all physical conditions

**Q155. PHY**

During radioactive beta-plus decay (positron emission), what happens to the total nucleon (mass) number ( $A$ ) of the daughter nucleus?

- (A) It decreases by one unit
- (B) It increases by one unit
- (C) It remains conserved (unchanged)
- (D) It decreases by two units

**Q156. PHY**

Neglecting air resistance, which of the following mathematical expressions represents a conserved constant of motion for a body of mass  $m$  falling freely under gravity from height  $h$ ?

- (A)  $mgh + mv^2$
- (B)  $mgh - mv^2$
- (C)  $mgh + \frac{1}{2}mv^2$
- (D)  $mgh - \frac{1}{2}mv^2$

**Q157. PHY**

The product of the frequency ( $f$ ) and wavelength ( $\lambda$ ) of a progressive wave equals its:

- (A) Instantaneous displacement
- (B) Wave amplitude
- (C) Propagation speed ( $v$ )
- (D) Time period ( $T$ )

**Q158. PHY**

Two solid spheres of masses 10 kg and 40 kg are dropped simultaneously from the same height in a vacuum. Which of the following physical quantities is identical for both bodies at every point during their fall?

- (A) Gravitational acceleration ( $g$ )
- (B) Instantaneous kinetic energy
- (C) Instantaneous potential energy
- (D) Rate of energy expenditure (power)

**Q159. PHY**

A body of mass 4 kg moves along a circular path of radius 2 m under the action of a centripetal force. When the body completes one full revolution, what is the net work done by the centripetal force?

- (A) 16 J
- (B) Zero
- (C) 8 J
- (D) 6 J

**Q160. PHY**

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

- (A)  $3.6 \times 10^3 \text{ J}$
- (B)  $3.6 \times 10^4 \text{ J}$
- (C)  $3.6 \times 10^6 \text{ J}$  (3.6 MJ)
- (D)  $3.6 \times 10^9 \text{ J}$

**Q161. PHY**

In a stationary (standing) wave, the spatial distance between two consecutive displacement nodes or two consecutive antinodes is:

- (A)  $\lambda$
- (B)  $\lambda/2$
- (C)  $\lambda/4$
- (D)  $2\lambda$

**Q162. PHY**

If the fundamental frequency of a stretched string fixed at both ends is 50 Hz, the frequency of its fourth harmonic is:

- (A) 200 Hz
- (B) 150 Hz
- (C) 12.5 Hz
- (D) 250 Hz

**Q163. PHY**

A projectile is launched horizontally from a cliff with an initial velocity of 19.6 m/s. Neglecting air resistance, what will be the magnitude of its horizontal velocity component after 2.0 seconds of flight?

- (A) 4.9 m/s
- (B) 9.8 m/s
- (C) 19.6 m/s
- (D) 39.2 m/s

**Q164. PHY**

In ideal projectile motion near the surface of the Earth, the acceleration of the projectile in the horizontal direction:

- (A) Remains constant at  $9.8 \text{ m/s}^2$
- (B) Varies linearly with elapsed time
- (C) Is strictly zero
- (D) Increases as the projectile descends

**Q165. PHY**

In vibratory or oscillatory motion, the maximum displacement of an oscillating particle on either side of its mean equilibrium position is defined as its:

- (A) Total path distance
- (B) Instantaneous displacement
- (C) Amplitude ( $x_0$ )
- (D) Frequency ( $f$ )

**Q166. PHY**

A thermodynamic process in which a gas undergoes expansion or compression without performing any boundary work on the surroundings ( $W = 0$ ) is classified as an:

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

**Q167. PHY**

The peak induced electromotive force ( $E_0$ ) generated by a rotating armature coil in an AC generator can be increased by:

- (A) Decreasing the cross-sectional area of the coil
- (B) Decreasing the magnetic flux density of the field poles
- (C) Increasing the cross-sectional area of the coil
- (D) Decreasing the rotational frequency of the armature

**Q168. PHY**

The primary engineering function of an electrical power transformer is to:

- (A) Transform alternating current and voltage from one potential level to another
- (B) Convert alternating current into direct current
- (C) Convert mechanical energy into electrical energy
- (D) Convert direct current into alternating current

**Q169. PHY**

A single semiconductor p-n junction diode conducting current in only one forward direction is utilized in electronic circuits as a:

- (A) Full-wave bridge rectifier
- (B) Linear signal amplifier
- (C) Radio frequency transmitter
- (D) Half-wave rectifier

**Q170. PHY**

The radioactive noble gas radon-222 ( $^{222}\text{Rn}$ ) has a nuclear half-life of approximately:

- (A) 3.8 minutes
- (B) 3.8 days
- (C) 3.8 months
- (D) 38 years

**Q171. PHY**

Two capacitors with capacitances of  $6.0\ \mu\text{F}$  and  $12.0\ \mu\text{F}$  are connected in series across a  $200\ \text{V}$  DC supply. What is the electric charge stored on each capacitor?

- (A)  $8.0 \times 10^{-4}\ \text{C}$  on each capacitor
- (B)  $8.0\ \mu\text{C}$  on each capacitor
- (C)  $8.0 \times 10^4\ \text{C}$  and  $16.0 \times 10^4\ \text{C}$ , respectively
- (D)  $800\ \text{C}$  on each capacitor

**Q172. PHY**

A uniform cylindrical conducting wire has resistance  $R$ . If the wire is drawn out such that its length is doubled while its cross-sectional radius remains constant, what is its new resistance?

- (A)  $R/2$
- (B)  $R$
- (C)  $4R$
- (D)  $2R$

**Q173. PHY**

The speed of sound in dry air at  $0^\circ\text{C}$  is  $332\ \text{m/s}$ . What is the speed of sound in air when the temperature rises to  $50^\circ\text{C}$ ?

- (A)  $300\ \text{m/s}$
- (B)  $332\ \text{m/s}$
- (C)  $362\ \text{m/s}$
- (D)  $382\ \text{m/s}$

**Q174. PHY**

A force of magnitude  $2F$  acting on a mass of  $10\ \text{kg}$  produces an acceleration of  $30\ \text{m/s}^2$ . A second force of magnitude  $5F$  acting on an unknown mass  $M$  produces an acceleration of  $25\ \text{m/s}^2$ . What is the value of mass  $M$ ?

- (A)  $30\ \text{kg}$
- (B)  $21\ \text{kg}$
- (C)  $4.8\ \text{kg}$
- (D)  $3.3\ \text{kg}$

**Q175. PHY**

The primary function of an AC power transformer is to convert:

- (A) One direct voltage into another direct voltage of different magnitude
- (B) One alternating voltage into another alternating voltage of different magnitude
- (C) A high alternating voltage into a low direct voltage
- (D) A low direct voltage into a high direct voltage

**Q176. PHY**

An excited atom undergoes a downward electronic transition from energy level  $E_2$  to a lower level  $E_1$ . In terms of Planck's constant ( $h$ ) and the speed of light ( $c$ ), the wavelength ( $\lambda$ ) of the emitted photon is:

- (A)  $(E_2 - E_1) / hc$
- (B)  $hc/E_2 - hc/E_1$
- (C)  $hc / (E_2 - E_1)$
- (D)  $c / [h(E_2 - E_1)]$

## ENG SECTION: ENGLISH

Questions 177 to 194 (18 MCQs)

Q177. ENG

Identify the sentence fragment among the following options:

- (A) He went to the store.
- (B) Quickly, before the rain started.
- (C) The cat sat on the windowsill.
- (D) She prepared a delicious meal.

Q178. ENG

Identify the sentence that exhibits the incorrect use of an apostrophe:

- (A) That is Mary's book.
- (B) The dog's leash is in the car.
- (C) Its a beautiful day outside.
- (D) The children's toys are in the playroom.

Q179. ENG

Which of the following sentences demonstrates the grammatically correct use of the past perfect tense?

- (A) She will go to the store yesterday.
- (B) They will be eating lunch now.
- (C) He had finished his homework before dinner.
- (D) We are meeting them tomorrow.

Q180. ENG

Which of the following sentences follows standard English word order for adverbs of frequency and temporal adverbial phrases?

- (A) She usually goes jogging in the evening.
- (B) In the evening goes she usually for jogging.
- (C) She goes to the usually for jogging evening.
- (D) Usually she for jogging goes in the evening.

Q181. ENG

What is the most appropriate and polite response to the question: 'How was your day at school?'

- (A) I am going to the park.
- (B) My favorite subject is math.
- (C) It was great, thanks for asking!
- (D) I don't like school.

Q182. ENG

Identify the grammatical error in the sentence: 'His the car is red.'

- (A) The sentence is grammatically correct as written
- (B) The definite article 'the' cannot follow a possessive determiner ('his')
- (C) The subject and verb do not agree
- (D) The predicate adjective 'red' must precede the verb

Q183. ENG

What is the direct antonym of the word 'generous'?

- (A) Selfish
- (B) Charitable
- (C) Benevolent
- (D) Altruistic

Q184. ENG

Complete the sentence with the appropriate verb: 'The Sun began to \_\_\_\_\_ behind the mountains, casting a warm and beautiful glow across the valley.'

- (A) Rise
- (B) Set
- (C) Shine
- (D) Sleep

Q185. ENG

Select the appropriate word to complete the sentence: 'After a long, stressful day at work, Sarah found \_\_\_\_\_ in her favorite book, escaping into a captivating world.'

- (A) Solace
- (B) Chaos
- (C) Endurance
- (D) Agony

Q186. ENG

Which of the following sentences exhibits incorrect punctuation due to a comma splice?

- (A) I am going to the store; do you need anything?
- (B) I am going to the store, so do you need anything?
- (C) I am going to the store: do you need anything?
- (D) I am going to the store, do you need anything?

Q187. ENG

Which of the following sentences exhibits completely correct grammatical and spelling structure?

- (A) They're playing soccer.
- (B) They playing soccer.
- (C) Their playing soccer.
- (D) They have play soccer.

Q188. ENG

Choose the sentence that correctly employs the apostrophe to indicate singular possession:

- (A) The cats toys are in the corner.
- (B) The cat's toys are in the corner.
- (C) The cats' toys are in the corner.
- (D) The cats' toys' are in the corner.

Q189. ENG

Which indefinite article correctly completes the sentence: 'He lives in \_\_\_\_\_ old house.'

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

Q190. ENG

Identify the grammatical mistake in the use of prepositions in the sentence: 'She is good at cooking in the kitchen.'

- (A) The sentence is grammatically correct as written
- (B) The preposition 'at' should be omitted
- (C) The preposition 'in' should be replaced with 'on'
- (D) The gerund 'cooking' should be replaced with an infinitive

**Q191.** ENG

Which of the following sentences demonstrates correct subject-verb agreement?

- (A) The cat are sleeping.
- (B) The cats is sleeping.
- (C) The cats has sleeping.
- (D) The cats are sleeping.

**Q192.** ENG

Read the following passage to answer the question:

"Nobody knows when fiction started. Perhaps the first storyteller was a prehistoric mother trying to explain the world to her children, or maybe it was a hunter talking about his adventure around the campfire. Who can tell? What we do know, though, is that storytelling was a purely oral activity around 800 BC. Myths and tales were passed down by word of mouth and had to be popularized by each new generation of storytellers. This oral tradition is the only example of Homer, a professional storyteller who lived in the eighth century BC."

Based on the passage, the contextual meaning of the word 'fiction' is:

- (A) Invented oral or written narrative
- (B) Academic textbook
- (C) Factual scientific prose
- (D) Historical truth

**Q193.** ENG

According to the passage on early storytelling, myths and ancient tales were originally preserved and passed down across generations by:

- (A) Written scriptures
- (B) Carved stone tablets
- (C) Word of mouth (oral tradition)
- (D) Parchment scrolls

**Q194.** ENG

It is explicitly emphasized in the reading passage that the practice of storytelling:

- (A) Began strictly as a formal written exercise
- (B) Became unpopular after the development of writing
- (C) Was invented exclusively by Homer in ancient Greece
- (D) Possibly originated in prehistoric times

## LOGIC SECTION: LOGICAL REASONING

Questions 195 to 200 (6 MCQs)

Q195. LOGIC

Consider the following statements regarding the ages of Essa and Moosa:

- Essa is strictly younger than Moosa.
- Let  $X$  = twice Essa's age ( $X = 2E$ ).
- Let  $Y$  = Moosa's age ( $Y = M$ ).

Which of the following statements must be true regarding the mathematical relationship between  $X$  and  $Y$ ?

- (A)  $X$  is always strictly greater than  $Y$
- (B)  $Y$  is always strictly greater than  $X$
- (C)  $X$  is always equal to  $Y$
- (D) The relationship between  $X$  and  $Y$  cannot be determined from the given information

Q196. LOGIC

Look carefully at the sequence of symbols depicted below:



Which option correctly completes the logical progression by transforming both curved elements into fully enclosed geometric semicircles?

- (A) Figure with an open top arc and open bottom arc
- (B) Figure with an open top arc and closed bottom semicircle
- (C) Figure with a closed top semicircle and open bottom arc
- (D) Figure with both top and bottom elements fully closed into complete semicircles

Q197. LOGIC

In an academic class of 50 students, Sara's rank is five positions below the top-ranking student, Faiq. What is Sara's rank counted from the bottom of the class?

- (A) 5th
- (B) 15th
- (C) 45th
- (D) 46th

Q198. LOGIC

In a substitution cipher code, 'blue' is called 'green', 'green' is called 'white', 'white' is called 'red', and 'red' is called 'yellow'. Under this artificial code language, what is the color of milk?

- (A) White
- (B) Green
- (C) Yellow
- (D) Red

Q199. LOGIC

**Statement:** The English language proficiency scores of students in XYZ High School are significantly below the municipal town average.

**Courses of Action:**

- I. All English language teachers in XYZ High School should be dismissed immediately and replaced with new ones.
- II. The English language teachers in XYZ High School should be provided a comprehensive pedagogical training course.

Which of the proposed courses of action is most appropriate?

- (A) Only course of action I is appropriate
- (B) Only course of action II is appropriate
- (C) Both courses of action I and II are appropriate
- (D) Neither course of action I nor II is appropriate

Q200. LOGIC

**Read the two statements carefully and select the correct causal relationship:**

- Statement I:** It was raining cats and dogs throughout the afternoon.
- Statement II:** The inter-school football match was cancelled.

Which option correctly describes the relationship between the two statements?

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

## OFFICIAL VERIFIED ANSWER KEY

DUHS Karachi MDCAT 2023 Official Paper - Rapid Self-Grading Grid

[Online Portal >](#)

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

## SUBJECT-WISE PERFORMANCE BREAKDOWN

| SUBJECT           | MAX | YOUR SCORE  | ACCURACY |
|-------------------|-----|-------------|----------|
| Biology           | 68  | <div></div> | ----- %  |
| Chemistry         | 54  | <div></div> | ----- %  |
| Physics           | 54  | <div></div> | ----- %  |
| English           | 18  | <div></div> | ----- %  |
| Logical Reasoning | 6   | <div></div> | ----- %  |
| TOTAL             | 200 | -----       | ----- %  |

## PMDC PROVINCIAL MERIT FORMULA

## Official Weightage Law:

- MDCAT Component (50%): (Your Score / 200) × 50
- FSc / HSSC Component (40%): (FSc Marks / 1100) × 40
- Matric / SSC Component (10%): (Matric Marks / 1100) × 10

Estimated Provincial Merit Aggregate: ----- %

## PROPOLIS COGNITIVE ERROR AUTOPSIES

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

### Question #1 Key: (A)

BIOLOGY  
05. Acellular Life

Which of the following best characterizes the viruses with un-enveloped plus-strand RNA?

#### CORE CONCEPT & DERIVATION

Viruses are classified on the basis of their capsid morphology, presence or absence of an envelope, and genetic material. An un-enveloped (naked) plus-strand RNA virus possesses a single-stranded RNA genome that can directly serve as mRNA and lacks an outer lipid bilayer envelope.

#### Formula / Rule / Reaction:

Factual recall / Qualitative concept.

#### Solution:

- The term 'un-enveloped' explicitly denotes the absence of a lipid membranous envelope surrounding the protein capsid.
- Plus-strand (positive-sense) viral RNA directly acts as mRNA in the host cytoplasm for immediate translation of viral proteins.

#### Why other options are incorrect:

- **Option B:** These viruses possess single-stranded RNA as their genetic material, not DNA.
- **Option C:** Plus-strand RNA acts directly as mRNA without requiring intermediate transcription by an RNA-dependent RNA polymerase.
- **Option D:** They are explicitly un-enveloped (naked) and do not contain a host-derived membrane envelope.

### Question #2 Key: (C)

BIOLOGY  
05. Acellular Life

Through which of the following animals does rabies predominantly spread to humans?

#### CORE CONCEPT & DERIVATION

Rabies is an acute, fatal viral disease of the central nervous system caused by a rhabdovirus (lyssavirus). It is primarily transmitted to humans through the bite or saliva of infected canines.

#### Formula / Rule / Reaction:

Factual recall / Qualitative concept.

#### Solution:

- According to the Sindh Textbook Board Biology syllabus, domestic dogs serve as the primary reservoir and vector for human rabies transmission worldwide, accounting for over 95 percent of all human rabies exposures.
- Transmission occurs via contaminated saliva inoculated through bite wounds or mucosal abrasions.

#### Why other options are incorrect:

- **Option A:** Cats can harbor rabies, but they are not the primary transmission reservoir for human infections in provincial health epidemiology.
- **Option B:** Foxes are wild reservoirs in certain temperate regions, but domestic dogs are the overwhelming vector for human cases in Pakistan.
- **Option D:** Pigs are rarely infected and do not act as significant vectors for rabies transmission.

### Question #3 Key: (B)

BIOLOGY  
05. Acellular Life

The type of hepatitis that passes vertically from mother to her child during pregnancy and child...

#### CORE CONCEPT & DERIVATION

Hepatitis B is an enveloped DNA virus (Hepadnaviridae) that is transmitted via infected blood, blood products, body secretions, sexual contact, and vertically from mother to fetus during pregnancy and delivery.

#### Formula / Rule / Reaction:

Factual recall / Qualitative concept.

#### Solution:

- Sindh Textbook Board Biology Chapter 5 states that Hepatitis B (serum hepatitis) is transmitted through body fluids, shared needles, sexual contact, and vertically from an infected mother to child during gestation and delivery.
- Note on board key: Some unverified answer keys incorrectly selected C; however, HBV is the benchmark textbook example of perinatal vertical transmission.

#### Why other options are incorrect:

- **Option A:** Hepatitis A virus is an infectious hepatitis transmitted primarily via the fecal-oral route through contaminated food or water.
- **Option C:** While Hepatitis C can undergo vertical transmission, the risk is much lower (approx 5 percent) compared to Hepatitis B (up to 90 percent in HBeAg-positive mothers), and HBV is the primary textbook answer.
- **Option D:** Hepatitis D is a defective satellite virus that requires concurrent HBV infection and is transmitted primarily by parenteral exposure.

### Question #4 Key: (B)

BIOLOGY  
17. Biotechnology

A virus enters the host body and produces DNA from an RNA template. Which enzyme is required for...

#### CORE CONCEPT & DERIVATION

Retroviruses possess an RNA genome and must convert it into complementary DNA (cDNA) to integrate into the host cell chromosome. This reverse flow of genetic information is catalyzed by RNA-dependent DNA polymerase (reverse transcriptase).

#### Formula / Rule / Reaction:



#### Solution:

- Reverse transcriptase uses the single-stranded viral RNA template to synthesize a complementary DNA strand, reversing the canonical central dogma of molecular biology.
- Retroviruses such as Human Immunodeficiency Virus (HIV) depend on this enzyme for replication.

#### Why other options are incorrect:

- **Option A:** Standard transcriptases (RNA polymerases) synthesize RNA from a DNA template.
- **Option C:** Oxidoreductases catalyze oxidation-reduction reactions, playing no role in nucleic acid reverse transcription.
- **Option D:** Ligases join phosphodiester nicks in nucleic acid backbones but cannot synthesize DNA from an RNA template.

**Question #5** Key: (D)BIOLOGY  
04. Bioenergetics

Which of the following is the end product of alcoholic anaerobic respiration?

**CORE CONCEPT & DERIVATION**

Anaerobic respiration in yeast and certain plant tissues follows the glycolytic pathway to produce pyruvate, which is subsequently converted into ethanol and carbon dioxide to regenerate oxidized  $\text{NAD}^+$ .

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

- Glycolysis converts one molecule of glucose into two molecules of pyruvate.
- In the absence of oxygen, pyruvate is decarboxylated to acetaldehyde and then reduced to ethyl alcohol (ethanol).

**Why other options are incorrect:**

- Option A:** Methyl alcohol (methanol) is toxic and is not produced during biological fermentation.
- Option B:** Acetaldehyde is an intermediate product of alcoholic fermentation, not the final organic end product.
- Option C:** Formaldehyde is a one-carbon toxic aldehyde not involved in cellular fermentation.

**Question #6** Key: (C)BIOLOGY  
04. Bioenergetics

What is the primary physiological importance of the Krebs cycle?

**CORE CONCEPT & DERIVATION**

The Krebs cycle (citric acid cycle) oxidizes acetyl-CoA into carbon dioxide, capturing high-energy electrons in the form of NADH and  $\text{FADH}_2$ . These reduced electron carriers subsequently enter the respiratory electron transport chain to generate ATP via oxidative phosphorylation.

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

- Although the Krebs cycle generates only 1 ATP (or GTP) directly per turn by substrate-level phosphorylation, it generates 3 NADH and 1  $\text{FADH}_2$ .
- These coenzymes fuel the proton gradient in the inner mitochondrial membrane, producing the bulk of cellular ATP through oxidative phosphorylation.

**Why other options are incorrect:**

- Option A:** While intermediates can feed into anabolic pathways, generating amino acids is not the primary bioenergetic purpose of the cycle.
- Option B:** The cycle does not produce vitamins; rather, vitamins like niacin and riboflavin are cofactors required for its enzymes.
- Option D:** Pyruvic acid is the substrate entering the link reaction to form acetyl-CoA, not a product of the Krebs cycle.

**Question #7** Key: (A)BIOLOGY  
04. Bioenergetics

The initial carbon dioxide acceptor in the Calvin cycle is:

**CORE CONCEPT & DERIVATION**

During the carbon fixation phase of the dark reaction (Calvin cycle), carbon dioxide combines with a 5-carbon phosphorylated sugar called Ribulose-1,5-bisphosphate (RuBP), catalyzed by the enzyme RuBisCO.

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

- Ribulose-1,5-bisphosphate (RuBP) serves as the designated carbon dioxide acceptor in the stroma of chloroplasts.
- The resulting unstable 6-carbon intermediate immediately hydrolyzes into two molecules of 3-phosphoglycerate (PGA).

**Why other options are incorrect:**

- Option B:** Ribulose monophosphate (RuMP) is converted to RuBP by phosphoribulokinase before it can accept carbon dioxide.
- Option C:** 3-Phosphoglycerate (PGA) is the first stable product formed after carbon fixation, not the acceptor.
- Option D:** Phosphoglyceraldehyde (PGAL) is the reduced 3-carbon carbohydrate produced later during the reduction phase.

**Question #8** Key: (B)BIOLOGY  
04. Bioenergetics

Anaerobic respiration, compared to aerobic respiration, produces:

**CORE CONCEPT & DERIVATION**

Anaerobic respiration breaks down glucose incompletely without oxygen, whereas aerobic respiration completely oxidizes glucose into carbon dioxide and water, extracting significantly more energy.

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

- Anaerobic glycolysis produces a net yield of only 2 ATP molecules per glucose molecule.
- Aerobic respiration yields 36 to 38 ATP per glucose, making anaerobic respiration far less productive in terms of total ATP output.

**Why other options are incorrect:**

- Option A:** Aerobic respiration yields roughly 18 times more ATP than anaerobic pathways.
- Option C:** The ATP yields are unequal due to incomplete versus complete oxidation of glucose.
- Option D:** Anaerobic respiration produces a net of 2 ATPs via substrate-level phosphorylation during glycolysis.

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

In carbohydrates, hydrogen and oxygen are mostly present in the ratio of 2:1, which is why they...

**CORE CONCEPT & DERIVATION**

Carbohydrates are polyhydroxy aldehydes, polyhydroxy ketones, or substances that yield such units upon hydrolysis. Their empirical formula is typically  $C_x(H_2O)_y$ , giving the impression of carbon combined with water molecules.

**Formula / Rule / Reaction:**

General formula:  $C_n(H_2O)_n$  (Hydrogen : Oxygen ratio = 2 : 1)

**Solution:**

- Because hydrogen and oxygen are present in the same 2:1 ratio as water, early chemists designated these organic compounds 'hydrates of carbon' or 'hydrated carbons'.
- This etymology forms the root word 'carbohydrate'.

**Why other options are incorrect:**

- Option A:** Carbon monoxide is a diatomic inorganic gas with the formula CO.
- Option B:** Carbon dioxide is an inorganic gas with the formula  $CO_2$ .
- Option D:** Trioses are specific three-carbon monosaccharides, not the general collective term for all carbohydrates.

**Question #10** Key: (A)BIOLOGY  
02. Biomolecules

How much of a temperature rise ( $^{\circ}C$ ) is observed, as per the definition of specific heat capacity...

**CORE CONCEPT & DERIVATION**

Specific heat capacity of water is defined as the amount of heat energy required to raise the temperature of one gram of water by exactly one degree Celsius (specifically from  $14.5^{\circ}C$  to  $15.5^{\circ}C$ ).

**Formula / Rule / Reaction:**

$$Q = mc\Delta T \Rightarrow \Delta T = \frac{Q}{mc} = \frac{1 \text{ cal}}{(1 \text{ g})(1 \text{ cal/g} \cdot ^{\circ}C)} = 1^{\circ}C$$

**Solution:**

- By standard physical definition, the specific heat capacity of water is  $1.0 \text{ cal/g} \cdot ^{\circ}C$  (or  $4.184 \text{ J/g} \cdot ^{\circ}C$ ).
- Therefore, supplying 1 calorie of heat to 1 gram of water produces an exact temperature rise of  $1^{\circ}C$ .

**Why other options are incorrect:**

- Option B:** A  $2^{\circ}C$  rise requires 2 calories per gram of water.
- Option C:** A  $3^{\circ}C$  rise requires 3 calories per gram of water.
- Option D:** A  $10^{\circ}C$  rise requires 10 calories per gram of water.

**Question #11** Key: (D)BIOLOGY  
02. Biomolecules

Which chemical compound maintains approximately the same percentage (around 70%) in both bacter...

**CORE CONCEPT & DERIVATION**

Water is the most abundant chemical compound in living organisms, serving as the universal solvent and dispersion medium for cellular biochemical reactions.

**Formula / Rule / Reaction:**

Sindh Textbook Board chemical composition comparison:

Bacterial Cell Water: 70% | Mammalian Cell Water: 70%

**Solution:**

- According to the textbook comparative table of cellular composition, water accounts for 70 percent of total cell mass in both bacterial and mammalian cells.
- Proteins constitute 15 percent in bacteria versus 18 percent in mammals; carbohydrates constitute 3 percent versus 4 percent; lipids constitute 2 percent versus 3 percent.

**Why other options are incorrect:**

- Option A:** Carbohydrates account for 3 percent of bacterial cell mass and 4 percent of mammalian cell mass.
- Option B:** Proteins account for 15 percent of bacterial cell mass and 18 percent of mammalian cell mass.
- Option C:** Lipids account for 2 percent of bacterial cell mass and 3 percent of mammalian cell mass.

**Question #12** Key: (A)BIOLOGY  
02. Biomolecules

Glyceraldehyde and dihydroxyacetone are classic examples of which group of carbohydrates?

**CORE CONCEPT & DERIVATION**

Monosaccharides are simple sugars classified based on the number of carbon atoms present in their molecular skeleton. Sugars with three carbon atoms are called trioses.

**Formula / Rule / Reaction:**

General Triose formula:  $C_3H_6O_3$

Aldotriose: Glyceraldehyde | Ketotriose: Dihydroxyacetone

**Solution:**

- Glyceraldehyde (an aldo-sugar) and dihydroxyacetone (a keto-sugar) both possess 3 carbon atoms.
- They serve as vital metabolic intermediates in the glycolytic pathway and photosynthesis.

**Why other options are incorrect:**

- Option B:** Tetroses are 4-carbon sugars, such as erythrose.
- Option C:** Pentoses are 5-carbon sugars, such as ribose and deoxyribose.
- Option D:** Hexoses are 6-carbon sugars, such as glucose, fructose, and galactose.

**Question #13** Key: (D)BIOLOGY  
02. Biomolecules

A compound formed by an ester bond between one molecule of fatty acid and one molecule of long-...

**CORE CONCEPT & DERIVATION**

Waxes are simple lipids that consist of esters of long-chain fatty acids with long-chain monohydric alcohols, functioning as protective waterproof coatings on plant leaves, fruits, and animal fur.

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

- Unlike acylglycerols, which contain glycerol (a trihydric alcohol) bonded to up to three fatty acids, waxes contain a single long-chain alcohol bonded to a single fatty acid.
- Examples include beeswax, cutin, and suberin.

**Why other options are incorrect:**

- **Option A:** Saturated acylglycerols consist of glycerol esterified with saturated fatty acids.
- **Option B:** Unsaturated acylglycerols contain glycerol esterified with unsaturated fatty acids containing double bonds.
- **Option C:** Phospholipids contain glycerol esterified with two fatty acids and a phosphate-nitrogenous group.

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

Lysozyme represents which basic structural level of proteins?

**CORE CONCEPT & DERIVATION**

Proteins exhibit four levels of structural organization. A single polypeptide chain that folds into a compact, globular, functional three-dimensional conformation stabilized by hydrophobic interactions, hydrogen bonds, ionic bonds, and disulfide bridges exhibits tertiary structure.

**Formula / Rule / Reaction:**

Factual recall / Qualitative concept.

**Solution:**

- Lysozyme is an antibacterial enzyme found in tears, saliva, and egg white that consists of a single polypeptide chain of 129 amino acids.
- It folds into a compact globular tertiary structure with a specific active site cleft. It lacks multiple subunits, so it does not possess a quaternary structure.

**Why other options are incorrect:**

- **Option A:** Primary structure refers solely to the linear sequence of amino acids linked by peptide bonds.
- **Option B:** Secondary structure refers to local recurring conformations such as alpha-helices and beta-pleated sheets.
- **Option D:** Quaternary structure requires the spatial aggregation of two or more distinct polypeptide subunits (e.g., hemoglobin).

**Question #15** Key: (B)BIOLOGY  
02. Biomolecules

Which of the following compounds is regarded as the common precursor for the biosynthesis of st...

**CORE CONCEPT & DERIVATION**

Steroids are lipids characterized by a carbon skeleton consisting of four fused rings (cyclopentanoperhydrophenanthrene ring). Cholesterol is the parent steroid from which all vertebrate steroid hormones are synthesized.

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

- Cholesterol is present in animal cell membranes to modulate fluidity and serves as the precursor for sex hormones (testosterone, estrogens, progesterone), adrenocortical hormones, and bile salts.

**Why other options are incorrect:**

- **Option A:** Waxes are long-chain esters that serve protective barrier functions, not hormone synthesis.
- **Option C:** Phospholipids form the structural lipid bilayer of membranes and do not synthesize steroid rings.
- **Option D:** Acylglycerols (triglycerides) function as energy storage reservoirs.

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

Which organelle is designated as the powerhouse of the cell?

**CORE CONCEPT & DERIVATION**

Mitochondria are double-membrane-bound organelles where pyruvate oxidation, the Krebs cycle, and electron transport-coupled oxidative phosphorylation take place, generating the vast majority of cellular ATP.

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

- The inner mitochondrial membrane contains respiratory assemblies, electron transport chains, and  $\text{F}_0 - \text{F}_1$  ATP synthase complexes.
- Because they produce chemical potential energy in the form of ATP to power cell activities, mitochondria are known as the 'powerhouses' of the cell.

**Why other options are incorrect:**

- **Option A:** Ribosomes are protein synthesis factories of the cell.
- **Option B:** The Golgi apparatus is responsible for sorting, modifying, and packaging cellular secretions.
- **Option D:** Chloroplasts conduct photosynthesis in green plant cells, producing carbohydrates rather than functioning as the general powerhouse for metabolic consumption.

**Question #17** Key: (B)BIOLOGY  
02. Biomolecules

A phospholipid molecule has a hydrophilic head and two hydrophobic tails. Where are the fatty acids?

**CORE CONCEPT & DERIVATION**

Phospholipids are amphipathic molecules. In an aqueous environment, they spontaneously form a bilayer where hydrophobic non-polar tails face away from water and hydrophilic polar heads face the aqueous surfaces.

**Formula / Rule / Reaction:**

Bilayer arrangement:

Water (outside)  $\longleftrightarrow$  Polar heads | Hydrophobic fatty acid tails (interior) | Polar heads  $\longleftrightarrow$  Water (inside)

**Solution:**

- The two long-chain fatty acid tails of phospholipids are non-polar and hydrophobic.
- To avoid contact with water, the tails are sequestered in the interior of the membrane bilayer, creating a hydrophobic core.

**Why other options are incorrect:**

- Option A:** The surfaces are lined by the polar phosphate-glycerol heads interacting with the aqueous extracellular fluid.
- Option C:** Contact with the exterior aqueous medium is chemically unfavorable for non-polar hydrocarbon tails due to hydrophobic exclusion.
- Option D:** Transmembrane protein domains span across the membrane, but individual fatty acid tails reside within their respective leaflet interior.

**Question #18** Key: (C)BIOLOGY  
01. Cell

Which of the following congenital lysosomal storage diseases typically leads to progressive neurodegeneration?

**CORE CONCEPT & DERIVATION**

Lysosomal storage diseases are inherited metabolic disorders caused by a deficiency of specific hydrolytic enzymes, resulting in the abnormal accumulation of undigested macromolecules inside lysosomes.

**Formula / Rule / Reaction:**

Factual recall / Qualitative concept.

**Solution:**

- Tay-Sachs disease is an autosomal recessive lysosomal storage disease caused by the absence of the enzyme hexosaminidase A.
- This leads to the toxic accumulation of gangliosides (glycolipids) in brain cells, causing mental deterioration, motor loss, blindness, and death typically around 3 years of age.

**Why other options are incorrect:**

- Option A:** Pompe disease is caused by alpha-glucosidase deficiency leading to glycogen accumulation, primarily affecting muscle and cardiac tissue.
- Option B:** Gaucher disease involves glucocerebrosidase deficiency and glucocerebroside storage, presenting with hepatosplenomegaly and bone lesions, with many patients surviving well into adulthood.
- Option D:** Krabbe disease involves galactosylceramidase deficiency; while neurodegenerative, Tay-Sachs is the explicit textbook benchmark associated with gangliosides and death by age 3.

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

Which of the following terms best describes the functional permeability of the plasma membrane?

**CORE CONCEPT & DERIVATION**

The plasma membrane acts as a barrier that allows certain substances (such as small non-polar molecules and water) to pass across while restricting the movement of large, polar, or charged solutes. This property is known as differential, selective, or semi-permeability.

**Formula / Rule / Reaction:**

Factual recall / Qualitative concept.

**Solution:**

- The hydrophobic interior of the phospholipid bilayer, combined with transport proteins, allows the membrane to regulate internal cellular homeostasis by acting as a semipermeable barrier.

**Why other options are incorrect:**

- Option A:** A completely permeable membrane (like a plant cell wall) allows all solutes to pass indiscriminately without regulation.
- Option B:** An impermeable membrane prevents all substance movement, which would cause cell starvation and waste toxicity.
- Option C:** Freely permeable membranes do not exercise selective control over transport.

**Question #20** Key: (C)BIOLOGY  
01. Cell

What is the cementing intercellular layer that holds the primary walls of two adjacent plant cells together?

**CORE CONCEPT & DERIVATION**

During cytokinesis in plant cells, the phragmoplast vesicles fuse to form the cell plate, which matures into the pectin-rich cementing layer known as the middle lamella.

**Formula / Rule / Reaction:**

Plant Wall Stratification: Secondary Wall  $\rightarrow$  Primary Wall  $\rightarrow$  **Middle Lamella**  $\leftarrow$  Primary Wall

**Solution:**

- The middle lamella is composed primarily of calcium and magnesium pectates.
- It functions as an intercellular glue, binding neighboring plant cell walls together.

**Why other options are incorrect:**

- Option A:** The primary wall is a true cellulosic wall layer deposited directly inside the middle lamella by a growing cell.
- Option B:** The secondary wall is deposited between the primary wall and plasma membrane in mature, non-dividing cells.
- Option D:** The plasma membrane is the living lipid bilayer boundary of the protoplast, located beneath the cell wall.

**Question #21** Key: (C)BIOLOGY  
03. Enzymes

The structure and arrangement of membrane proteins embedded within a dynamic lipid bilayer was ...

**CORE CONCEPT & DERIVATION**

The fluid mosaic model, proposed by S.J. Singer and G.L. Nicolson in 1972, conceptualizes the biological membrane as a two-dimensional liquid of oriented lipid bilayer into which globular proteins are partially or wholly embedded.

**Formula / Rule / Reaction:**

*Factual recall / Qualitative concept.*

**Solution:**

- According to the fluid mosaic model, membrane lipids provide a fluid matrix, while proteins are arranged in a 'mosaic' pattern, capable of lateral movement within the bilayer.

**Why other options are incorrect:**

- Option A:** The lock and key model was proposed by Emil Fischer to describe enzyme-substrate specificity.
- Option B:** The induced fit model was proposed by Daniel Koshland to describe dynamic enzyme active site adaptation.
- Option D:** The unit membrane (sandwich) model was proposed by Danielli and Davson, suggesting a static lipid bilayer sandwiched between continuous protein sheets.

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

Which of the following physiological functions is primarily associated with lysosomes?

**CORE CONCEPT & DERIVATION**

Lysosomes are single-membrane-bound cytoplasmic organelles containing acid hydrolases capable of digesting all major classes of biological macromolecules, damaged organelles (autophagy), and engulfed foreign particles (phagocytosis).

**Formula / Rule / Reaction:**

*Factual recall / Qualitative concept.*

**Solution:**

- Lysosomes maintain an acidic internal pH (approx 4.5 to 5.0) and carry out intracellular digestion through phagocytic, autophagic, and autolytic activities.

**Why other options are incorrect:**

- Option A:** Protein synthesis is performed by ribosomes.
- Option B:** Processing, chemical modification, and packaging are functions of the Golgi apparatus.
- Option D:** Lipid synthesis is carried out by the smooth endoplasmic reticulum.

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

Approximately how long does it take for a complete action potential cycle to occur in a typical ...

**CORE CONCEPT & DERIVATION**

An action potential is a rapid, transient reversal of the resting membrane potential across the axolemma, characterized by rapid depolarization followed by repolarization.

**Formula / Rule / Reaction:**

Duration of typical neuronal action potential  $\approx$  1 to 3 milliseconds (ms)

**Solution:**

- During an action potential, voltage-gated  $\text{Na}^+$  channels open and inactivate rapidly, followed by the opening of voltage-gated  $\text{K}^+$  channels.
- The entire sequence of depolarization, repolarization, and return toward resting potential requires only a few milliseconds (approx 2 to 4 ms).

**Why other options are incorrect:**

- Option A:** Minutes represent an immense physiological timeframe; thousands of action potentials can fire within a single minute.
- Option C:** Hours apply to chronic developmental processes, not electrical impulses.
- Option D:** Seconds is far too slow; neuronal signaling operates on the millisecond timescale.

**Question #24** Key: (A)BIOLOGY  
12. Nervous Coordination

Which specific part of the limbic system in the human brain is involved in the consolidation of ...

**CORE CONCEPT & DERIVATION**

The limbic system regulates emotions, motivation, and memory. Within this system, the hippocampus is the primary anatomical structure required for the consolidation of declarative information from short-term to long-term memory.

**Formula / Rule / Reaction:**

*Factual recall / Qualitative concept.*

**Solution:**

- The hippocampus, located in the medial temporal lobe, processes episodic and spatial information and coordinates its storage into neocortical circuits as long-term memory.
- Damage to the hippocampus results in anterograde amnesia (inability to form new long-term memories).

**Why other options are incorrect:**

- Option B:** The cerebellum coordinates voluntary muscular movement, balance, and procedural (motor) memory.
- Option C:** The cerebrum stores long-term memories across its cortices, but the hippocampus is specifically responsible for the consolidation process.
- Option D:** The pons serves as a bridge connecting the cerebellum with the brainstem and helps regulate respiration.

**Question #25** Key: (B)BIOLOGY  
12. Nervous Coordination

A reflex arc that involves only a single sensory neuron and a single motor neuron with one cent...

**CORE CONCEPT & DERIVATION**

Reflexes are classified by the number of synapses within the central nervous system. A reflex pathway consisting solely of a sensory afferent neuron synapsing directly onto an efferent motor neuron is monosynaptic.

**Formula / Rule / Reaction:**

Stimulus → Receptor  $\xrightarrow{\text{Sensory Neuron}}$  [1 Synapse in CNS]  $\xrightarrow{\text{Motor Neuron}}$  Effector

**Solution:**

- When a reflex arc bypasses interneurons and contains only one synapse between the sensory and motor neuron, it is termed a monosynaptic reflex.
- A classic physiological example is the knee-jerk (patellar stretch) reflex.

**Why other options are incorrect:**

- Option A:** A synapse is the junction between two neurons, not the complete reflex transmission pathway.
- Option C:** A polysynaptic reflex involves one or more interneurons mediating between sensory and motor pathways.
- Option D:** The synaptic cleft is the fluid-filled physical gap separating presynaptic and postsynaptic membranes.

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

Which ion influx is required at the presynaptic terminal to trigger the exocytosis of neurotran...

**CORE CONCEPT & DERIVATION**

When an action potential arrives at the axon terminal, membrane depolarization triggers the opening of voltage-gated calcium channels. The influx of extracellular calcium ions is the obligatory stimulus for neurotransmitter exocytosis.

**Formula / Rule / Reaction:**

Depolarization of terminal → Opening of voltage-gated  $\text{Ca}^{2+}$  channels → Intracellular  $[\text{Ca}^{2+}] \uparrow \rightarrow$  SNARE-mediated exocytosis

**Solution:**

- The rise in intracellular  $\text{Ca}^{2+}$  promotes the binding of synaptotagmin, causing synaptic vesicles to fuse with the presynaptic terminal membrane.
- Neurotransmitters are released into the synaptic cleft via exocytosis.

**Why other options are incorrect:**

- Option A:** Sodium influx is responsible for the depolarization phase along the axon, but does not directly mediate vesicle fusion.
- Option B:** Potassium efflux is responsible for repolarizing the axonal membrane.
- Option D:** Chloride influx produces hyperpolarization (inhibitory postsynaptic potentials), not vesicle release.

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

Which of the following biological functions does dopamine serve in the human nervous system?

**CORE CONCEPT & DERIVATION**

Dopamine is a monoamine catecholamine synthesized from tyrosine. It acts as an important neurotransmitter in the central nervous system, particularly in pathways controlling motor coordination, reward, motivation, and cognition.

**Formula / Rule / Reaction:**

Biosynthetic pathway:

L-Tyrosine → L-DOPA → Dopamine

**Solution:**

- Dopamine functions as a central neurotransmitter.
- Degeneration of dopaminergic neurons in the substantia nigra leads to Parkinson's disease, characterized by resting tremors and muscle rigidity.

**Why other options are incorrect:**

- Option A:** Dopamine is a physiological messenger that activates D1-like and D2-like receptors, not a non-specific transmission blocker.
- Option C:** General anesthetics are exogenous pharmacological agents, not endogenous neurochemical transmitters.
- Option D:** Sedatives are pharmacological depressants; while dopamine agonists/antagonists modulate arousal, dopamine itself is classified chemically and functionally as a neurotransmitter.

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

Which major division of the human brain is responsible for higher cognitive functions such as c...

**CORE CONCEPT & DERIVATION**

The cerebrum is the largest and most developed portion of the human forebrain. Its outer layer, the cerebral cortex, contains functional centers responsible for sensory perception, voluntary motor output, speech, memory, intelligence, reasoning, and judgment.

**Formula / Rule / Reaction:**

Factual recall / Qualitative concept.

**Solution:**

- The frontal lobes of the cerebral hemispheres govern executive decision-making, creative thinking, contemplation, and personality.

**Why other options are incorrect:**

- Option A:** The medulla oblongata controls autonomic homeostatic reflexes such as heart rate, blood pressure, swallowing, and respiration.
- Option B:** The cerebellum coordinates muscular movement, posture, and motor coordination.
- Option D:** The hypothalamus regulates autonomic functions, body temperature, hunger, thirst, and neuroendocrine secretions via the pituitary gland.

**Question #29** Key: (D)BIOLOGY  
14. Reproduction

What stage of embryonic development is formed when the blastula folds inward (invaginates)?

**CORE CONCEPT & DERIVATION**

Gastrulation is the developmental process involving dramatic morphogenetic cell movements (such as invagination and epiboly) that transform the single-layered blastula into a multi-layered embryo called the gastrula.

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

- The inward folding (invagination) of cells of the blastula forms the primitive gut (archenteron) and establishes the embryonic germ layers (ectoderm, mesoderm, and endoderm).
- The resulting developmental stage is called the gastrula.

**Why other options are incorrect:**

- Option A:** The morula is an earlier stage consisting of a solid ball of blastomeres prior to blastocoel formation.
- Option B:** The blastocoel is the fluid-filled central cavity inside the blastula.
- Option C:** The blastopore is the opening produced by invagination into the archenteron, not the entire embryo stage itself.

**Question #30** Key: (B)BIOLOGY  
15. Inheritance / Variation & Genetics

Which biological phenomenon describes a life cycle where an asexual form produces a sexual form...

**CORE CONCEPT & DERIVATION**

Alternation of generations (metagenesis in certain cnidarians and haplodiplontic cycles in plants) is a life cycle pattern where a haploid sexual gametophyte generation alternates regularly with a diploid asexual sporophyte generation.

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

- The regular alternation between a sexual reproductive phase (gamete-producing) and an asexual reproductive phase (spore-producing or budding) is known as alternation of generations.

**Why other options are incorrect:**

- Option A:** Colonial organization refers to independent individual cells or organisms living aggregated together.
- Option C:** Parasitism is a symbiotic relationship where one organism benefits at the metabolic expense of a host.
- Option D:** Polymorphism describes the structural coexistence of more than one distinct morphological form in the same species (e.g., polyps and medusae in Obelia).

**Question #31** Key: (D)BIOLOGY  
02. Biomolecules

Which of the following represents the red coral reef material historically used by Hakeems in p...

**CORE CONCEPT & DERIVATION**

Certain colonial anthozoan cnidarians secrete a stony calcareous skeleton of calcium carbonate that forms coral reefs. Red coral (\*Corallium rubrum\*) has economic, ornamental, and pharmaceutical uses.

**Formula / Rule / Reaction:**

Factual recall / Qualitative concept.

**Solution:**

- According to the Sindh Textbook Board Biology textbook (Chapter on Kingdom Animalia), red coral, known in traditional medicine as 'Marjan', is powdered and utilized by Hakeems in Unani and eastern medicinal preparations.

**Why other options are incorrect:**

- Option A:** Diamond is a crystalline allotrope of elemental carbon, not derived from biological coral reefs.
- Option B:** Emerald is a green gemstone composed of the mineral beryl (beryllium aluminum cyclosilicate).
- Option C:** Ruby is a pink to blood-red gemstone consisting of the mineral corundum (aluminum oxide).

**Question #32** Key: (A)BIOLOGY  
16. Evolution

Evolutionary progress toward the development of organ systems in cnidarians is first indicated ...

**CORE CONCEPT & DERIVATION**

Cnidarians are diploblastic eumetazoans showing tissue grade of organization. They represent the earliest branch of animal evolution exhibiting a digestive cavity (enteron) and a coordinated diffuse nervous system called a nerve net.

**Formula / Rule / Reaction:**

Factual recall / Qualitative concept.

**Solution:**

The evolution of a sac-like digestive enteron combined with an interconnected network of non-polarized nerve cells (nerve net) marks the transition from cellular aggregates to tissue and organ system precursors.

**Why other options are incorrect:**

- Option B:** Cnidarians possess radial symmetry, not bilateral symmetry.
- Option C:** Cnidarians lack a coelom; they are acoelomate and diploblastic.
- Option D:** Cnidarians remain at the tissue grade of organization; true organs do not emerge until the triploblastic acoelomates (Platyhelminthes).

**Question #33** Key: (D)BIOLOGY  
03. Enzymes

What is the optimum pH for the catalytic activity of pepsin in the human stomach?

**CORE CONCEPT & DERIVATION**

Every enzyme operates maximally at a specific optimum pH. Pepsin, an endopeptidase secreted by gastric chief cells, requires a strongly acidic environment maintained by hydrochloric acid to achieve its active catalytic conformation.

**Formula / Rule / Reaction:**

Sindh Textbook Board Table of Optimum pH:

Pepsin: pH 1.4 – 1.5

**Solution:**

- The Sindh Textbook Board Biology XI (Chapter on Enzymes) specifies the optimum pH of pepsin as 1.4.
- In neutral or alkaline pH, pepsin is irreversibly denatured and inactivated.

**Why other options are incorrect:**

- Option A:** A pH of 3.0 is higher than the narrow optimum range of human pepsin, resulting in significantly lower catalytic rates.
- Option B:** While general physiology texts sometimes approximate pepsin activity around pH 2, the exact textbook figure printed in the STB past paper curriculum is 1.4.
- Option C:** pH 2.5 is above the peak optimum of gastric pepsin.

**Question #34** Key: (B)BIOLOGY  
03. Enzymes

At equilibrium, a scientist added more substrate and observed a transient increase in the react...

**CORE CONCEPT & DERIVATION**

In multi-step enzymatic pathways, the rate of reaction can be controlled by feedback inhibition, where the accumulation of the final metabolic end product allosterically inhibits the first enzyme of the pathway to prevent unnecessary overproduction.

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

- Initial substrate addition pushed the reaction forward, generating high concentrations of product.
- Once the end product reached inhibitory levels, it bound to allosteric sites on regulatory enzymes, turning off catalysis and rendering the reaction rate insensitive to further substrate addition.

**Why other options are incorrect:**

- Option A:** Feedback inhibition is completely reversible; the enzyme is not permanently denatured or broken.
- Option C:** If active sites were still free, adding more substrate would have increased the reaction rate further.
- Option D:** Fresh intact substrate was added by the experimenter; degradation of substrate does not explain saturation-independent plateauing.

**Question #35** Key: (A)BIOLOGY  
03. Enzymes

Penicillin blocks the active site of the transpeptidase enzyme that bacteria use to cross-link ...

**CORE CONCEPT & DERIVATION**

Competitive inhibitors are chemical compounds whose molecular structure closely resembles the normal substrate. They compete directly with the substrate for binding to the enzyme's catalytic active site.

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

- Penicillin resembles the D-alanyl-D-alanine terminus of bacterial cell wall peptidoglycan.
- It binds directly into the active site of bacterial transpeptidase, blocking cell wall synthesis via competitive active-site inhibition.

**Why other options are incorrect:**

- Option B:** Non-competitive inhibitors bind to an allosteric site away from the active site, not to the active site itself.
- Option C:** Feedback inhibition is an endogenous pathway regulation performed by normal metabolic end products, not an exogenous antibiotic.
- Option D:** Allosteric activation increases enzymatic activity, whereas penicillin inhibits and halts bacterial cell wall assembly.

**Question #36** Key: (D)BIOLOGY  
03. Enzymes

The three-dimensional conformation and catalytic geometry of an enzyme's active site is altered...

**CORE CONCEPT & DERIVATION**

Non-competitive inhibitors bind to a specific regulatory site on the enzyme other than the catalytic active site, known as the allosteric site. This binding induces a conformational change that distorts the active site geometry.

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

- Because the inhibitor does not bind at the active site, increasing substrate concentration cannot overcome the inhibition.
- The induced conformational change renders the enzyme catalytically inactive or significantly less efficient.

**Why other options are incorrect:**

- Option A:** Irreversible binding typically involves covalent attachment, but the prompt specifically describes conformational active-site alteration via non-active site binding.
- Option B:** Competitive inhibitors bind directly within the active site without changing the overall folding conformation of the enzyme.
- Option C:** Substrate-level phosphorylation is a metabolic mechanism of ATP generation, completely unrelated to enzyme inhibition.

**Question #37** Key: (B)BIOLOGY  
03. Enzymes

A chemical substance that binds to an enzyme in place of the natural substrate but is not converted...

**CORE CONCEPT & DERIVATION**

Enzyme inhibitors are chemical substances that interact with enzymes, either at the active site or allosterically, and decrease or halt the rate of catalysis without undergoing conversion into products.

**Formula / Rule / Reaction:**

Factual recall / Qualitative concept.

**Solution:**

- Inhibitors react with enzymes in place of the substrate, preventing the normal catalytic formation of products.
- They can be competitive, non-competitive, or uncompetitive in nature.

**Why other options are incorrect:**

- Option A:** Accelerators (catalysts or activators) increase the rate of reaction.
- Option C:** Coenzymes are organic non-protein helper molecules (like NAD<sup>+</sup> or FAD) required for enzyme catalytic activity.
- Option D:** Activators bind to enzymes to increase their affinity for the substrate and enhance reaction velocity.

**Question #38** Key: (C)BIOLOGY  
16. Evolution

Which of the following transitional fossil organisms provides definitive evidence for the evolution...

**CORE CONCEPT & DERIVATION**

Transitional fossils exhibit intermediate morphological characteristics between an ancestral group and its derived descendant group. \*Archaeopteryx lithographica\* is the classic transitional link between non-avian theropod dinosaurs (reptiles) and modern birds.

**Formula / Rule / Reaction:**

Factual recall / Qualitative concept.

**Solution:**

- Discovered in 1861 in Bavarian limestone, \*Archaeopteryx\* possessed reptilian traits (teeth, clawed fingers on wings, long bony tail) alongside avian traits (feathers, wishbone, wings).

**Why other options are incorrect:**

- Option A:** Mammals evolved from synapsid reptiles (therapsids), not representing a link between reptiles and birds.
- Option B:** Fishes are ancestral to early tetrapods (amphibians), not a direct transitional link from reptiles to birds.
- Option D:** Arthropods are invertebrates belonging to the protostome lineage, completely unrelated to vertebrate avian transitions.

**Question #39** Key: (D)BIOLOGY  
16. Evolution

The ancient fossil bird Archaeopteryx possessed teeth, clawed wing fingers, and a long tail...

**CORE CONCEPT & DERIVATION**

Phylogenetic analysis of anatomical characters indicates that modern birds (Aves) are avian dinosaurs that evolved from bipedal, carnivorous theropod reptiles during the Jurassic period.

**Formula / Rule / Reaction:**

Theropod Reptiles → Transitional Avian Ancestors (e.g., Archaeopteryx) → Modern Birds

**Solution:**

- Modern birds lack teeth, have fused tail vertebrae (pygostyle), and lack clawed wing digits.
- The presence of reptilian socketed teeth, separate vertebrae extending along the entire tail, and clawed forelimbs in \*Archaeopteryx\* demonstrates that birds are modified descendants of reptiles.

**Why other options are incorrect:**

- Option A:** Insects are protostome invertebrates with an exoskeleton of chitin, lacking all chordate traits.
- Option B:** Pisces (fishes) gave rise to early amphibians, not directly to birds.
- Option C:** Amphibians gave rise to early cotylosaur reptiles, which subsequently diverged into diapsid reptilian lineages.

**Question #40** Key: (B)BIOLOGY  
16. Evolution

Artificial selection in animal and plant breeding provides compelling evidence for evolution. T...

**CORE CONCEPT & DERIVATION**

Artificial selection is the deliberate breeding of individuals by humans to propagate desired phenotypic traits. Charles Darwin utilized the rapid morphological diversification of domesticated pigeons, dogs, and agricultural crops as evidence that selection can modify species over time.

**Formula / Rule / Reaction:**

Factual recall / Qualitative concept.

**Solution:**

- According to the Sindh Textbook Board syllabus, artificial selection is embodied in the process of 'domestication'.
- By selecting specific wild ancestral individuals, humans generated wide varieties of domestic dogs, livestock, and grains over relatively brief geological periods.

**Why other options are incorrect:**

- Option A:** Vestigial organs are rudimentary structures that have lost their ancestral function, such as the human vermiform appendix.
- Option C:** Spontaneous mutations are random molecular DNA alterations, not guided selective breeding.
- Option D:** Homology refers to similarity in anatomical structures resulting from common ancestry (e.g., vertebrate forelimbs).

**Question #41** **Key: (D)**BIOLOGY  
16. Evolution

Carolus Linnaeus, the renowned Swedish botanist and taxonomist, was an ardent proponent of which...

**CORE CONCEPT & DERIVATION**

Prior to the formulation of evolutionary theory, the prevailing biological paradigm held that all living species were created in their present static forms by divine intervention and remained immutable over time. This concept is termed the Theory of Special Creation.

**Formula / Rule / Reaction:**

*Factual recall / Qualitative concept.*

**Solution:**

- Carolus Linnaeus believed that species were fixed and unchangeable products of special creation, famously stating that there are as many species as the infinite beings produced in the beginning.

**Why other options are incorrect:**

- **Option A:** Catastrophism was championed by the French paleontologist Georges Cuvier.
- **Option B:** The theory of inheritance of acquired characteristics was formulated by Jean-Baptiste de Lamarck.
- **Option C:** The theory of evolution by natural selection was formulated jointly by Charles Darwin and Alfred Russel Wallace.

**Question #42** **Key: (A)**BIOLOGY  
07. Circulation / Transport

What is the total volume of blood pumped per minute by the left ventricle into the systemic circulation...

**CORE CONCEPT & DERIVATION**

Cardiac output is the primary physiological parameter measuring the volumetric pumping performance of the ventricles over a one-minute duration.

**Formula / Rule / Reaction:**

$$\text{Cardiac Output (CO)} = \text{Stroke Volume (SV)} \times \text{Heart Rate (HR)}$$

$$\text{CO} \approx 70 \text{ mL/beat} \times 72 \text{ beats/min} \approx 5040 \text{ mL/min (approx 5 L/min)}$$

**Solution:**

- Stroke volume is the volume ejected per single contraction.
- When multiplied by the heart rate (beats per minute), the resulting total volume pumped per minute is defined as cardiac output.

**Why other options are incorrect:**

- **Option B:** Stroke volume is the volume of blood pumped out with each individual heartbeat (approx 70 mL), not per minute.
- **Option C:** Systolic volume refers to the volume during ventricular systole, not the time-rate output.
- **Option D:** End-diastolic volume is the total volume of blood filling the ventricle at the end of diastole (approx 120 mL).

**Question #43** **Key: (D)**BIOLOGY  
06. Digestion/Nutrition

Which digestive enzyme is synthesized and secreted in an inactive state (as a zymogen) to prevent...

**CORE CONCEPT & DERIVATION**

Powerful proteolytic enzymes that hydrolyze internal peptide bonds are produced and stored as inactive precursor proenzymes (zymogens) to prevent enzymatic lysis of cellular proteins within the secretory chief cells.

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

- Pepsin is a powerful protein-cleaving enzyme capable of destroying structural and functional proteins of the gastric mucosa.
- It is secreted by chief (peptic) cells as inactive pepsinogen and is only activated upon exposure to hydrochloric acid in the gastric lumen.

**Why other options are incorrect:**

- **Option A:** Lactase is a brush-border disaccharidase that digests lactose into glucose and galactose without threatening cellular integrity.
- **Option B:** Sucrase is a disaccharidase hydrolyzing sucrose; carbohydrate-cleaving enzymes are not hazardous to the cellular structure and are not secreted as zymogens.
- **Option C:** Maltase hydrolyzes maltose into two glucose units and is active on the enterocyte brush border.

**Question #44** **Key: (A)**BIOLOGY  
06. Digestion/Nutrition

The carnivorous adaptation observed in insectivorous plants is primarily an evolutionary response to...

**CORE CONCEPT & DERIVATION**

Insectivorous plants grow in acidic, waterlogged, bogs and swampy soils where nitrates and ammonium compounds are severely depleted due to continuous leaching and slow decomposition.

**Formula / Rule / Reaction:**

*Factual recall / Qualitative concept.*

**Solution:**

- To survive in nitrogen-poor soils, carnivorous plants evolved specialized trapping mechanisms to capture, digest, and absorb insects as a nitrogenous nutritional supplement.
- The digested animal proteins supply essential amino acids and nitrogen for plant growth.

**Why other options are incorrect:**

- **Option B:** Potassium deficiency is not the primary evolutionary pressure driving the evolution of carnivory in plants.
- **Option C:** Sulphur is readily available in many acidic bogs as sulphates and is not the driver of insect trapping.
- **Option D:** Calcium is present in variable concentrations, but nitrogen is the universally scarce macroelement in insectivorous habitats.

**Question #45** **Key: (D)**BIOLOGY  
06. Digestion/Nutrition

In nutritional and ecological terms, the insectivorous plant sundew (*Drosera*) is categorized as...

**CORE CONCEPT & DERIVATION**

Carnivorous plants possess chlorophyll and carry out normal oxygenic photosynthesis to synthesize their own carbohydrates, but they trap and digest insects to obtain supplementary nitrogenous organic compounds.

**Formula / Rule / Reaction:**

Nutritional categorization:

Photosynthetic (Autotrophic for carbon) + Carnivorous (Heterotrophic for nitrogen)

**Solution:**

- Sundew (\**Drosera*\*) has green leaves equipped with chlorophyll to carry out light-dependent carbon fixation, making it autotrophic.
- It secretes proteolytic enzymes to digest ensnared insects and absorbs nitrogen compounds, making it partially heterotrophic.

**Why other options are incorrect:**

- **Option A:** Calling it purely autotrophic ignores its obligatory predatory trapping mechanism for nitrogen acquisition.
- **Option B:** Purely heterotrophic organisms lack chlorophyll and cannot synthesize organic carbon from carbon dioxide.
- **Option C:** Holozoic nutrition involves internal ingestion and alimentary digestion, which is restricted to animals.

**Question #46** **Key: (D)**BIOLOGY  
07. Circulation/Transport

Which of the following statements is anatomically and functionally correct regarding the semilunar valves...

**CORE CONCEPT & DERIVATION**

The semilunar valves consist of three pocket-like cusps situated at the base of the two major outflow vessels leaving the heart: the aortic valve at the base of the aorta and the pulmonary valve at the base of the pulmonary trunk.

**Formula / Rule / Reaction:**

Ventricular Diastole:  $P_{\text{artery}} > P_{\text{ventricle}} \rightarrow$  Semilunar valves snap shut (Second heart sound,  $S_2$ )

**Solution:**

- When the ventricles contract, semilunar valves open into the outflow arteries.
- When the ventricles relax, back pressure of arterial blood fills the pocket-like cusps, closing the valves and preventing regurgitation of blood back into the ventricles.

**Why other options are incorrect:**

- **Option A:** Veins contain pocket valves throughout their length, but these are venous valves, not the cardiac semilunar valves.
- **Option B:** Muscular and elastic arterial walls cushion pulsatile jerks via the Windkessel effect, not valves.
- **Option C:** Capillaries lack valves; blood flow through capillaries is regulated by precapillary sphincters in metarterioles.

**Question #47** **Key: (D)**BIOLOGY  
09. Respiration / Gaseous Exchange

The average total lung capacity of an adult human is approximately 5 litres. What proportion of...

**CORE CONCEPT & DERIVATION**

Total lung capacity (TLC) is the maximum volume of air that the lungs can contain following maximal inspiration. Vital capacity (VC) is the maximum volume of air that can be exhaled following maximal inspiration.

**Formula / Rule / Reaction:**

$$\text{Fraction} = \frac{\text{Vital Capacity (VC)}}{\text{Total Lung Capacity (TLC)}} = \frac{4.0 \text{ L}}{5.0 \text{ L}} = 0.8 = 80\%$$

**Solution:**

- In an adult human, total lung capacity averages approximately 5.0 liters, while vital capacity averages approximately 4.0 liters (the remaining 1.0 to 1.2 liters being the non-expressible residual volume).
- Calculating the fraction gives:  $\frac{4}{5} \times 100 = 80\%$  (or 0.8).

**Why other options are incorrect:**

- **Option A:** 10 percent (0.5 L) corresponds to the normal resting tidal volume (500 mL).
- **Option B:** 40 percent (2.0 L) represents an incomplete inspiratory effort.
- **Option C:** 60 percent (3.0 L) corresponds to inspiratory capacity alone, omitting expiratory reserve volume.

**Question #48** **Key: (A)**BIOLOGY  
06. Digestion/Nutrition

In ecological and trophic classification, the earthworm is classified as a:

**CORE CONCEPT & DERIVATION**

Detritivores are heterotrophic organisms that obtain nutrients by consuming decomposing organic plant and animal material (detritus) as well as organic matter in the soil.

**Formula / Rule / Reaction:**

Factual recall / Qualitative concept.

**Solution:**

- Earthworms burrow through soil, ingesting decaying leaves, soil organic matter, and microorganisms.
- They mechanically grind this detritus in their muscular gizzard and excrete nutrient-rich worm castings, fulfilling the definition of a detritivore.

**Why other options are incorrect:**

- **Option B:** Fluid feeders suck nutrient-rich biological fluids from living hosts (e.g., female mosquitoes, aphids, leeches).
- **Option C:** Macrophagous feeders seize and consume large whole prey or large pieces of food (e.g., predatory carnivores).
- **Option D:** Microphagous suspension feeders filter microscopic food particles from water currents (e.g., sponges, mussels).

**Question #49** Key: (A)BIOLOGY  
04. Bioenergetics

Photosynthetic sulfur bacteria utilize hydrogen sulfide (H<sub>2</sub>S) instead of water as an electron d...

**CORE CONCEPT & DERIVATION**

Anoxygenic photosynthetic bacteria (such as purple and green sulfur bacteria) do not use water as a reducing agent. Instead, they utilize hydrogen sulfide (H<sub>2</sub>S), so they do not produce oxygen as a byproduct.

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

- Because hydrogen sulfide is oxidized to yield electrons and protons, elemental sulfur globules are deposited instead of releasing molecular oxygen gas.

**Why other options are incorrect:**

- Option B:** Phosphorus is an essential nutrient for nucleic acids but is not a byproduct of photolysis.
- Option C:** Calcium is a divalent mineral that does not act as a photolytic byproduct.
- Option D:** Magnesium forms the coordination center of bacteriochlorophyll molecules, not an excreted byproduct.

**Question #50** Key: (B)BIOLOGY  
17. Biotechnology

Which of the following genetically engineered bacteria is widely utilized in biotechnology to p...

**CORE CONCEPT & DERIVATION**

Recombinant DNA technology employs bacterial host expression systems for the production of therapeutic human polypeptides. Plasmids carrying the synthetic human insulin or growth hormone gene are transformed into \*Escherichia coli\*.

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

- \*Escherichia coli\* is the model host organism used extensively in commercial biomanufacturing to produce recombinant human insulin (humulin) and human growth hormone (somatotropin).

**Why other options are incorrect:**

- Option A:** \*Streptococcus pneumoniae\* (Pneumococcus) is a human respiratory pathogen historically famous for Griffith's transformation experiment.
- Option C:** \*Rhizobium leguminosarum\* is a symbiotic nitrogen-fixing bacterium inhabiting the root nodules of leguminous plants.
- Option D:** \*Nostoc commune\* is a filamentous cyanobacterium capable of oxygenic photosynthesis and nitrogen fixation.

**Question #51** Key: (D)BIOLOGY  
01. Cell

The bacterial cell wall is chemically composed of:

**CORE CONCEPT & DERIVATION**

The eubacterial cell wall is composed of peptidoglycan (murein), a macromolecular polymer consisting of repeating disaccharide units cross-linked by short oligopeptide chains.

**Formula / Rule / Reaction:**

Peptidoglycan = Polysaccharide backbone (NAG + NAM) + Tetrapeptide cross-links (Amino acid

**Solution:**

- The alternating amino sugars N-acetylglucosamine (NAG) and N-acetylmuramic acid (NAM) provide the carbohydrate backbone.
- These sugar chains are cross-linked by short peptide chains composed of amino acids, forming a rigid sacculus that protects the bacterium against osmotic lysis.

**Why other options are incorrect:**

- Option A:** Cellulose and pectin form the primary cell wall of plants, completely absent in bacterial walls.
- Option B:** Cutin is a waxy lipid polymer found on plant epidermal surfaces.
- Option C:** Chitin forms the cell wall of true fungi and the exoskeleton of arthropods.

**Question #52** Key: (B)BIOLOGY  
17. Biotechnology

Which of the following extrachromosomal genetic elements serves as an essential vector in recom...

**CORE CONCEPT & DERIVATION**

Plasmids are small, circular, double-stranded, self-replicating extrachromosomal DNA molecules found naturally in bacteria. They serve as gene-cloning vectors to transfer foreign genes into target host cells.

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

- Plasmids possess an origin of replication (ori), selectable antibiotic marker genes, and unique restriction endonuclease recognition sites (polylinkers).
- These molecular attributes make plasmids ideal vectors for molecular cloning.

**Why other options are incorrect:**

- Option A:** Plastids are double-membrane semi-autonomous metabolic organelles found in photosynthetic plant and algal cells.
- Option C:** The nucleoid is the irregularly shaped cytoplasmic region containing the bacterial main circular genomic chromosome.
- Option D:** Pili are tubular proteinaceous surface appendages used for bacterial conjugation and attachment.

**Question #53** Key: (A)BIOLOGY  
01. Cell

Membranous infoldings of the bacterial plasma membrane that assist in cell division and initiate...

**CORE CONCEPT & DERIVATION**

Mesosomes are convoluted, vesicular, or lamellar invaginations of the prokaryotic plasma membrane that increase surface area for respiratory enzymes and anchor the bacterial chromosome during binary fission.

**Formula / Rule / Reaction:**

Factual recall / Qualitative concept.

**Solution:**

- According to the Sindh Textbook Board Biology syllabus, mesosomes are internal extensions of the bacterial cell membrane involved in DNA replication, chromosome distribution to daughter cells, and cellular respiration.

**Why other options are incorrect:**

- Option B:** Peroxisomes are eukaryotic microbodies containing catalase and oxidases involved in hydrogen peroxide metabolism.
- Option C:** Glyoxysomes are specialized plant microbodies that convert stored fatty acids into carbohydrates via the glyoxylate cycle.
- Option D:** Nucleosomes are fundamental eukaryotic chromatin units composed of DNA wrapped around an octamer of basic histone proteins.

**Question #54** Key: (B)BIOLOGY  
14. Reproduction

During human embryonic development, the testes originate inside the abdominal cavity. In which...

**CORE CONCEPT & DERIVATION**

Spermatogenesis requires an environment approximately 2 to 3 degrees Celsius below core body temperature. The testes migrate through the inguinal canals during the third trimester of fetal gestation to reside within the extra-abdominal scrotum.

**Formula / Rule / Reaction:**

Thermoregulatory requirement:

$$T_{\text{scrotum}} = T_{\text{core}} - (2^{\circ}\text{C to } 3^{\circ}\text{C}) \approx 34^{\circ}\text{C to } 35^{\circ}\text{C}$$

**Solution:**

- The scrotum is a cutaneous pouch suspended outside the abdominopelvic cavity that houses the testes, epididymides, and spermatic cords.
- Failure of the testes to descend into the scrotum before birth is termed cryptorchidism, which leads to sterility if uncorrected.

**Why other options are incorrect:**

- Option A:** The peritoneal sac lines the internal abdominal cavity; retaining the testes within the peritoneum prevents normal spermatogenesis due to elevated core temperature.
- Option C:** The inguinal pouch or canal is the transient passage through which the testes descend, not their final anatomical destination.
- Option D:** The seminal vesicle is an accessory reproductive gland that secretes fructose-rich alkaline seminal fluid.

**Question #55** Key: (A)BIOLOGY  
14. Reproduction

During the process of ovulation, which anatomical structure captures and draws the secondary oocyte...

**CORE CONCEPT & DERIVATION**

Upon ovulation, the Graafian follicle ruptures, extruding the secondary oocyte into the peritoneal cavity. The expanded, funnel-shaped infundibulum of the oviduct (fallopian tube), equipped with ciliated fimbriae, sweeps the oocyte into the lumen.

**Formula / Rule / Reaction:**

Ruptured Follicle → Peritoneal Cavity  $\xrightarrow{\text{Ciliated Fimbrial Currents}}$  Oviduct (Fallopian Tube)

**Solution:**

- The fimbriae at the ovarian end of the oviducts create fluid currents via ciliary motion that actively draw the released ovum into the fallopian tube.

**Why other options are incorrect:**

- Option B:** The uterus is the thick muscular organ where embryonic implantation and fetal gestation occur, situated downstream of the oviducts.
- Option C:** The vagina is the female copulatory organ and birth canal, positioned inferior to the uterine cervix.
- Option D:** The ureter is an excretory duct carrying urine from the kidney to the urinary bladder.

**Question #56** Key: (C)BIOLOGY  
14. Reproduction

Following ovulation, the collapsed, ruptured Graafian follicle transforms under the influence of...

**CORE CONCEPT & DERIVATION**

Under the endocrine stimulation of luteinizing hormone (LH), the granulosa and theca cells of the ruptured mature follicle proliferate and luteinize, forming a temporary yellowish endocrine structure called the corpus luteum.

**Formula / Rule / Reaction:**

Ruptured Follicle  $\xrightarrow{\text{LH Surge}}$  Corpus Luteum  $\xrightarrow{\text{Secretes}}$  Progesterone + Estrogen

**Solution:**

- The corpus luteum secretes large amounts of progesterone, which thickens and vascularizes the endometrium to prepare for blastocyst implantation.
- If pregnancy does not occur, the corpus luteum degenerates into a white fibrous scar called the corpus albicans.

**Why other options are incorrect:**

- Option A:** The corpus callosum is a dense tract of transverse commissural nerve fibers connecting the left and right cerebral hemispheres.
- Option B:** The corpus albicans is the inactive fibrous scar tissue remaining after the involution and regression of the corpus luteum.
- Option D:** Follicular atresia refers to the apoptotic degeneration of immature ovarian follicles before reaching ovulation.

**Question #57** Key: (D)BIOLOGY  
14. Reproduction

In humans, rabbits, and other placental mammals, fertilization of the ovum typically takes plac...

**CORE CONCEPT & DERIVATION**

Fertilization is the union of a viable sperm with a secondary oocyte. In placental mammals, this physiological event occurs in the proximal portion of the oviduct, specifically the ampullary-isthmic junction of the fallopian tube.

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

- The ampulla of the fallopian tube provides the biochemical and physiological microenvironment required for capacitated sperm to undergo the acrosome reaction and penetrate the zona pellucida.
- The resulting zygote undergoes early cleavage divisions as it travels toward the uterus.

**Why other options are incorrect:**

- Option A:** The ovary produces and releases the oocyte; intra-ovarian fertilization is abnormal and non-viable.
- Option B:** The uterus is the site of blastocyst implantation and gestational nourishment, arriving approximately 5 to 7 days post-fertilization.
- Option C:** The cervix acts as a selective mucosal gateway for sperm entry, not the site of syngamy.

**Question #58** Key: (B)BIOLOGY  
14. Reproduction

The corpus luteum in female mammals is located in the:

**CORE CONCEPT & DERIVATION**

The corpus luteum is a dynamic endocrine gland situated inside the ovarian stroma that produces high titers of progesterone and moderate estrogen during the luteal (secretory) phase of the menstrual cycle.

**Formula / Rule / Reaction:**

Factual recall / Qualitative concept.

**Solution:**

- The corpus luteum develops within the cortical parenchyma of the ovary from the follicular wall following ovum discharge.
- Its primary role is the endocrine secretion of progesterone, which maintains the secretory endometrium and suppresses gonadotropin-releasing hormone (GnRH) via negative feedback.

**Why other options are incorrect:**

- Option A:** The cerebral commissure connecting the hemispheres is the corpus callosum.
- Option C:** The pacemaker initiating heart contractions is the sinoatrial (SA) node.
- Option D:** Cutaneous mechanical receptors include Pacinian, Meissner, and Ruffini corpuscles.

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

In the human axial skeleton, the ribs are articulated to the thoracic vertebrae through:

**CORE CONCEPT & DERIVATION**

Joints are classified functionally by the degree of movement they permit. Partially movable joints (amphiarthroses) permit limited motion, essential for the expansion and contraction of the thoracic cage during respiration.

**Formula / Rule / Reaction:**

Factual recall / Qualitative concept.

**Solution:**

- Costovertebral articulations connect the heads and tubercles of ribs with the demi-facets of thoracic vertebrae.
- According to the Sindh Textbook Board syllabus, these articulations are classified as partially movable joints that allow the thoracic cage to elevate and expand during breathing.

**Why other options are incorrect:**

- Option A:** Fixed joints (synarthroses) permit no movement whatsoever, exemplified by cranial sutures.
- Option B:** Ball-and-socket joints permit multi-axial rotational movement, found only at the shoulder and hip joints.
- Option C:** Sutures are immovable fibrous joints restricted exclusively to the skull bones.

**Question #60** Key: (A)BIOLOGY  
11. Support & Movement

Which internal cavities are present at diarthrodial joints and contain a viscous fluid that red...

**CORE CONCEPT & DERIVATION**

Synovial joints are characterized by the presence of a fluid-filled joint cavity enclosed by an articular capsule. The inner synovial membrane secretes synovial fluid rich in hyaluronic acid and lubricin to minimize mechanical friction.

**Formula / Rule / Reaction:**

Factual recall / Qualitative concept.

**Solution:**

- The synovial cavity is the space between the articulating surfaces of bones.
- Synovial fluid acts as a lubricant and hydraulic shock absorber, nourishing the avascular articular hyaline cartilage.

**Why other options are incorrect:**

- Option B:** Ventricles are communicating internal cavities within the brain that produce and circulate cerebrospinal fluid.
- Option C:** The acetabulum is the deep cup-shaped bony socket of the hip bone, not a fluid-filled lubricating cavity itself.
- Option D:** The pleural cavity surrounds the lungs in the thorax, lubricating pulmonary expansion.

**Question #61** Key: (A)BIOLOGY  
11. Support & Movement

Which type of muscle tissue forms the tunica media of blood vessels and regulates their luminal...

**CORE CONCEPT & DERIVATION**

Vascular smooth muscle cells are arranged circumferentially within the middle layer (tunica media) of arterial and venous walls. Their contraction (vasoconstriction) and relaxation (vasodilation) regulate systemic vascular resistance and blood flow.

**Formula / Rule / Reaction:**

Sympathetic Tone  $\uparrow$   $\rightarrow$  Vascular Smooth Muscle Contraction  $\rightarrow$  Vasoconstriction  $\rightarrow$  Lumen Diameter  $\downarrow$

**Solution:**

- Smooth muscle is non-striated, involuntary, spindle-shaped, and regulated by autonomic nerves, hormones, and local metabolites.
- By altering vessel diameter, smooth muscle directly regulates systemic blood pressure.

**Why other options are incorrect:**

- **Option B:** Skeletal muscle is striated, multinucleated, and voluntary, attached to bones to move the skeleton.
- **Option C:** Cardiac muscle is striated and branched, found exclusively in the myocardium of the heart.
- **Option D:** Voluntary muscle is under conscious somatic nervous control and cannot regulate visceral vascular tone.

**Question #62** Key: (B)BIOLOGY  
15. Inheritance / Variation & Genetics

When Gregor Mendel crossed two true-breeding homozygous pea plants with contrasting traits, the...

**CORE CONCEPT & DERIVATION**

Mendel's Law of Dominance states that when two individuals with homozygous contrasting traits are crossed, the allele that masks the expression of the other in the heterozygous condition is dominant, and only the dominant trait is expressed in the  $F_1$  phenotype.

**Formula / Rule / Reaction:**

$P_1 : AA \text{ (Dominant)} \times aa \text{ (Recessive)} \Rightarrow F_1 : Aa \text{ (Heterozygous, displays Dominant phenotype)}$

**Solution:**

- In monohybrid crosses (e.g., pure round  $RR$  crossed with pure wrinkled  $rr$ ), all  $F_1$  progeny possess the genotype  $Rr$ .
- Because the round allele is completely dominant, 100 percent of the  $F_1$  offspring display the dominant parental phenotype.

**Why other options are incorrect:**

- **Option A:** The recessive trait is masked in the heterozygous  $F_1$  generation and only re-emerges in the  $F_2$  generation.
- **Option C:** Intermediate blending characterizes incomplete dominance (e.g., \*Mirabilis jalapa\*), which violates classical Mendelian complete dominance.
- **Option D:** The  $F_1$  generation is phenotypically uniform, not a mixed mosaic.

**Question #63** Key: (D)BIOLOGY  
15. Inheritance / Variation & Genetics

In a dihybrid cross between \*Pisum sativum\* plants producing Yellow/Round seeds and Green/Wrink...

**CORE CONCEPT & DERIVATION**

Mendel's Law of Independent Assortment states that alleles of two or more different gene pairs assort independently of one another during gamete formation, generating novel recombinant non-parental phenotypic classes in the  $F_2$  generation.

**Formula / Rule / Reaction:**

Parental types: Yellow/Round (9/16) + Green/Wrinkled (1/16)

Recombinant types :Yellow/Wrinkled (3/16) + Green/Round (3/16)

**Solution:**

- The original parental combinations were Yellow/Round and Green/Wrinkled.
- The appearance of the new recombinant combinations (Yellow/Wrinkled at 3/16 and Green/Round at 3/16) proves that the genes for seed color and seed shape assort into gametes completely independently.

**Why other options are incorrect:**

- **Option A:** 9/16 and 1/16 represent the parental phenotypic combinations, which would occur even if the genes were tightly linked.
- **Option B:** 6/16 is not a single phenotypic class in a classical dihybrid ratio.
- **Option C:** 2/16 is an incorrect mathematical fraction that does not appear in a standard 16-square Punnett board.

**Question #64** Key: (C)BIOLOGY  
11. Support & Movement

An orthopedic radiograph of a patient's stiff, crippled joint reveals erosion and hardening of ...

**CORE CONCEPT & DERIVATION**

Arthritis is an inflammatory or degenerative disorder of the joints characterized by pain, stiffness, articular cartilage degradation, and calcification of surrounding connective tissues, causing joint deformities.

**Formula / Rule / Reaction:**

Factual recall / Qualitative concept.

**Solution:**

- Degenerative joint disease (such as osteoarthritis) results in the progressive erosion and hardening of articular cartilage accompanied by abnormal subchondral bone remodeling and calcium deposition.
- This produces joint rigidity, ankylosis, and functional disability.

**Why other options are incorrect:**

- **Option A:** A slipped (herniated) disc involves the displacement of the nucleus pulposus through a ruptured annulus fibrosus in the vertebral column.
- **Option B:** Spondylosis refers specifically to age-related degenerative osteoarthritic changes localized to the vertebral spine.
- **Option D:** Sciatica is radiating neuropathic pain along the sciatic nerve resulting from compression of lumbar nerve roots.

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

Which of the following inherited disorders is characterized by a failure of the physiological b...

**CORE CONCEPT & DERIVATION**

Hemophilia is an X-linked recessive genetic coagulopathy characterized by a deficiency or qualitative defect in essential blood-clotting factors, resulting in delayed fibrin formation and life-threatening prolonged bleeding.

**Formula / Rule / Reaction:**

Hemophilia A: Factor VIII deficiency | Hemophilia B: Factor IX deficiency

**Solution:**

- Individuals with hemophilia fail to produce sufficient active prothrombinase/intrinsic tenase complexes, preventing the conversion of prothrombin to thrombin.
- Minor trauma can lead to extensive internal hemorrhages into joints (hemarthroses) and soft tissues.

**Why other options are incorrect:**

- Option A:** Color blindness is an X-linked recessive condition involving defects in cone photopigments, impairing red-green color discrimination.
- Option C:** Diabetes mellitus is a metabolic endocrine disorder involving insulin deficiency or peripheral insulin resistance.
- Option D:** Alkaptonuria is an autosomal recessive inborn error of tyrosine metabolism caused by homogentisate 1,2-dioxygenase deficiency.

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

In human genetics, multiple allelism is classically demonstrated by the inheritance of:

**CORE CONCEPT & DERIVATION**

Multiple alleles refer to the presence of three or more alternative forms of a gene occupying the same homologous genetic locus across individuals in a population.

**Formula / Rule / Reaction:**ABO gene locus contains 3 alleles:  $I^A$ ,  $I^B$ ,  $i \Rightarrow$  6 genotypes, 4 phenotypes**Solution:**

- The human ABO blood group system on chromosome 9 is controlled by three alleles:  $I^A$ ,  $I^B$ , and  $i$ .
- $I^A$  and  $I^B$  are codominant with respect to each other, and both are completely dominant over the null allele  $i$ .

**Why other options are incorrect:**

- Option B:** Phenylketonuria is an autosomal recessive disorder caused by mutations in the phenylalanine hydroxylase (PAH) gene.
- Option C:** Red-green color blindness is an X-linked recessive monogenic trait.
- Option D:** Sickle cell anemia is an autosomal recessive disorder caused by a specific single point mutation (Glu6Val) in the  $\beta$ -globin gene.

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

Polygenic inheritance, where multiple independent pairs of genes exert an additive effect on a ...

**CORE CONCEPT & DERIVATION**

Quantitative traits that exhibit a continuous spectrum of phenotypes within a population without distinct categorical gaps are controlled by the cumulative effect of multiple genes (polygenes), known as polygenic inheritance.

**Formula / Rule / Reaction:**

Phenotypic Distribution: Bell-shaped Gaussian curve (e.g., Human height, skin color, seed weight)

**Solution:**

- Because several non-allelic genes contribute additively to the same phenotypic character, polygenic inheritance produces continuous variation displaying a normal bell-shaped frequency distribution curve.

**Why other options are incorrect:**

- Option A:** Codominance involves the full, simultaneous phenotypic expression of both alleles in a single heterozygous gene locus (e.g., AB blood type).
- Option B:** Incomplete dominance results in an intermediate heterozygous phenotype at a single gene locus.
- Option D:** Discontinuous variation presents distinct, non-overlapping phenotypic categories (e.g., ABO blood groups, tongue rolling) controlled by one or two major genes.

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

Mr. X and Mrs. X both possess the heterozygous genotype [Formula] for the ABO blood group. What...

**CORE CONCEPT & DERIVATION**

In a monohybrid cross between two individuals heterozygous for a dominant allele and a recessive null allele, standard Mendelian segregation yields a 3:1 phenotypic ratio among the offspring.

**Formula / Rule / Reaction:**Cross:  $I^A i \times I^A i \Rightarrow$  Genotypes:  $1 I^A I^A : 2 I^A i : 1 ii$ **Solution:**

- Offspring with genotypes  $I^A I^A$  (1/4) and  $I^A i$  (2/4) will express Blood Group 'A', giving a combined probability of  $3/4 = 0.75$ .
- Offspring with genotype  $ii$  (1/4) will express Blood Group 'O', giving a probability of  $1/4 = 0.25$ .

**Why other options are incorrect:**

- Option A:** Assumes complete homozygosity of dominant alleles in one parent.
- Option C:** Represents a test-cross ratio between a heterozygote and a homozygous recessive parent.
- Option D:** Reverses the 3:1 dominant-to-recessive Mendelian expectation.

## Question #69 Key: (B)

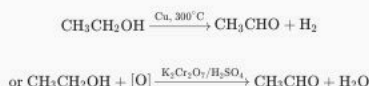
CHEMISTRY  
16. Alcohols & Phenols

Which of the following chemical processes converts ethyl alcohol into acetaldehyde in the labor...

## CORE CONCEPT &amp; DERIVATION

Primary alcohols undergo mild oxidation or catalytic dehydrogenation to yield aldehydes. Passing ethanol vapor over heated copper catalyst at 300°C removes molecular hydrogen, converting it directly to acetaldehyde.

Formula / Rule / Reaction:



Solution:

- The removal of two hydrogen atoms from ethanol (one from the hydroxyl group and one from the alpha-carbon) is a dehydrogenation/oxidation reaction that produces acetaldehyde.

Why other options are incorrect:

- Option A:** Polymerization joins multiple monomeric units into a high-molecular-weight polymer.
- Option C:** Esterification is the condensation reaction between an alcohol and a carboxylic acid to produce an ester and water.
- Option D:** Reduction of an alcohol would yield an alkane, not an aldehyde.

## Question #70 Key: (A)

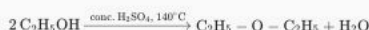
CHEMISTRY  
16. Alcohols & Phenols

Which organic product is predominantly formed when excess ethyl alcohol is heated with concentr...

## CORE CONCEPT &amp; DERIVATION

Dehydration of ethanol with concentrated sulfuric acid is temperature-dependent. At 140°C with excess ethanol, bimolecular intermolecular dehydration occurs via an S<sub>N</sub>2 pathway, producing diethyl ether.

Formula / Rule / Reaction:



Solution:

- At the lower temperature of 140°C with excess alcohol, an ethyloxonium intermediate is attacked by a second ethanol molecule to yield diethyl ether.
- At a higher temperature (170°C to 180°C) with excess acid, intramolecular elimination occurs, yielding ethene.

Why other options are incorrect:

- Option B:** Dimethyl ether requires methanol as the starting material.
- Option C:** Ethene is the major product formed at the higher temperature of 170°C via intramolecular elimination.
- Option D:** Acetylene (ethyne) requires vicinal or geminal dihaloalkane dehydrohalogenation.

## Question #71 Key: (D)

CHEMISTRY  
17. Aldehydes & Ketones

Which of the following compounds gives a positive iodoform test (yellow precipitate of [Formula...]

## CORE CONCEPT &amp; DERIVATION

The haloform (iodoform) reaction is given by compounds containing the methyl ketone group ( $\text{CH}_3 - \text{C} = \text{O}$ ) or alcohols capable of being oxidized to methyl carbonyls ( $\text{CH}_3 - \text{CH}(\text{OH}) -$ ).

Formula / Rule / Reaction:



Solution:

- Acetone contains the requisite terminal methyl carbonyl group ( $\text{CH}_3 - \text{C} = \text{O}$ ).
- Halogenation of the methyl group under basic conditions followed by nucleophilic cleavage generates a bright yellow precipitate of iodoform ( $\text{CHI}_3$ ).

Why other options are incorrect:

- Option A:** Methanol lacks the  $\text{CH}_3 - \text{CH}(\text{OH}) -$  structural group and cannot be oxidized to an aldehyde with a methyl ketone terminus.
- Option B:** Acetic acid contains a hydroxyl attached to the carbonyl group, which resists electrophilic halogenation and cleavage.
- Option C:** Acetic anhydride hydrolyzes in basic solution to acetate anions, which do not give the iodoform reaction.

## Question #72 Key: (B)

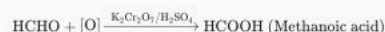
CHEMISTRY  
18. Carboxylic Acids

Which of the following organic carboxylic acids is formed when formaldehyde is oxidized with ac...

## CORE CONCEPT &amp; DERIVATION

Aldehydes are readily oxidized by strong oxidizing agents such as acidified potassium dichromate to carboxylic acids containing the same number of carbon atoms.

Formula / Rule / Reaction:



Solution:

- Formaldehyde (methanal) possesses one carbon atom.
- Oxidation inserts an oxygen atom into the formyl  $\text{C} - \text{H}$  bond, converting it into methanoic acid (formic acid).

Why other options are incorrect:

- Option A:** Methanol is the reduction product of formaldehyde, not its oxidation product.
- Option C:** Acetone is a 3-carbon ketone and cannot be generated from a 1-carbon aldehyde.
- Option D:** Acetaldehyde contains 2 carbon atoms; oxidation does not add a new carbon atom.

## Question #73 Key: (A)

CHEMISTRY  
17. Aldehydes & Ketones

Dry distillation of which of the following calcium salts of carboxylic acids produces acetone i...

## CORE CONCEPT &amp; DERIVATION

Pyrolysis (dry distillation) of dry calcium salts of carboxylic acids results in thermal decarboxylation, yielding symmetrical or unsymmetrical ketones and calcium carbonate.

Formula / Rule / Reaction:



Solution:

- Heating dry calcium acetate eliminates calcium carbonate, joining the two methyl radicals to the carbonyl group to generate acetone (propan-2-one).

Why other options are incorrect:

- **Option B:** Dry distillation of calcium formate  $(\text{HCOO})_2\text{Ca}$  yields formaldehyde ( $\text{HCHO}$ ).
- **Option C:** Dry distillation of calcium propionate yields diethyl ketone (pentan-3-one).
- **Option D:** Dry distillation of calcium benzoate yields benzophenone.

## Question #74 Key: (A)

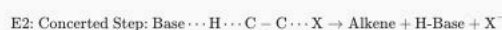
CHEMISTRY  
15. Alkyl Halides

Dehydrohalogenation of alkyl halides by a strong base occurs via [Formula] or [Formula] mechanism...

## CORE CONCEPT &amp; DERIVATION

Elimination unimolecular (E1) proceeds via a stepwise mechanism involving carbocation formation, whereas elimination bimolecular (E2) is a concerted, single-step bimolecular process.

Formula / Rule / Reaction:



Solution:

- E1 involves two separate steps: ionization to generate a carbocation intermediate followed by deprotonation by the base.
- E2 involves simultaneous proton abstraction, carbon-carbon double-bond formation, and leaving group departure in a single transition state.

Why other options are incorrect:

- **Option B:** Only E2 is concerted; E1 cannot occur in a single step because it requires an intermediate.
- **Option C:** E2 does not involve two steps; it has no carbocation intermediate.
- **Option D:** Inverts the true mechanistic orders of E1 and E2.

## Question #75 Key: (D)

CHEMISTRY  
13. Fundamental Principles of Organic Chemistry

Which of the following haloalkanes is an example of a tertiary ([Formula]) alkyl halide?

## CORE CONCEPT &amp; DERIVATION

In a tertiary ( $3^\circ$ ) alkyl halide, the halogen atom is bonded to a tertiary carbon atom, which is directly attached to three other carbon atoms.

Formula / Rule / Reaction:



Solution:

- In 2-bromo-2-methylbutane, carbon-2 carries the bromine atom and is simultaneously bonded to three carbon groups (two methyl groups and one ethyl group).
- Therefore, it is a tertiary alkyl halide.

Why other options are incorrect:

- **Option A:** 2-Chlorobutane is a secondary ( $2^\circ$ ) alkyl halide because C-2 is bonded to two other carbons.
- **Option B:** 1-Chloro-2-methylpentane is a primary ( $1^\circ$ ) alkyl halide because C-1 is bonded to only one other carbon.
- **Option C:** 2-Bromo-3-methylbutane is a secondary ( $2^\circ$ ) alkyl halide because C-2 is bonded to two other carbons.

## Question #76 Key: (C)

CHEMISTRY  
02. Atomic Structure

According to Bohr's atomic model, the radius of the first orbit of hydrogen is [Formula]. Which...

## CORE CONCEPT &amp; DERIVATION

In the Bohr model of the hydrogen atom, the radius of the  $n^{\text{th}}$  stationary orbit is directly proportional to the square of the principal quantum number ( $n^2$ ).

Formula / Rule / Reaction:

$$r_n = r_1 \times n^2 \implies n^2 = \frac{r_n}{r_1}$$

Solution:

- Given  $r_1 = 0.53 \text{ \AA}$  and  $r_n = 4.77 \text{ \AA}$ :
- $$n^2 = \frac{4.77}{0.53} = 9$$
- $$n = \sqrt{9} = 3$$
- Thus, the radius of  $4.77 \text{ \AA}$  corresponds to the third Bohr orbit.

Why other options are incorrect:

- **Option A:** For  $n = 1$ ,  $r_1 = 0.53 \text{ \AA}$ .
- **Option B:** For  $n = 2$ ,  $r_2 = 0.53 \times 2^2 = 2.12 \text{ \AA}$ .
- **Option D:** For  $n = 4$ ,  $r_4 = 0.53 \times 4^2 = 8.48 \text{ \AA}$ .

## Question #77 Key: (B)

CHEMISTRY  
02. Atomic Structure

Which of the following atomic subshells possesses only a single spatial orientation in a magnet...

## CORE CONCEPT &amp; DERIVATION

The number of spatial orientations of an atomic orbital is determined by the magnetic quantum number ( $m_l$ ), which takes values from  $-l$  to  $+l$ , giving a total of  $2l + 1$  orientations.

## Formula / Rule / Reaction:

$$\text{Number of orientations} = 2l + 1$$

$$\text{For s orbital: } l = 0 \Rightarrow m_l = 0 \Rightarrow 2(0) + 1 = 1 \text{ orientation}$$

## Solution:

- The s-orbital is spherically symmetrical around the nucleus.
- Because  $l = 0$ , it has only one magnetic quantum value ( $m_l = 0$ ), meaning it possesses only one spatial orientation.

## Why other options are incorrect:

- Option A:** For the p subshell,  $l = 1$ , yielding  $2(1) + 1 = 3$  orientations ( $p_x, p_y, p_z$ ).
- Option C:** For the d subshell,  $l = 2$ , yielding  $2(2) + 1 = 5$  orientations.
- Option D:** For the f subshell,  $l = 3$ , yielding  $2(3) + 1 = 7$  orientations.

## Question #78 Key: (A)

CHEMISTRY  
02. Atomic Structure

What is the rest mass of a single proton relative to an electron?

## CORE CONCEPT &amp; DERIVATION

The rest mass of a proton is approximately  $1.6726 \times 10^{-27}$  kg, whereas the rest mass of an electron is  $9.109 \times 10^{-31}$  kg.

## Formula / Rule / Reaction:

$$\frac{m_p}{m_e} = \frac{1.6726 \times 10^{-27} \text{ kg}}{9.109 \times 10^{-31} \text{ kg}} \approx 1836.15$$

## Solution:

- Dividing the proton mass by the electron mass reveals that a proton is approximately 1836 times heavier than an electron.

## Why other options are incorrect:

- Option B:** A positron is the antiparticle of an electron and has an identical rest mass to an electron (approx 1/1836 of a proton).
- Option C:** The electron is roughly 1836 times lighter than a proton.
- Option D:** A proton has a mass nearly equal to one neutron (within 0.14 percent), not 1836 neutrons.

## Question #79 Key: (D)

CHEMISTRY  
02. Atomic Structure

Which of the following subatomic properties differs among the isoelectronic ions [Formula] (Z = ...)

## CORE CONCEPT &amp; DERIVATION

Isoelectronic species possess the identical number of electrons and identical electronic configurations, but retain different nuclear charges (different atomic numbers and proton counts).

## Formula / Rule / Reaction:

$$\text{Protons: } \text{Na}^+ = 11, \text{Mg}^{2+} = 12, \text{Al}^{3+} = 13$$

$$\text{Electrons: } 11 - 1 = 10, 12 - 2 = 10, 13 - 3 = 10 \Rightarrow [\text{Ne}] 1s^2 2s^2 2p^6$$

## Solution:

- All three ions have 10 electrons, 2 occupied electron shells, and the electron configuration  $1s^2 2s^2 2p^6$ .
- They differ strictly in their nuclear proton count, with  $\text{Na}^+$  having 11,  $\text{Mg}^{2+}$  having 12, and  $\text{Al}^{3+}$  having 13 protons.

## Why other options are incorrect:

- Option A:** All three ions possess exactly 2 principal shells (K and L shells).
- Option B:** Each species has lost valence electrons to attain exactly 10 electrons.
- Option C:** All three share the identical noble gas neon configuration  $1s^2 2s^2 2p^6$ .

## Question #80 Key: (B)

CHEMISTRY  
18. Carboxylic Acids

What is the systematic IUPAC name of stearic acid ([Formula])?

## CORE CONCEPT &amp; DERIVATION

Saturated fatty acids are named systematically by replacing the terminal '-e' of the corresponding alkane name with the suffix '-oic acid'.

## Formula / Rule / Reaction:

$$\text{Total Carbons} = 17 \text{ (alkyl chain)} + 1 \text{ (carboxyl group)} = 18 \text{ carbons} \Rightarrow \text{Octadecane} + \text{-oic acid}$$

## Solution:

- Stearic acid has the molecular formula  $\text{CH}_3(\text{CH}_2)_{16}\text{COOH}$ , containing an unbranched chain of 18 carbon atoms.
- Its IUPAC name is octadecanoic acid.

## Why other options are incorrect:

- Option A:** Hexanoic acid (caproic acid) contains 6 carbon atoms.
- Option C:** Octanoic acid (caprylic acid) contains 8 carbon atoms.
- Option D:** Hexadecanoic acid (palmitic acid) contains 16 carbon atoms.

## Question #81 Key: (B)

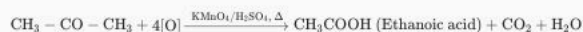
CHEMISTRY  
18. Carboxylic Acids

Which of the following carboxylic acids is formed when acetone is oxidized under vigorous conditions...

## CORE CONCEPT &amp; DERIVATION

Ketones resist mild oxidation. Under vigorous oxidizing conditions, carbon-carbon bond cleavage occurs on either side of the carbonyl carbon, generating carboxylic acids with fewer carbon atoms than the parent ketone.

## Formula / Rule / Reaction:



## Solution:

- Acetone contains 3 carbon atoms.
- Vigorous oxidation cleaves one C – C bond, converting the two-carbon fragment into ethanoic (acetic) acid, while the cleaved one-carbon fragment oxidizes completely to CO<sub>2</sub> and water.

## Why other options are incorrect:

- Option A:** Formic acid (methanoic acid) is unstable under these harsh conditions and oxidizes directly to CO<sub>2</sub>.
- Option C:** Propanoic acid contains 3 carbon atoms; oxidation cannot preserve all 3 carbons without adding oxygen without bond cleavage.
- Option D:** Butyric acid contains 4 carbons, which is impossible to form from a 3-carbon ketone.

## Question #82 Key: (D)

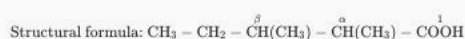
CHEMISTRY  
18. Carboxylic Acids

What is the systematic IUPAC name of [Formula] -dimethylvaleric acid?

## CORE CONCEPT &amp; DERIVATION

In common nomenclature, valeric acid refers to pentanoic acid (a 5-carbon straight-chain acid). The carbon adjacent to the carboxyl carbon is designated α (C-2), and the next carbon is β (C-3).

## Formula / Rule / Reaction:



## Solution:

- The principal functional group is the carboxylic acid, numbered as C-1.
- The α position corresponds to C-2, and the β position corresponds to C-3.
- With methyl substituents at C-2 and C-3 on a 5-carbon parent pentanoic acid chain, the systematic IUPAC name is 2,3-dimethylpentanoic acid.

## Why other options are incorrect:

- Option A:** Hexanoic acid corresponds to caproic acid (6 carbons), not valeric acid.
- Option B:** Represents a hexanoic acid with substituents at C-3 and C-4.
- Option C:** Designates substituents at the β and γ positions of pentanoic acid, not α and β.

## Question #83 Key: (C)

CHEMISTRY  
01. Stoichiometry

What volume of oxygen gas ([Formula]) at STP is stoichiometrically required for the complete ...

## CORE CONCEPT &amp; DERIVATION

According to Gay-Lussac's Law of Combining Volumes and Avogadro's Law, the volumes of reacting gases at identical temperature and pressure are proportional to their stoichiometric coefficients in a balanced chemical equation.

## Formula / Rule / Reaction:



Volume ratio: 1 volume C<sub>2</sub>H<sub>4</sub> : 3 volumes O<sub>2</sub>

## Solution:

- From the balanced equation, 1 dm<sup>3</sup> of ethene requires 3 dm<sup>3</sup> of oxygen gas.
- For 500 dm<sup>3</sup> of ethene:

$$V_{\text{O}_2} = 500 \text{ dm}^3 \times 3 = 1500 \text{ dm}^3$$

## Why other options are incorrect:

- Option A:** 500 dm<sup>3</sup> assumes an equimolar 1:1 reaction, violating stoichiometry.
- Option B:** 1000 dm<sup>3</sup> represents the volume of CO<sub>2</sub> produced, not O<sub>2</sub> consumed.
- Option D:** 2000 dm<sup>3</sup> corresponds to a 1:4 stoichiometric ratio.

## Question #84 Key: (D)

CHEMISTRY  
12. Transition Elements

An element has a valence shell electronic configuration of [Formula]. To which periodic group ...

## CORE CONCEPT &amp; DERIVATION

For main-group (representative) elements in the p-block, the traditional subgroup 'A' number equals the total number of electrons in the outermost s and p subshells.

## Formula / Rule / Reaction:

$$\text{Valence electrons} = ns^2 + np^1 = 2 + 1 = 3 \Rightarrow \text{Group III-A (Group 13)}$$

## Solution:

- The principal quantum number  $n = 4$  places the element in Period 4.
- With 3 valence electrons in the outermost shell ( $4s^2 4p^1$ ), it belongs to Group III-A (specifically, Gallium,  $Z = 31$ ).

## Why other options are incorrect:

- Option A:** Group I-B consists of transition coinage metals ( $d^{10} s^1$ , such as Cu, Ag, Au).
- Option B:** Group II-B elements possess filled d subshells and two valence s electrons ( $d^{10} s^2$ , such as Zn, Cd, Hg).
- Option C:** Group I-A alkali metals possess a single valence s electron ( $ns^1$ ).

## Question #85 Key: (B)

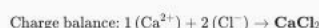
CHEMISTRY  
01. Stoichiometry

Calcium ( $Z = 20$ ) combines with chlorine ( $Z = 17$ ) to form an ionic compound. What is the empiric...

## CORE CONCEPT &amp; DERIVATION

Ionic compounds must be electrically neutral. The total positive charge contributed by the metal cations must balance the total negative charge contributed by the non-metal anions.

## Formula / Rule / Reaction:



## Solution:

- Calcium loses two valence electrons to achieve the argon noble-gas octet, forming a  $\text{Ca}^{2+}$  cation.
- Each chlorine atom requires one electron to achieve an octet, forming a  $\text{Cl}^-$  anion.
- Two chloride ions are required to balance one calcium ion, yielding the formula  $\text{CaCl}_2$ .

## Why other options are incorrect:

- Option A:**  $\text{CaCl}$  would carry an uncompensated net +1 electrical charge.
- Option C:**  $\text{Ca}_2\text{Cl}_2$  is not in simplest empirical whole-number ratio.
- Option D:**  $\text{Ca}_2\text{Cl}$  violates stoichiometric octet charge neutrality.

## Question #86 Key: (C)

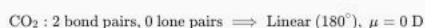
CHEMISTRY  
03. Chemical Bonding

Carbon dioxide ([Formula]) and sulfur dioxide ([Formula]) are triatomic triatomic oxides. W...

## CORE CONCEPT &amp; DERIVATION

VSEPR theory dictates molecular geometry based on electron domain repulsion. A molecule with polar bonds will have a zero net dipole moment if its shape is symmetrical, causing individual bond dipoles to cancel.

## Formula / Rule / Reaction:



## Solution:

- In  $\text{CO}_2$ , the central carbon has no lone pairs; the two  $\text{C}=\text{O}$  dipoles are equal in magnitude and point in opposite directions, canceling out completely (non-polar,  $\mu = 0$ ).
- In  $\text{SO}_2$ , the central sulfur has a lone pair that exerts repulsion, forcing an angular (bent) geometry where the two  $\text{S}-\text{O}$  bond dipoles do not cancel (polar,  $\mu = 1.63 \text{ D}$ ).

## Why other options are incorrect:

- Option A:**  $\text{SO}_2$  is not linear due to the lone pair on sulfur, making it distinctly polar.
- Option B:** Completely inverts the geometries and polarities of the two molecules.
- Option D:**  $\text{CO}_2$  is linear, not angular, and is non-polar.

## Question #87 Key: (C)

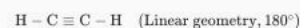
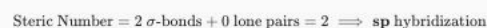
CHEMISTRY  
03. Chemical Bonding

What hybridization state is exhibited by the carbon atoms in an ethyne (acetylene, [Formula]) ...

## CORE CONCEPT &amp; DERIVATION

In ethyne, each carbon atom forms one  $\sigma$ -bond with a hydrogen atom and one  $\sigma$ -bond with the adjacent carbon atom, leaving two unhybridized p-orbitals to form two perpendicular  $\pi$ -bonds.

## Formula / Rule / Reaction:



## Solution:

- Mixing one 2s and one 2p orbital on each carbon produces two linear sp hybrid orbitals oriented at  $180^\circ$ .
- The two unhybridized p-orbitals ( $p_y$  and  $p_z$ ) overlap laterally to form the two  $\pi$ -bonds of the carbon-carbon triple bond.

## Why other options are incorrect:

- Option A:**  $sp^3$  hybridization produces a tetrahedral geometry characteristic of alkanes like ethane ( $\text{C}_2\text{H}_6$ ).
- Option B:**  $sp^2$  hybridization produces a trigonal planar geometry characteristic of alkenes like ethene ( $\text{C}_2\text{H}_4$ ).
- Option D:**  $dsp^2$  hybridization produces square planar geometry in transition metal coordination complexes.

## Question #88 Key: (C)

CHEMISTRY  
07. Equilibrium

For which of the following gaseous equilibrium reactions does the equilibrium constant [Formula]...

## CORE CONCEPT &amp; DERIVATION

The mathematical relationship between the pressure equilibrium constant ( $K_p$ ) and the concentration equilibrium constant ( $K_c$ ) depends on the change in the number of gaseous moles ( $\Delta n_g$ ).

## Formula / Rule / Reaction:

$$K_p = K_c(RT)^{\Delta n_g} \quad \text{where } \Delta n_g = \sum n_{\text{products(g)}} - \sum n_{\text{reactants(g)}}$$

$$\text{When } \Delta n_g = 0 \Rightarrow (RT)^0 = 1 \Rightarrow K_p = K_c$$

## Solution:

- For  $\text{H}_2(g) + \text{I}_2(g) \rightleftharpoons 2 \text{HI}(g)$ :  
$$\Delta n_g = 2 - (1 + 1) = 2 - 2 = 0$$
- Because  $\Delta n_g = 0$ ,  $K_p = K_c(RT)^0 = K_c$ .

## Why other options are incorrect:

- Option A:**  $\Delta n_g = 2 - 4 = -2$ , so  $K_p = K_c(RT)^{-2}$ .
- Option B:**  $\Delta n_g = 2 - 1 = +1$ , so  $K_p = K_c(RT)^{+1}$ .
- Option D:**  $\Delta n_g = 2 - 3 = -1$ , so  $K_p = K_c(RT)^{-1}$ .

## Question #89 Key: (D)

CHEMISTRY  
07. Equilibrium

Which of the following reaction conditions will shift the equilibrium to favor the maximum yield...

## CORE CONCEPT &amp; DERIVATION

According to Le Chatelier's Principle, if a stress is applied to a system at dynamic equilibrium, the system shifts in the direction that counteracts that stress. The Haber synthesis of ammonia is an exothermic reaction.

Formula / Rule / Reaction:



Solution:

- Because the forward reaction releases heat (exothermic), lowering the temperature removes heat, driving the equilibrium forward toward product formation.
- In practice, an optimum compromised temperature of approximately 450°C is employed alongside a catalyst to maintain an economically viable reaction rate.

Why other options are incorrect:

- Option A:** Increasing temperature shifts the equilibrium in the endothermic reverse direction, decomposing ammonia into nitrogen and hydrogen.
- Option B:** Decreasing reactant concentrations shifts the equilibrium to the left to replace them, reducing ammonia yield.
- Option C:** Because the forward reaction reduces the number of gas moles (4 moles to 2 moles), decreasing pressure shifts the equilibrium toward the side with more moles (the reactants).

## Question #90 Key: (C)

CHEMISTRY  
07. Equilibrium

Which of the following statements is true for any reversible chemical reaction that has attained...

## CORE CONCEPT &amp; DERIVATION

Chemical equilibrium is a dynamic state where the rate of the forward reaction equals the rate of the reverse reaction, resulting in constant macroscopic concentrations of all reactants and products over time.

Formula / Rule / Reaction:

$$R_{\text{forward}} = R_{\text{backward}} \implies \frac{d[\text{Reactants}]}{dt} = \frac{d[\text{Products}]}{dt} = 0$$

Solution:

- Dynamic equilibrium does not mean the concentrations of reactants and products are equal; it requires that their rates of interconversion be exactly identical.

Why other options are incorrect:

- Option A:** If the forward rate exceeded the backward rate, the system would still be shifting toward the right, not at equilibrium.
- Option B:** If the backward rate exceeded the forward rate, the system would still be shifting toward the left.
- Option D:** Chemical equilibrium is dynamic, not static; forward and backward reactions continue perpetually at equal rates.

## Question #91 Key: (B)

CHEMISTRY  
14. Hydrocarbons

When benzene reacts with isopropyl chloride in the presence of anhydrous [Formula] as a Lewis a...

## CORE CONCEPT &amp; DERIVATION

Electrophilic aromatic substitution in which an alkyl group replaces an aromatic hydrogen atom in the presence of a Lewis acid catalyst is known as Friedel-Crafts alkylation.

Formula / Rule / Reaction:



Solution:

- The Lewis acid  $\text{AlCl}_3$  abstracts a chloride ion from isopropyl chloride, generating a secondary carbocation electrophile  $((\text{CH}_3)_2\text{CH}^+)$ .
- The carbocation attacks the aromatic benzene ring to form an arenium ion intermediate, which loses a proton to yield isopropylbenzene.

Why other options are incorrect:

- Option A:** Friedel-Crafts acylation utilizes an acyl halide ( $\text{R-CO-Cl}$ ) to introduce an acyl group, forming an aromatic ketone.
- Option C:** Halogenation introduces a halogen atom ( $-\text{Cl}$ ,  $-\text{Br}$ ) using molecular halogen and a ferric halide catalyst.
- Option D:** Sulfonation introduces a sulfonic acid group ( $-\text{SO}_3\text{H}$ ) using fuming sulfuric acid.

## Question #92 Key: (B)

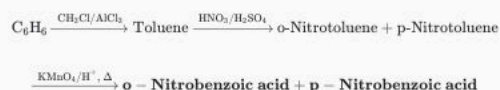
CHEMISTRY  
14. Hydrocarbons

Benzene is subjected sequentially to: (1) Friedel-Crafts alkylation with [Formula], (2) Nitrat...

## CORE CONCEPT &amp; DERIVATION

Substituents already present on a benzene ring determine the regioselectivity of subsequent substitutions. An alkyl group (methyl) is an electron-donating ortho/para-director, whereas oxidation of alkyl side chains converts them into meta-directing carboxyl groups.

Formula / Rule / Reaction:



Solution:

- Step 1: Alkylation of benzene yields toluene (methylbenzene).
- Step 2: The methyl group is an activating ortho/para-director. Nitration directs the incoming nitro group to the ortho and para positions, yielding o-nitrotoluene and p-nitrotoluene.
- Step 3: Vigorous oxidation with potassium permanganate oxidizes the benzylic methyl group into a carboxylic acid ( $-\text{COOH}$ ) without altering the nitro group positions, yielding a mixture of o-nitrobenzoic acid and p-nitrobenzoic acid.

Why other options are incorrect:

- Option A:** m-Nitrobenzoic acid would only form if oxidation preceded nitration, because the carboxyl group is a meta-director.
- Option C:** Omits the oxidation step and assumes incorrect meta-direction by a methyl group.
- Option D:** Represents the intermediate products after Step 2, omitting the final oxidation step.

**Question #93** Key: (B)CHEMISTRY  
16. Alcohols & Phenols

Isopropyl chloride is structurally classified as a:

**CORE CONCEPT & DERIVATION**

Alkyl halides are classified as primary (1°), secondary (2°), or tertiary (3°) depending on whether the carbon atom bearing the halogen is attached to one, two, or three other carbon atoms.

Formula / Rule / Reaction:



Solution:

- The chlorine atom is attached to the central secondary carbon (C-2), which is directly bonded to two methyl carbon atoms.
- Therefore, isopropyl chloride (2-chloropropane) is a secondary alkyl halide.

Why other options are incorrect:

- Option A:** In a primary alkyl halide, the halogenated carbon is attached to only one other carbon (e.g., n-propyl chloride).
- Option C:** In a tertiary alkyl halide, the halogenated carbon is attached to three carbons (e.g., tert-butyl chloride).
- Option D:** Carbon cannot form five bonds; quaternary alkyl halides do not exist.

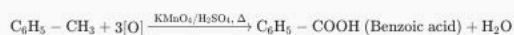
**Question #94** Key: (D)CHEMISTRY  
16. Alcohols & Phenols

What is the primary organic product obtained when toluene is heated with acidified potassium permanganate?

**CORE CONCEPT & DERIVATION**

Regardless of alkyl chain length, any aromatic side chain possessing at least one benzylic hydrogen atom is oxidized by hot acidified  $\text{KMnO}_4$  to a carboxylic acid group attached directly to the benzene ring.

Formula / Rule / Reaction:



Solution:

- The benzylic carbon of toluene contains three benzylic hydrogen atoms.
- Vigorous permanganate oxidation cleaves the C-H bonds and oxidizes the methyl group completely to a carboxyl group, producing benzoic acid.

Why other options are incorrect:

- Option A:** o-Nitrotoluene is formed by nitration using nitric acid, not by permanganate oxidation.
- Option B:** p-Nitrotoluene is also a nitration product.
- Option C:** Benzaldehyde is an intermediate stage obtained by controlled mild oxidation (e.g., Etard reaction using chromyl chloride), not with hot acidified  $\text{KMnO}_4$ .

**Question #95** Key: (C)CHEMISTRY  
18. Carboxylic Acids

What is the systematic IUPAC name of chloroform ([Formula])?

**CORE CONCEPT & DERIVATION**

Halogenated derivatives of alkanes are named systematically by prefixing the halogen name (with appropriate multiplying prefixes di-, tri-, tetra-) to the parent alkane name.

Formula / Rule / Reaction:

Parent alkane: Methane (1 Carbon) | Substituents: 3 Chlorine atoms  $\Rightarrow$  **Trichloromethane**

Solution:

- Chloroform has the chemical formula  $\text{CHCl}_3$ .
- Because three chlorine atoms are bonded to a single carbon atom, its IUPAC name is trichloromethane.

Why other options are incorrect:

- Option A:** Chloromethane is methyl chloride ( $\text{CH}_3\text{Cl}$ ).
- Option B:** Dichloromethane is methylene chloride ( $\text{CH}_2\text{Cl}_2$ ).
- Option D:** Tetrachloromethane is carbon tetrachloride ( $\text{CCl}_4$ ).

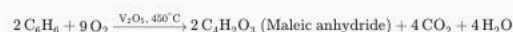
**Question #96** Key: (D)CHEMISTRY  
14. Hydrocarbons

Catalytic vapor-phase oxidation of benzene with air over vanadium pentoxide ([Formula]) at 450°C...

**CORE CONCEPT & DERIVATION**

Although benzene is highly stable toward normal oxidizing agents due to resonance stabilization, it undergoes oxidative ring cleavage at elevated temperatures in the presence of a vanadium pentoxide catalyst to form maleic anhydride.

Formula / Rule / Reaction:



Solution:

- At 450°C over  $\text{V}_2\text{O}_5$ , two adjacent carbon atoms of the benzene ring are lost as carbon dioxide, and the remaining 4-carbon fragment dehydrates into the cyclic unsaturated anhydride known as maleic anhydride.

Why other options are incorrect:

- Option A:** Acetylene is a two-carbon alkyne; cracking, not catalytic oxidation of benzene, produces alkynes.
- Option B:** Phenol is synthesized industrially via the cumene process or Dow process, not direct  $\text{V}_2\text{O}_5$  oxidation of benzene.
- Option C:** Toluene contains an additional methyl group, which cannot be introduced by oxidation.

## Question #97 Key: (C)

CHEMISTRY  
10. Electrochemistry

What is the oxidation state of manganese (Mn) in potassium manganate ([Formula])?

## CORE CONCEPT &amp; DERIVATION

The algebraic sum of the oxidation numbers of all atoms in a neutral chemical compound must equal zero.

Formula / Rule / Reaction:

$$\sum \text{Oxidation Numbers} = 2(+1) + x + 4(-2) = 0$$

Solution:

- Potassium has an oxidation state of +1, and oxygen has an oxidation state of -2.

$$2(+1) + x + 4(-2) = 0$$

$$+2 + x - 8 = 0$$

$$x - 6 = 0 \implies x = +6$$

- Therefore, the oxidation state of Mn in  $\text{K}_2\text{MnO}_4$  is +6.

Why other options are incorrect:

- Option A:** +2 is the oxidation state of Mn in manganous salts such as  $\text{MnSO}_4$ .
- Option B:** +4 is the oxidation state of Mn in manganese dioxide ( $\text{MnO}_2$ ).
- Option D:** +7 is the oxidation state of Mn in potassium permanganate ( $\text{KMnO}_4$ ).

## Question #98 Key: (B)

CHEMISTRY  
10. Electrochemistry

In the standard electrochemical series based on IUPAC reduction potentials, what is the sign of...

## CORE CONCEPT &amp; DERIVATION

By IUPAC convention, the standard reduction potential of the standard hydrogen electrode (SHE) is set at 0.00 V. Metals with a greater tendency to lose electrons (undergo oxidation) than hydrogen have negative standard reduction potentials.

Formula / Rule / Reaction:

$$E_{\text{SHE}}^{\circ} = 0.00 \text{ V} \implies E_{\text{red}}^{\circ} < 0 \text{ for metals above hydrogen (e.g., Zn, Fe, Mg, Na, Li)}$$

Solution:

- Metals above hydrogen in the electrochemical series are more electropositive and stronger reducing agents than hydrogen.
- Their standard reduction potentials are negative, meaning they can displace hydrogen gas from dilute acids.

Why other options are incorrect:

- Option A:** Only the standard hydrogen electrode has a potential assigned exactly as zero.
- Option C:** Metals positioned below hydrogen (such as Cu, Ag, Pt, Au) have positive standard reduction potentials.
- Option D:** A positive value corresponds to noble metals below hydrogen.

## Question #99 Key: (B)

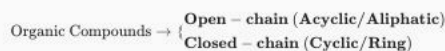
CHEMISTRY  
13. Fundamental Principles of Organic Chemistry

On the basis of their fundamental carbon skeleton structure, organic compounds are broadly divi...

## CORE CONCEPT &amp; DERIVATION

Organic compounds are classified based on the arrangement of carbon atoms into two primary divisions: open-chain (aliphatic or acyclic) compounds and closed-chain (cyclic or ring) compounds.

Formula / Rule / Reaction:



Solution:

- Open-chain compounds contain straight or branched open carbon chains (e.g., alkanes, alkenes, alkynes).
- Closed-chain compounds contain atoms joined to form one or more rings (further subdivided into homocyclic and heterocyclic compounds).

Why other options are incorrect:

- Option A:** All organic compounds inherently contain carbon; 'non-carbon' compounds are inorganic.
- Option C:** Homocyclic and heterocyclic compounds are subdivisions of cyclic compounds, not the primary highest-level classification.
- Option D:** Aromatic compounds represent a specific subclass of homocyclic/heterocyclic cyclic compounds.

## Question #100 Key: (A)

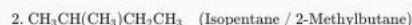
CHEMISTRY  
13. Fundamental Principles of Organic Chemistry

Which of the following sets correctly lists the three structural chain isomers of pentane ([Fo...

## CORE CONCEPT &amp; DERIVATION

Chain (skeletal) isomers share the identical molecular formula but differ in the branching arrangement of the carbon carbon skeleton. The alkane pentane ( $\text{C}_5\text{H}_{12}$ ) has three structural isomers.

Formula / Rule / Reaction:



Solution:

- All three molecules possess the identical molecular formula  $\text{C}_5\text{H}_{12}$ .
- They comprise the straight 5-carbon chain (n-pentane), the 4-carbon chain with a methyl branch (2-methylbutane), and the 3-carbon chain with two methyl branches (2,2-dimethylpropane).

Why other options are incorrect:

- Option B:** 2,3-Dimethylbutane has 6 carbons ( $\text{C}_6\text{H}_{14}$ ), which is an isomer of hexane.
- Option C:** 3-Methylbutane is identical to 2-methylbutane (incorrect numbering), and 2,2-dimethylpentane contains 7 carbons.
- Option D:** 2-Methylpentane contains 6 carbons (an isomer of hexane).

## Question #101 Key: (A)

CHEMISTRY  
13. Fundamental Principles of Organic Chemistry

Which structural isomerism is exhibited between propanal and propanone (acetone)?

## CORE CONCEPT &amp; DERIVATION

Functional group isomers possess the identical molecular formula but contain entirely different functional groups, conferring distinctly different chemical properties upon the molecules.

## Formula / Rule / Reaction:

Molecular Formula:  $C_3H_6O$ Propanal (Aldehyde):  $CH_3CH_2CHO$  | Propanone (Ketone):  $CH_3COCH_3$ 

## Solution:

- Both propanal and acetone share the molecular formula  $C_3H_6O$ .
- Propanal contains a terminal formyl (aldehyde) group, whereas acetone contains an internal carbonyl (keto) group, demonstrating functional group isomerism.

## Why other options are incorrect:

- Option B:** Chain isomerism involves differences in the branching of the carbon skeleton with the same functional group.
- Option C:** Position isomerism involves the same functional group attached at different positions along the same carbon chain.
- Option D:** Metamerism involves unequal distribution of carbon atoms on either side of the same polyvalent functional group (e.g., in ethers).

## Question #102 Key: (D)

CHEMISTRY  
04. GasesAccording to Boyle's law, the graphical plot of gas volume ( $V$ ) versus applied pressure ( $P$ ) at c...

## CORE CONCEPT &amp; DERIVATION

Boyle's law states that at constant temperature, the volume of a fixed mass of an ideal gas is inversely proportional to the applied pressure, yielding an isotherm that takes the geometric form of a rectangular hyperbola.

## Formula / Rule / Reaction:

$$P \propto \frac{1}{V} \Rightarrow PV = k \quad (\text{Equation of a Rectangular Hyperbola})$$

## Solution:

- A plot of  $V$  versus  $P$  is non-linear, forming a hyperbolic curve that approaches both axes asymptotically without touching them.
- A straight line is obtained only when plotting  $V$  versus  $1/P$  or  $PV$  versus  $P$ .

## Why other options are incorrect:

- Option A:** A straight line passing through the origin is obtained for Charles's law ( $V$  vs  $T$ ) or Gay-Lussac's law ( $P$  vs  $T$ ).
- Option B:** The relationship remains smoothly hyperbolic throughout the ideal range without transitioning into a straight line.
- Option C:** A horizontal line is obtained when plotting the product  $PV$  against  $P$ , not  $V$  against  $P$ .

## Question #103 Key: (A)

CHEMISTRY  
04. GasesA sample of nitrogen gas occupies [Formula] at [Formula] and  $25^\circ\text{C}$ . If the pressure is increased...

## CORE CONCEPT &amp; DERIVATION

The combined gas law relates the pressure, volume, and absolute thermodynamic temperature of a fixed quantity of gas across two equilibrium states.

## Formula / Rule / Reaction:

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \Rightarrow V_2 = V_1 \left( \frac{P_1}{P_2} \right) \left( \frac{T_2}{T_1} \right)$$

## Solution:

- Convert temperatures to Kelvin:  $T_1 = 25 + 273.15 = 298.15 \text{ K}$  and  $T_2 = 50 + 273.15 = 323.15 \text{ K}$ .

- Substitute values:

$$V_2 = 1.0 \text{ dm}^3 \times \left( \frac{1.0 \text{ atm}}{2.0 \text{ atm}} \right) \times \left( \frac{323.15 \text{ K}}{298.15 \text{ K}} \right)$$

$$V_2 = 1.0 \times 0.5 \times 1.0838 = 0.542 \text{ dm}^3$$

## Why other options are incorrect:

- Option B:** Represents doubling the volume instead of halving it under doubled pressure.
- Option C:** Occurs if pressure and temperature values are inverted.
- Option D:** Mathematically inconsistent with an inverse pressure relationship.

## Question #104 Key: (A)

CHEMISTRY  
04. Gases

Which of the following temperatures corresponds to absolute zero on the Celsius scale?

## CORE CONCEPT &amp; DERIVATION

Absolute zero is the lowest theoretical temperature at which the entropy and kinetic energy of an ideal gas reach their minimum zero value, defined precisely as 0 Kelvin.

## Formula / Rule / Reaction:

$$T(\text{K}) = t(^{\circ}\text{C}) + 273.16 \Rightarrow 0 \text{ K} = -273.16^{\circ}\text{C}$$

## Solution:

- According to the Sindh Textbook Board Chemistry syllabus, absolute zero on the Celsius temperature scale is established as  $-273.16^{\circ}\text{C}$  (or  $-273.15^{\circ}\text{C}$ ).
- At this temperature, the volume of an ideal gas theoretically contracts to zero.

## Why other options are incorrect:

- Option B:** Absolute zero on the Kelvin scale is 0 K; negative Kelvin temperatures do not exist in classical thermodynamics.
- Option C:**  $0^{\circ}\text{C}$  is the freezing point of water at standard atmospheric pressure (273.15 K).
- Option D:**  $32^{\circ}\text{F}$  is the freezing point of water on the Fahrenheit scale.

## Question #105 Key: (C)

CHEMISTRY  
01. Stoichiometry

An organic compound contains 40.0% Carbon, 6.67% Hydrogen, and 53.3% Oxygen by mass. What is th...

## CORE CONCEPT &amp; DERIVATION

The empirical formula reflects the simplest whole-number ratio of atoms of each element present in a compound, determined by dividing percent compositions by respective atomic masses.

## Formula / Rule / Reaction:

$$\text{Moles of element} = \frac{\% \text{ Composition}}{\text{Atomic Mass}}$$

## Solution:

- Moles of Carbon:  $40.0/12 = 3.33$
- Moles of Hydrogen:  $6.67/1.008 = 6.62$
- Moles of Oxygen:  $53.3/16 = 3.33$
- Divide each value by the smallest molar value (3.33):
- $C = \frac{3.33}{3.33} = 1, \quad H = \frac{6.62}{3.33} \approx 2, \quad O = \frac{3.33}{3.33} = 1$
- The simplest atomic ratio is 1 : 2 : 1, giving the empirical formula  $CH_2O$ .

## Why other options are incorrect:

- **Option A:**  $CH_3O$  requires approximately 9.7% Hydrogen by mass.
- **Option B:**  $C_2H_3O$  corresponds to a 2 : 3 : 1 ratio, inconsistent with the stoichiometric calculation.
- **Option D:**  $C_2H_2O$  possesses a 1 : 1 carbon-to-hydrogen ratio.

## Question #106 Key: (A)

CHEMISTRY  
01. Stoichiometry

Given the balanced reaction: [Formula]. If [Formula] of [Formula] reacts with [Formula] of [Fo...

## CORE CONCEPT &amp; DERIVATION

The limiting reactant is the chemical reactant that produces the least amount of product and is completely consumed first, terminating the reaction.

## Formula / Rule / Reaction:

$$\text{Molar mass of } CS_2 = 12 + 2(32) = 76 \text{ g/mol} \quad | \quad \text{Molar mass of } O_2 = 32 \text{ g/mol}$$

## Solution:

- Calculate moles of reactants:
- $\text{Moles of } CS_2 = \frac{7.6 \text{ g}}{76 \text{ g/mol}} = 0.10 \text{ mol}$
- $\text{Moles of } O_2 = \frac{12.8 \text{ g}}{32 \text{ g/mol}} = 0.40 \text{ mol}$
- According to the equation, 0.10 mol of  $CS_2$  requires  $0.10 \times 3 = 0.30 \text{ mol}$  of  $O_2$ .
- Because 0.40 mol of  $O_2$  is available, oxygen is in stoichiometric excess (0.10 mol excess), and  $CS_2$  is completely consumed first as the limiting reactant.

## Why other options are incorrect:

- **Option B:**  $O_2$  is the excess reactant since only 0.30 moles are consumed out of the 0.40 moles supplied.
- **Option C:**  $CO_2$  is a reaction product, not a reacting species.
- **Option D:**  $SO_2$  is a reaction product.

## Question #107 Key: (B)

CHEMISTRY  
05. Liquids

Water rises spontaneously in a narrow glass capillary tube primarily because:

## CORE CONCEPT &amp; DERIVATION

Capillary action is governed by the competition between adhesive forces (attraction between unlike molecules, such as water and glass) and cohesive forces (attraction between like molecules, such as water and water).

## Formula / Rule / Reaction:

$$\text{Capillary Rise Condition: } F_{\text{adhesive}} > F_{\text{cohesive}} \implies \text{Concave meniscus, contact angle } \theta < 90^\circ$$

## Solution:

- Water molecules form strong hydrogen bonds with the oxygen atoms of the polar silicate glass surface (adhesion).
- Because adhesion exceeds the intermolecular cohesive forces of water, water wets the glass surface and climbs upward until balanced by the downward weight of the liquid column.

## Why other options are incorrect:

- **Option A:** If adhesive and cohesive forces were equal, the liquid would form a flat surface without capillary rise or depression.
- **Option C:** If cohesive forces exceed adhesive forces, the liquid experiences capillary depression with a convex meniscus (as seen in mercury).
- **Option D:** Surface tension and contact wettability drive capillary action, not external barometric pressure.

## Question #108 Key: (A)

CHEMISTRY  
05. Liquids

Which of the following physical variables directly determines the temperature at which a liquid...

## CORE CONCEPT &amp; DERIVATION

The boiling point of a liquid is the specific temperature at which its equilibrium vapor pressure becomes equal to the external pressure exerted upon its liquid surface.

## Formula / Rule / Reaction:

$$\text{Condition for Boiling: } P_{\text{vap}}(T) = P_{\text{ext}}$$

## Solution:

- When external pressure increases (e.g., in a pressure cooker), the liquid must be heated to a higher temperature so its vapor pressure matches the elevated pressure, raising the boiling point.
- When external pressure decreases (e.g., at high altitudes), the boiling point decreases accordingly.

## Why other options are incorrect:

- **Option B:** Surrounding ambient temperature affects the rate of heat loss or warming, but does not alter the thermodynamic boiling point.
- **Option C:** The container volume has no influence on the intensive thermodynamic vapor-pressure equilibrium.
- **Option D:** Mass is an extensive property; boiling point is an intensive colligative-independent property.

## Question #109 Key: (C)

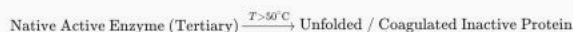
CHEMISTRY  
19. Macromolecules / Biochemistry

Human enzymes typically exhibit optimum activity between 37°C and 50°C. If the temperature is  $T > 50^\circ\text{C}$ ...

## CORE CONCEPT &amp; DERIVATION

Enzymes are globular proteins with specific three-dimensional conformations. Excessive thermal energy disrupts non-covalent stabilizing bonds (hydrogen bonds, ionic attractions, and hydrophobic interactions), leading to denaturation.

## Formula / Rule / Reaction:



## Solution:

- Above the optimum thermal threshold, increased molecular vibration breaks the tertiary folding pattern.
- The catalytic active site unfolds and changes shape irreversibly, permanently inactivating the enzyme.

## Why other options are incorrect:

- Option A:** Thermal denaturation unfolds the secondary and tertiary conformations without breaking covalent primary peptide bonds.
- Option B:** Freezing occurs at sub-zero temperatures and is reversible upon gentle thawing.
- Option D:** Saturation occurs at high substrate concentrations, which increases or plateaus reaction velocity rather than permanently destroying the enzyme.

## Question #110 Key: (A)

CHEMISTRY  
16. Alcohols & Phenols

The controlled oxidation of secondary propyl alcohol (propan-2-ol) with acidified potassium dic...

## CORE CONCEPT &amp; DERIVATION

Secondary alcohols undergo oxidation via the removal of two hydrogen atoms (one from the hydroxyl group and one from the secondary carbon atom) to yield ketones with the same number of carbon atoms.

## Formula / Rule / Reaction:



## Solution:

- Secondary propyl alcohol (propan-2-ol) contains three carbon atoms with the hydroxyl attached at C-2.
- Oxidation dehydrogenates this secondary carbinol group directly into a carbonyl group, producing propan-2-one (acetone).

## Why other options are incorrect:

- Option B:** Acetaldehyde is formed by the oxidation of a primary alcohol (ethanol).
- Option C:** Ethyl alcohol is a primary 2-carbon alcohol, not an oxidation product of a 3-carbon secondary alcohol.
- Option D:** n-Propyl alcohol is the primary structural isomer of isopropyl alcohol.

## Question #111 Key: (C)

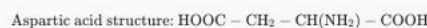
CHEMISTRY  
19. Macromolecules / Biochemistry

Which of the following biological compounds contains both an amino group ( $-\text{NH}_2$ ) and a carboxyl...

## CORE CONCEPT &amp; DERIVATION

Amino acids are bifunctional organic compounds containing at least one amino group ( $-\text{NH}_2$ ) and at least one carboxyl group ( $-\text{COOH}$ ) bonded to the alpha-carbon atom.

## Formula / Rule / Reaction:



## Solution:

- Aspartic acid (2-aminobutanedioic acid) contains an amino group, an  $\alpha$ -carboxyl group, and a  $\beta$ -carboxylic acid side-chain group, classifying it as an acidic  $\alpha$ -amino acid.

## Why other options are incorrect:

- Option A:** Benzoic acid is a simple aromatic carboxylic acid ( $\text{C}_6\text{H}_5\text{COOH}$ ) lacking an amino group.
- Option B:** Palmitic acid is a 16-carbon saturated fatty acid ( $\text{C}_{15}\text{H}_{31}\text{COOH}$ ) lacking an amino group.
- Option D:** Aniline is an aromatic amine ( $\text{C}_6\text{H}_5\text{NH}_2$ ) lacking a carboxyl group.

## Question #112 Key: (A)

CHEMISTRY  
08. Reaction Kinetics

What is the overall order of a chemical reaction if its specific reaction rate constant ( $k$ ) is ...

## CORE CONCEPT &amp; DERIVATION

The general dimensional formula for the units of a reaction rate constant  $k$  depends on the overall reaction order  $n$ .

## Formula / Rule / Reaction:

$$\text{Units of } k = (\text{mol} \cdot \text{dm}^{-3})^{1-n} \cdot \text{s}^{-1}$$

## Solution:

- Setting  $n = 1$ :
- Units of  $k = (\text{mol} \cdot \text{dm}^{-3})^{1-1} \cdot \text{s}^{-1} = (\text{mol} \cdot \text{dm}^{-3})^0 \cdot \text{s}^{-1} = \text{s}^{-1}$
- Therefore, a rate constant with the unit  $\text{s}^{-1}$  indicates a first-order reaction.

## Why other options are incorrect:

- Option B:** For a second-order reaction ( $n = 2$ ), the units are  $\text{dm}^3 \cdot \text{mol}^{-1} \cdot \text{s}^{-1}$ .
- Option C:** For a third-order reaction ( $n = 3$ ), the units are  $\text{dm}^6 \cdot \text{mol}^{-2} \cdot \text{s}^{-1}$ .
- Option D:** For a zero-order reaction ( $n = 0$ ), the units are  $\text{mol} \cdot \text{dm}^{-3} \cdot \text{s}^{-1}$ .

## Question #113 Key: (C)

CHEMISTRY  
08. Reaction Kinetics

Which of the following best characterizes the reaction kinetics of aqueous ionic reactions betw...

## CORE CONCEPT &amp; DERIVATION

In aqueous solution, ionic compounds dissociate completely into hydrated cations and anions. Because no covalent bonds need to be broken before new bonds are formed, the activation energy is nearly zero.

## Formula / Rule / Reaction:



## Solution:

- Precipitation and neutralization reactions involve the electrostatic attraction of oppositely charged mobile ions.
- These reactions proceed almost instantaneously (within  $10^{-12}$  to  $10^{-9}$  seconds) upon mixing.

## Why other options are incorrect:

- Option A:** Slow rates characterize reactions involving the cleavage and reorganization of strong covalent bonds (e.g., esterification).
- Option B:** Organic rearrangements exhibit moderate activation energies, unlike barrierless aqueous ionic combinations.
- Option D:** Ionic combinations are highly spontaneous with negative changes in Gibbs free energy.

## Question #114 Key: (B)

CHEMISTRY  
11. S & P Block Elements

What is the general periodic trend in metallic character as one descends a group of p-block ele...

## CORE CONCEPT &amp; DERIVATION

Metallic character is defined as the propensity of an element to lose valence electrons (electropositivity). Moving down any group, the number of electron shells increases, expanding atomic radius and shielding the valence shell from the nucleus.

## Formula / Rule / Reaction:

Down a Group: Atomic Radius  $\uparrow \Rightarrow$  Ionization Energy  $\downarrow \Rightarrow$  Metallic Character  $\uparrow$

## Solution:

- In Group 14, Carbon is a non-metal, Silicon and Germanium are metalloids, while Tin and Lead are distinct metals.
- Thus, metallic character increases down every p-block group.
- Note on board errata: Certain flawed answer keys miscoded this question as decreasing; however, STB and universal chemical principles confirm that metallic character increases down the group.

## Why other options are incorrect:

- Option A:** Metallic character decreases across a period from left to right, not down a group.
- Option C:** Atomic properties change continuously with increasing principal quantum numbers.
- Option D:** While d-block contraction can modulate increments, the overall group trend remains an increase in metallic character.

## Question #115 Key: (C)

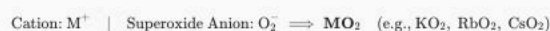
CHEMISTRY  
11. S & P Block Elements

A superoxide of an alkali metal (M belonging to Group I-A) possesses which of the following gen...

## CORE CONCEPT &amp; DERIVATION

The larger alkali metals (potassium, rubidium, and cesium) react with excess oxygen to form stable superoxides containing the paramagnetic superoxide anion  $\text{O}_2^-$ .

## Formula / Rule / Reaction:



## Solution:

- In a superoxide, the average oxidation state of each oxygen atom is  $-1/2$ .
- Because Group I-A alkali metals form univalent cations ( $\text{M}^+$ ), electrical neutrality requires a 1:1 stoichiometry with the  $\text{O}_2^-$  ion, yielding  $\text{MO}_2$ .

## Why other options are incorrect:

- Option A:**  $\text{M}_2\text{O}$  is the formula for a normal oxide containing the oxide ion  $\text{O}^{2-}$  (e.g.,  $\text{Li}_2\text{O}$ ).
- Option B:**  $\text{M}_2\text{O}_3$  is the formula for a group III-A sesquioxide.
- Option D:**  $\text{M}_2\text{O}_2$  is the formula for a peroxide containing the peroxide ion  $\text{O}_2^{2-}$  (e.g.,  $\text{Na}_2\text{O}_2$ ).

## Question #116 Key: (D)

CHEMISTRY  
11. S & P Block Elements

Which pair of elements differs markedly from the other members of their respective periodic gro...

## CORE CONCEPT &amp; DERIVATION

The first member of each representative group (Period 2) exhibits anomalous properties compared to its heavier congeners. This is caused by an exceptionally small atomic/ionic radius, high polarizing power (charge-to-size ratio), high electronegativity, and the absence of vacant d-orbitals.

## Formula / Rule / Reaction:

$$\text{Polarizing Power} \propto \frac{\text{Ionic Charge}}{(\text{Ionic Radius})^2}$$

## Solution:

- Lithium (Group I-A) and Beryllium (Group II-A) exhibit anomalous covalent behavior, form sparingly soluble salts, and show diagonal relationships with Magnesium and Aluminum, respectively.

## Why other options are incorrect:

- Option A:** Potassium and Calcium are Period 4 elements with large ionic radii and typical ionic behaviors.
- Option B:** Sodium and Magnesium are Period 3 elements that follow standard group trends without anomalous non-metallic covalent character.
- Option C:** Cesium and Barium are heavy electropositive elements at the bottom of the s-block that exhibit purely ionic character.

## Question #117 Key: (D)

CHEMISTRY  
06. Solids

Which of the following solids is classified as a three-dimensional network covalent crystal?

## CORE CONCEPT &amp; DERIVATION

Covalent network crystals consist of atoms held together throughout the entire crystal lattice by continuous, directional covalent bonds, resulting in exceptional hardness and very high melting points.

## Formula / Rule / Reaction:

Diamond: Each Carbon is  $sp^3$  hybridized and tetrahedrally bonded to 4 other Carbons ( $d_{C-C} = 1.54 \text{ \AA}$ )

## Solution:

- In diamond, every carbon atom forms four strong covalent  $\sigma$ -bonds in a rigid, giant 3D macromolecular network.
- NaCl, KI, and  $MgBr_2$  are ionic crystals held together by non-directional electrostatic lattice attractions.

## Why other options are incorrect:

- Option A:** NaCl is an ionic crystal composed of  $Na^+$  and  $Cl^-$  ions arranged in a face-centered cubic lattice.
- Option B:** KI is an ionic crystal.
- Option C:**  $MgBr_2$  is an ionic crystal.

## Question #118 Key: (D)

CHEMISTRY  
06. Solids

The lattice points of a molecular crystal (such as solid iodine or dry ice) are held together b...

## CORE CONCEPT &amp; DERIVATION

Molecular crystals are composed of discrete neutral molecules occupying the lattice sites. The cohesive forces holding these molecules together in the solid state are weak intermolecular forces (van der Waals forces, dipole-dipole attractions, or hydrogen bonds).

## Formula / Rule / Reaction:

Factual recall / Qualitative concept.

## Solution:

- Because the intermolecular forces holding molecular crystals together are relatively weak van der Waals interactions, these crystals are typically soft, exhibit low melting points, and are non-conductors of electricity.

## Why other options are incorrect:

- Option A:** Ionic bonds hold ionic crystals (e.g., NaCl) together.
- Option B:** Metallic bonds hold metal lattices together via delocalized valence electrons.
- Option C:** Network covalent bonds hold atomic crystals (e.g., diamond, quartz) together.

## Question #119 Key: (D)

CHEMISTRY  
09. Thermochemistry

According to classical thermodynamics, what is the mathematical expression for the First Law of...

## CORE CONCEPT &amp; DERIVATION

The First Law of Thermodynamics is the law of conservation of energy applied to thermodynamic systems: the change in internal energy equals the net heat added to the system minus the work done by the system.

## Formula / Rule / Reaction:

$$\Delta E = q - w \quad (\text{where } w = P\Delta V = \text{work done by the system})$$

## Solution:

- In the Sindh Textbook Board syllabus convention, heat absorbed by the system is positive ( $+q$ ) and work done by the system expanding against external pressure is positive ( $+w$ ).
- Therefore, the net change in internal energy is:  $\Delta E = q - w$ .

## Why other options are incorrect:

- Option A:**  $\Delta E = q + w$  represents the IUPAC convention where work done on the system is assigned a positive sign.
- Option B:** Represents heat released and work done simultaneously depleting energy without positive heat input.
- Option C:** Incorrect signs for both heat and work.

## Question #120 Key: (B)

CHEMISTRY  
09. Thermochemistry

According to the First Law of Thermodynamics at constant pressure, the change in enthalpy (Fo...

## CORE CONCEPT &amp; DERIVATION

Enthalpy ( $H$ ) is defined as the total heat content of a system, equal to internal energy plus the product of pressure and volume.

## Formula / Rule / Reaction:

$$H = E + PV \implies \Delta H = \Delta E + \Delta(PV)$$

$$\text{At constant pressure: } \Delta H = \Delta E + P\Delta V$$

## Solution:

- Under isobaric conditions,  $\Delta(PV) = P\Delta V$ .
- Because  $q_p = \Delta E + P\Delta V$ , the change in enthalpy  $\Delta H$  equals the heat transferred at constant pressure:  $\Delta H = \Delta E + P\Delta V$ .

## Why other options are incorrect:

- Option A:**  $\Delta E - P\Delta V$  incorrectly subtracts pressure-volume work from internal energy.
- Option C:** Uses negative values for both state functions.
- Option D:** Inverts the internal energy sign.

**Question #121** Key: (C)CHEMISTRY  
12. Transition Elements

Why do transition metals readily form non-stoichiometric interstitial compounds with small non-....

**CORE CONCEPT & DERIVATION**

Transition metals crystallize in close-packed metallic structures (hcp, ccp, or bcc) containing interstitial voids (tetrahedral and octahedral sites) large enough to accommodate small non-metal atoms without significantly expanding the host lattice.

**Formula / Rule / Reaction:**

Factual recall / Qualitative concept.

**Solution:**

- Small non-metal atoms (H, B, C, N) enter and occupy the interstitial holes within the rigid crystal lattices of transition metals.
- This forms hard, high-melting interstitial compounds (such as TiC, Fe<sub>3</sub>C, VH<sub>0.56</sub>) that retain metallic luster and electrical conductivity.

**Why other options are incorrect:**

- **Option A:** Unpaired d-electrons explain paramagnetism, but do not create interstitial spatial cavities.
- **Option B:** Electronic transitions between  $t_{2g}$  and  $e_g$  d-orbitals explain the colors of coordination complexes.
- **Option D:** Reduction potentials dictate redox activity, not the physical insertion of atoms into interstitial voids.

**Question #122** Key: (B)CHEMISTRY  
12. Transition Elements

In coordination chemistry, the ligand diethylenetriamine (dien) acts as a:

**CORE CONCEPT & DERIVATION**

The denticity of a ligand refers to the number of donor atoms possessing lone pairs of electrons through which the ligand can coordinate simultaneously to a central metal ion.

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

- Diethylenetriamine contains three basic nitrogen donor atoms, each possessing an unshared lone pair of electrons.
- Because it coordinates to a central transition metal ion through all three nitrogen atoms, it is classified as a tridentate ligand.

**Why other options are incorrect:**

- **Option A:** Ethylenediamine (en) is a bidentate ligand with 2 nitrogen donor atoms.
- **Option C:** Tetraethylenepentamine is a pentadentate ligand with 5 nitrogen donor atoms.
- **Option D:** Ethylenediaminetetraacetate (EDTA) is a classic hexadentate ligand.

**Question #123** Key: (C)PHYSICS  
15. Atomic Spectra

In the emission spectrum of atomic hydrogen, which spectral series occurs in the far-ultraviolet...

**CORE CONCEPT & DERIVATION**

The spectral lines of atomic hydrogen are grouped into series according to the lower principal quantum number ( $n_1$ ) of the electronic transition.

**Formula / Rule / Reaction:**

$$\frac{1}{\lambda} = R_H \left( \frac{1}{n_1^2} - \frac{1}{n_2^2} \right) \quad \text{For Lyman: } n_1 = 1, n_2 = 2, 3, 4, \dots$$

**Solution:**

- Transitions ending at the ground state ( $n_1 = 1$ ) involve the largest energy gaps, emitting high-frequency photons with wavelengths between 91 nm and 122 nm.
- This wavelength range lies entirely in the far-ultraviolet region, characterizing the Lyman series.

**Why other options are incorrect:**

- **Option A:** The Paschen series ( $n_1 = 3$ ) lies in the near-infrared region.
- **Option B:** The Balmer series ( $n_1 = 2$ ) lies in the visible spectrum.
- **Option D:** The Pfund series ( $n_1 = 5$ ) lies in the far-infrared region.

**Question #124** Key: (D)PHYSICS  
09. Current Electricity

Ohm's law ( $V = IR$ ) is strictly valid for a metallic conductor only if its:

**CORE CONCEPT & DERIVATION**

Ohm's law states that the current flowing through a metallic conductor is directly proportional to the potential difference across its ends, provided the physical state and temperature of the conductor remain unchanged.

**Formula / Rule / Reaction:**

$$I \propto V \implies V = IR \quad (R = \text{constant when } T = \text{constant})$$

**Solution:**

- Resistance in metals increases with temperature due to increased lattice ion vibrations scattering conduction electrons.
- Therefore, a linear ohmic relationship holds only when the temperature remains strictly constant.

**Why other options are incorrect:**

- **Option A:** At extremely high temperatures, resistance becomes excessively large and non-linear.
- **Option B:** If temperature rises, resistance increases, producing a non-linear non-ohmic curve (as seen in incandescent lamp filaments).
- **Option C:** Physical dimensions must remain constant during the test.

**Question #125** Key: (D)PHYSICS  
13. Electronics

A direct current (DC) that maintains a constant magnitude and unidirectional flow over time is ...

**CORE CONCEPT & DERIVATION**

Direct current involves the unidirectional flow of electric charge. When the rate of charge flow remains invariant with respect to time, it is designated as a steady direct current.

Formula / Rule / Reaction:

$$I(t) = \text{constant} \implies \frac{dI}{dt} = 0$$

Solution:

- A steady current delivers a constant magnitude of electric current over time without ripples or pulsations, typically supplied by chemical storage batteries.

Why other options are incorrect:

- **Option A:** Eddy currents are closed circulating loops of induced electric current generated in bulk conductors by changing magnetic fields.
- **Option B:** Surge current is a brief, transient high-amplitude spike of current during sudden circuit energization.
- **Option C:** Leakage current is unwanted parasitic current flowing across insulation barriers to ground.

**Question #126** Key: (B)PHYSICS  
09. Current Electricity

In an electrical circuit containing a real chemical battery connected to an external load resis...

**CORE CONCEPT & DERIVATION**

A real voltage source is modeled as an ideal electromotive force (E) in series with its internal resistance (r). All current that circulates through the external load must also pass through the internal electrolyte of the battery.

Formula / Rule / Reaction:

$$I = \frac{E}{R + r} \implies R_{\text{total}} = R + r$$

Solution:

- Because the current through the load is identical to the current passing through the internal resistance, the internal resistance is wired in series with the external load.

Why other options are incorrect:

- **Option A:** If connected in parallel, the total resistance would decrease and the terminal voltage would not drop with increasing load current.
- **Option C:** Internal resistance is an intrinsic physical property of the electrolyte and plates through which circuit current must pass.
- **Option D:** Internal resistance can only be neglected when  $r \ll R$ .

**Question #127** Key: (D)PHYSICS  
09. Current Electricity

The potential difference measured across the external output terminals of a battery when an act...

**CORE CONCEPT & DERIVATION**

Terminal potential difference ( $V_t$ ) is the net voltage available across the battery terminals when it is discharging into an external circuit, reduced from its open-circuit EMF by the internal voltage drop across its internal resistance.

Formula / Rule / Reaction:

$$V_t = E - Ir$$

Solution:

- When current flows, internal resistance dissipates potential equal to  $Ir$ .
- The remaining voltage available to the external load at the terminals is the terminal potential difference.

Why other options are incorrect:

- **Option A:** Electromotive force (E) is the open-circuit potential difference when no current is drawn ( $I = 0$ ).
- **Option B:** Back EMF is an opposing induced voltage generated by running electric motors.
- **Option C:** Internal potential gradient describes spatial potential drop per unit distance within the electrolyte.

**Question #128** Key: (D)PHYSICS  
03. Work & Energy

An energy expenditure rate of 1 Joule per second (1 J/s) is equivalent to:

**CORE CONCEPT & DERIVATION**

Power is the time rate at which work is done or energy is transformed. In the SI metric system, the derived unit of power is the Watt.

Formula / Rule / Reaction:

$$P = \frac{W}{t} \implies 1 \text{ Watt} = \frac{1 \text{ Joule}}{1 \text{ Second}} = 1 \text{ J} \cdot \text{s}^{-1}$$

Solution:

- By definition, consuming or transferring energy at the rate of one joule per second equals one watt.

Why other options are incorrect:

- **Option A:** The Kelvin is the base SI unit of thermodynamic temperature.
- **Option B:** The Newton is the derived SI unit of force ( $1 \text{ N} = 1 \text{ kg} \cdot \text{m/s}^2$ ).
- **Option C:** The Tesla is the derived SI unit of magnetic flux density ( $1 \text{ T} = 1 \text{ Wb/m}^2$ ).

**Question #129** **Key: (B)**PHYSICS  
14. Dawn of Modern Physics

According to the de Broglie hypothesis and quantum electrodynamics, what is the momentum (p) of...

**CORE CONCEPT & DERIVATION**

Photons possess zero rest mass but carry relativistic momentum related to their energy and wavelength by the Planck-Einstein relation.

Formula / Rule / Reaction:

$$E = hf = \frac{hc}{\lambda} \quad \text{and} \quad E = pc \implies p = \frac{E}{c} = \frac{h}{\lambda}$$

Solution:

- Equating the relativistic energy formulas yields the photon momentum:  $p = \frac{h}{\lambda}$ , where  $h$  is Planck's constant.

Why other options are incorrect:

- Option A:**  $h\lambda$  has dimensions of action multiplied by length, dimensionally incorrect for momentum.
- Option C:**  $\lambda/h$  is the reciprocal of momentum.
- Option D:** Represents the square of momentum, not momentum itself.

**Question #130** **Key: (C)**PHYSICS  
05. Waves

If monochromatic light possesses a wavelength of [Formula], what is its frequency in a vacuum?

**CORE CONCEPT & DERIVATION**

The propagation velocity of electromagnetic radiation in a vacuum relates its frequency and wavelength through the wave equation.

Formula / Rule / Reaction:

$$c = f\lambda \implies f = \frac{c}{\lambda} \quad (c = 3.0 \times 10^8 \text{ m/s})$$

Solution:

- Substitute  $c = 3.0 \times 10^8 \text{ m/s}$  and  $\lambda = 3.0 \times 10^{-7} \text{ m}$ :

$$f = \frac{3.0 \times 10^8 \text{ m/s}}{3.0 \times 10^{-7} \text{ m}} = 1.0 \times 10^8 - (-7) = 1.0 \times 10^{15} \text{ Hz}$$

Why other options are incorrect:

- Option A:** Off by two orders of magnitude due to power subtraction errors.
- Option B:** Corresponds to an incorrect wavelength of  $3.0 \times 10^{-6} \text{ m}$  (infrared).
- Option D:** Corresponds to a wavelength of  $3.0 \times 10^{-8} \text{ m}$  (extreme ultraviolet).

**Question #131** **Key: (A)**PHYSICS  
14. Dawn of Modern Physics

According to Planck's quantum theory, the energy carried by an individual photon is determined...

**CORE CONCEPT & DERIVATION**

Planck's quantum postulate states that radiant energy is emitted, absorbed, and transferred in discrete bundles called quanta (photons). The energy of each photon is directly proportional to its frequency.

Formula / Rule / Reaction:

$$E = hf = \frac{hc}{\lambda}$$

Solution:

- Because Planck's constant  $h$  is universal, the energy of a photon depends exclusively on its oscillation frequency  $f$ .

Why other options are incorrect:

- Option B:** Beam intensity determines the number of photons arriving per unit area per second, not the energy of an individual photon.
- Option C:** Classical wave theory associates energy with wave amplitude squared, but quantum mechanics establishes that photon energy is amplitude-independent.
- Option D:** In a vacuum, all electromagnetic waves travel at the identical speed  $c$  regardless of photon energy.

**Question #132** **Key: (B)**PHYSICS  
11. Electromagnetic Induction

The operational principle of an electrical transformer is based upon:

**CORE CONCEPT & DERIVATION**

Mutual induction is the electromagnetic phenomenon whereby an alternating current in a primary coil creates a continuously changing magnetic flux in a common ferromagnetic core, inducing an alternating electromotive force across a secondary coil.

Formula / Rule / Reaction:

$$E_s = -N_s \frac{d\Phi_B}{dt} = -M \frac{dI_p}{dt}$$

Solution:

- Transformers use two electrically isolated coils wound on a mutual soft iron core.
- Changing primary current transfers electrical energy to the secondary coil exclusively via mutual induction.

Why other options are incorrect:

- Option A:** Self-induction is the generation of an opposing induced EMF within the same coil carrying changing current (as in chokes and inductors).
- Option C:** Motional EMF is generated when a physical conductor moves mechanically across a magnetic field.
- Option D:** Magnetic torque acts on a current loop to rotate an electric motor armature.

**Question #133** Key: (A)PHYSICS  
11. Electromagnetic Induction

An ideal step-down transformer has 500 turns on its primary winding and 250 turns on its second...

**CORE CONCEPT & DERIVATION**

In an ideal transformer, the ratio of the secondary induced voltage to the primary applied voltage equals the turns ratio of the secondary to primary windings.

Formula / Rule / Reaction:

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} \Rightarrow V_s = V_p \left( \frac{N_s}{N_p} \right)$$

Solution:

- Given  $N_p = 500$  and  $N_s = 250$ :

$$V_s = V_p \left( \frac{250}{500} \right) = \frac{1}{2} V_p = 0.5 V_p$$

- Therefore, the output voltage is exactly half of the input voltage.

Why other options are incorrect:

- Option B:** Equal voltages occur only in an isolation transformer with a 1 : 1 turns ratio.
- Option C:** Doubling the voltage requires a step-up transformer with  $N_s = 2N_p$ .
- Option D:** Output voltage is non-zero as long as an alternating input voltage is supplied.

**Question #134** Key: (D)PHYSICS  
10. Electromagnetism

The magnetic flux passing perpendicularly through a unit surface area is defined as the:

**CORE CONCEPT & DERIVATION**

Magnetic flux density ( $B$ ), also known as magnetic field strength or magnetic induction, is the measure of magnetic flux passing per unit area perpendicular to the direction of the magnetic field lines.

Formula / Rule / Reaction:

$$B = \frac{\Phi_B}{A} \quad (\text{Units: } \frac{\text{Weber}}{\text{m}^2} = \text{Tesla})$$

Solution:

- Magnetic flux per unit area is mathematically  $\Phi/A = B$ , which defines magnetic flux density.

Why other options are incorrect:

- Option A:** Total line count represents total magnetic flux ( $\Phi$ ), not flux divided by area.
- Option B:** Magnetic dipole moment is the product of current and loop area ( $M = IA$ ).
- Option C:** Vector potential  $\vec{A}$  satisfies  $\vec{B} = \nabla \times \vec{A}$ .

**Question #135** Key: (A)PHYSICS  
10. Electromagnetism

The scalar (dot) product of magnetic induction ( $B$ ) and the area vector ( $A$ ) of a flat surface eq...

**CORE CONCEPT & DERIVATION**

Magnetic flux is a scalar quantity defined as the dot product of the uniform magnetic induction vector  $\vec{B}$  and the surface area vector  $\vec{A}$ .

Formula / Rule / Reaction:

$$\Phi_B = \vec{B} \cdot \vec{A} = BA \cos \theta$$

Solution:

- The scalar product  $\vec{B} \cdot \vec{A}$  accounts for the projection of the magnetic field perpendicular to the surface, representing the magnetic flux.

Why other options are incorrect:

- Option B:** Magnetic permeability ( $\mu$ ) is an intensive medium property measured in Henry per meter.
- Option C:** Magnetic field intensity ( $H$ ) relates to  $B$  via  $B = \mu H$ .
- Option D:** Pole strength is measured in Ampere-meters, not Weber.

**Question #136** Key: (D)PHYSICS  
10. Electromagnetism

Conceptually, the magnetic flux passing through an oriented planar surface provides a quantitat...

**CORE CONCEPT & DERIVATION**

In Faraday's line representation of fields, the total number of magnetic field lines (lines of induction) passing through a given surface area placed perpendicular to the field represents the magnetic flux.

Formula / Rule / Reaction:

$$\Phi_B = \int \vec{B} \cdot d\vec{A} \propto \text{Total number of field lines intercepted}$$

Solution:

- According to the Sindh Textbook Board Physics syllabus, magnetic flux represents the total number of magnetic lines of force passing through a given surface element.

Why other options are incorrect:

- Option A:** Geometric area is only one component of flux, which also requires magnetic field strength.
- Option B:** Magnetic fields are produced by charge motion, but flux does not measure total static charge.
- Option C:** The time derivative of flux gives induced EMF, not force rates.

**Question #137** Key: (A)PHYSICS  
08. Electrostatics

The rate of change of electric potential with respect to spatial distance ((Formula)) is term...

**CORE CONCEPT & DERIVATION**

The spatial variation of electric potential along a given direction is defined as the potential gradient. The negative gradient of electric potential equals the electric field intensity.

Formula / Rule / Reaction:

$$E = -\frac{\Delta V}{\Delta r} = -\text{Potential Gradient}$$

Solution:

- Potential gradient represents the change in electrical potential per unit distance.
- Its negative sign indicates that the electric field points in the direction of steepest potential decrease.

Why other options are incorrect:

- **Option B:** Surface charge density is electric charge per unit surface area ( $\sigma = q/A$ ).
- **Option C:** Permittivity ( $\epsilon_0$ ) is a physical constant measuring a medium's resistance to electric field formation.
- **Option D:** Electrostatic flux density refers to electric displacement field lines per unit area.

**Question #138** Key: (D)PHYSICS  
08. Electrostatics

The amount of kinetic energy acquired by an electron when accelerated across an electrostatic p...

**CORE CONCEPT & DERIVATION**

The electron-volt (eV) is an atomic unit of energy defined as the work done in accelerating an elementary charge through an electrical potential difference of one volt.

Formula / Rule / Reaction:

$$W = q\Delta V = (1.602 \times 10^{-19} \text{ C})(1 \text{ V}) = 1.602 \times 10^{-19} \text{ J} = 1 \text{ eV}$$

Solution:

- An electron carrying fundamental charge  $e = 1.602 \times 10^{-19} \text{ C}$  accelerated through 1 V gains exactly 1 eV of kinetic energy.

Why other options are incorrect:

- **Option A:** 1 keV =  $10^3 \text{ eV}$ , acquired across a potential difference of 1000 Volts.
- **Option B:** 1 MeV =  $10^6 \text{ eV}$ , acquired across one million Volts.
- **Option C:** 1 GeV =  $10^9 \text{ eV}$ , acquired across one billion Volts.

**Question #139** Key: (C)PHYSICS  
08. Electrostatics

Which fundamental law of physics establishes that the electrostatic force between two stationary...

**CORE CONCEPT & DERIVATION**

Coulomb's law governs the electrostatic interaction between two point charges at rest in a vacuum or dielectric medium.

Formula / Rule / Reaction:

$$F = k \frac{|q_1 q_2|}{r^2} = \frac{1}{4\pi\epsilon_0} \frac{|q_1 q_2|}{r^2}$$

Solution:

- Formulated by Charles-Augustin de Coulomb in 1785, this inverse-square relationship quantifies the mutual attractive or repulsive electrostatic forces between point charges.

Why other options are incorrect:

- **Option A:** Ohm's law relates current, voltage, and electrical resistance in conductors.
- **Option B:** Lenz's law dictates the polarity of induced electromotive forces opposing the changing flux.
- **Option D:** Ampere's circuital law relates magnetic field integration along a closed loop to the enclosed electric current.

**Question #140** Key: (B)PHYSICS  
08. Electrostatics

Physically, the electric field surrounding an isolated point charge represents the:

**CORE CONCEPT & DERIVATION**

An electric field is an intrinsic alteration of space surrounding any charged entity such that any second test charge brought into this region experiences an electrostatic Lorentz force.

Formula / Rule / Reaction:

$$\vec{E} = \frac{\vec{F}}{q_0} \quad (\text{Force per unit positive test charge})$$

Solution:

- The electric field defines the physical domain surrounding a source charge where its electrostatic influence acts on other charged particles.

Why other options are incorrect:

- **Option A:** The nuclear radius is a microscopic subatomic spatial boundary (approx  $10^{-15} \text{ m}$ ), whereas the electric field extends infinitely into space.
- **Option C:** Field lines map force vectors, not deterministic orbital paths.
- **Option D:** Electric field is a vector force field, not a kinematic velocity parameter.

**Question #141** Key: (A)PHYSICS  
08. Electrostatics

The electric field intensity unit of 1 Newton per Coulomb (1 N/C) is dimensionally and physical...

**CORE CONCEPT & DERIVATION**

Electric field strength can be derived from the force experienced by a unit charge ( $F/q$ , in N/C) or from the negative spatial gradient of electric potential ( $-\Delta V/\Delta r$ , in V/m).

**Formula / Rule / Reaction:**

$$\text{Unit Equivalence: } \frac{\text{V}}{\text{m}} = \frac{\text{J/C}}{\text{m}} = \frac{\text{N} \cdot \text{m}}{\text{C} \cdot \text{m}} = \frac{\text{N}}{\text{C}}$$

**Solution:**

- Because 1 Volt equals 1 Joule per Coulomb, dividing by meters yields Newton-meters per Coulomb-meter, which simplifies to Newtons per Coulomb.

**Why other options are incorrect:**

- Option B:** 1 J/C equals 1 Volt, which is the unit of electric potential, not electric field strength.
- Option C:** 1 C/m<sup>2</sup> is the SI unit of surface charge density or electric displacement.
- Option D:** Dimensionally incompatible with electric field strength.

**Question #142** Key: (D)PHYSICS  
04. Rotational & Circular Motion

What is the linear acceleration produced when a net horizontal force of 10 N acts upon a body of mass 0.5 kg?

**CORE CONCEPT & DERIVATION**

According to Newton's Second Law of Motion, the acceleration of an object is directly proportional to the net applied force and inversely proportional to its mass.

**Formula / Rule / Reaction:**

$$F = ma \implies a = \frac{F}{m}$$

**Solution:**

- Given  $F = 10 \text{ N}$  and  $m = 0.5 \text{ kg}$ :

$$a = \frac{10 \text{ N}}{0.5 \text{ kg}} = 10 \times 2 = 20 \text{ m/s}^2$$

**Why other options are incorrect:**

- Option A:** 40 m/s<sup>2</sup> results from using an incorrect mass of 0.25 kg.
- Option B:** 5 m/s<sup>2</sup> results from multiplying force by mass instead of dividing.
- Option C:** 10 m/s<sup>2</sup> corresponds to a mass of 1.0 kg.

**Question #143** Key: (B)PHYSICS  
02. Force & Motion

The time rate of change of linear momentum of a moving body equals the net force acting on it.

**CORE CONCEPT & DERIVATION**

Sir Isaac Newton originally stated his second law of motion in terms of momentum: the rate of change of linear momentum of a body is directly proportional to the applied resultant force and occurs along the direction of that force.

**Formula / Rule / Reaction:**

$$\vec{F} = \frac{d\vec{p}}{dt} = \frac{d(m\vec{v})}{dt} = m \frac{d\vec{v}}{dt} = m\vec{a} \quad (\text{when } m = \text{constant})$$

**Solution:**

- The differential rate  $d\vec{p}/dt$  equals the resultant force  $\vec{F}$  acting on the body.

**Why other options are incorrect:**

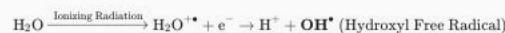
- Option A:** Acceleration is the time rate of change of velocity ( $d\vec{v}/dt$ ).
- Option C:** Velocity is the time rate of change of displacement ( $d\vec{r}/dt$ ).
- Option D:** Work is the line integral of force over displacement ( $W = \int \vec{F} \cdot d\vec{r}$ ).

**Question #144** Key: (A)PHYSICS  
16. Nuclear Physics

Ionizing nuclear radiations (such as alpha, beta, and gamma rays) are biologically hazardous because they can cause DNA damage and cell death.

**CORE CONCEPT & DERIVATION**

High-energy ionizing radiation possesses sufficient kinetic energy to eject orbital electrons from target atoms. In biological systems, the radiolysis of cellular water generates destructive free radicals and cations that break DNA strands and disrupt cell division.

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

- Ionization disrupts molecular structures inside living cells.
- Hydroxyl free radicals cause DNA double-strand breaks, base damage, and lipid peroxidation, leading to mutations or cell death.

**Why other options are incorrect:**

- Option B:** Low-level ionizing radiation causes extensive biological damage without any measurable macroscopic temperature rise.
- Option C:** Radiation alterations are fundamentally chemical and biochemical in nature.
- Option D:** Radiation does not freeze cellular fluids.

**Question #145** Key: (D)PHYSICS  
04. Rotational & Circular Motion

In uniform circular motion, what kinematic change causes centripetal acceleration to act on the object?

**CORE CONCEPT & DERIVATION**

Velocity is a vector quantity possessing both magnitude (speed) and direction. An object moving in a circle at constant speed is still accelerating because the direction of its tangential velocity vector changes continuously at every point along the circular arc.

**Formula / Rule / Reaction:**

$$\vec{a}_c = \frac{d\vec{v}}{dt} \quad | \quad |a_c| = \frac{v^2}{r} = \omega^2 r \quad (\text{Directed radially inward})$$

**Solution:**

- Even if linear speed remains constant, the continuous rotation of the direction vector produces a net acceleration pointing toward the center of curvature.

**Why other options are incorrect:**

- Option A:** In uniform circular motion, the magnitude of velocity (speed) is constant.
- Option B:** The mass of the body remains constant throughout the motion.
- Option C:** Tangential speed is constant in uniform circular motion.

**Question #146** Key: (C)PHYSICS  
04. Rotational & Circular Motion

One radian is an SI derived angular unit equivalent to approximately how many degrees?

**CORE CONCEPT & DERIVATION**

A radian is the plane angle subtended at the center of a circle by an arc whose arc length equals the radius of the circle.

**Formula / Rule / Reaction:**

$$2\pi \text{ radians} = 360^\circ \Rightarrow 1 \text{ radian} = \frac{360^\circ}{2\pi} = \frac{180^\circ}{\pi} \approx \frac{180^\circ}{3.14159}$$

**Solution:**

$$1 \text{ rad} = \frac{180^\circ}{3.14159} \approx 57.296^\circ \approx 57.3^\circ$$

**Why other options are incorrect:**

- **Option A:**  $0.573^\circ$  is two orders of magnitude too small.
- **Option B:**  $5.73^\circ$  is an arithmetic decimal-place error.
- **Option D:**  $573^\circ$  is an order of magnitude larger than the true value.

**Question #147** Key: (C)PHYSICS  
04. Rotational & Circular Motion

A bicycle wheel accelerates uniformly from rest, achieving an angular velocity of [Formula] in...

**CORE CONCEPT & DERIVATION**

Angular acceleration ( $\alpha$ ) is the time rate of change of angular velocity ( $\omega$ ).

**Formula / Rule / Reaction:**

$$\alpha = \frac{\omega_f - \omega_i}{\Delta t}$$

**Solution:**

- Given  $\omega_i = 0 \text{ rad/s}$ ,  $\omega_f = 6.28 \text{ rad/s}$ , and  $\Delta t = 2.0 \text{ s}$ :

$$\alpha = \frac{6.28 - 0}{2.0} = 3.14 \text{ rad/s}^2$$

**Why other options are incorrect:**

- **Option A:**  $1.00 \text{ rad/s}^2$  is mathematically incorrect.
- **Option B:**  $1.50 \text{ rad/s}^2$  does not match the computed quotient.
- **Option D:**  $6.28 \text{ rad/s}^2$  assumes the angular velocity was achieved in 1.0 second rather than 2.0 seconds.

**Question #148** Key: (B)PHYSICS  
04. Rotational & Circular Motion

For an object executing circular motion of radius  $r$ , the ratio of its tangential linear velocit...

**CORE CONCEPT & DERIVATION**

Linear tangential speed along a circular path relates directly to angular rotational speed through the radial distance from the axis of rotation.

**Formula / Rule / Reaction:**

$$v = r\omega \Rightarrow \omega = \frac{v}{r}$$

**Solution:**

- Dividing tangential velocity  $v$  by radius  $r$  yields angular velocity  $\omega$ , expressed in radians per second.

**Why other options are incorrect:**

- **Option A:** Angular displacement is arc length divided by radius ( $\theta = s/r$ ).
- **Option C:** Angular acceleration is tangential acceleration divided by radius ( $\alpha = a_t/r$ ).
- **Option D:** Angular momentum is  $L = mvr$ .

**Question #149** Key: (A)PHYSICS  
07. Thermodynamics

The pressure-volume ( $P$ - $V$ ) indicator diagram for which classical gas law is geometrically identi...

**CORE CONCEPT & DERIVATION**

An isothermal process is defined as a thermodynamic change occurring at constant temperature. Boyle's law describes the pressure-volume behavior of an ideal gas specifically at constant temperature.

**Formula / Rule / Reaction:**

$$\text{Isothermal Process: } T = \text{constant} \Rightarrow PV = \text{constant (Boyle's Law)}$$

**Solution:**

- Both an isothermal thermodynamic process and Boyle's law maintain constant temperature.
- Consequently, their  $P - V$  curves are both hyperbolic isotherms.

**Why other options are incorrect:**

- **Option B:** Charles's law operates at constant pressure (isobaric), yielding a straight line on a  $V - T$  plot.
- **Option C:** Avogadro's law relates volume to mole quantity at constant temperature and pressure.
- **Option D:** Gay-Lussac's law operates at constant volume (isochoric), yielding a vertical line on a  $P - V$  plot.

**Question #150** Key: (B)PHYSICS  
04. Rotational & Circular Motion

When sudden heavy rain wets a highway, a moving car is prone to skidding primarily because:

**CORE CONCEPT & DERIVATION**

Traction between rubber tires and road surfaces relies on static friction. A layer of rainwater creates a thin film between the tire and asphalt (hydroplaning), drastically reducing the coefficient of friction.

**Formula / Rule / Reaction:**

$$f_s = \mu_s N \quad (\mu_s \text{ decreases significantly on wet roads})$$

**Solution:**

- With reduced frictional force, the road cannot supply the centripetal and braking forces required to maintain control during turning or braking.
- Consequently, the vehicle skids, losing mechanical balance and directional stability.
- Note on board key: Certain question archives alternate between Option B and an unconventional theoretical interpretation regarding rainwater accumulation (Option D); however, physical and medical past paper keys consistently identify tire friction reduction and loss of balance as the correct physiological/applied physics answer.

**Why other options are incorrect:**

- **Option A:** Engine output depends on fuel combustion within closed cylinders, not external rainwater.
- **Option C:** Vehicle motion remains subject to external gravitational, normal, and reduced frictional forces.
- **Option D:** While water drops fall onto the car, the fraction of mass added is negligible compared to the 1000+ kg mass of the vehicle.

**Question #151** Key: (B)PHYSICS  
05. Waves

Which of the following technological applications operates directly on the principle of the Doppler effect?

**CORE CONCEPT & DERIVATION**

The Doppler effect refers to the apparent shift in the observed frequency of a wave caused by relative motion between the wave source and the observer. In traffic radar speed guns, microwave signals reflected from a moving vehicle undergo a frequency shift proportional to vehicle speed.

**Formula / Rule / Reaction:**

$$\Delta f = \frac{2v}{c} f_0 \implies v = \frac{c \Delta f}{2 f_0}$$

**Solution:**

- Microwave pulses transmitted toward a moving automobile reflect back with a shifted frequency.
- By measuring the beat frequency ( $\Delta f$ ) between the emitted and returned waves, the device calculates the instantaneous speed of the automobile.

**Why other options are incorrect:**

- **Option A:** Holography operates on the principle of wave interference and optical coherence, not frequency shifts.
- **Option C:** Refractometry and Snell's law determine the speed of light in optical media.
- **Option D:** Endoscopy relies on total internal reflection within flexible glass fiber bundles.

**Question #152** Key: (D)PHYSICS  
05. Waves

Which of the following wave phenomena can be exhibited by longitudinal sound waves in an elastic medium?

**CORE CONCEPT & DERIVATION**

The Principle of Superposition states that when two or more waves traverse the same medium simultaneously, the resultant displacement at any point equals the vector sum of their individual displacements. All waves, whether transverse or longitudinal, exhibit superposition.

**Formula / Rule / Reaction:**

$$y_{\text{net}}(x, t) = y_1(x, t) + y_2(x, t)$$

**Solution:**

- Longitudinal sound waves undergo constructive and destructive interference, forming standing waves and acoustic beats via the superposition principle.
- Because their particle vibrations are parallel to the direction of propagation, longitudinal waves cannot undergo polarization.

**Why other options are incorrect:**

- **Option A:** Polarization is restricted exclusively to transverse waves whose oscillations are perpendicular to the propagation vector.
- **Option B:** Photoelectric emission is a quantum particle phenomenon produced by electromagnetic radiation striking metal surfaces.
- **Option C:** Sound waves are mechanical pressure waves requiring an elastic material medium, not electromagnetic fields.

**Question #153** Key: (D)PHYSICS  
07. Thermodynamics

Which thermodynamic state variable or property of a system remains strictly constant during an adiabatic process?

**CORE CONCEPT & DERIVATION**

An adiabatic process is defined as a thermodynamic transformation that occurs inside a thermally insulated system where no heat enters or leaves the system across its boundaries.

**Formula / Rule / Reaction:**

$$\Delta Q = 0 \implies Q = \text{constant} \quad \text{and} \quad \Delta U = -W$$

**Solution:**

- Because the boundary is thermally non-conducting (insulated), heat transfer is zero ( $\Delta Q = 0$ ).
- During adiabatic compression, temperature, pressure, and internal energy all increase, while during adiabatic expansion, they decrease; only the heat transferred remains zero.

**Why other options are incorrect:**

- **Option A:** Temperature varies continuously in an adiabatic process as work is done at the expense of internal energy.
- **Option B:** An isochoric process is one where volume remains constant ( $\Delta V = 0$ ).
- **Option C:** An isobaric process is one where pressure remains constant ( $\Delta P = 0$ ).

**Question #154** Key: (C)PHYSICS  
08. Electrostatics

According to Gauss's law, the net electric flux traversing a closed Gaussian surface enclosing a positive charge is proportional to the net enclosed charge.

**CORE CONCEPT & DERIVATION**

Gauss's law states that the total outward electric flux through any arbitrary closed imaginary boundary (Gaussian surface) depends solely on the net electric charge enclosed divided by the permittivity of the medium.

**Formula / Rule / Reaction:**

$$\Phi_e = \oint \vec{E} \cdot d\vec{A} = \frac{q_{\text{enclosed}}}{\epsilon_0}$$

**Solution:**

- Because every electric field line originating from the positive point charge must eventually cross the enclosing boundary regardless of its topography, the net flux is independent of the shape, volume, or surface area of the enclosure.

**Why other options are incorrect:**

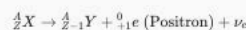
- **Option A:** Electric flux is directly proportional to the enclosed charge, not inversely proportional.
- **Option B:** Moving the charge to any position within the closed volume does not change the total number of field lines exiting the surface.
- **Option D:** Net flux is zero only if the net enclosed charge is zero.

**Question #155** Key: (C)PHYSICS  
16. Nuclear Physics

During radioactive beta-plus decay (positron emission), what happens to the total nucleon (mass...

**CORE CONCEPT & DERIVATION**

In beta-plus ( $\beta^+$ ) decay, an intranuclear proton converts into a neutron, emitting a positron and an electron neutrino. While the atomic number ( $Z$ ) decreases by 1, the total mass number ( $A$ ) remains conserved.

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

- Because one proton is converted into one neutron, the total count of nucleons ( $A = Z + N$ ) remains unchanged.
- Therefore, the mass number  $A$  is conserved.

**Why other options are incorrect:**

- Option A:** The atomic number  $Z$  decreases by one unit, not the mass number  $A$ .
- Option B:** The mass number does not increase in any mode of spontaneous radioactive disintegration.
- Option D:** Alpha decay decreases the mass number by 4 units, not beta-plus decay.

**Question #156** Key: (C)PHYSICS  
03. Work & Energy

Neglecting air resistance, which of the following mathematical expressions represents a conserv...

**CORE CONCEPT & DERIVATION**

The Law of Conservation of Mechanical Energy states that in an isolated conservative gravitational field, the sum of gravitational potential energy and translational kinetic energy remains constant at every point along the descent.

**Formula / Rule / Reaction:**

$$E_{\text{total}} = U + K = mgh + \frac{1}{2}mv^2 = \text{constant}$$

**Solution:**

- As the body falls, loss in potential energy ( $-\Delta U$ ) is converted into an equal gain in kinetic energy ( $+\Delta K$ ).
- The sum  $mgh + \frac{1}{2}mv^2$  remains invariant throughout the free fall.

**Why other options are incorrect:**

- Option A:** Omits the factor of  $1/2$  from the kinetic energy term.
- Option B:** Subtracts kinetic energy and omits the factor of  $1/2$ .
- Option D:** Subtracts kinetic energy instead of summing total energy components.

**Question #157** Key: (C)PHYSICS  
05. Waves

The product of the frequency ( $f$ ) and wavelength ( $\lambda$ ) of a progressive wave equals its:

**CORE CONCEPT & DERIVATION**

The fundamental wave equation relates the speed of propagation of a periodic wave to its temporal frequency and spatial wavelength.

**Formula / Rule / Reaction:**

$$v = \frac{\text{Distance}}{\text{Time}} = \frac{\lambda}{T} = f\lambda$$

**Solution:**

- Because frequency is the reciprocal of the time period ( $f = 1/T$ ), multiplying frequency by wavelength yields the wave propagation speed  $v$ .

**Why other options are incorrect:**

- Option A:** Displacement is the instantaneous position offset of an oscillating particle from equilibrium.
- Option B:** Amplitude is the maximum peak displacement of the wave oscillation.
- Option D:** Time period is the duration required for one complete wave cycle, equal to  $1/f$ .

**Question #158** Key: (A)PHYSICS  
02. Force & Motion

Two solid spheres of masses  $[M_1]$  and  $[M_2]$  are dropped simultaneously from the same height...

**CORE CONCEPT & DERIVATION**

According to Galileo's law of falling bodies and Newton's Universal Law of Gravitation, the gravitational acceleration experienced by a body is independent of the mass of the falling object.

**Formula / Rule / Reaction:**

$$g = \frac{GM_E}{R_E^2} \implies F = mg \implies a = \frac{F}{m} = g$$

**Solution:**

- Both objects experience the identical downward acceleration  $g \approx 9.8 \text{ m/s}^2$  regardless of their masses.
- Consequently, they fall with identical instantaneous velocities and strike the ground at the identical time.

**Why other options are incorrect:**

- Option B:** Kinetic energy ( $K = \frac{1}{2}mv^2$ ) is directly proportional to mass; the 40 kg mass has 4 times the kinetic energy of the 10 kg mass.
- Option C:** Potential energy ( $U = mgh$ ) is proportional to mass; the 40 kg body has 4 times greater potential energy.
- Option D:** Power delivered by gravity ( $P = mgv$ ) is 4 times greater for the 40 kg sphere.

**Question #159** Key: (B)PHYSICS  
04. Rotational & Circular Motion

A body of mass [Formula] moves along a circular path of radius [Formula] under the action of a ...

**CORE CONCEPT & DERIVATION**

Work done by a force is defined by the scalar product of the force vector and the displacement vector. The centripetal force acts radially inward, perpendicular to the instantaneous tangential displacement at every point along the circular trajectory.

**Formula / Rule / Reaction:**

$$W = \vec{F}_c \cdot \Delta \vec{s} = F_c \Delta s \cos(90^\circ) = 0$$

**Solution:**

- Because the angle between the centripetal force and the instantaneous displacement is always  $90^\circ$  ( $\cos 90^\circ = 0$ ), the instantaneous power and work done are identically zero throughout the motion.
- Additionally, for a complete closed loop, net displacement is zero.

**Why other options are incorrect:**

- Option A:** 16 J is an arbitrary non-zero calculation that ignores perpendicularity.
- Option C:** 8 J erroneously multiplies force by radius without applying vector dot products.
- Option D:** Centripetal forces can never perform mechanical work in uniform circular motion.

**Question #160** Key: (C)PHYSICS  
03. Work & Energy

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

**CORE CONCEPT & DERIVATION**

The kilowatt-hour is a commercial unit of electrical energy, defined as the energy consumed by an electrical load operating at a power of one kilowatt for a duration of one hour.

**Formula / Rule / Reaction:**

$$1 \text{ kWh} = (1 \text{ kW}) \times (1 \text{ h}) = (1000 \text{ W}) \times (3600 \text{ s}) = 3.6 \times 10^6 \text{ J} = 3.6 \text{ MJ}$$

**Solution:**

- Converting kilowatts to watts (1000 J/s) and hours to seconds (3600 s) yields 3,600,000 Joules or 3.6 MJ.

**Why other options are incorrect:**

- Option A:**  $3.6 \times 10^3 \text{ J}$  represents 1 watt-hour, not 1 kilowatt-hour.
- Option B:** Off by two orders of magnitude due to arithmetic conversion errors.
- Option D:**  $3.6 \times 10^9 \text{ J}$  represents 1 megawatt-hour (1 MWh).

**Question #161** Key: (B)PHYSICS  
05. Waves

In a stationary (standing) wave, the spatial distance between two consecutive displacement node...

**CORE CONCEPT & DERIVATION**

A standing wave results from the superposition of two identical waves traveling in opposite directions. Nodes are points of zero amplitude, while antinodes are points of maximum amplitude.

**Formula / Rule / Reaction:**

$$\text{Distance between two consecutive nodes} = \frac{\lambda}{2}$$

$$\text{Distance between two consecutive antinodes} = \frac{\lambda}{2}$$

$$\text{Distance between a node and an adjacent antinode} = \frac{\lambda}{4}$$

**Solution:**

- A full wavelength ( $\lambda$ ) spans two complete loops of a standing wave.
- Each individual loop bounded by two successive nodes occupies exactly half a wavelength ( $\lambda/2$ ).

**Why other options are incorrect:**

- Option A:**  $\lambda$  is the distance between three consecutive nodes (spanning two loops).
- Option C:**  $\lambda/4$  is the distance separating an adjacent node and antinode.
- Option D:**  $2\lambda$  spans four complete loops of the standing wave pattern.

**Question #162** Key: (A)PHYSICS  
05. Waves

If the fundamental frequency of a stretched string fixed at both ends is [Formula], the freque...

**CORE CONCEPT & DERIVATION**

For a stretched string fixed at both ends, the resonant harmonic frequencies are integral multiples of the fundamental frequency ( $f_1$ ).

**Formula / Rule / Reaction:**

$$f_n = n f_1 \quad \text{where } n = 1, 2, 3, 4, \dots$$

**Solution:**

- For the fourth harmonic,  $n = 4$ :

$$f_4 = 4 \times f_1 = 4 \times 50 \text{ Hz} = 200 \text{ Hz}$$

**Why other options are incorrect:**

- Option B:** 150 Hz corresponds to the third harmonic ( $n = 3$ ).
- Option C:** 12.5 Hz results from dividing 50 by 4, which is physically incorrect.
- Option D:** 250 Hz corresponds to the fifth harmonic ( $n = 5$ ).

**Question #163** Key: (C)PHYSICS  
02. Force & Motion

A projectile is launched horizontally from a cliff with an initial velocity of [Formula]. Negl...

**CORE CONCEPT & DERIVATION**

In projectile motion, horizontal and vertical motions are independent. Because gravity acts strictly in the vertical direction, the horizontal acceleration is zero, meaning the horizontal velocity remains constant throughout the flight.

**Formula / Rule / Reaction:**

$$a_x = 0 \implies v_x(t) = v_{0x} = \text{constant}$$

**Solution:**

- The initial horizontal velocity is  $v_{0x} = 19.6 \text{ m/s}$ .
- Because no horizontal force acts on the projectile,  $v_x(2 \text{ s}) = 19.6 \text{ m/s}$ .

**Why other options are incorrect:**

- **Option A:**  $4.9 \text{ m/s}$  is an incorrect fraction of the velocity.
- **Option B:**  $9.8 \text{ m/s}$  confuses the velocity value with gravitational acceleration  $g$ .
- **Option D:**  $39.2 \text{ m/s}$  mistakenly adds vertical acceleration effects to the horizontal component.

**Question #164** Key: (C)PHYSICS  
02. Force & Motion

In ideal projectile motion near the surface of the Earth, the acceleration of the projectile in...

**CORE CONCEPT & DERIVATION**

Projectile motion is two-dimensional motion under the sole influence of gravity. The gravitational force vector points vertically downward toward the center of the Earth, exerting zero force component in the horizontal plane.

**Formula / Rule / Reaction:**

$$F_x = 0 \implies a_x = \frac{F_x}{m} = 0$$

**Solution:**

- Because air resistance is neglected and gravity has no horizontal component, the horizontal acceleration is identically zero.

**Why other options are incorrect:**

- **Option A:**  $9.8 \text{ m/s}^2$  is the downward vertical acceleration ( $a_y = -g$ ), not the horizontal acceleration.
- **Option B:** Acceleration remains uniform and does not vary with time.
- **Option D:** Horizontal velocity and acceleration remain unaffected by descent altitude.

**Question #165** Key: (C)PHYSICS  
05. Waves

In vibratory or oscillatory motion, the maximum displacement of an oscillating particle on either...

**CORE CONCEPT & DERIVATION**

In simple harmonic motion, the position varies sinusoidally about the central equilibrium point. The maximum absolute displacement reached by the oscillator is termed its amplitude.

**Formula / Rule / Reaction:**

$$x(t) = x_0 \sin(\omega t + \phi) \implies x_{\text{max}} = x_0 = \text{Amplitude}$$

**Solution:**

- Amplitude measures the maximum distance from the central equilibrium position to an extreme turning point.

**Why other options are incorrect:**

- **Option A:** Total path distance is the total length traveled during oscillations (e.g.,  $4x_0$  per complete cycle).
- **Option B:** Instantaneous displacement is the position of the particle at any given instant in time.
- **Option D:** Frequency is the number of complete vibrational cycles executed per second.

**Question #166** Key: (C)PHYSICS  
07. Thermodynamics

A thermodynamic process in which a gas undergoes expansion or compression without performing an...

**CORE CONCEPT & DERIVATION**

Boundary work done by an expanding or contracting fluid depends on volumetric displacement. In an isochoric process, the system volume is held strictly constant.

**Formula / Rule / Reaction:**

$$W = \int P dV \quad \text{When } V = \text{constant} \implies dV = 0 \implies W = 0$$

**Solution:**

- Because the rigid container walls do not move,  $\Delta V = 0$ , and the external mechanical work performed is identically zero.
- By the First Law of Thermodynamics, all added heat goes directly into changing internal energy:  $\Delta U = Q_v$ .

**Why other options are incorrect:**

- **Option A:** In an isothermal process, work is performed equal to  $nRT \ln(V_2/V_1)$ .
- **Option B:** In an isobaric process, work performed is  $P\Delta V \neq 0$ .
- **Option D:** In an adiabatic process, work is performed at the expense of internal energy ( $W = -\Delta U$ ).

**Question #167** Key: (C)PHYSICS  
11. Electromagnetic Induction

The peak induced electromotive force ( [Formula] ) generated by a rotating armature coil in an ...

**CORE CONCEPT & DERIVATION**

According to Faraday's law of electromagnetic induction, rotating a planar coil in a uniform magnetic field induces an alternating EMF whose peak magnitude depends on turns, field strength, area, and angular velocity.

**Formula / Rule / Reaction:**

$$E_0 = NBA\omega = 2\pi NBAf$$

**Solution:**

- Because peak EMF is directly proportional to coil area ( $E_0 \propto A$ ), increasing the cross-sectional area of the armature coil directly increases the induced output EMF.

**Why other options are incorrect:**

- Option A:** Decreasing the area decreases the magnetic flux linkage, reducing induced EMF.
- Option B:** Decreasing the magnetic field strength reduces peak EMF.
- Option D:** Decreasing rotational speed lowers the time rate of change of flux, reducing output voltage.

**Question #168** Key: (A)PHYSICS  
11. Electromagnetic Induction

The primary engineering function of an electrical power transformer is to:

**CORE CONCEPT & DERIVATION**

A transformer is a static electrical machine that transfers alternating electrical power between circuits through mutual electromagnetic induction, stepping voltages up or down at constant frequency.

**Formula / Rule / Reaction:**

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s} \quad (\text{Power}_{\text{in}} \approx \text{Power}_{\text{out}})$$

**Solution:**

- Transformers step alternating voltages up for efficient long-distance transmission and step them down for safe domestic and industrial distribution.

**Why other options are incorrect:**

- Option B:** Converting alternating current into direct current is rectification, performed by semiconductor diodes.
- Option C:** Converting mechanical energy into electrical energy is generation, performed by electric dynamos/generators.
- Option D:** Converting direct current into alternating current is inversion, performed by electronic inverters.

**Question #169** Key: (D)PHYSICS  
13. Electronics

A single semiconductor p-n junction diode conducting current in only one forward direction is U...

**CORE CONCEPT & DERIVATION**

A p-n junction diode permits current flow when forward-biased and blocks current flow when reverse-biased. When placed in series with an alternating voltage, it allows only one half of the AC cycle to pass, functioning as a half-wave rectifier.

**Formula / Rule / Reaction:**

$$\text{AC Input: } V(t) = V_0 \sin(\omega t) \xrightarrow{\text{Single Diode}} \text{Pulsating DC output over positive half-cycles only}$$

**Solution:**

- During the positive half-cycle, the diode is forward-biased and conducts current through the load.
- During the negative half-cycle, the diode is reverse-biased and blocks current, converting AC into half-wave pulsating DC.

**Why other options are incorrect:**

- Option A:** Full-wave rectification requires a center-tapped transformer with two diodes or a four-diode bridge network.
- Option B:** Amplification requires a three-terminal active device such as a bipolar junction transistor (BJT) or FET.
- Option C:** A transmitter requires oscillators and antenna modulation circuitry.

**Question #170** Key: (B)PHYSICS  
16. Nuclear Physics

The radioactive noble gas radon-222 ( $^{222}\text{Rn}$ ) has a nuclear half-life of approximately:

**CORE CONCEPT & DERIVATION**

Radioactive half-life ( $T_{1/2}$ ) is the time required for half the radioactive parent nuclei in a sample to decay into daughter nuclei.

**Formula / Rule / Reaction:**

$$N(t) = N_0 \left(\frac{1}{2}\right)^{t/T_{1/2}} \quad \text{For Radon-222: } T_{1/2} = 3.82 \text{ days}$$

**Solution:**

- According to the Sindh Textbook Board Nuclear Physics syllabus, radon-222 decays by alpha emission with a characteristic half-life of 3.8 days.

**Why other options are incorrect:**

- Option A:** 3.8 minutes is too short for radon-222 (radon-219/actinon has a half-life of seconds).
- Option C:** 3.8 months is far too long for gaseous radon isotopes.
- Option D:** 38 years does not match any natural radon isotope.

**Question #171** Key: (A)PHYSICS  
08. Electrostatics

Two capacitors with capacitances of [Formula] and [Formula] are connected in series across a [F]...

**CORE CONCEPT & DERIVATION**

In a series capacitive circuit, electric charge cannot accumulate between isolated plates; therefore, every capacitor in the series string stores the identical quantity of electric charge equal to the total circuit charge ( $Q_{\text{total}} = Q_1 = Q_2$ ).

**Formula / Rule / Reaction:**

$$\frac{1}{C_{\text{eq}}} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{C_1 + C_2}{C_1 C_2} \Rightarrow C_{\text{eq}} = \frac{6 \times 12}{6 + 12} = \frac{72}{18} = 4.0 \mu\text{F}$$

$$Q = C_{\text{eq}} V$$

**Solution:**

- Calculate equivalent capacitance:  $C_{\text{eq}} = 4.0 \mu\text{F} = 4.0 \times 10^{-6} \text{ F}$ .
- Calculate charge:
- $Q = (4.0 \times 10^{-6} \text{ F}) \times 200 \text{ V} = 8.0 \times 10^{-4} \text{ C}$
- Because they are in series, both capacitors hold  $8.0 \times 10^{-4} \text{ C}$ .

**Why other options are incorrect:**

- Option B:**  $8.0 \mu\text{C}$  results from omitting the multiplication factor of 100 in the voltage.
- Option C:** In series, charges cannot differ between capacitors.
- Option D:** 800 Coulombs is an enormous charge, overlooking the micro-farad ( $10^{-6}$ ) factor.

**Question #172** Key: (D)PHYSICS  
09. Current Electricity

A uniform cylindrical conducting wire has resistance  $R$ . If the wire is drawn out such that its...

**CORE CONCEPT & DERIVATION**

Electrical resistance depends directly on length and resistivity, and inversely on cross-sectional area. When the problem explicitly specifies that cross-sectional radius (and area) is held constant, resistance is directly proportional to length.

**Formula / Rule / Reaction:**

$$R = \rho \frac{L}{A} \Rightarrow R \propto L \quad (\text{when } A = \text{constant})$$

**Solution:**

- Given  $L' = 2L$  and  $A' = A$ :
- $R' = \rho \frac{2L}{A} = 2(\rho \frac{L}{A}) = 2R$
- Note: If the wire had been stretched with volume conservation (where area shrinks as length doubles), the resistance would be  $4R$ ; however, because the prompt explicitly stipulates that 'its radius stays constant', the answer is  $2R$ .

**Why other options are incorrect:**

- Option A:**  $R/2$  corresponds to halving the length.
- Option B:** Resistance must increase when length increases.
- Option C:**  $4R$  applies only when the wire stretches under constant mass/volume, causing the radius to decrease by  $1/\sqrt{2}$ .

**Question #173** Key: (C)PHYSICS  
05. Waves

The speed of sound in dry air at  $0^\circ\text{C}$  is [Formula]. What is the speed of sound in air when the ...

**CORE CONCEPT & DERIVATION**

The velocity of acoustic waves in a gas increases with temperature because higher temperatures increase molecular velocity and gas elasticity. For small temperature increments, the speed increases by approximately  $0.61 \text{ m/s}$  per degree Celsius.

**Formula / Rule / Reaction:**

$$v_t = v_0 + 0.61 t (^\circ\text{C})$$

**Solution:**

- Substitute  $v_0 = 332 \text{ m/s}$  and  $t = 50^\circ\text{C}$ :
- $v_{50} = 332 + (0.61 \times 50) = 332 + 30.5 = 362.5 \text{ m/s} \approx 362 \text{ m/s}$

**Why other options are incorrect:**

- Option A:**  $300 \text{ m/s}$  corresponds to a temperature well below  $0^\circ\text{C}$ .
- Option B:**  $332 \text{ m/s}$  is the baseline speed at  $0^\circ\text{C}$  without thermal correction.
- Option D:**  $382 \text{ m/s}$  overestimates the thermal coefficient of sound speed.

**Question #174** Key: (A)PHYSICS  
02. Force & Motion

A force of magnitude  $2F$  acting on a mass of [Formula] produces an acceleration of [Formula]. A...

**CORE CONCEPT & DERIVATION**

Newton's Second Law states that force equals mass times acceleration ( $F = ma$ ). Solving for the base force unit  $F$  allows the determination of the unknown mass in the second case.

**Formula / Rule / Reaction:**

$$F_1 = m_1 a_1 \Rightarrow 2F = (10 \text{ kg})(30 \text{ m/s}^2) = 300 \text{ N} \Rightarrow F = 150 \text{ N}$$

$$F_2 = M a_2 \Rightarrow 5F = M(25 \text{ m/s}^2)$$

**Solution:**

- Calculate  $F_2$ :
- $F_2 = 5 \times 150 \text{ N} = 750 \text{ N}$
- Solve for mass  $M$ :
- $M = \frac{F_2}{a_2} = \frac{750 \text{ N}}{25 \text{ m/s}^2} = 30 \text{ kg}$

**Why other options are incorrect:**

- Option B:**  $21 \text{ kg}$  is an arithmetic error.
- Option C:**  $4.8 \text{ kg}$  inverts the ratio of accelerations.
- Option D:**  $3.3 \text{ kg}$  results from dividing by  $5F$  incorrectly.

**Question #175** **Key: (B)**PHYSICS  
11. Electromagnetic Induction

The primary function of an AC power transformer is to convert:

**CORE CONCEPT & DERIVATION**

Transformers require continuously alternating magnetic flux to induce voltages in secondary coils. Consequently, they operate exclusively on alternating current (AC) and cannot transform constant DC voltages.

Formula / Rule / Reaction:

$$V_{s,AC} = V_{p,AC} \left( \frac{N_s}{N_p} \right)$$

Solution:

- A transformer converts an alternating voltage at one level into an alternating voltage at another level at the identical operating frequency.

Why other options are incorrect:

- **Option A:** DC voltages produce static magnetic fields with zero time rate of change ( $d\Phi/dt = 0$ ), producing zero secondary EMF.
- **Option C:** Converting AC to DC is rectification, accomplished by diode circuits.
- **Option D:** Transforming DC requires solid-state DC-DC buck/boost converters, not magnetic induction transformers.

**Question #176** **Key: (C)**PHYSICS  
15. Atomic Spectra

An excited atom undergoes a downward electronic transition from energy level [Formula] to a low...

**CORE CONCEPT & DERIVATION**

According to Bohr's third frequency condition, the energy carried away by an emitted photon equals the difference in energy between the initial and final stationary states.

Formula / Rule / Reaction:

$$\Delta E = E_2 - E_1 = hf = h \frac{c}{\lambda} \implies \lambda = \frac{hc}{E_2 - E_1}$$

Solution:

- Rearranging the quantum equation to isolate wavelength  $\lambda$  gives  $\lambda = \frac{hc}{E_2 - E_1}$ .

Why other options are incorrect:

- **Option A:**  $(E_2 - E_1)/hc$  is the wave number ( $\bar{\nu} = 1/\lambda$ ), the reciprocal of wavelength.
- **Option B:** Mathematically invalid separation of the denominator terms.
- **Option D:** Inverts Planck's constant in the expression.

**Question #177** **Key: (B)**ENGLISH  
05. Active-Passive Voice, Reported Speech & Syntax

Identify the sentence fragment among the following options:

**CORE CONCEPT & DERIVATION**

A complete sentence must contain at least one independent clause possessing both a grammatical subject and a finite predicate verb while expressing a complete thought. A dependent clause or phrase standing alone is a sentence fragment.

Formula / Rule / Reaction:

Independent Clause = Subject + Finite Verb + Complete Thought

Solution:

- 'Quickly, before the rain started' consists of an adverb and a subordinate temporal clause introduced by 'before'.
- It lacks an independent subject and main predicate verb, leaving the thought incomplete and making it a sentence fragment.

Why other options are incorrect:

- **Option A:** 'He went to the store' is a complete independent clause (Subject: He; Verb: went).
- **Option C:** 'The cat sat on the windowsill' is a complete sentence (Subject: The cat; Verb: sat).
- **Option D:** 'She prepared a delicious meal' is a complete sentence (Subject: She; Verb: prepared).

**Question #178** **Key: (C)**ENGLISH  
06. Punctuation, Capitalization & Reading Comprehension

Identify the sentence that exhibits the incorrect use of an apostrophe:

**CORE CONCEPT & DERIVATION**

'It's' (with an apostrophe) is the contraction for 'it is' or 'it has', whereas 'its' (without an apostrophe) is the possessive determiner.

Formula / Rule / Reaction:

Contraction: **It's** = It is | Possessive pronoun: **Its** = Belonging to it

Solution:

- In the sentence 'Its a beautiful day outside', the intended meaning is 'It is a beautiful day outside'.
- The apostrophe was erroneously omitted; it must be written as 'It's'.

Why other options are incorrect:

- **Option A:** 'Mary's book' correctly uses an apostrophe to indicate singular possession.
- **Option B:** 'The dog's leash' correctly indicates possession belonging to the dog.
- **Option D:** 'The children's toys' correctly forms the possessive of an irregular plural noun ('children').

**Question #179** Key: (C)ENGLISH  
04. Subject-Verb Agreement, Tenses & Conditionals

Which of the following sentences demonstrates the grammatically correct use of the past perfect...

**CORE CONCEPT & DERIVATION**

The past perfect tense is formed using the auxiliary 'had' followed by the past participle of the main verb, denoting an action completed in the past prior to another past event or specified past time.

**Formula / Rule / Reaction:**

Past Perfect Structure: Subject + **had** + **V<sub>3</sub> (Past Participle)** + ...

**Solution:**

- 'He had finished his homework before dinner' correctly employs the auxiliary 'had' with the past participle 'finished' to show completion prior to dinner.

**Why other options are incorrect:**

- **Option A:** Combines the future auxiliary 'will' with the past temporal adverb 'yesterday' (tense clash).
- **Option B:** Uses the future continuous tense with the present temporal adverb 'now'.
- **Option D:** Uses the present continuous tense to denote a scheduled future event.

**Question #180** Key: (A)ENGLISH  
05. Active-Passive Voice, Reported Speech & Syntax

Which of the following sentences follows standard English word order for adverbs of frequency a...

**CORE CONCEPT & DERIVATION**

Standard declarative English syntax places adverbs of frequency (such as 'usually', 'always', 'often') immediately before the main lexical verb, while prepositional phrases of time appear naturally at the end of the clause.

**Formula / Rule / Reaction:**

Order: Subject + Adverb of Frequency + Main Verb + Gerund / Object + Adverbial of Time

**Solution:**

- 'She' (Subject) + 'usually' (Adverb of frequency) + 'goes' (Verb) + 'jogging' (Gerund) + 'in the evening' (Prepositional phrase of time) adheres to correct grammatical syntax.

**Why other options are incorrect:**

- **Option B:** Inverts subject and verb ('goes she') without an interrogative or negative inversion trigger.
- **Option C:** Fractures prepositional phrases and misplaces the adverb.
- **Option D:** Separates the verb from its subject with an awkward prepositional phrase.

**Question #181** Key: (C)ENGLISH  
06. Punctuation, Capitalization & Reading Comprehension

What is the most appropriate and polite response to the question: 'How was your day at school?'

**CORE CONCEPT & DERIVATION**

Conversational pragmatic competence requires answering an inquiry with a socially appropriate, relevant, and contextually coherent response that directly addresses the prompt.

**Formula / Rule / Reaction:**

Factual recall / Qualitative concept.

**Solution:**

- 'It was great, thanks for asking!' directly answers the evaluation of the day ('It was great') and acknowledges the interlocutor politely ('thanks for asking').

**Why other options are incorrect:**

- **Option A:** Discusses a future activity rather than answering how the school day was.
- **Option B:** States a personal academic preference without evaluating how the day went.
- **Option D:** Expresses an abrupt general negative opinion without answering the question about the specific day.

**Question #182** Key: (B)ENGLISH  
06. Punctuation, Capitalization & Reading Comprehension

Identify the grammatical error in the sentence: 'His the car is red.'

**CORE CONCEPT & DERIVATION**

In English grammar, possessive determiners ('his', 'her', 'my') and definite articles ('the') are both central determiners. A noun phrase cannot take two central determiners simultaneously before the same head noun.

**Formula / Rule / Reaction:**

Incorrect: Possessive Determiner + Definite Article + Noun  $\Rightarrow$  Correct: His car is red.

**Solution:**

- The article 'the' is redundant and ungrammatical when placed directly after 'his'.
- Omitting 'the' produces the correct sentence: 'His car is red'.

**Why other options are incorrect:**

- **Option A:** The sentence contains a double determiner error and is grammatically incorrect.
- **Option C:** 'Car' (singular) agrees with 'is' (singular verb).
- **Option D:** 'Red' is correctly positioned as a predicate adjective following the linking verb 'is'.

**Question #183** Key: (A)ENGLISH  
01. Vocabulary, Synonyms, Antonyms & Spelling

What is the direct antonym of the word 'generous'?

**CORE CONCEPT & DERIVATION**

An antonym is a word having a meaning directly opposite to that of another word. 'Generous' means willing to give and share unselfishly.

**Formula / Rule / Reaction:**Generous (giving / unselfish)  $\longleftrightarrow$  Selfish / Stingy (mean/self – centered)**Solution:**

- 'Selfish' denotes being concerned predominantly with one's own personal profit or pleasure at the expense of others, making it the direct antonym of generous.

**Why other options are incorrect:**

- Option B:** 'Charitable' is a synonym of generous.
- Option C:** 'Benevolent' is a synonym meaning well-meaning and kindly.
- Option D:** 'Altruistic' is a synonym denoting selfless concern for others.

**Question #184** Key: (B)ENGLISH  
01. Vocabulary, Synonyms, Antonyms & Spelling

Complete the sentence with the appropriate verb: 'The Sun began to \_\_\_\_\_ behind the mountains....'

**CORE CONCEPT & DERIVATION**

Lexical collocations and narrative coherence require verbs that match the context of an evening twilight glow cast as the sun descends behind a mountain horizon.

**Formula / Rule / Reaction:**

Contextual vocabulary selection.

**Solution:**

- The verb 'set' describes the descent of the sun beneath the horizon at dusk, which creates evening twilight glows across valleys.
- Note on board key: Certain early question keys listed 'Rise'; however, standard English usage and the Sindh Textbook Board past paper keys select 'Set' as the coherent lexical fit.

**Why other options are incorrect:**

- Option A:** The sun rising behind mountains initiates dawn, whereas the descriptive idiom 'behind the mountains, casting a warm glow' typically portrays sunset.
- Option C:** 'Shine' does not take the directional particle 'behind' in the sense of disappearing beneath the horizon.
- Option D:** 'Sleep' is an inappropriate figurative personification in standard prose.

**Question #185** Key: (A)ENGLISH  
01. Vocabulary, Synonyms, Antonyms & Spelling

Select the appropriate word to complete the sentence: 'After a long, stressful day at work, Sar....'

**CORE CONCEPT & DERIVATION**

Contextual vocabulary requires selecting a noun that represents comfort, consolation, or relief from stress.

**Formula / Rule / Reaction:**

Definition: Solace = comfort or consolation in a time of distress or sadness.

**Solution:**

- 'Solace' perfectly fits the context of finding peaceful psychological relief in reading after a stressful day.

**Why other options are incorrect:**

- Option B:** 'Chaos' means complete disorder and confusion, the opposite of peaceful escapism.
- Option C:** 'Endurance' means the capacity to withstand hardship, not the comfort derived from reading.
- Option D:** 'Agony' denotes extreme physical or mental suffering.

**Question #186** Key: (D)ENGLISH  
06. Punctuation, Capitalization & Reading Comprehension

Which of the following sentences exhibits incorrect punctuation due to a comma splice?

**CORE CONCEPT & DERIVATION**

A comma splice occurs when two independent clauses are joined solely with a comma without an accompanying coordinating conjunction (FANBOYS). Independent clauses must be joined by a semicolon, a colon, or a coordinating conjunction.

**Formula / Rule / Reaction:**

Comma Splice (Error): Independent Clause+, +Independent Clause

**Solution:**

- 'I am going to the store' and 'do you need anything?' are both independent clauses.
- Joining them with only a comma in Option D creates an ungrammatical comma splice.

**Why other options are incorrect:**

- Option A:** Uses a semicolon correctly to join two related independent clauses.
- Option B:** Uses a coordinating conjunction ('so') preceded by a comma.
- Option C:** Uses a colon where the second clause explains or amplifies the first.

**Question #187** Key: (A)ENGLISH  
04. Subject-Verb Agreement, Tenses & Conditionals

Which of the following sentences exhibits completely correct grammatical and spelling structure....

**CORE CONCEPT & DERIVATION**

The present continuous tense requires the subject, the correct conjugated form of the auxiliary verb 'to be', and the present participle (-ing) form of the main verb.

**Formula / Rule / Reaction:**Subject + Auxiliary (are) + Verb-ing  $\Rightarrow$  They are playing = They're playing**Solution:**

- 'They're' is the correct contraction of 'they are', forming a grammatically valid present continuous sentence.

**Why other options are incorrect:**

- Option B:** Lacks the obligatory auxiliary verb 'are'.
- Option C:** Confuses the possessive determiner 'their' with the pronoun-verb contraction 'they're'.
- Option D:** Uses the bare infinitive 'play' instead of the past participle 'played' after the auxiliary 'have'.

**Question #188** Key: (B)ENGLISH  
06. Punctuation, Capitalization & Reading Comprehension

Choose the sentence that correctly employs the apostrophe to indicate singular possession:

**CORE CONCEPT & DERIVATION**

To indicate possession for a singular noun not ending in s, an apostrophe followed by the letter 's' is added to the noun.

**Formula / Rule / Reaction:**Singular Possessive: Noun + 's  $\Rightarrow$  cat's**Solution:**

- 'The cat's toys' correctly shows that the toys belong to a single cat.

**Why other options are incorrect:**

- Option A:** 'Cats toys' omits the apostrophe, creating an ungrammatical plural noun adjunct.
- Option C:** 'Cats' toys' indicates plural possession (belonging to multiple cats), not singular.
- Option D:** Erroneously places an apostrophe on the noun 'toys'.

**Question #189** **Key: (B)**ENGLISH  
03. Parts of Speech, Prepositions & Modifiers

Which indefinite article correctly completes the sentence: 'He lives in \_\_\_\_\_ old house.'

**CORE CONCEPT & DERIVATION**

The indefinite article 'an' is used before singular countable nouns modified by adjectives that begin with a vowel sound (such as /ou/ in 'old').

**Formula / Rule / Reaction:**

Vowel sound onset (/o\upsilonpsilon/) ⇒ an old house

**Solution:**

- Because the word 'old' begins with a vowel sound, the indefinite article 'an' must precede it.

**Why other options are incorrect:**

- Option A:** 'A' is used before consonant sounds (e.g., 'a house', 'a new house').
- Option C:** 'The' is the definite article, which specifies a unique previously identified house rather than introducing an indefinite one.
- Option D:** Singular countable nouns require an article in standard English.

**Question #190** **Key: (A)**ENGLISH  
03. Parts of Speech, Prepositions & Modifiers

Identify the grammatical mistake in the use of prepositions in the sentence: 'She is good at co...'

**CORE CONCEPT & DERIVATION**

The idiomatic construction 'good at' is the standard prepositional phrase denoting proficiency in an activity, and 'in the kitchen' correctly denotes spatial location.

**Formula / Rule / Reaction:**Proficiency idiom: **good at** + [Noun / Gerund] | Spatial idiom: **in** + [Enclosed room]**Solution:**

- Both prepositions are used correctly in their standard idiomatic contexts; no grammatical error exists.

**Why other options are incorrect:**

- Option B:** Omitting 'at' produces the ungrammatical phrase 'good cooking in the kitchen'.
- Option C:** 'On the kitchen' is incorrect for enclosed interior rooms.
- Option D:** 'Good at to cook' violates prepositional complement rules requiring a gerund.

**Question #191** **Key: (D)**ENGLISH  
04. Subject-Verb Agreement, Tenses & Conditionals

Which of the following sentences demonstrates correct subject-verb agreement?

**CORE CONCEPT & DERIVATION**

A plural subject requires a plural verb, whereas a singular subject requires a singular verb.

**Formula / Rule / Reaction:**

Plural Subject (Cats) + Plural Auxiliary (Are) + Present Participle (Sleeping)

**Solution:**

- 'Cats' is a plural noun and correctly pairs with the plural auxiliary verb 'are'.

**Why other options are incorrect:**

- Option A:** Singular subject 'cat' is mismatched with the plural verb 'are'.
- Option B:** Plural subject 'cats' is mismatched with the singular verb 'is'.
- Option C:** Uses 'has' with the present participle 'sleeping', violating auxiliary verb syntax.

**Question #192** **Key: (A)**ENGLISH  
06. Punctuation, Capitalization & Reading Comprehension

Read the following passage to answer the question: "Nobody knows when fiction started. Perhaps ..."

**CORE CONCEPT & DERIVATION**

Contextual meaning derives from how a word operates within a passage. Here, 'fiction' refers to stories, myths, and tales invented and related by storytellers.

**Formula / Rule / Reaction:**

Contextual vocabulary analysis.

**Solution:**

- The passage equates fiction with imaginative storytelling, campfire adventures, and traditional tales passed down across generations, matching the definition of a narrative.

**Why other options are incorrect:**

- Option B:** Textbooks contain didactic non-fiction instruction.
- Option C:** Scientific prose reports factual empirical observations.
- Option D:** Truth denotes factuality, which is the antonym of fiction.

**Question #193** **Key: (C)**ENGLISH  
06. Punctuation, Capitalization & Reading Comprehension

According to the passage on early storytelling, myths and ancient tales were originally preserv...

**CORE CONCEPT & DERIVATION**

Direct reading comprehension requires locating explicit factual details stated in the text.

**Formula / Rule / Reaction:**

Text Citation: "Myths and tales were passed down by word of mouth and had to be popularized by each new generation of storytellers."

**Solution:**

- The passage explicitly states that before the advent of widespread written records, stories were shared as a purely oral activity through word of mouth.

**Why other options are incorrect:**

- Option A:** Written scriptures developed later in literate antiquity.
- Option B:** Carved stone inscriptions are physical epigraphic records, not oral transmissions.
- Option D:** Parchment scrolls are written media.

**Question #194** **Key: (D)**ENGLISH  
06. Punctuation, Capitalization & Reading Comprehension

It is explicitly emphasized in the reading passage that the practice of storytelling:

**CORE CONCEPT & DERIVATION**

Identifying main ideas and explicit textual claims in reading comprehension.

**Formula / Rule / Reaction:**

Text Citation: "Perhaps the first storyteller was a prehistoric mother trying to explain the world to her children..."

**Solution:**

- The author speculates that storytelling began long before recorded history, dating back to prehistoric mothers and campfire hunters.

**Why other options are incorrect:**

- Option A:** The passage states it began as a purely oral activity, not written.
- Option B:** The text does not claim storytelling became unpopular after writing was invented.
- Option C:** Homer is cited as a notable practitioner of the pre-existing oral tradition, not its sole inventor.

**Question #195** Key: (D)LOGICAL REASONING  
09. Word Problems on Ages

Consider the following statements regarding the ages of Essa and Moosa: • Essa is strictly younger...

**CORE CONCEPT & DERIVATION**

In algebraic inequalities, establishing an invariant relationship between a multiple of a smaller variable and an unconstrained larger variable requires specific numerical bounds.

**Formula / Rule / Reaction:**

$$\text{Given: } E < M, \quad X = 2E, \quad Y = M$$

**Solution:**

- Case 1: Let Essa = 10 and Moosa = 12 (Essa < Moosa). Then  $X = 2(10) = 20$  and  $Y = 12$ . Here,  $X > Y$ .
- Case 2: Let Essa = 2 and Moosa = 10 (Essa < Moosa). Then  $X = 2(2) = 4$  and  $Y = 10$ . Here,  $X < Y$ .
- Case 3: Let Essa = 5 and Moosa = 10 (Essa < Moosa). Then  $X = 2(5) = 10$  and  $Y = 10$ . Here,  $X = Y$ .
- Because  $X$  can be greater than, less than, or equal to  $Y$  depending on the values, the relationship cannot be uniquely determined.

**Why other options are incorrect:**

- **Option A:** Fails when Essa's age is less than half of Moosa's age.
- **Option B:** Fails when Essa's age is greater than half of Moosa's age.
- **Option C:** Holds only under the isolated condition where Moosa is exactly twice Essa's age.

**Question #196** Key: (D)LOGICAL REASONING  
14. Direction, Distance & Spatial/Visual Patterns

Look carefully at the sequence of symbols depicted below: ? Which option correctly completes th...

**CORE CONCEPT & DERIVATION**

Abstract diagrammatic reasoning requires identifying the step-by-step transformation rules applied across a spatial matrix or sequence.

**Formula / Rule / Reaction:**

Transformation rule: In Box 1, both arcs are open curves. In Box 2, the upper arc is enclosed into a closed semicircle. In Box 3, the bottom curve begins closure. Therefore, Box 4 must feature both the top and bottom curves completely closed into distinct semicircles.

**Solution:**

- The sequential progression closes the open perimeter paths into enclosed planar semicircles from top to bottom.
- Figure D completes this progression with two fully closed semicircles.

**Why other options are incorrect:**

- **Option A:** Reverts to the initial unclosed state of Box 1.
- **Option B:** Leaves the top semicircle open, violating the progressive closure achieved in Step 2.
- **Option C:** Leaves the bottom semicircle incomplete, failing to advance beyond Box 3.

**Question #197** Key: (C)LOGICAL REASONING  
12. Linear Ranking, Ordering & Inequalities

In an academic class of 50 students, Sara's rank is five positions below the top-ranking student...

**CORE CONCEPT & DERIVATION**

In linear ranking problems, the rank of an individual from the opposite end is calculated by subtracting their rank from the top from the total number of individuals, plus one.

**Formula / Rule / Reaction:**

$$\text{Rank from Bottom} = \text{Total Students} - \text{Rank from Top} + 1$$

**Solution:**

- The top student, Faiq, holds Rank 1.
- Sara is five ranks below Faiq: Sara's Rank from Top =  $1 + 5 = 6$ .
- Sara's rank from the bottom is:
- $\text{Rank from Bottom} = 50 - 6 + 1 = 45\text{th}$

**Why other options are incorrect:**

- **Option A:** 5th confuses the ranking difference with her final position from the bottom.
- **Option B:** 15th is an arbitrary number.
- **Option D:** 46th occurs if one assumes Sara is at rank 5 rather than 5 positions below rank 1 ( $50 - 5 + 1 = 46$ ).

**Question #198** Key: (D)LOGICAL REASONING  
08. Letter Series & Coding-Decoding

In a substitution cipher code, 'blue' is called 'green', 'green' is called 'white', 'white' is ...

**CORE CONCEPT & DERIVATION**

In artificial substitution cipher problems, determine the factual identity of the object in reality and then substitute it with the assigned encoded label.

**Formula / Rule / Reaction:**

$$\text{Factual Color of Milk} = \text{'White'} \xrightarrow{\text{Code Rule: 'white' is called 'red'}} \text{'Red'}$$

**Solution:**

- In reality, cow's milk is white.
- According to the cipher rules, 'white is called red'.
- Therefore, the coded color of milk is red.

**Why other options are incorrect:**

- **Option A:** 'White' is the factual color in reality, but fails to apply the coded cipher.
- **Option B:** 'Green' is the code name for blue.
- **Option C:** 'Yellow' is the code name for red.

**Question #199** **Key: (B)**LOGICAL REASONING  
03. Courses of Action & Decision-Making

Statement: The English language proficiency scores of students in XYZ High School are significant.

**CORE CONCEPT & DERIVATION**

A valid administrative course of action must be a constructive, logical, feasible, and proportional solution that directly addresses the root deficiency without causing disproportionate harm.

**Formula / Rule / Reaction:**

Administrative reasoning principle: Corrective upskilling takes precedence over summary termination.

**Solution:**

- Course of action II directly addresses the pedagogical skill gap by upskilling existing faculty through professional development and training courses.
- Course of action I is extreme, punitive, administratively disruptive, and disproportionate as an initial corrective measure.

**Why other options are incorrect:**

- **Option A:** Punitive wholesale termination is extreme and does not guarantee that replacement teachers will perform better without training.
- **Option C:** Because Course I is flawed, both cannot be correct.
- **Option D:** Fails to recognize that Course II is a constructive institutional remedy.

**Question #200** **Key: (A)**LOGICAL REASONING  
02. Cause and Effect Analysis

Read the two statements carefully and select the correct causal relationship: Statement I: It w...

**CORE CONCEPT & DERIVATION**

Causal analysis requires determining whether an antecedent event (cause) generated sufficient and necessary conditions to produce the consequent event (effect).

**Formula / Rule / Reaction:**

Antecedent (Torrential Rain)  $\Rightarrow$  Waterlogged Pitch  $\Rightarrow$  Consequent (Match Cancelled)

**Solution:**

- 'Raining cats and dogs' is an idiomatic expression denoting heavy downpours.
- Heavy rainfall creates waterlogged playing fields, directly causing the cancellation of outdoor sporting events.
- Therefore, Statement I is the cause, and Statement II is its direct effect.

**Why other options are incorrect:**

- **Option B:** Canceling an athletic match cannot cause rain to fall from the sky.
- **Option C:** The two events are directly causally connected, not independent.
- **Option D:** They represent a direct cause-and-effect pair, not isolated effects of separate causes.